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Front page image: word cloud of the present doctoral research (retrieved from Voyant Tools).

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LIST OF ACRONYMS

AGU	– American Geophysical Union
AWG	– Anthropocene Working Group
BAHC	– Biosphere Aspects of the Hydrological Cycle
ESSC	– Earth System Science Committee
ESSP	– Earth System Science Partnership
$E_n(D)$	– Normalized engagement factor per discipline
$E_o(D)$	– Observed engagement factor per discipline
F_n	– Normalized relative frequency
GSSA	– Global Standard Stratigraphic Age
GSSC	– Geological Society of London Stratigraphy Commission
GSSP	– Global Boundary Stratotype Section and Point
ICS	– International Commission on Stratigraphy
IGBP	– International Geosphere-Biosphere Programme
IGBP-SC	– International Geosphere-Biosphere Programme Scientific Committee
IHDP	– International Human Dimensions Programme on Global Environmental Change
IHOPE	– Integrated History and future Of People on Earth
IMA	– International Mineralogical Association
IUGS	– International Union of Geological Sciences
NACSN	– North American Commission on Stratigraphic Nomenclature
NASA	– National Aeronautics and Space Administration
R(D)	– Records per discipline
SQS	– Subcommission on Quaternary Stratigraphy

By the sweat of your face you shall eat bread,
till you return to the ground, for out of it you were taken;
for you are dust, and to dust you shall return.

—*Genesis* 3:19

Even dust if piled can become a mountain.

—Japanese proverb

INTRODUCTION

The following research is a historical and philosophical study on the birth and epistemology of a scientific hypothesis – the Anthropocene Hypothesis.

The Anthropocene Hypothesis is a recently formulated scientific hypothesis advanced by the Anthropocene Working Group (AWG), a stratigraphy-oriented research group of multidisciplinary membership established by the Subcommission of Quaternary Stratigraphy (SQS) in the summer of 2009. The group was assembled to assess whether sufficient stratigraphic evidence exists to warrant formal ratification of an Anthropocene time unit in the geological time scale and international chronostratigraphic chart.[1] Such a unit would be defined and characterized by the stratigraphic footprint of *Homo sapiens* in the geological records. The hypothesis that the group has been advancing is that, indeed, sufficient stratigraphic markers of anthropogenic origin *do exist* to grant formal recognition of an Anthropocene Epoch/Series. This would also imply ending the Holocene Epoch (and thus the Meghalayan Age) – the current and officially recognized geological epoch. The proposed beginning for this post-Holocene epoch would be located around the 1950s. This time frame coincides with a range of stratigraphic markers, in particular geochemical markers associated with nuclear and thermonuclear atomic bomb testing, detectable in core samples collected from environmental archives around the world. The hypothesis has ignited a wide range of debates across academia and among the public over the meaning, validity, utility, and broader social and ethical implications of formalizing the Anthropocene as an anthropogenically induced unit of geological time.

The Anthropocene Hypothesis is the stratigraphic formulation or 'variant' of the broader 'Anthropocene' concept. The term 'Anthropocene' has a long prehistory (and paleohistory), but in its modern usage it was first coined by chemist and Nobel laureate Paul Crutzen in late February 2000, during

[1] Since the present research will repeatedly engage with geological time, the latest version (i.e., v2021/07) of the international chronostratigraphic chart / geological time scale is provided in the Appendix for reference.

a Scientific Committee meeting of the International Geosphere-Biosphere Programme in Cuernavaca, Mexico. The term gradually made its way through academia, until after 2009 it generated a surge of interest that saw the proliferation of 'Anthropocene'-related publications, initiatives, conferences, university classes, exhibitions, artistic expressions, and more. A large number of scholars, especially in the human and social sciences, have engaged with the term by dissecting and deconstructing its meaning, assumptions, and rhetoric. Some have reformulated the notion under different terminological variants, such as the 'Capitalocene,' 'Novacene,' 'Pyrocene,' or 'Technocene' – to name only a few. The major outcome of this surge in interest is that the research that has emerged from this multidisciplinary interaction provides a broad spectrum of viewpoints for investigating the 'Anthropocene' as a polysemantic object.

However, this remarkable swell in popularity has also made it problematic to define the 'Anthropocene' in a multifunctional way – a problem this research frames as the 'issue of definition.' This is a particularly relevant predicament when contextualized in the broader discourse of a cultural chasm between humanities and social sciences on the one end, and the natural sciences on the other end – a divide similar to what physicist and novelist Charles Percy Snow famously described in the late 1950s in terms of 'two cultures.' Indeed, 'Anthropocene' scholars (e.g., Bostic & Howey, 2017; Ellis, 2016a; Horn & Bergthaller, 2020; Toivanen et al., 2017) have already observed forms of disengagement, isolation, or even antagonism seemingly replicating this intellectual and cultural segregation.

A solution to this problem (i.e., the issue of definition) is advanced in this research. The solution consists of distinguishing between the '*Anthropocene*' as a boundary object and the *Anthropocene Hypothesis*: the former corresponds to a boundary object of multidisciplinary meaning and use, and the latter represents the particular stratigraphic (or geological) formulation of the 'Anthropocene.' Recent scholarship (Thomas et al., 2020; Zalasiewicz et al., 2018; Zalasiewicz et al., 2019b; Zalasiewicz et al., 2021) has advanced a similar distinction to clarify the purpose and meaning of the 'geological Anthropocene' or 'stratigraphical Anthropocene' as a discrete and delimited research agenda. However, it is recognized that this distinction, and the semantic tension within it, has not yet been thoroughly examined – especially from the standpoint of the philosophical analysis of scientific knowledge.

This distinction frames the central object of analysis of the present research – that is, the Anthropocene Hypothesis. Justifying and articulating this conceptual separation in a way that is useful and replicable in academic as well as public discourse is one of the main targets of the present endeavor. Indeed, the study implements this distinction as a premise while simultaneously explaining the epistemic advantages and practical benefits of adopting this stance.

Attempting to legitimize and delineate a theoretical separation between 'Anthropocene' and Anthropocene Hypothesis is the first goal of the research. The second goal is to answer two interrelated questions stemming consequentially from the first goal, namely, *What is the Anthropocene Hypothesis?* and *What does it mean for the Anthropocene Hypothesis to represent a* scientific *hypothesis?*

The first question emerges naturally from the distinction advanced. If the hypothesis is to be treated as a discrete theoretical entity related to, but conceptually distinct from, the 'Anthropocene,' then those epistemic properties defining the Anthropocene Hypothesis as a separate entity need to be identified. Such properties should warrant necessary and sufficient reasons for treating the Anthropocene Hypothesis as a discrete theoretical object distinct from the 'Anthropocene,' beyond merely representing an interpretation of the latter.

The second question relates to the nature of the Anthropocene Hypothesis. It is argued that the hypothesis represents a *scientific* hypothesis, specifically a *stratigraphic* hypothesis. As a scientific hypothesis, it exhibits epistemic virtues (e.g., intelligibility, utility, explanatory power) traditionally discussed, defined, and ascribed by philosophers of science to scientific praxis and thought. As a stratigraphic hypothesis, it reflects the production of scientific ideas according to the specific epistemic context wherein the hypothesis situates – that is, stratigraphic research. These are among the epistemic characteristics that distinguish the Anthropocene Hypothesis from the 'Anthropocene' concept, and that make the hypothesis an object of interest in the philosophy of science – particularly the philosophy of geology. This is an important point, in that philosophy of science has fundamentally been only a minor voice both in the 'Anthropocene' and Anthropocene Hypothesis debates. In a way, this research encourages further commitment from the philosophy of science community to the epistemology of stratigraphic classification, and to the Anthropocene Hypothesis as a scientific idea.

Studying the *birth* and *epistemology* of the Anthropocene Hypothesis is considered a suitable strategy for providing satisfactory answers to both questions. But what precisely does it mean to study the 'birth' and 'epistemology' of the Anthropocene Hypothesis? How can these aspects help answer the questions posed above?

Reconstructing the *birth* of the hypothesis means identifying those circumstances that led a group of geologists to consider defining the 'Anthropocene' on stratigraphic grounds. This requires probing into the historical, intellectual, disciplinary, and social context in which the hypothesis was generated. As anticipated, the Anthropocene Hypothesis represents a particular interpretation of the 'Anthropocene' concept. This means that understanding the origins of the Anthropocene Hypothesis requires understanding how the 'Anthropocene' concept evolved across the academic, and particularly the scientific, landscape during the term's early years of existence. It also requires understanding the broader context that the 'Anthropocene' has engendered over the past decade, namely, the new knowledge domain of Anthropocene Studies. Representing a discrete theoretical entity does not imply that the Anthropocene Hypothesis is entirely removed from the broader discourses gravitating around the 'Anthropocene.' On the contrary, it may be argued that the hypothesis is situated at the epicenter of such discourse and debate. Therefore, it is important to frame the context surrounding and preceding the Anthropocene Hypothesis to understand the nature and meaning of the hypothesis as a scientific and stratigraphic hypothesis.

Studying the *epistemology* of the Anthropocene Hypothesis means delineating those central knowledge statements underpinning the identity of the hypothesis as well as determining which (if any) epistemic virtues characterize the hypothesis. These knowledge statements can be extrapolated from research material articulating the methodological, theoretical, and empirical outline of the hypothesis, and then reformulated in philosophical terms. They are expressed in various forms, from normative-methodological (e.g., what constitutes *geological* evidence for the hypothesis, which norms of stratigraphic classification the hypothesis adheres to or challenges, etc.) to descriptive-observational (e.g., empirical evidence). Analyzing these statements grants deeper insight into their logical and semantic implications, providing conceptual and semantic clarification in addition to offering critical viewpoints of methodological and theoretical utility. Assessing whether a certain set of epistemic virtues can be identified ensures the theoretical legitimacy (*sensu lato*) of the hypothesis as a *scientific* hypothesis. This is particularly important because the very stratigraphic nature as well as scientificity of the hypothesis has been questioned from both inside and outside the stratigraphic and geological community. The research attempts to show that, indeed, the hypothesis *does* exhibit some epistemic virtues that allow it to be characterized (from a philosophical standpoint) as a scientific hypothesis.

Philosophical analysis in the form of conceptual and linguistic analysis is the primary means to achieve the targets set in this research. However, as philosopher Wesley Salmon (1982) once stated, "philosophy which remains out of contact with other disciplines runs the great risk of becoming quite sterile" (p. 282). This means that philosophy alone cannot thoroughly investigate the range of factors characterizing the Anthropocene Hypothesis as a scientific hypothesis without the risk of falling into abstract ideas of science detached from the 'practical' fabric of scientific knowledge. The hypothesis is part of a social, historical, and scientific context that has epistemic significance in informing and influencing its formulation as well as its scientific status. Therefore, an *interdisciplinary approach* defines the operating method of the present research. This method incorporates quantitative and qualitative linguistics, methods of stratigraphic and geological classification, conceptual history, and history of science. Each of these disciplinary areas provides methods considered adequate means for investigating the birth and epistemology of the hypothesis in question. The particular methods used, and the problems they tackle, are discussed in their respective chapters and sections.

The underlying tone of this research is primarily descriptive. It seeks to explore the origins and nature of the Anthropocene Hypothesis as a scientific hypothesis based on meticulously scrutinized data. It refrains from judging whether the proposed epoch should or should not be formalized, or whether formal ratification of an Anthropocene unit would be beneficial for science and society at large. However, because utter objectivity is methodologically unattainable, limited portions of the research make assertions whose intent surpasses description. This is particularly the case concerning accusations of ideological science behind the Anthropocene Hypothesis, but it also pertains to ascribing certain epistemic virtues to the hypothesis, the scope and aim of the hypothesis, its novelty in geological research, and its overall legitimacy as a scientific hypothesis. Here, some arguments are advanced that take a stance in favor of the recognition of Anthropocene Hypothesis as a legitimate, and unprecedent in its kind, *scientific* hypothesis. The implications of embracing this viewpoint are also discussed.

The research is structured as five chapters, followed by the conclusion and an appendix. Each chapter raises questions whose answers are indispensable in tackling the central goals of this research.

Chapter 1 frames the broader multidisciplinary framework of the Anthropocene Hypothesis. The following questions are raised: *What is the 'Anthropocene'? What distinguishes it from the Anthropocene Hypothesis? What use is it to distinguish between the 'Anthropocene' and the Anthropocene Hypothesis?* To answer these questions, the chapter investigates the recently established field of Anthropocene Studies and the main research trajectories informing it. Anthropocene Studies represents a multi- and interdisciplinary field of knowledge converging in the study of the 'Anthropocene' as a global phenomenon of an anthropogenic nature. After exploring the primary research trajectories informing this nascent field of inquiry, the theoretical and practical distinction between the 'Anthropocene' as a boundary object and the Anthropocene Hypothesis as a stratigraphic variant is advanced. This separation underpins the rest of the research, delimiting its scope of inquiry to the Anthropocene Hypothesis, but also enabling an analysis of the semantic tensions between these two theoretical units.

Chapter 2 reconstructs the birth of the Anthropocene Hypothesis through complementary quantitative and qualitative analyses. The following questions are raised: *What happened during the early history of the 'Anthropocene' concept? How was the term used, and by whom? How did the 'Anthropocene' engender the birth of the Anthropocene Hypothesis?* To answer these questions, the chapter probes into the early history of the 'Anthropocene' by surveying a corpus of literature using the term during its first decade of existence (i.e., 2000–2009). From a quantitative standpoint, the research uses text mining techniques to identify salient properties of a corpus of 670 written records. This analysis provides a quantitative overview of the early history of the 'Anthropocene' concept in academic literature. From a qualitative viewpoint, a selected pool of texts is analyzed through discourse analysis. These texts are considered emblematic of the ways the term 'Anthropocene' was perceived, assimilated, and used. Additionally, the qualitative analysis uses personal communication with authors who played a role in the assimilation and popularization of the term. Reconstructing the early history of the 'Anthropocene' is considered a necessary precondition for reconstructing the birth of the Anthropocene Hypothesis.

Chapter 3 explores and discusses the empirical body that makes the Anthropocene Hypothesis a stratigraphic hypothesis, and it reviews alternative and competing hypotheses. The following questions are raised: *What is the empirical body of the Anthropocene Hypothesis? What alternative stratigraphic, and broader scientific, proposals have advocated for a scientifically useful 'Anthropocene'?* The latest scientific evidence gathered by the research gravitating around the AWG is surveyed to answer the former question. The survey is paralleled to an examination of the basic definitions, principles, and procedures of stratigraphic classification which inform the epistemology of the Anthropocene Hypothesis. Then, the panorama of extant scientific hypotheses about the 'Anthropocene' and its beginning is discussed. Locating the beginning of the proposed unit has been one of the most discussed aspects of the Anthropocene Hypothesis. Therefore, discussing the spectrum of alternative proposals is considered a necessary ingredient in framing the epistemology of the proposal advanced by the AWG.

Chapter 4 delineates an epistemological outline (in a strict sense) of the Anthropocene Hypothesis. The following questions are raised*: What are the epistemological implications of considering the Anthropocene Hypothesis* *a* scientific *hypothesis? Which epistemic virtues (if any) does the Anthropocene Hypothesis exhibit that are traditionally defined by philosophers of science? What does extant philosophical scholarship have to say about the 'Anthropocene' and the Anthropocene Hypothesis?* Answering these questions requires first framing the reception of the 'Anthropocene' in extant philosophical scholarship, assessing which philosophical domains absorbed the 'Anthropocene' as a philosophical category. Particular attention is given to the apparent lack of interest from philosophy of science in either the 'Anthropocene' or the Anthropocene Hypothesis. After reasons informing this circumstance are given, a few contributions from the philosophy of science are discussed. Subsequently, influential models in philosophy of science are used to determine whether or not the Anthropocene Hypothesis exhibits epistemic characteristics and virtues commonly said to define science and scientific knowledge. These models focus primarily on the epistemology of historical hypotheses, and on the nature of scientific explanation and scientific understanding.

Lastly, Chapter 5 focuses on the critical debates about the 'Anthropocene' concept and the Anthropocene Hypothesis that have emerged over the past decade. The following questions are raised: *What arguments have been advanced against the 'Anthropocene' and its stratigraphic interpretation? What difference is there between arguments against the 'Anthropocene' and those against the Anthropocene Hypothesis? Which aspects of the hypothesis have been particularly contested?* These questions are answered by converging and unifying independent lines of critique into single and easily identifiable arguments. The chapter explores how each of these identified arguments relates to the 'Anthropocene' or the Anthropocene Hypothesis, thus providing a roadmap to navigate the multiple lines of critique advanced in Anthropocene Studies. This is a useful endeavor not merely in strengthening the conceptual separation posited in this research, but also in asking whether arguments against the 'Anthropocene' equally hold against the Anthropocene Hypothesis. In particular, the arguments against the Anthropocene Hypothesis are scrutinized and discussed in light of their role in negotiating the evidence, and in light of the broader epistemology of hypothesis.

The research aims to contribute mainly to three areas of academic scholarship. First, it is a contribution to the *history and philosophy of science*, for which it serves a twofold purpose. On the one hand, it represents a case study of the birth and epistemology of a scientific hypothesis, specifically a stratigraphic hypothesis. Several applications could emerge from it – for instance, by comparing it to the emergence of similar scientific hypotheses, or by framing it within larger theoretical discourses on science. On the other hand, it encourages scholars in the history and philosophy of science to contribute to the Anthropocene Hypothesis debates. In doing so, it also promotes interest in the philosophy of geology, a largely underrepresented discipline in extant philosophy of science. Indeed, this knowledge domain is considered crucial in developing philosophical analyses of the Anthropocene Hypothesis because of its focus on the epistemology of geology. Nevertheless, this domain still remains a largely uncharted territory.

Second, it represents a contribution to *Anthropocene Studies*, a nascent field of inquiry gravitating around the 'Anthropocene' as a hub concept framing the present anthropogenic impact on the planet. The term has established itself as a successful category among academics as well as the public, which suggests that, regardless of the final outcome of the Anthropocene Hypothesis, the term may be here to stay. If this is the case, then an analysis elucidating the conceptual relationship between the 'Anthropocene' and the Anthropocene Hypothesis can only be beneficial in providing tools to further explore the semantic territories this term has to offer.

The third contribution is to *interdisciplinary research*. The interdisciplinary methods of inquiry adopted here make the overall endeavor an example of interdisciplinary work – and hopefully a successful one. Despite interdisciplinary research being "widely considered a hothouse for innovation, and the only plausible approach to complex problems such as climate change" (Bromham et al., 2016, p. 684), it still faces major difficulties primarily related to funding opportunities. University-based segregation of disciplines and issues inherent in developing functional models of interdisciplinarity (Heikkurinen et al., 2016; Inkpen & DesRoches, 2019; Toivanen et al., 2017) are also major obstacles to launching interdisciplinary projects. Amidst these practical and theoretical difficulties, perhaps the best remedy is to trial and error. Therefore, this study attempts to converge interdisciplinary methods of analysis. This is done without the aim of developing an interdisciplinary framework, but rather as an experiment that converges methods and theories across the disciplines at the forefront of research on both the 'Anthropocene' and Anthropocene Hypothesis.

Lastly, it should be noted that the history of the Anthropocene Hypothesis is still history in the making. The AWG is still presenting findings and results in support of the hypothesis, and a formal proposal to the International Commission of Stratigraphy is yet to be forwarded. Research on the Anthropocene Hypothesis, and on the 'Anthropocene' at large, is currently being conducted. Necessarily, this makes this overall effort somewhat incomplete in respect to the ultimate fate of the proposal of formal stratigraphic recognition of an Anthropocene Epoch (or other unit levels). Nevertheless, abundant empirical as well as theoretical research has emerged from the Anthropocene Hypothesis to make a discrete analysis of the hypothesis not only feasible, but also useful – if not necessary. The present research develops on this broad range of research literature.

If *Homo sapiens* has truly become a geological agent capable of leaving an indelible sign in the Earth's geohistory, then the scientific arguments supporting this idea need proper consideration. This effort has a broader societal as well as existential significance in highlighting (more or less implicitly) the ontological role of humans in the past, present, and future history of the Earth.

CHAPTER 1

FRAMING THE ANTHROPOCENE HYPOTHESIS

What is this world on which we live? How did life arise here? What is our future?
Among the myriad subjects of human curiosity and endeavor,
our Earth – its restless oceans and atmosphere, its shifting layers of rock and ice,
and its extraordinary variety of life –
has always been a center of our attention.

—NASA National Research Council, *Earth System Science: A Closer View*

The Anthropocene Hypothesis is one among several variants of the 'Anthropocene' concept – specifically, its *stratigraphic* or *geological* variant. Connecting sensitive discourses on historical responsibility, climate change, global warming, sustainability, and humans, the 'Anthropocene' has become an overarching social, political, and academic category for framing and discussing the present human–Earth relationship. A large pool of disciplines from different knowledge domains have used their knowledge, methods, and experience to dissect, deconstruct, shape, readapt, and transform the 'Anthropocene' concept. The present chapter seeks to frame the Anthropocene Hypothesis within this particularly explorative and still unfolding research landscape. In doing so, the object of the overall research is also delimited and defined.

Hence, section 1.1 introduces the research landscape gravitating around the 'Anthropocene' idea. It provides a condensed overview of the global 'Anthropocene' research agenda, whose multidisciplinary effort has engendered the nascent field of Anthropocene Studies. An analysis of this in-the-making field of study is conducted based on the multidisciplinary and transdisciplinary (Balbo et al., 2020) reach of the 'Anthropocene' idea. Connected to the emergence of this field of study, this section also introduces the *issue of definition* – an issue pertaining the multidisciplinary understanding, use, and application of the 'Anthropocene' concept. Indeed, with the 'Anthropocene' as a theoretical entity shared amongst a wide spectrum of disciplinary fields of knowledge, it is now difficult to encapsulate its meaning into a standardized definition without the risk of losing some of its distinctive nuances.

Section 1.2 focuses on broader historical and geohistorical research trends that have emerged within Anthropocene Studies. Four discrete research trajectories are identified as engendering the multidisciplinary historical study of the 'Anthropocene,' namely, its history as a geological time unit, as an Earth System singularity, as a historical rupture, and as a theoretical entity. Each trajectory is analyzed individually by reviewing existing literature and providing additional critical remarks to the debate. Examining this literature is functional to locating this research as an attempt to study the conceptual history and epistemology of the 'Anthropocene' as a scientific idea.

Finally, section 1.3 outlines the methodological and theoretical premises that are implemented. First, it distinguishes two general ways the 'Anthropocene' concept is implemented in extant research: as a descriptive 'Anthropocene' and a normative 'Anthropocene.' After framing the present research within the limits of the descriptive 'Anthropocene,' a separation between the 'Anthropocene' concept and the Anthropocene Hypothesis is promoted. Lastly, an explanation of the methodologies used to approach the Anthropocene Hypothesis is given.

The research systematically highlights the 'Anthropocene' (with apostrophes) as a broader and polysemantic conceptual and linguistic category (within or outside natural sciences) to distinguish it both from the Anthropocene Hypothesis, and from the Anthropocene (without apostrophes) as a proposed unit of geological time. This linguistic remark should facilitate the theoretical distinction underpinning the aim of this overall endeavor as well clarify what conceptual unit is being treated throughout the sections.

1.1 The 'Anthropocene' and Anthropocene Studies

What is the 'Anthropocene'?

The 'Anthropocene' is a term used to identify a proposed geological time unit with disputed meanings and starting dates. The concept encompasses a diversified range of scientific evidence suggesting a departure from the Holocene Earth System conditions. The term was first popularized by Nobel laureate Paul Crutzen in 2000, later gaining momentum after a dedicated stratigraphic research group, the Anthropocene Working Group (AWG), was established in 2009 by the Subcommission on Quaternary Stratigraphy (SQS), part of the International Commission on Stratigraphy (ICS), itself part of the larger International Union of Geological Sciences (IUGS). The AWG has been tasked to examine whether sufficient evidence exists to warrant the possible recognition of the Anthropocene as a distinct unit of the international chronostratigraphic chart, which serves as basis for the geological time scale. In simpler words, the group is assessing whether the Earth is entering a new phase of its geological history – one marked by of human activities.

The term has also seen usage among other scientific communities, where it emphasizes other aspects of the human–Earth relationship. For instance, in the Earth System science community, the 'Anthropocene' is understood as a time interval of considerable anthropogenic disruption of Earth System functioning, beginning (at least) with the Industrial Revolution, and increasing markedly after the 1950s (Steffen et al., 2016; Steffen et al., 2020; Steffen et al., 2018). In ecology and evolutionary biology, the term is often found in literature addressing the ongoing sixth major extinction event in life's documented history – one considered anthropogenic (Ceballos et al., 2017; Pena Rodrigues & Lira, 2019). Across scientific disciplines, the term is often used to frame environmental research on the local and global impact of humans on the Earth.

These opening paragraphs briefly summarize the scientific research revolving around the 'Anthropocene.' This research provides a *scientific understanding* of the 'Anthropocene' as a geological time unit, as an Earth System singularity, or as an event in the Earth's life history. However, the 'Anthropocene' debate is not utterly exhausted by and within the scientific research agendas. Scientific understanding constitutes but one form of understanding of the 'Anthropocene' among a landscape of possible 'understandings' that authors have framed as the 'Anthropo-scene' (Castree, 2015; Lorimer, 2017). In the years following the popularization of the term, and the formation of the AWG, several disciplines outside the realm of the natural sciences have been critically approaching the term. This surge in multidisciplinary interest came especially from the humanities and social sciences, whose contributions to the 'Anthropocene' engendered a debate that has paved the way for additional narratives to those portrayed by the natural sciences (Bonneuil, 2015). Today, the term 'Anthropocene' does not merely reflect the geological signatures of humans on the planet – it mirrors the "general concept of accelerating human influences on Earth" (Chin et al., 2016, p. 1), and the social and cultural challenges that come with it. In the words of environmental historian Libby Robin (2014a), the 'Anthropocene' is not exclusively a scientific hypothesis: it has become a "metaphor for a changing society" (p. 19).

Thus, understanding the 'Anthropocene' as a metaphor or 'boundary object'[2] requires an understanding of the disciplinary contexts, goals, and methods of analysis approaching this concept, and of how interplays within this network of knowledge shape its multiple definitions. During the past decade, this network has gradually begun to grow into a distinct field of study – namely, Anthropocene Studies.[3] This research zone is characterized, first and foremost, by its multidisciplinarity. As it will be explained in this subchapter, this aspect constitutes both a strength and a weakness.

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[2] The term 'boundary object' is borrowed here from the traditional sociological sense provided by Susan Leigh Star and James R. Griesemer referring to an abstract or concrete object with different meanings in different social worlds, plastic enough to adapt to contexts but robust enough to maintain an identity (Star & Griesemer, 1989). The designation is not embraced to discuss the core object of this present research (the Anthropocene Hypothesis), but it considered suitable to explain the nature of the 'Anthropocene' concept (discussed later in section 1.3.2).

[3] The designation 'Anthropocene Studies' does not follow the apostrophizing criteria set at the beginning of the chapter.

1.1.1 Anthropocene Studies

The trans-, inter-, and multidisciplinary[4] study of the 'Anthropocene' as a broader geological, historical, cultural, and social phenomenon (Toivanen et al., 2017) is the central aim of the emerging academic field of Anthropocene Studies. This inchoate, "scholarship-in-the-making" (Swanson et al., 2015) research landscape aims at debating, researching, teaching, and representing the 'Anthropocene' in its every aspect, from geological time unit and Earth System disruption to socio-historical transition, intellectual provocation, and cultural, artistic, religious (Bedford-Strohm, 2017), and popular phenomenon. This multidisciplinary effort is horizontal, meaning no discipline sits on the sideline or as ancillary to another; political, meaning the research conducted does not passively describe the 'Anthropocene' but seeks to inform policy makers and the public (Bostic & Howey, 2017); and educational, insofar as it promotes educational programs advocating environmental awareness and societal transformation (Adorno, 2020; Leinfelder, 2013).

Historian Christophe Bonneuil identifies four 'grand narratives' informing the 'Anthropocene' and its study, namely, (1) the naturalist, which he considers the mainstream one, portrayed by the natural sciences and media; (2) the post-naturalist, mainly represented by the eco-pragmatist school of thought (Dalby, 2016); (3) the eco-catastrophist, portrayed by predictions of worldwide ecological collapse; and (4) the eco-Marxist, portrayed by the link between the Anthropocene and capitalism. Another outline of Anthropocene Studies is provided by Toivanen et al. (2017), focusing on four *approaches* rather than *narratives* – that is, the geological approach (based on stratigraphic evidence), the biological approach (based on the long-term impact of humans on the biosphere), the social approach (based on the historicization of the biological and stratigraphic approaches into a social context), and the cultural approach (based on creative and speculative understanding of the 'Anthropocene').

Yet to establish itself as a fully institutionalized disciplinary domain or field of knowledge, Anthropocene Studies is fueled not exclusively by individual thinkers engaging with the 'Anthropocene' concept, but also by the formation of research communities, online and publishing platforms, and dedicated projects worldwide. For instance, between 2013 and 2014, the Haus der Kulturen der Welt (HKW) of Berlin[5] hosted a pioneering event in Europe – the Anthropocene Project[6] (HKW, 2014) – connecting academics, independent researchers, and the public in a multidisciplinary and non-disciplinary conversation on the Anthropocene. Its main long-term outcome, the joint HKW–Max Planck Institute for the History of Science *Anthropocene Curriculum*, is an ongoing project exploring "pathways toward a new interdisciplinary culture of knowledge and education" (HKW, 2013). The strong educational motif of the *Curriculum* may be considered an important moment in the development of Anthropocene Studies. In the so-called 'Science Station' of Unter den Linden in Berlin, sixteen artistic panels by graphic designer Nele Brönne have been

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[4] See Darian-Smith and McCarty (2016) on the difference between various types of interaction between disciplines.
[5] Other educational and artistic projects held in Germany are described in Leinfelder et al., 2012 and Leinfelder, 2013.
[6] To be distinguished from the visual culture–oriented 'Anthropocene project' developed by Nicholas de Pencier, Edward Burtynsky, and Jennifer Baichwal (https://theanthropocene.org/, accessed on May 23, 2021).

exposed as representative of the 'Anthropocene,' including a panel (both in German and English) shortly explaining the meaning and implication of the 'Anthropocene' to the several thousands of daily *Berliner Verkehrsbetriebe* guests.[7]

In the years following the establishment of the AWG, the Anthropocene also became an object of interest for environmental humanists (Castree, 2014b). Their primary focus has been retracing the (environmental) history of this proposed epoch, for instance, by stressing its colonial and capitalist matrix – bringing scholars to coin conceptual alternatives such as (among many) the Thanatocene (Bonneuil & Fressoz, 2016), Plantationocene (Haraway, 2015), or Capitalocene (Moore, 2016b),[8] to name only a few – to highlight the historical mechanisms that caused the 'Anthropocene.'[9] Scholars from ecocriticism and postcolonial theory joined the conversation by addressing normative issues such as the ethical and moral implications of living in the 'Anthropocene' (Zylinska, 2014), the seemingly generalizing notion of *Anthropos* (from the Greek ἄνθρωπος, meaning 'human') implicit in the term 'Anthropocene' (Emmett & Lekan, 2016), or the question concerning responsibility (Dalby, 2007b; Neimanis et al., 2015) and colonial thinking (Simpson, 2020). Social scientists too have addressed the term by considering the cultural-ladenness of the 'Anthropocene' concept, while also criticizing it as a Western product of social forms of inequality based on "huge social, cultural and technological differences across time and space" (Ellis, 2016a, p. 192). Literary theorist Heidi Bostic and anthropologist Meghan Howey summarize Anthropocene research in the humanities and social sciences as a matter of questions asked: "Although defining the 'when' of the Anthropocene is important, the who, what, where and why are equally, if not more, compelling and challenging questions we [in the liberal arts] must ask" (Bostic & Howey, 2017, p. 105).

Scholarly interest in the notion of the 'Anthropocene' has not limited itself to the mere interest of experts in geology, environmental history, or other disciplinary domains. University departments and research institutes have also begun to explore this uncharted territory by establishing dedicated research centers. Examples of such initiatives are the AURA (Aarhus University Research on the Anthropocene) project, hosted by Aarhus University in Denmark from September 2013 to December 2018; the Centre for Biogeochemistry in the Anthropocene, under the Faculty of Mathematics and Natural Sciences at the University of Oslo, launched in 2018; a Center of Anthropocene Studies (CAS) opened in June 2018 by the Korea Advanced Institute of Science and Technology in Daedeok, South Korea; the Leverhulme Centre for Anthropocene Biodiversity in York, the product of a partnership between four different universities,[10] operating since November 2019; and a 'Biodiverse Anthropocenes' research program was launched in 2021, hosted by the University of Oulu. Since 2017, Department I of the Max Planck Institute for the History of

[7] The initiative is a joint project of the Humboldt-Universität zu Berlin, Schiel-Projektgesellschaft, the exhibition agency TheGreenEyl, and the Office for Precarious Concepts. As of September 3, 2021, the panels are still exposed.
[8] The term 'Capitalocene' is discussed separately in section 1.2.3; 'Thanatocene' stresses the overall effects of the military–industrial complex to the environment; and 'Plantationocene' underscores the "power relations and economic, environmental, and social inequalities" (Moore et al., 2020) engendering the 'Anthropocene.'
[9] A useful source with some of the terminological variants proposed thus far in Anthropocene Studies is provided by literary theorist Steven Mentz (2020), who mockingly entitled his blog article "The Neologismcene."
[10] The universities: Australian National University, University of St. Andrew, Université de Sherbrooke, and the University of York.

Science of Berlin has been hosting a research group dedicated to 'Knowledge in and of the Anthropocene.' The Department of Geography at the University of Cambridge offers a 11-month Master of Philosophy degree in Anthropocene Studies covering a wide transdisciplinary selection of topics, from dendrochronology and climatology to climate engineering and human migration. An MSc. program 'Strategy and Design for the Anthropocene' is offered by the ESC Clermont Business School in France. Courses addressing several aspects of the 'Anthropocene' are now being offered worldwide, especially among Anglo-Saxon universities. The educational aspect of the 'Anthropocene' has now gained momentum, especially in disciplines concerning human–environment interactions such as environmental history (Adorno, 2020).

Dedicated publishing platforms have also been developed in the past decade, from peer-reviewed journals to blogs and virtual exhibitions. As part of its mission to promote planetary awareness and foster stewardship, the website Globaïa[11] was launched in 2009. In June 2012, Globaïa opened the United Nations Conference on Sustainable Development (otherwise known as Earth Summit or Rio+20) with a three-and-a-half-minute-long video introducing the 'Anthropocene' – a "new geological epoch dominated by humanity" (Globaïa, 2012). In cooperation with other research institutions, Globaïa also launched the website Anthropocene.info on occasion of the World Economic Forum in Davos and COP21 in Paris in 2015. The website provides visitors with an interactive list of proposed starting dates for the Anthropocene in the larger context of the history of the genus *Homo*.[12]

The first issue of *Anthropocene* – a journal by Elsevier – was published in September 2013 to advance "research on human interactions with Earth systems" (Chin et al., 2013, p. 1). *Elementa: Science of the Anthropocene* begun publishing in December 2013, focusing on the interaction between humans and natural systems from a physical, chemical, and biological point of view. In April 2014, *The Anthropocene Review* published its first issue, promoting the necessity "to communicate among disciplines and conceptual frameworks" (Oldfield et al., 2014, p. 5), and to foster interdisciplinary research on the Anthropocene. None of these journals emerged directly in support of the quest to formalize the Anthropocene on the geological time scale. Rather, they commonly understood the 'Anthropocene' as a broader phenomenon requiring diversified and interactive knowledge and platforms of research. As such, they laid the foundations for the emergence of Anthropocene Studies as an academic phenomenon characterized by "an ample transdisciplinary background, major philosophical questions and huge challenges and debates" (Hardt, 2017, p. 9). In 2017, an *Encyclopedia of the Anthropocene* was published, and the term now features in major encyclopedias as well.[13]

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[11] https://globaia.org/ (accessed on June 14, 2020).
[12] Timeline available at http://www.anthropocene.info/anthropocene-timeline.php (accessed on June 14, 2020). The website also provides additional information on the Anthropocene from an Earth System science perspective (e.g., Great Acceleration graphs, Planetary Boundaries, etc.).
[13] *Encyclopædia Britannica* is an example. Interestingly, the Anthropocene is visually represented on the geological time scale under the entry 'Geologic time' (https://www.britannica.com/science/geologic-time, accessed on June 30, 2020). Some early appearances of the term 'Anthropocene' in various scientific encyclopedias are mentioned later in section 2.1.3.

It is hard to assess how evenly 'Anthropocene' research is now distributed among the academic disciplines involved in Anthropocene Studies, and how much each individual discipline has contributed in the 'Anthropocene' debates. Social scientist Judith N. Hardt seems to consider Earth System science and positivistic epistemology to heavily inform Anthropocene Studies, a challenge that social and political sciences must face in developing a form of "anthropocene thinking" (Hardt, 2017, p. 8). Whereas this claim seems to suggest that natural science is dominating the debate, as also argued by other critics of the 'Anthropocene' narrative (Bonneuil, 2015; Moore, 2016c), the recent years have seen humanities, social sciences, and arts engaging and shaping the term more than the natural sciences. This is confirmed by the spawning of terminological variants, each following a discrete research trajectory within the broader 'Anthropocene' category. Simply overviewing the results of Googling 'anthropocene cfp' (i.e., 'call for papers') also shows a predominantly humanistic interest in the term (as of 2021).

Determining how the various forms of multi-, inter-, and transdisciplinarity in Anthropocene Studies should be conducted *in practice* has remained an open question that has hardly found a commonly accepted solution so far. This issue has been clearly outlined by a team of humanists and social scientists working on multidisciplinarity. Based on a threefold modality of interdisciplinarity outlined by Barry et al. (2008),[14] Toivanen et al. (2017) find the agonistic-antagonistic mode, conceived not as synthesis nor as division of labor but as "criticism of or opposition to the intellectual, ethical or political limits of established disciplines" (Barry et al., 2008, p. 29), as the "best route toward a fruitful advancement of science and knowledge" (Toivanen et al., 2017, p. 4) in Anthropocene Studies. Much of the 'Anthropocene' debate has indeed been based on forms of antagonism, especially between the humanities and natural sciences, that encouraged rather than halted further research on both sides.

Even among a broader, non-academic audience, the 'Anthropocene' has echoed through artistic forms and expressions – most notably, music and art exhibitions. "Anthropocene" is a 2016 song by former Pakistani rapper Shayan Afridi, or 'Samsa,' as well as the 2017 album title from US-American singer and songwriter Peter Oren. The term 'Anthropocene' appears in English musician Nick Mulvey's song and music video "In the Anthropocene," and also in *Miss Anthropocene*, the studio album title from Canadian musician Claire Elise Boucher, professionally known as Grimes.[15] A key contribution to opening the term to a broader audience was Jennifer Baichwal, Nicholas de Pencier, and Edward Burtynsky's documentary film *The Anthropocene*, premiered in 2018. The term saw increasing interest among museum and gallery exhibitions too, from the Deutsches Museum's *Welcome to the Anthropocene* of 2014–2016 to the art exhibition *Anthropocene* held in Chelsea in 2018, curated by Elisabeth Johs. An Anthropocene exhibition is expected to take place in Tallinn in 2023. Symbolic of the non-academic interest in the term is a wristwatch from the

[14] The three modes of interdisciplinarity are 'integrative-synthesis' mode, 'subordination-service' mode, and 'agonistic-antagonistic' mode.

[15] These offer just a glimpse of the musical reception of the 'Anthropocene.' Additional artistic and musical adaptations of the term are listed in Erle Ellis's *Anthropocene: A Very Short Introduction* (Ellis, 2018, p. 142). See also Currier (2014) for a contribution in ecomusicology.

British watch company Christopher Ward named 'Anthropocene,' an opera from Stuart MacRae and Louise Welsh,[16] and even a post-apocalyptic thriller directed by Emir Skalonja named *Anthropocene*.

In fact, art has become a major contributor to Anthropocene Studies in recent years. Rather than a mere visual tool for personal interpretation and realization of the art object, 'art in the Anthropocene' is a tool "to share meaning and transform values" (Davis & Turpin, 2015a, p. 3) at the intersection of aesthetics, politics, environmental awareness, and knowledge (Davis & Turpin, 2015b). Such is, for example, the 'Aerocene' project initially launched by Argentinian contemporary artist Tomás Saraceno. His flying sculptures (*Museo Aero Solar*), fueled by wind or solar power, met the 'Anthropocene' idea in a 2014–2015 art exhibition held in Toulouse to form an *Anthropocène Monument* – a solar sculpture made of reused plastic bags. The exhibition brought humanists and scientists together to discuss the meaning and representation of the 'Anthropocene' as object of sensorial interpretation, but also as a time calling for action (Latour & Davis, 2015; Saraceno et al., 2015).

Among the main venues where the term gained attention and spread are academic journals as well as media outlets. Already in 2003, the editorial of *Nature* opened its 424th volume with a "Welcome to the Anthropocene" (Nature, 2003) – only the first of a series of many 'welcomes' to the epoch.[17] In 2004, the term appeared in *The New York Times*, where it was stated that "[i]t is now clear that the Earth has entered the so-called Anthropocene Era" (Wallström et al., 2004). In 2008, it was *BBC News'* turn to recognize the term (Pease, 2008), followed by the popular *Economist* headline "The geology of the planet: Welcome to the Anthropocene" (Economist, 2011). After a few appearances in *The Guardian* (Carrington, 2016; Sample, 2014), its widespread adoption made it harder to track its use in media platforms.

Over the years, the 'Anthropocene' has become more than an object of exclusive scholarly interest. The term has transgressed the boundaries of academia, resonating in many aspects of human society – from journalism and music to art and museology. However, on the edge of this exponential interest in the term in both public discourse and scholarly research, it has become hard to delineate a shared framework for defining the 'Anthropocene' in a multifunctional fashion. The semantics of the term has become blurred, oftentimes falling into relativism by merely becoming a matter of subjective interpretation. This recognized issue (Delanty & Mota, 2017; Jahn et al., 2015; Luciano, 2019; Semal, 2015; Stallins, 2020) is a central problem for the development of Anthropocene Studies, a field already facing problems related to its novelty and contested nature. In some ways, Anthropocene Studies seems to replicate the same issues that philosopher of science Peter Godfrey-Smith identified in the field of Artificial Life. This is a new field of knowledge that emerged during the 1980s and 1990s seeking to merge computer science and biology to model living systems. Discussing Thomas Kuhn's idea of normal science, Godfrey-Smith (2003) argued that "there was not nearly enough work that *built on"* literature on Artificial Life (p. 85), halting further

[16] Information about the opera is available at https://www.scottishopera.org.uk/shows/anthropocene/ (accessed on February 8, 2021).

[17] The list (where "Welcome to the Anthropocene" appears in the title) includes: Nature (2003), Crutzen (2005), Baum (2008), deBuys (2008), Dalby (2011), Economist (2011), Anthropocene.info (2012), Clémençon (2012), Slaughter (2012), AESS (2014), Möllers et al. (2015), Dyer (2016), di Chiro (2017), Major (2017), and Lewis and Maslin (2018).

developments of the field. Another reason for Artificial Life not to transition into “anything resembling a normal science” was its “premature commercialization” (ibid.) – namely, the necessity of ‘selling’ the idea for academic rewards outside the rationale of genuine puzzle-solving typical of normal science. Although Artificial Life is now seeing new vigor thanks to increased computing power and efficiency of simulators, its original issues are to some degree analogous to those that Anthropocene Studies is currently facing.

Not all scholars (either natural scientists or humanists) agree on the usefulness of the term. A recurrent line of accusation has been the seemingly ideological aspect of the ‘Anthropocene’ – that is, the term “provides the ideational underpinning for a particular view of the world” (Baskin, 2015, p. 10) that is self-legitimizing. This view questions the genuine ‘scientificity’ of the term, accused of being a political statement rather than a scientific commitment (Finney & Edwards, 2016). Further criticism addresses the very usefulness of the term, considering it unnecessary or useless because the extent of human action is already reflected “throughout the Holocene” (Morrison, 2015, p. 76), or because of the negligible effects of human civilizations on the geological record (Visconti, 2014). Sociologist Eileen Crist criticizes the poor choice of a name, for the term seems to offer “no added substantive content, no specific empirical or ethical overtones, no higher vision ensconced within it” (Crist, 2013, p. 142). Radical forms of criticism go as far as considering the term as an academic invention (Visconti, 2014), a form of supreme narcissism (Jensen, 2013), a pop culture phenomenon (Autin & Holbrook, 2012), or simply nonsense, “a fad, a bandwagon, a way of marketing research as cutting-edge and relevant” (Scourse, 2016). Some of this criticism addresses the sociological aspect of Anthropocene Studies, redirecting criticism toward the very nature of some research conducted by the academic enterprise. A more thorough discussion of criticism of the Anthropocene (and the Anthropocene Hypothesis) is provided in Chapter 5.

Despite fierce criticism, and regardless of the outcome of the proposal for formal recognition, it seems that the ‘Anthropocene’ is here to stay. As geologist David Rull (2018) has pointed out (with a critical overtone), for “non-geologists, formalization seems not to be relevant and the term is freely used” (p. 5). If this is the case, then the term may endure by embracing new meanings and trajectories (as is already happening) in the years ahead.

1.1.2 The Issue of Definition

The development of Anthropocene Studies as a multidisciplinary field of knowledge is a symptom of widespread interest among academic as well as public audiences in this captivating term. While this newborn research field has proven to be a creative hub for diverse disciplinary discourses, it faces a major hindrance in establishing a multifunctional framework for the involved disciplines to discuss and debate the ‘Anthropocene.’ Such is the issue of definition – that is, how to define the ‘Anthropocene’ in a way that (1) it is not exclusively a matter of subjective interpretation, (2) it is not exclusive of a single disciplinary domain, and (3) it is a sharable and functional object among disciplines. This issue manifests in several ways, from multiple extant definitions (even within the same field of knowledge) to the relatively recent nature of the term attracting hasty attention through media coverage.

Because the 'Anthropocene' concept diversifies primarily through and across disciplinary domains, defining it 'Anthropocene' heavily relies on the discipline one is situated in (if not even on one's personal taste in music). Within the realm of the natural sciences alone, scholars have identified at least three definitions: a proposed interval in geological history, a rupture in the functioning of the Earth System, and the cumulative footprint of humans on the planet, from urbanization to resource extraction (Hamilton et al., 2015b). Social theorist and environmental humanist Ben Dibley (2012) finds seven units of meaning that the term 'Anthropocene' encapsulates, namely (1) a geological epoch and discourse, (2) a folding of historical and geological time, (3) a narrative of the consequences of globalization and modernity on the concept of freedom, (4) an ambivalent reiteration of the nature–culture dichotomy, (5) attachment, dependency and responsibility toward the Earth, (6) the financialization of the Earth System, and (7) the development of a common future outside the semantics of the modernist ideal of Progress. Crutzen himself cannot avoid noticing how defining the Anthropocene has now become "a more difficult task than giving a scientific talk" (Crutzen, 2015, p. 32). Geologist Whitney J. Autin (2016) surveyed possible meanings of the Anthropocene, focusing on the multiple conceptual dichotomies the concept has generated (e.g., formal vs. informal Anthropocene, good vs. bad Anthropocene, conservative vs. liberal politics, artistic nostalgia vs. dystopias) and perceptions of the 'Anthropocene' across disciplines.[18]

Whereas interested scholars have perhaps acknowledged a common understanding of the underlying geological denotation of the 'Anthropocene,' they have been battling over what to consider the most pressing aspects to tackle *in* and *about* this newly proposed epoch – confirming the agonistic-antagonistic multidisciplinary model of Anthropocene Studies suggested by Toivanen et al. (2017). Within this research model, the very first definition of the 'Anthropocene,' which emerged from the natural sciences, became contested. Is the 'Anthropocene' more than a geological epoch? What if its properties extended well beyond the realm of geology? To what extent did current modes of existence bring about the 'Anthropocene'? And which societies are more responsible for its dawn? Humanists and social scientists answer these questions by claiming the 'Anthropocene' cannot be defined exclusively in geological and Earth System science terms (Bostic & Howey, 2017; Ellis, 2016a; Lewis & Maslin, 2015a).

This line of inquiry excludes the 'easy' solution of simply ascribing to the 'Anthropocene' its 'true meaning' based on the narrative of the natural sciences. For instance, 'Anthropocene' researchers and literary theorists Eva Horn and Hannes Bergthaller (who are mentioned again later in this chapter) provide an extended definition of 'Anthropocene,' whilst also highlighting the issues emerging in Anthropocene Studies:

> The Anthropocene is a concept which challenges the foundations of humanities scholarship as it is traditionally understood. It calls not only for closer engagement with the natural sciences but also

[18] See also Zalasiewicz et al. (2021, Table 1) for similar summary of extant interpretations of the concept of 'Anthropocene.'

> for a synthetic approach bringing together insights from the various subdisciplines in the humanities and social sciences which have addressed themselves to ecological questions in the past. […] The difficulties of an introduction to the Anthropocene lie not only in the disciplinary breadth of the subject, but also in the rapid pace at which the surrounding debates have been, and still are, unfolding. (Horn & Bergthaller, 2020, p. III)

Raising conceptual challenges in delineating the 'ontology' of the 'Anthropocene,' namely *what makes* or *what are the properties of* the 'Anthropocene,' is essential for advancing the global research agenda on this global phenomenon. However, the surge in academic and popular interest brought about the pragmatic necessity of having a shared definition of the 'Anthropocene' for cross-functional purposes. Furthermore, difficulties of communications between domains of knowledge has been exacerbating the 'two cultures' (Snow, 1959) to the point that "quite a few contributions from the humanities tend to either ignore the scientific debates or even reject the sciences as inherently technocratic and hegemonic" (Horn & Bergthaller, 2020), and vice-versa. On top of this, the 'Anthropocene' has been characterized in different ways, more commonly as idea, concept, or hypothesis, but also as thesis (Davis & Turpin, 2015b; Hamilton et al., 2015b), theory (Luciano, 2018), meta-concept (Oliveira, 2019), effect (GRAID, 2016), event (Bauer et al., 2021; Brannen, 2019a), interdisciplinary theoretical framework (Trischler, 2014), transdisciplinary project (ibid.), elevator concept (Crist, 2013, footnote 40), boundary object (Braje & Lauer, 2020), conjecture (Olsson, 2021), or threshold concept (Clark, 2015), therefore adding a semantic component to the issue of definition.

These facts, when combined with occasional inaccurate or hasty media coverage (Carrington, 2016; Rull, 2016) and the lack of a broader theoretical framework, resulted in confusing, colliding, and mistaken interpretations of this new concept, with unavoidable and significant consequences for conceptual clarity. This is particularly true for the educational aspect of the 'Anthropocene.'

How, then, to provide a multidisciplinary and multifunctional definition of the 'Anthropocene'? Posing this fundamental question in Anthropocene Studies serves two purposes.

First, it warns about a core issue that reverberates in any research conducted in Anthropocene Studies – that is, the necessity of clarifying what *about* the 'Anthropocene' is being addressed. This simple, yet occasionally overshadowed, issue often results in contrasting methodologies of analysis (e.g., *historical* events used as primary data for *stratigraphic* research), proliferation of terminological variants ('Phagocene,' 'Anglocene,' 'Plantationocene,' 'Pyrocene,'[19] etc.), or equalization of the 'Anthropocene' to other environmental discourses, such as global warming, ecological reflexivity, or climate change. This recurrence does not help, but rather muddies multidisciplinary research efforts, giving rise to suspicions or skepticism toward the value of the term (Visconti, 2014).

[19] The terms 'Phagocene' and 'Anglocene' were coined by historians Christophe Bonneuil and Jean-Baptiste Fressoz in their 2016 monograph *The Shock of the Anthropocene*. The terms indicate, respectively, the role of consumerism, and the outsized contribution of the United Kingdom and USA to the dawn of the Anthropocene. The term 'Pyrocene' was first coined by environmental historian Stephen J. Pyne (2015), highlighting the role of fires in the 'Anthropocene.'

Second, it raises the question of whether it is necessary to have a cross-functional definition of the concept. Indeed, as it has been implicit so far, a cross-functional definition is essential for the field of Anthropocene Studies especially in facing relativism or interpretative anarchism – that is, any interpretation of the 'Anthropocene' being valid by virtue of being an interpretation. This is an especially pressing matter for the educational aspect of defining the term. For instance, one could consider any interpretation of the concept to be valid insofar as it provides a clear pedagogical understanding of it. Regardless of the criteria to determine the validity of any interpretation, the lack of a shared semantic framework must be acknowledged, for it constitutes a major theoretical point to address in the development of Anthropocene Studies.

Acknowledging these difficulties in defining the term, the ecocritic and environmental humanist Jeremy Davies (2018) as well as the AWG (Zalasiewicz et al., 2019b, para. 1.1; see also Zalasiewicz et al., 2021) even attempted to define it based on what the 'Anthropocene' is *not*. That is because the word, already considered by many to be worn out, "has been tossed into debate much more frequently than it has been explained or defined" (Davies, 2018, p. 6). Despite the aims of this strategy are to counter some forms of criticism toward the term (such as its being 'anthropocentric'), it might be insufficient to simply define the new epoch based on its criticism. That is because this approach still requires knowledge of the ontology of the 'Anthropocene,' which is implicit in the approach (otherwise, it would be impossible to assess what the 'Anthropocene' is not). Delineating this implicit ontology is precisely the issue at stake.

Another attempt to provide a unifying reference framework for Anthropocene Studies is given by plant ecologist Simon Lewis and Earth System scientist Mark Maslin (2015a, 2015b, 2018a). In a popular article published in *Nature* in 2015, the scholars advanced a definition of the 'Anthropocene' that would link humanities and geological research, hence providing a transparent framework (Lewis & Maslin, 2015b) for Anthropocene Studies. The link is established by considering the broader meaning of the starting dates to the epoch they propose, namely 1610 (coinciding with the European colonization of the Americas) and 1964 (coinciding with a peak in nuclear testing fallout). These dates, they argue, reflect major anthropogenic signals of importance in geological research and, at the same time, turning points in the history of humankind. Their argument constitutes an attempt to link historical, social, and geological research by outlining multidisciplinary criteria to set the beginning of the 'Anthropocene' (the importance of setting a beginning in geological and broader academic research is discussed in section 3.2; Lewis and Maslin's proposals are discussed in sections 3.2.3.2 and 3.2.4.3).

Anthropologists Todd Braje and Matthew Lauer (2020) suggest abandoning "the search for and debate over Anthropocene definitions" because "we risk losing out on the real power and promise of the concept" (p. 8). The potential and utility of the concept can best be grasped by considering it a 'boundary object,' ensuring "communication across disciplines by creating a shared vocabulary, and acknowledging that no one discipline has a privileged framework for describing the current epoch" (ibid.). In other words, attempting to define the term would only reduce underlying collaborative and multidisciplinary efforts informing Anthropocene Studies. As later argued, the broader 'Anthropocene' idea is in fact best represented as a boundary object. However, this understanding of the 'Anthropocene' differs from its stratigraphic or geological variant – namely, the Anthropocene Hypothesis. This theoretical entity does require definition, and should best be framed as a scientific (stratigraphic) hypothesis rather than a boundary object.

There are many further attempts to clarify the term, or to provide a general operating framework for the 'Anthropocene' research communities worldwide. What is important to stress in this section is that the fundamental issue in defining the 'Anthropocene' is not so much the multidisciplinary nature of the term, or the debate surrounding it; nor exclusively the rapid pace at which the 'Anthropocene' has been spreading among disciplines outside the natural sciences. Rather, it is rooted in the lack – or difficulties in forging – a set of shared methodologies for multidisciplinary research among disciplines, particularly among different fields of knowledge, such as humanities and the natural sciences. Consequentially, no shared framework (linguistic, conceptual, or methodological) can ease the translation and operationalization of the term among knowledge domains. This issue – to some extent a contemporary replica of the 'two cultures,' but also, as it should be noted, a consequence of consistent low funding of interdisciplinary research (Bromham et al., 2016) – sits at the core of many of the conflicts between human and social sciences on the one hand, and natural and applied sciences on the other, and is vividly manifesting in Anthropocene Studies.

What definition is adopted within this present research, then? As already highlighted in the introduction to this work, the present investigation adopts the definition of 'Anthropocene' shaped by the stratigraphic and geological discourse. Specifically, the object of research is the Anthropocene Hypothesis, or geological or stratigraphic formulation or variant of the 'Anthropocene.' A more accurate definition of the Anthropocene Hypothesis is provided in section 1.3, together with a description of the differences between the 'Anthropocene' concept and the Anthropocene Hypothesis. Delineating the conceptual history and epistemology of the Anthropocene Hypothesis is the primary target of this overall endeavor. Without necessarily considering it *the* answer to the issue of defining the 'Anthropocene' for a common, cross-functional framework, this choice is rather based on the nature of the object and scope of the present research – that is, delineating the conceptual history and epistemology of the Anthropocene Hypothesis to differentiate as a theoretical entity from the broader 'Anthropocene' category.

It might be reasonable to believe that advancing a definition might vanquish the issue of clarity right away. Unfortunately, this is not the case. The definition hereby adopted is only a momentary and partial solution to the scope of the research. Providing an operating definition of the 'Anthropocene' is a necessary but insufficient requirement for conducting a sound analysis of the term. Humanists and natural scientists might agree on the definition of a 'geological Anthropocene,' but that would not solve semantic barriers behind their *understanding* of the 'Anthropocene.' That is because the term 'Anthropocene' has no meaning in isolation – in fact, its meaning is drawn from the determined semantic/conceptual network that implements the term. This form of 'semantic holism' – a central theme in the philosophy of language and theory of meaning of the 20th century – is another major challenge for the development of a multidisciplinary framework to understand the 'Anthropocene,' especially considering the novelty and contested status of the term.

The polysemy of the term represents a double-edged sword. On the one hand, the term has seen much and diversified publicity. As a result, it seems to lack semantic depth to the point that, as an umbrella category, it means everything and nothing. This is an epistemic weakness. On the other hand, the plurality of definitions offered by scholarly engagement have transformed the term into a hub for critical discussions, connecting themes within the environmental agenda, but also among different disciplinary domains. This is an epistemic strength. Ultimately, the term 'Anthropocene' is a concept-in-the-making, so any last judgement on its utility, meaning, or fate is yet to be declared

1.2 Histories of the 'Anthropocene'

A central heuristic in defining the 'Anthropocene,' and thus in framing the Anthropocene Hypothesis, is retracing its conceptual history because it provides key insights on the term's semantics. A suitable starting point for such analysis is inquiring into the plurality of meanings the phrase 'history of the Anthropocene' entails.

Section 1.1 highlighted the interest that the term has sparked in academia as well as in popular culture. This interest engendered a spectrum of research trajectories and criticism (discussed in Chapter 5) concerning multiple aspects of the 'Anthropocene.' Because of the transdisciplinary nature of the 'Anthropocene,' encompassing scientific claims, moral and political claims, calls for social change, environmental activism, and artistic expressions, many of the themes developed within Anthropocene Studies overlap with one another – sometimes in a conflicting fashion.

This is especially true in mapping the history of the 'Anthropocene,' where frictions between historians and natural scientists arose over the societal importance of selecting a starting date (Maslin & Lewis, 2020). Following this line of criticism, the geohistory of the Anthropocene as a geological time unit became contested, opening new parallel histories of the 'Anthropocene' as a scientific or broader concept. In fact, a spectrum of these can be traced depending on how the term is defined, and where the emphasis in 'history of the Anthropocene' is placed. Some are:

- The history of the Anthropocene as a geological time unit
- The history of the 'Anthropocene' as an Earth System singularity
- The *history* of the 'Anthropocene'
- The history of the 'Anthropocene' idea/term

These four themes or 'histories' represent distinguishable narratives in Anthropocene Studies, each stemming from specific disciplinary or methodological approaches to the 'Anthropocene.' The following sections overview each of these separately, highlighting their crucial role in debates on the new epoch while also providing a 'background' history of it.

It should be noted that these four clusters do not necessarily reflect the way that 'Anthropocene' research is conducted in practice. Geology, Earth System science, environmental history, and conceptual history often share literature, methodologies, and multidisciplinary efforts. The very textual cradle of the Anthropocene is an example of this. Paul Crutzen and Eugene Stoermer's seminal IGBP article (Crutzen & Stoermer, 2000) included elements of geology (i.e., redefining the Holocene), Earth System science (i.e., the proxies they provided), environmental history (i.e., the role of the Industrial Revolution), and conceptual history (i.e., terminological precursors such as the Anthropozoic) – in addition to an original normative connotation. The clusters outlined represent epistemic categories to help focalize discrete research trends within the larger research network engendering Anthropocene Studies. It is considered both linguistically and conceptually practical to distinguish between these approaches not solely for the purpose of locating the research hereby conducted, but also for providing a cross-functional outlook of the historical research landscape within the blurred field of Anthropocene Studies.

1.2.1 The History of the Anthropocene as a Geological Time Unit

Natural sciences read the history of the Earth through the eyes of radiometric dating,[20] the basic technique upon which (broadly speaking) the disciplines of modern absolute geochronology and chronostratigraphy reconstruct the Earth's history. Radiometric dating allows us to measure the absolute age of materials such as fossils or rocks buried in deep time. Geochronology and chronostratigraphy reconstruct and divides the Earth's geohistory in the geological units of eon/eonothem, era/erathem, period/system, epoch/series, and age/stage.[21] Currently, we are situated in the Phanerozoic Eon (last 541 million years), in the Cenozoic Era (last 66 million years), in the Quaternary Period (last 2.58 million years), in the Holocene Epoch (last 11,700 years), in the Meghalayan Age (last 4,250 years). The Anthropocene Hypothesis locates the beginning of an Anthropocene unit to the 1950s – that is, the last 70 years.

To put the history of humans in the context of geological time, the emergence of the genus *Homo* with our ancestor *Homo habilis* is believed to date back 2.1 Ma,[22] representing around 0.046% of the Earth's

[20] The metaphor implicitly assumes the Earth's history as that represented by absolute time.
[21] The dual nomenclature reflects the duality adopted in geology between a geological time scale (based on geochronological units, i.e., those on the left side of the slash), and the parallel international chronostratigraphic chart (based on chronostratigraphic units, i.e., those on the right side of the slash). The meaning of 'geochronology' and 'chronostratigraphy' is explained in more details in section 3.1.2.6.
[22] 'Ma' stands for 'millions of years ago.' There seems to be a debate in Earth sciences over the usage of the proper abbreviation to address geological time (see also Wikipedia page https://en.wikipedia.org/wiki/Myr, section 'Debate,' accessed on May 23, 2021. Last revision: March 1, 2021, 23:14 CET by ClueBot NG). This debate is confirmed by the existence of multiple variants across geological literature, such as 'Ma BP,' 'MyBP,' 'myrbp,' or simply 'million years BP' – where Before Present (BP) has been commonly assumed to be the year 1950 CE (dates using BP are more

history. About 1.8–1.7 Ma, *Homo erectus* began controlling fire. Our species, *Homo sapiens*, whose oldest fossils retrieved date to 300 ka (Hublin, 2017), coincides with roughly 0.0066% of the Earth's history. The transition from hunter-gatherer forms of society to agriculture and domestication, known as the Neolithic revolution, began around 12 ka (Baker, 2009), only accounting for 0.00026% of the Earth's history. The Great Acceleration (Steffen et al., 2015; Steffen et al., 2004c), namely, a period of surges in socio-economic and Earth System trends that followed WWII roughly coinciding with the dawn of the Anthropocene, has the duration of an average human lifespan. These figures are often cited by critics of the hypothesis as showing the geological insignificance of the proposed time unit, whose stratigraphic layer (i.e., anthropogenic sediments) is either too thin or not "sufficiently distinct, and adequately dated at the global scale, for a Holocene/Anthropocene boundary to be substantiated on stratigraphic grounds" (Gibbard & Walker, 2014, p. 7). On the other hand, advocates of a formal Anthropocene time unit have argued that, despite the short time scale, the pace and spatial distribution of anthropogenic sediments should redirect the focus on the *magnitude* of the proposed epoch rather than its relative geological length (Zalasiewicz et al., 2017b).

But where does the Anthropocene figure within the Earth's history? In other words, when does the history of the Anthropocene as a geological time unit begin?

Several proposals have been advanced to determine the beginning of the Anthropocene – from as early as the use of fire and the Neolithic revolution, to the onset of the Great Acceleration. Surveying the extant literature reveals more than a dozen different starting dates that have been suggested by researchers. Based on how far back in time they extend, this spectrum of hypotheses can be clustered into four different categories – namely, paleoanthropocene hypotheses (1.8 Ma to 13.8 ka), early Anthropocene hypotheses (11 ka to 2 ka), modern Anthropocene hypotheses (1500 CE to 1900 CE), and contemporary Anthropocene hypotheses (1945 CE to 1964 CE). Some of these hypotheses set its beginning from as far back as 1.8 Ma (Glikson, 2013) to the beginning of the Holocene (Smith & Zeder, 2013). Others locate its beginning in the Industrial Revolution, or as recent as 1964, coinciding with a peak in ^{14}C (radiocarbon) caused by nuclear bomb testing (Lewis & Maslin, 2015a, 2015b, 2018a). Discussions about the beginning of the proposed epoch bear a significant epistemic value for the Anthropocene research agenda. This epistemic value is discussed separately, along with a thorough discussion of each relevant proposed starting date, throughout section 3.2.

One of the most discussed alternatives proposed so far is the Ruddiman Hypothesis, named after its originator William F. Ruddiman, a paleoclimatologist at the University of Virginia. The Ruddiman

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commonly used for the Pleistocene and the Holocene). The present research adopts the distinction proposed by Aubry et al. (2009b), while maintaining the year 2000 as a conventional signpost for defining the 'present.' The authors consider the 1950-CE-based definition of 'before present' a "misconception" (p. 103), and suggest using 'annus' and its multiples (e.g., 'ka,' 'Ma,' 'Ga,' etc.) to address geohistorical *dates* "as a point in time derived from the rock record" (p. 104). Parallelly, they recommend using 'year' and its multiples (e.g., 'kyr,' 'Myr,' Gyr,' etc.) to express the *duration* of geohistorical times. This framework is also consistent with the guidelines of the *International Stratigraphic Guide* (Salvador, 1994), and with the terminology adopted for the geological time scale / international chronostratigraphic chart.

Hypothesis, sometimes referred to as the Early Anthropocene Hypothesis,[23] dates the beginning of the proposed epoch during the Neolithic revolution, around 7 ka or 5 ka (Ruddiman, 2003, 2017; Ruddiman et al., 2008; Ruddiman et al., 2014). This hypothesis is based on paleoclimate evidence of an increase in CO_2 (carbon dioxide) and CH_4 (methane), between 7 ka and 5 ka respectively. This increase cannot seem to be fully attributed to natural forces, in that it appears to abruptly detour from the Earth-orbital–driven changes in CO_2 and CH_4 of the past 350,000 years. Furthermore, the Holocene, which represents a warmer period between glacial ages, seems anomalous in its late part compared to previous interglaciations of the past 800,000 years. This evidence leads Ruddiman to the conclusion that "millennia ago farming began to transform landscapes sufficiently to emit greenhouse gases and extend the natural warmth of the current interglaciation that had been initiated by orbital variations" (Ruddiman, 2017, p. 4).[24]

By stretching the beginning of the anthropogenic signature on the geological records to thousands of years, the Ruddiman Hypothesis provides a much longer history to the epoch in question compared to the current AWG stance which, following a vote held online on May 21, 2019, decided to locate the onset of the Anthropocene around the mid-twentieth century.[25] This coincides with sudden widespread bomb testing that scattered artificial radionuclides (radioactive atoms) in the atmosphere, considered by the group majority to be a global and synchronous proxy for marking the beginning of the proposed epoch. The stratigraphic markers associated to this signal are discussed more thoroughly in section 3.1.

Being the dedicated geological research group studying the Anthropocene in the international geological community (viz. the IUGS, the ICS, and the SQS), the AWG constitutes the leading voice in the scientific debate over the Anthropocene. Thus, the history of the Anthropocene as a geological time unit is largely dependent upon the group's research trajectory and final goal – that is, to seek formal ratification of the proposed time unit on the geological time scale. The question of whether the Anthropocene's geohistory is independent of formal recognition is an open one. It could be argued that, from an Earth System science perspective, the 'Anthropocene' as a state of affairs is happening regardless of the formal recognition attributed by the competent geological authorities. This would confer the Anthropocene a different ontological designation than a geological time unit, for example, an 'event'[26] (Bauer et al., 2021; Bonneuil & Fressoz, 2016; Brannen, 2019a; Hamilton, 2016; Horn & Bergthaller, 2020), 'stage' (in a non-geological sense), 'phase,' or 'singularity.'

The geological time scale represents an interesting and much debated epistemological ground. Looking at the history of certain time units, such as the Quaternary or the Devonian Periods (or even the

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[23] As later explained in section 3.2.2, multiple variants exist that can be identified as early Anthropocene hypotheses. Hence, it is considered more appropriate to address Ruddiman's formulation as the Ruddiman Hypothesis rather than the Early Anthropocene (or Anthropogenic) Hypothesis, as it is sometimes referred to in extant Anthropocene literature.

[24] Interestingly, neither in his 2014 nor his 2017 papers does Ruddiman make explicit use of the term 'Anthropocene.'

[25] The vote results are available on http://quaternary.stratigraphy.org/working-groups/anthropocene/ (accessed on May 23, 2021).

[26] The Greek etymology of the term 'epoch' is ἐποχή, notoriously known in philosophy and epistemology as 'suspension of judgement,' but also meaning cessation, retention, or pause. Horn and Bergthaller (2020, p. 159) suggest it should be translated as 'event' or 'break.'

Holocene, see Warde et al., 2017), the path of formal ratification is far from a smooth one. It often involves fierce clashes between subcultures in geological research, each promoting their own view of what does, and what does not, constitute appropriate geological evidence (Aubry et al., 2009a; Kerr, 2008; Rudwick, 1985). These circumstances, together with constantly improved data and research methods, have caused changes to the geological time scale many times throughout its history. However, from the point of view of *philosophical realism*, the geohistory of the Earth is utterly independent of us. All is left for us is signs that scientific research assembles into a coherent history of the Earth. Hence, what we call Phanerozoic, the current 541 million-year-old eon determined by an increase in complex multicellular life, existed *independently* of us – that is to say, a non-human civilization equipped with radiometric dating technology would observe approximately the same characteristics that distinguish the Phanerozoic Eon (e.g., the appearance of complex multicellular life).[27]

This digression brings us to the following point: Would the 'Anthropocene' still exist *independently* of a formal approval? In other words, to what extent does the 'Anthropocene' *exist*, and exist outside the realms of mere geological classification? Unless dissolving the epoch into socio-constructivism, the possibility that the characteristics of this time interval *could* now be independent of social agreement should be discussed. In fact, this is what has been advocated by the AWG, which claims that if these characteristics "were driven by any other means – such as by meteorite impact, volcanic eruptions or the actions of another species – then they would have exactly the same importance geologically"; and that an Anthropocene Series, namely, a chronostratigraphic counterpart of a geological epoch, "can be dug into, sampled […] and hit with a hammer" (Zalasiewicz et al., 2019b, p. 3). These statements seek to qualify the 'Anthropocene' as something substantially different from historical labels – such as the Renaissance or the Middle Ages – and confer the proposed time unit the same ontological status of other units on the geological time scale.

Stressing these theoretical points is of fundamental importance in assessing the ontological status of an Anthropocene stratigraphic unit as something existing independently of us, yet caused by us. Considering the stratigraphy of this epoch as forever inscribed in the Earth's history is surely a strong statement with important repercussions on the problem of definition stressed in 1.1.2. As will be explained in chapter 4, this kind of question should stimulate the necessity of a critical insight from the philosophy of geology, a much needed and underrated branch of philosophy of science.

1.2.2 The History of the 'Anthropocene' as an Earth System Singularity

Scholars have also suggested considering the history of the 'Anthropocene' from an Earth System science point of view (Bonneuil, 2015; Bonneuil & Fressoz, 2016; Hamilton, 2016, 2017; Hamilton et al., 2015b;

[27] Naturally, this is not to say that an alien civilization would use the same stratigraphic and chronostratigraphic features (e.g. GSSP, see section 3.1.2.6) to characterize what we recognize (and name) as the Phanerozoic. Nevertheless, they would recognize distinguished markers in strata that would suggest the proliferation of complex multicellular life. This mental experiment is also considered in section 5.2.1.

Syvitski et al., 2020). This approach understands the history of the 'Anthropocene' as the interval in which anthropogenic activities became so significant as to alter the functioning of the Earth System. In this context, the 'Anthropocene' is not necessarily seen as a geological time unit, but rather as a time interval when humans became a predominant force in the functioning of the Earth System – representing a singularity or no-analogue state (Steffen et al., 2004b). Within this knowledge domain, the issue of geological formalization is less of a pressing epistemic concern.

But what is the Earth System? And what is Earth System science?

Earth System science is the multidisciplinary study of global cycles of key chemical constituents taking place in the interaction between the Earth's 'spheres,' such as the biosphere, the atmosphere, or the hydrosphere. Due to their biological, geological, and chemical nature, these cycles are known as 'biogeochemical cycles.' These global-scale processes, from the carbon cycle and the water cycle to the oxygen cycle, are what inform the Earth's 'metabolism,' a cardinal concept explaining the planet's functioning. Earth System science focuses on the different properties that the planet exhibits as a complex, nonlinear system,[28] such as positive and negative feedback, self-regulating mechanisms, emergence, tipping points, and so forth. Eventually, Earth System scientists compare these properties to those of other known planets, or ponder the possible consequences of altering the Earth's mechanisms – as is the case with the course of human action.

A detailed history of the emergence and evolution of Earth System science is provided by Steffen (2020). Four crucial aspects can be observed in surveilling the history of the 'Earth System' concept: the application of system theory to the study of the Earth; the pioneering role of NASA; the formation of a multi-program Earth System Science Partnership; and the general increasing environmental awareness during the second half of the 20th century.

Many prototypical conceptions of the Earth as a 'system' – whether as a conscious living being, an entity with an internal purposeful scheme, or a holistic whole – are to be found in the history of human civilizations. However, in the context of modern science, the term 'system' acquired a specific meaning during the 20th century with the development of system theory, namely, the interdisciplinary study of the nature and functioning of 'systems' as groups of interacting entities in an interconnected network. The application of system theory to the study of the Earth began during the 1960s and 1970s with the formulation of James Lovelock and Lynn Margulis's popular Gaia Hypothesis.[29] In fact, here is where Earth System scientist Tim Lenton (2016) places the very cradle of the modern discipline of Earth System science. The Earth's functioning began to be considered as a dynamic complex system of interacting forces (especially the biosphere) whose properties cannot be reduced to, nor understood by, its elemental components.

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[28] In system theory, a *system* is a set of entities that interact with one another. The properties emerging from this interaction cannot be understood by looking at the individual entities: this phenomenon is called 'emergence.' *Nonlinearity* is the property of a system where output changes are not proportional to changes in input.

[29] The Gaia Hypothesis was promoted by James Lovelock in 1972, and refined through the years together with biologist Lynn Margulis (Lovelock, 1990). The hypothesis posits that organisms interacting with their surroundings generate an adaptive self-regulating mechanism that can maintain the Earth in a state of homeostasis.

A second important moment for the emergence of Earth System science was the establishment in 1983 of an Earth System Sciences Committee (ESSC) by the National Aeronautics and Space Administration (NASA). The first chairman, mathematician Francis Bretherton, popularized the 'Bretherton Diagram,' today still one of the most explicative illustrations of Earth System functioning. He also was part of the planning of the IGBP during the late 1980s, another crucial moment for the development of an international Earth System framework.

In 1986, the ESSC published its report *Earth System Science Overview: A Program for Global Change* (Earth System Sciences Committee NASA Advisory Council, 1986), one of the earliest documents attesting the goals and method of the then-newborn field of Earth System science. Here, the concept of 'Earth System' is implemented to promote and encourage a shift in knowledge to the understanding of the Earth's functioning. The report argued that such a shift is based on new parameters that observing the Earth System require, such as global observations programs, information systems, and numerical models to allow global measurements, documentation and prediction of global change, a unified information database, and worldwide political engagement.[30] Noticeably, these points do not solely highlight new methodological principles in studying the Earth, but also broaden the Earth System science boundaries to include social, political, and economic research: scientific understanding goes "hand in hand" (ibid., p. 10) with improving quality of life toward *sustainability* – another central concept in Earth System science (and environmental) discourse.

The multidisciplinary application of system theory to the study of the Earth brought about a profound transformation in the Earth Science communities – one that some contemporary scholars have compared to a Kuhnian-type paradigm shift (Hamilton, 2016; Hamilton & Grinevald, 2015). Research methods began to change. An educational program, the Earth System Science Education Program, was even created by a joint initiative of NASA and USRA (Universities Space Research Association) in 1991 and lasted through 2006 (Johnson, 2006). Such a shift of knowledge was openly acclaimed and promoted by the ESSC, whose 1988 report *Earth System Science: A Closer Overview*, announced that

> Many of the traditional Earth-science disciplines have reached maturity, bringing new and powerful research tools to bear on the study of the Earth as an integrated system of interacting components. We can now measure directly the inexorable motion of the Earth's crustal plates and their effects upon land topography. Global models of atmospheric circulation have permitted not only routine numerical weather prediction but also investigations of large-scale atmospheric dynamics, thus laying the foundation for *climate studies*. Three-dimensional models of *global ocean circulation*, building upon recent insights into the ocean-atmosphere interaction, will shortly be within our reach. Analyses of prehistoric *ice layers and ocean sediments* are revealing the range of past climatic variations and the cyclic influence of changing Earth-orbital parameters. The decisive importance of *global biology* in shaping many oceanic and atmospheric properties has also been recognized; forthcoming studies of ocean biota and terrestrial ecosystems will increasingly place these investigations on a firm, quantitative basis. Over the past 20 years, *atmospheric chemistry* has matured into a vigorous

[30] This is a major point for advocates of the 'Anthropocene' as a theoretical singularity in the genealogical debate explained in section 1.2.4. If the 'Anthropocene' emerges from an Earth System conceptual framework, then the characteristic features attributed by NASA could be easily transferred to the 'Anthropocene' core semantic unit.

> research field, opening our awareness of interactions of the atmosphere with chemical and biological processes in the oceans and on the land surface. All of these activities reflect a consensus of the international scientific community on the importance of understanding the operation of the Earth as a system. (National Research Council, 1988, p. 2, emphases added)

The 1988 *Earth System Science* report constituted a farsighted effort in expanding knowledge of the Earth both from a scientific and social perspective. It provided short- and long-term guidelines as well as recommendations for policymakers and scientists, and encouraged overcoming disciplinary boundaries to gain scientific understanding of the interaction among the Earth's layers, from oceans to atmosphere and biological systems. Most importantly, it provided an international reference framework for the concept of 'Earth System' that incorporated humans as a major component affecting and regulating it functioning in a seemingly equal way to other geophysical forces shaping the surface of the planet. This framework constituted the *episteme* (Foucault, 1970) of the 'Anthropocene' concept – that is, the conditions of the possibility for thinking the 'Anthropocene.' Not by coincidence, the disciplines and aspects emphasized in the above excerpt represent some of the main disciplinary domains wherein the concept of the 'Anthropocene' most appeared (as discussed in Chapter 2).

A third major step in the formation of a global research framework in Earth System science was the simultaneous development of four global change research programs, namely, the International Geosphere-Biosphere Program (IGBP, 1987–2015), the International Human Dimensions Programme on Global Environmental Change (IHDP, 1996–2014)[31], the World Climate Research Programme (WCRP, 1980–still active), and Diversitas (1991–2014)[32] (Ehlers & Krafft, 2006b; Hamilton, 2016; Leemans et al., 2009). Each of these programs focused on one or multiple aspects of global change. The IGBP pioneered the use of the Earth System framework to study the interaction between human systems and the Earth System (Uhrqvist, 2014), and played a crucial role in informing and popularizing the term 'Anthropocene' during its first decade of existence. The IHDP focused on the human dimension of global environmental change by promoting and coordinating research at the intersection of science and society. The WCRP (the only one of the four programs still active) aims at modelling and predicting climate and studies the possible consequence of human influence on it. Finally, as a joint UNESCO, SCOPE (Scientific Committee on Problems of the Environment), and IUBS (International Union of Biological Science) initiative, Diversitas focused on biodiversity and its link with sustainability and ecological research.

The apparent necessity of overcoming the research boundaries of each of these programs, and the common research areas, scopes, methods, and goals shared by each, led to the formation in 2001 of an Earth System Science Partnership (ESSP) under the sponsorship of the International Council for Science. The partnership particularly focused on "human-driven changes, which are multi-dimensional and have a cascading effect on the Earth System."[33] The ESSP represented an opportunity to further extend the

[31] The IHDP succeeded the Human Dimension Programme, which ran from 1991 to 1996.
[32] On December 31, 2014, Diversitas ended its operations and transitioned into Future Earth – a 10-year program launched in 2012.
[33] https://www.essp.org/about-us/, para. 2, accessed on May 23, 2021.

disciplinary base of global change research by facilitating the international flow of global change knowledge, developing an integrative ethical and methodological framework, and strengthening the links between science, politics, and the public. These were the guidelines drawn during the IGBP's Challenges of a Changing Earth: Global Change science meeting held in Amsterdam in 2001 (Steffen et al., 2002), from which the ESSP initiative took shape.

Lastly, through the second half of the 20th century, the increasing international awareness among politicians, the public, and scientific communities on the issue of human-induced global change and humanity's destructive potential decisively embodied the fourth (social) driving force that defined the backbone of the emerging Earth System science. Seminal textual works such as Rachel Carson's *Silent Spring* (1962), Paul Ehrlich's *The Population Bomb* (1968), the Club of Rome's report *The Limits to Growth* (1972), and the United Nation's *Our Common Future* (1987) called for local as well as global environmental agendas. Episodes such as the ozone hole detection, the Chernobyl disaster, or oil spills across the world's water bodies deeply impacted the social imaginary over the destructive potential of humankind. The years preceding and surrounding the birth of the concept of the Earth System were dense with increasing concerns over the influence of humans on the Earth, and the possibility of difficult (or even apocalyptic) future scenarios for human societies. To cope with this unwanted possibility, new knowledge at the intersection of science, politics, and economics was deemed necessary to understand the interaction between humans and the planet and to envision a sustainable future.

Having clarified the history and meaning of Earth System science, how does the 'Anthropocene' fit into this framework? And why does it represent an Earth System 'singularity'?

Introducing Earth System science in one of Oxford's popular *Very Short Introduction* series, Lenton (2016) identifies three revolutionary moments that transformed the Earth System throughout its history: (1) the appearance and spread of lifeforms; (2) the biologically induced transformation of the atmosphere from anoxygenic to one filled with oxygen through oxygenic photosynthesis (an event known as the Great Oxygenation); and (3) the appearance of complex life throughout the Cambrian Explosion.[34] The 'Anthropocene,' Lenton argues, constitutes a fourth revolutionary moment in the Earth System.

Several figures and measurements have been implemented as proxies to illustrate the magnitude of this singularity in the Earth System. One of these is the popular Keeling curve, named after atmospheric scientist Charles David Keeling (1928 – 2005). The curve (also used as their 'symbol' by the AWG) represents a daily-to-monthly record of global average of atmospheric carbon dioxide concentrations monitored by the Scripps Institution of Oceanography at UC San Diego through the Mauna Loa Observatory in Hawaii. The curve shows a steady increase in atmospheric CO_2 concentrations from 315 ppm in 1958 (when regular measurements began) to approximately 415 ppm in 2021.[35] This increase, almost unanimously considered of anthropogenic origins by scientists, is significantly beyond the upper limit of

[34] The Cambrian Explosion designated a diachronic interval taking place approximately 541 Ma where life complexity increased, and many animal phyla began to appear (in present geological records).
[35] Data is available online at https://scrippsco2.ucsd.edu/data/atmospheric_co2/ (accessed on September 16, 2021).

the Holocene atmospheric CO_2 concentration, estimated to be around 280-285 ppm (Indermühle et al., 1999; Ramussen, 2020).

The Stockholm Resilience Center's 'planetary boundaries' chart provides an overview of Earth System processes and their associated thresholds, both delineating an optimal operating state of human society and possible consequences of transgressing these thresholds (Rockström et al., 2009a; Rockström et al., 2009b). The staggering numbers in the accelerated rates of extinction, often linked to an increased conversion of land for agricultural purposes and associated reduction of all but one (i.e., the desert, see Molles, 2016, section 2.3) of the terrestrial biomes, unveil the likelihood of an ongoing, human-induced sixth Major Extinction Event (Barnosky et al., 2012; Barnosky et al., 2011; Kolbert, 2014). The 58% decrease in wildlife abundance recorded by the World Wildlife Fund (WWF) using the Living Planet Index (LPI) bears witness to a homogenization process that sees humans and livestock as roughly 96%[36] of all mammal biomass (Bar-On et al., 2018; Ceballos et al., 2017).

Perhaps the most popular among proxies used to visualize the 'Anthropocene' is the joint Earth System and socio-economic trend graphs charted by IGBP members representing the social and historical phenomenon known as the Great Acceleration (Steffen et al., 2015; Steffen et al., 2004c). According to McNeill and Engelke (2014, p. 213, note 4), the term 'Great Acceleration' was first used during the 96th Dahlem Workshop Held in June, 2005.[37] The term drew inspiration from Karl Polanyi's 1944 book *The Great Transformation*. The designation reflects a surge in socio-economic and Earth System trends, from population growth, primary energy use, water consumption, and international tourism, to atmospheric concentration of carbon dioxide, nitrous oxide, and methane, ocean acidification, tropical forest loss, and domesticated land, that characterized the second half of the 20th century. These changes of unprecedented pace and rate in the history of humanity saw their first visual representation in the IGBP's most relevant publication, the 2004 report *Global Change and the Earth System: A Planet Under Pressure* (Steffen et al., 2004c). The report uses two sets of twelve graphs each to visualize the major Earth System and socio-economic trends from 1750 to 2000, and their common peaks after 1950. In 2015, a research article published by Will Steffen and others on the then newly formed journal *Anthropocene Review* revised the graphs by providing

[36] The percentage (appearing, but not explained, on a *Guardian* article by Damian Carrington in 2018) is obtained by using data from Bar-On et al. (2018). According to their estimates, livestock, humans, and wild mammals constitute, respectively, 0.1, 0.06, and 0.007 Gt C (gigaton carbon, namely 10^{15} g of carbon) of all the Earth's biomass. Summing up the total, humans and livestock together constitute 95.8% of mammals' biomass.

[37] The Dahlem Workshop Series (or Dahlem Konferenzen) was a series of prestigious workshops that ran from 1974 to 2012 and were hosted in Berlin, originally funded by the Deutsche Forschungsgemeinschaft (German Research Foundation) and the Stifterverband für die Deutsche Wissenschaft (Donors' Association for German Science), and later supported by the Freie Universität of Berlin. The workshops (held in English) had around forty participants of international provenance discussing and working collectively on predetermined topics (originally scientific, although later workshops included contributions from human and social sciences). Paul Crutzen contributed twice as organizer, in 1992 (together with environmental scientist Johann Georg Goldammer) and 2003 (with climatologist Hans Joachim Schellnhuber and William C. Clark, a professor of international science, public policy, and human development). Further information on the workshops and the 'Dahelm Modell' are retrievable on the English Wikipedia page 'Dahelm Konferenzen,' and on the Freie Universität of Berlin webpage (https://www.fu-berlin.de/sites/dahlemkonferenzen/modell/index.html, accessed on January 13, 2021).

new proxies for the socio-economic trends. Together, these two sets of graphs provided a conceptual toolkit to visualize the trajectory of the 'Anthropocene' (Steffen et al., 2015).

With the increasing transformative role of humans on the planet, it became clear that any study of the Earth as a system would be incomplete if did not include the human factor. Studies on the biogeochemical cycles, or on the geophysical forces shaping the land surface, can now barely do without modelling human influences too. Thus, the Great Acceleration constitutes a double singularity: one in the history of humankind, and one in the history of the Earth System. In the former meaning, as explained, it identifies a historical time in (some) human civilizations where energy consumption has grown exponentially, with all causes and consequences linked to it. In the latter meaning, it identifies the pace through which a species (*Homo sapiens*) has so rapidly affected the Earth System. For instance, it took humans roughly two hundred years to double the atmospheric carbon dioxide concentration, or to fix more nitrogen than is produced naturally, severely affecting (among others) the global nitrogen cycle (Sullivan et al., 2014). These are just basic proxies signaling a singularity in the functioning of the Earth System. Humans are neither the first nor the only species actively modifying the Earth on a global scale. Precambrian cyanobacteria took about two-and-a-half billion years to oxygenate the atmosphere to the present state. Humans' signature on the planet is very far from this scale. However, the means and pace at which humans are not just affecting the atmosphere, but all of the Earth's biogeochemical cycles is unparalleled across extant living biota.

How does the Earth System science narrative differ from the geological one? Although research on the 'human factor' in the Earth System is conducted in close proximity with anthropogenic stratigraphy – often sharing research objects, methods, language, publication outlets, and academic figures (scholars who work on the 'Anthropocene' in Earth System discourse are also members of the AWG) – there is one important difference. The geological narrative focuses on the utility of formalizing the Anthropocene on the geological time scale, whereas Earth System science does not necessarily aim at achieving formal recognition of a geological (viz. geochronological and chronostratigraphic) time unit. Geologists look at what represents stratigraphic evidence. Not every mark and signal left by human activities can be considered to be stratigraphically significant. This is particularly the case if envisioning the temporal depth of such marks and signals to an order of magnitude of thousands to millions of years in the future (an argument discussed in section 5.2.1). Therefore, not all evidence of humans' influence on the Earth System does immediately translates into stratigraphic evidence. Nevertheless, evidence of a human-induced singularity on the Earth allowed Earth System scientists to hold to the term 'Anthropocene' as a useful scientific category, regardless of its formal stratigraphic status.

1.2.3 The *History* of the 'Anthropocene'

The 'history of the Anthropocene,' whether intended as a proposed geological time unit or as an Earth System singularity, has common conceptual ground (besides stemming from the natural sciences). In both narratives, the emphasis is placed on the definition and use of the term 'Anthropocene.' However, shifting the emphasis on the term 'history' rather than 'Anthropocene,' a substantially different approach emerges – namely, that of the *historical roots* of the Anthropocene, either as a geological time unit, singularity in the Earth System, or global historical phenomenon. This shift in emphasis transforms the 'Anthropocene' into a historical category.

Historical approaches to the 'Anthropocene' have become a major research trend in Anthropocene Studies. Their link with the natural sciences is exquisitely rendered by Horn and Bergthaller in their 2020 book *The Anthropocene: Key Issues for the Humanities*: "[t]he problems of scale raised by the Anthropocene are by no means restricted to questions of magnitude and the spatial dimensions of human agency […]. The term denotes a *geological* epoch, but to the extent that it has now become an important issue for the humanities, it *must* [emphasis added] also be viewed as a *historical* one" (Horn & Bergthaller, 2020, p. 157). Indeed, a second meaning that can be given to the phrase 'history of the Anthropocene' is 'history of human societies *behind* or *during* the Anthropocene.' This historicization of the epoch – what Bruno Latour addresses as "geo-story" (Latour, 2015, p. 154) – does not simply mean recounting the passive collection of all the historical occurrences coinciding with the emergence of the 'Anthropocene.' Rather, it means identifying the very historical causes that engendered it, namely, the modes of energy consumption among human societies that made this new epoch possible.

Why "*must"* the 'Anthropocene' also denote a historical epoch? A short answer is that understanding the 'Anthropocene' phenomenon requires a specific understanding of the historical, social, and economic conditions that caused it. The complex forms of social organizations behind the emergence of this time unit cannot be merely deduced from the category *Homo sapiens* – namely, from the set of biological properties that makes and identifies us as a species (Hornborg, 2015). Recognizing the historical drivers of the 'Anthropocene' is thus advantageous for both historical and geological research – for example, in understanding whether humankind will remain "the *active* geological force it is today, or whether it will be simply an *inertial* geological force subsequent to just a few decades of intensive fossil fuel burning" (Semal, 2015, p. 88).[38]

This historical research trend stems from a recurring theme in humanistic and social science scholarship on the 'Anthropocene' – that is, the convergence of geological and historical time. This theme seems to have been discussed for the first time (in the context of 'Anthropocene' research) by historian Dipesh Chakrabarty (2009) in his seminal paper "The Climate of History." His first of four theses, "Anthropogenic Explanations of Climate Change Spell the Collapse of the Age-old Humanist Distinction between Natural History and Human History," argues that attribution of geological agency to humans unwittingly implies dissolving the boundaries between human and geological history. Humans as a geological force is a separate, and more profound, claim than humans as biological agents, which Chakrabarty argues we have always been. Reflecting on the meaning of this convergence, the historian

[38] Section 3.1.1 provides an important clarification of the agency of humans in geological terms. While academic literature seems to identify humans as geological *forces* and *agents* interchangeably, a theoretical distinction between these two connotations is advanced.

identifies in a later contribution (Chakrabarty, 2015) a collision between three histories: the Earth System history, the history of life on Earth, and the history of post-industrial capitalist civilizations. The 'Anthropocene' locates at the nexus between these histories, therefore requiring a special kind of multidisciplinary attention.

An important theme emerged from historical and humanistic scholarship concerns criticism of the seemingly unifying notion of *Homo sapiens* or 'humans as geological agent' that the scientific narrative seems to convey. This usage seems to disregard individual contributions to the dawn of the 'Anthropocene,' and attribution of responsibility, especially from those on the colonizing side of history (Bonneuil, 2015; Bonneuil & Fressoz, 2016). Contextualizing the 'Anthropocene' (Biermann et al., 2016) is not spurred solely by the necessity of eluding an all-inclusive narrative, but also from a methodological requirement. As stated by human geographers Andreas Malm and Half Hornborg (quoting Lewis Gaddis), using *Homo sapiens* as an epistemic category "is like explaining the success of the Japanese fighter pilots in terms of the fact that prehumans evolved binocular vision and opposable thumbs" (Malm & Hornborg, 2014, p. 64). It is not false per se; it is rather a poor methodological choice. This criticism (discussed again in section 5.1.1) holds that the 'Anthropocene' is not to be understood as a direct product of human biology, but rather a product of specific modes of existences defined by the establishment of capitalism as the main driver of the world economy, and coincidentally as the main source of disruption of the Earth System. Further stressing this point, Malm and Hornborg consider the roots of this new epoch not to be anthropogenic, but rather *sociogenic* (ibid.). It is not humans that brought about the 'Anthropocene' by virtue of their being humans. It was a specific socially and historically established order that engendered it.

Considering the rise of capitalism in the 'Western' world as a turning point in the history of the 'Anthropocene' has had scholars coming up with terminological variants – which have been proliferating and extending, in large numbers, well beyond historical considerations. Probably, the most compelling alternative in Anthropocene Studies has been the 'Capitalocene.' The term was first coined by Andreas Malm when he was a graduate student at Lund in 2009, publicized by economist David Ruccio (2011, quoted in Moore, 2016), used by Donna Haraway (2015) since 2012, and finally popularized by Jason Moore in his 2016 edited volume *Anthropocene or Capitalocene? Nature, History, and the Crisis of Capitalism*.[39] Due to its popularity among the many terminological variants proposed, and being the hub of the historical discourse on the 'Anthropocene,' it is essential to spend a few lines on it.

As the term itself suggests, authors supporting this provocative idea do not focus on the stratigraphy of humans as a geological agent, but rather reflect upon the 'stratigraphy of capitalism.' This metaphor suggests looking at the environmental footprint of capitalism as a worldwide economic system (or as Moore suggest, as a 'world-ecology') whose fundamental strategy consists of the 'cheapening of Nature.' Nature (as he intends, capitalized) is an *ad hoc* ontological category at the core of capitalism's modes

[39] According to German environmental and science journalist Christian Schwägerl (2014, pp. 65, footnote 132), the term Capitalocene was coined by Freie Universität professor Elmar Altvater using its German variant 'Kapitalozän,' during a discussion at the German Council for Foreign Relations in Berlin. However, the year when the meeting took place is not specified.

of existence that served (and serves) instrumentally to distinguish humans among humans, and nature among nature. This 'Cheap Nature' (Moore, 2015, 2016b) has two interrelated meanings: the cheapening – i.e., the "work/energy and biophysical utility produced with minimal labor-power, and directly implicated in commodity production and exchange" (Moore, 2016c, p. 99) – of the economic value of 'Nature'; and its ethical degrading functional to its exploitation. The emergence of capitalism, with its roots in 16th-century power relations, can be read as the creation and appropriation of such Cheap Nature – the commodification of Nature set by the emerging, capitalist-oriented economic elites – and the adoption of political strategies, economic premises, and even ethical systems (see for instance White, 1967) to justify, legitimize, and ultimately implement this world-scale organization of Nature. As much postcolonial literature has stressed (e.g., Emmett & Lekan, 2016; Keerer, 2020; McQuillan, 2016; Swanson et al., 2015; Yusoff, 2019), such a world-system developed within a framework of systematic segregation and/or oppression of classes, races, genders, or minorities, and the polarization of capital and energy consumption, perpetrated by certain economic powers, such as states and trading companies.

Moore's conceptualization of 'Capitalocene' seeks to bring to light the historical and existing relations of Cheap Nature – relations that consisted (among others) in unbalanced forms of energy consumption, and thus in different attributions of responsibility toward anthropogenic environmental degradation across nations and societies. It also looks at the origins of capitalism as a world-ecology system that set the premises of much of today's organizational schemes of the web of life – including the ongoing sixth mass extinction event in the Earth's history (Ceballos et al., 2015; Ceballos et al., 2017; also discussed in section 3.1.2.4 in the context of biostratigraphy; Kolbert, 2014). In doing so, it also poses a critique to the geological narrative of the 'Anthropocene,' especially to its seemingly implicit subsumption of human cultures under an all-inclusive definition of *Anthropos*. 'Anthropocene' scholars have denounced this conceptual maneuver (see section 5.1.1), warning against a subtle reintroduction of a Cartesian dualism in the form of *Anthropos* and Nature, or the narrative's blindness to the relations between human societies and to capitalism as a 'world-ecology.' Moreover, the historical analysis challenges the historical account implicitly provided by the Earth System narrative, which locates the cradle of the 'Anthropocene' in the Industrial Revolution. Moore argues that in order to understand the origins of capitalism, and hence *how* we entered the 'Anthropocene,' we must look back to the 16th-century birth of Cheap Nature and Cheap Labor. Hence, locating (or limiting) the dawn of the 'Anthropocene' to the English Industrial Revolution implies ignoring centuries of capitalism-in-the-making, including the global-scale impact of colonialism.

Criticism to an all-inclusive discourse opened up the possibility of multiple 'Anthropocene*s*,' such as 'African Anthropocene' (Hecht, 2018), 'Asian Anthropocene' (Chatterjee, 2020; Kwai-Cheung & Yeung, 2019), or the 'billion black Anthropocenes' of Kathryn Yusoff (2019) – the latter introducing postcolonial black feminist literature into Anthropocene Studies. Integrating ethnographic approaches to social and historical analysis, these arguments provide alternative historical accounts that do not fall within an all-inclusive and partial history of the world. Being already in the 'Anthropocene', all humans must face, in one way or another, the consequences of having entered this new Earth System state and/or geological epoch.

However, how to *experience* it varies differently, hence not one but many *experienced* 'Anthropocene*s*' exist. This criticism is considered separately in Chapter 5.

Moore, and advocates of the 'Capitalocene' idea, seem to propose the term in opposition to that of 'Anthropocene.' They do not necessarily promote this within the geological arena, but rather in the broader discussion of anthropogenic impacts on the planet. The term 'Anthropocene,' they argue, seems to dissolve this discussion by implementing a geological and Earth System narrative that unifies humanity under a unique, responsible agent. More importantly, the 'Anthropocene' is blind to the historical and ethical questions that it implicitly posits. However, the 'Capitalocene' idea should not be understood in opposition – neither as a contradiction nor as a semantically conflictual concept unit – to that of 'Anthropocene.' Rather, the notions complement each other. Indeed, the 'Capitalocene' constitutes simultaneously an intellectual provocation and an integrative epistemic feature of the 'Anthropocene.' As an intellectual provocation, it challenges important aspects of the broader narrative developing from the scientific agenda, warning on issues at the intersection of science, politics, and the public sphere. As an integrative epistemic feature, it tells us what the 'Anthropocene' *is* and *how* it came to be through a historical lens – a focus that geosciences, in virtue of their own modes of knowledge-making, cannot fully reproduce. The historical approach unveils the social and cultural mechanisms (modes of relations, production, energy consumption, cultural drivers, etc.) that fueled the most environmentally transforming, and maybe most characteristically complex and peculiar, mode of existence in human history. The geological approach looks at the stratigraphic remnants of these social and cultural mechanisms.

An example of this historical approach is John McNeill and Peter Engelke's analysis of the environmental history of the 'Anthropocene' in their classic 2014 work *The Great Acceleration* (McNeill & Engelke, 2014). Without rejecting nor posing terminological alternatives to the Anthropocene Hypothesis – which places the beginning of the new epoch in the 1950s – the authors focus on what caused and characterized the surge in socio-economic trends that since 1945 have brought human societies into an unprecedent stage of energy production and consumption. The fossil fuel-based abundance of cheap energy that characterized many modern societies especially during the second half of the 20th century constitutes the center of the environmental history of the 'Anthropocene,' to the extent that "from almost any viewpoint energy seems to be at the heart of the new epoch" (p. 40). During this half-decade alone, global energy use increased fivefold with oil, coal, and natural gas representing 87% of global energy sources. This radical shift in energy production and consumption is co-amplified by an increasing world population, seemingly ever-expanding urbanization, and unprecedented global economic growth that set a path for "profound consequences for the world's air, water, and soil, as well as for human health" (p. 38). Some of these consequences will last in the deep future of geological time, making them characteristics of the 'Anthropocene.' Henceforth, the Great Acceleration, originally a term linked to an analysis of socio-historical nature, also represents an (environmental) analysis of the causes and characteristics of the proposed concept. And it does so by complementing, rather than opposing, the scientific research conducted by the AWG.

The analysis of McNeill and Engelke assumes the beginning of the 'Anthropocene' to be that promoted by the AWG. Therefore, its environmental history is only limited to the second half of the 20th century. Unlike Moore's, their analysis does not directly address capitalism and its roots as the main driver of the 'Anthropocene,' and only marginally extends to the onset of the Industrial Revolution. However, by locating cheap energy as the most characteristic feature of the new epoch, their approach resonates with the concepts of Cheap Nature and Cheap Labor drawn by Moore, implicitly considering these as characteristic features of the 'Anthropocene.' In doing so, McNeill and Engelke are addressing the link between capitalism and the 'Anthropocene,' providing a historically detailed and numerically explicative ontology of the epoch. Such analysis does not collide, neither conceptually nor linguistically, with the meaning the term 'Anthropocene' assumes within the scientific discourse. On the contrary, it provides further historical and sociological material to foster multidisciplinary research, compensating for levels and modes of analysis that the natural sciences, and in particular geological research, do not traditionally deepen into. Furthermore, by providing a localized environmental history of the 'Anthropocene,' McNeill and Engelke's analysis shows how the term – a practical label more than a macro-category – does not commit the sin of unifying the diverse roles and responsibilities of human societies in engendering the epoch. This is clear once the work of environmental historians and scientists interested in the 'Anthropocene' is understood as one research trajectory.

Considered from this perspective, the concepts of 'Capitalocene' and 'Anthropocene' are not opposed to one another, but are rather two faces of the same coin. They constitute different modes of approaching the same object – that is, humans' geological agency. Their differences lie in the methodologies of analysis: the historical approach looks at the social, economic, cultural, and political drivers; the geological approach looks at the stratigraphic (among other) evidence, and translates it in the context of deep time.

Capitalocene, Anglocene, Plantationocene, Technocene (López-Corona & Magallanes-Guijón, 2020), Chthulucene, and so forth: this wide spectrum of wordplays is not strictly speaking part of the geological conversation on formal recognition on the geological time scale. Rather, these neologisms all constitute intellectual provocations or theoretical addition. They stress specific ontological features of the 'Anthropocene,' highlighting one or more crucial social, ecological, or historical aspects that characterize the proposed epoch. In short, whilst the scientific narrative asks whether we are now living in the 'Anthropocene' (Zalasiewicz et al., 2008b), the historical narratives asks *how* and *why* we are living in the 'Anthropocene' (Moore, 2016c),[40] and what can be done about it. The environmental-historical line of research, where most of these variants originate, does not just stress the ontological and epistemological plurality of the 'Anthropocene' – it also embraces profound normative claims and goals. This approach is

[40] Jason Moore (2016c) takes this point as a form of criticism of the 'dominant argument,' which he considers to be the scientific one. The historian argues that this argument is not capable of answering the very question of *how* the 'Anthropocene' came to be without falling into a collection of data – such as demography, technological improvement, or energy consumption – that are supposedly blind to the common underlying organizational system that he traces in capitalism.

representative of what is defined in section 1.3.1 as the 'normative Anthropocene,' which differs in methods, scope, and aim from the 'descriptive Anthropocene.'

1.2.4 The History of the 'Anthropocene' Idea

A fourth approach to the 'history of the Anthropocene' is looking at the history of the 'Anthropocene' as theoretical and linguistic entity. This is a particularly pertinent approach for the present research because, if the birth of the Anthropocene Hypothesis ought to be reconstructed, then it is necessary to first consider the broader intellectual and conceptual history of the 'Anthropocene' idea. Before proceeding, it is important here to make a preliminary linguistic remark.

The present chapter highlighted an issue of definition emerging within Anthropocene Studies, and the burden is poses on extant 'Anthropocene' scholarship especially in terms of outlining a multidisciplinary framework. A reflection of this issue is that existing literature often implements the term 'Anthropocene' as in 'time unit,' 'Earth System singularity,' 'historical time,' and as an 'idea' interchangeably. Although usually the 'type' of 'Anthropocene' is more or less implicitly defined in the research texts, it is still important from an analytical standpoint to clarify which meaning is adopted. In fact, this clarification is at the very core of the four interpretations of 'history of the Anthropocene' outlined in this chapter. As anticipated at the beginning of the chapter, quotation marks are used to identify the 'Anthropocene' as the broader boundary object or theoretical/linguistic entity, differentiating it from the Anthropocene a proposed geological time unit, and from the Anthropocene Hypothesis.

Similar linguistic remarks have been raised by 'Anthropocene' scholars. For instance, Ruddiman et al. (2015) argue that a lowercase 'anthropocene' would "allow for modifiers appropriate to the specific interval under discussion, such as early agricultural or industrial" (ibid., p. 39). Closer to the strategy adopted in the present research, geologist Valentín Rull (2018) noted the necessity of distinguishing the Anthropocene from other formal units on a linguistic level. His observation originated from the issue of implicitly assuming the epoch-scale of the Anthropocene by using the '-cene' suffix, used for the seven epochs of the Cenozoic Era. He argues that, as the proposed time unit is not yet associated with a formal taxonomical level, its informal nature should be underlined by using quotation marks. However, using quotation marks does not aim at differentiating between formal and informal units, in that informal designations, such as 'Precambrian,' are commonly used in geological contexts without quotation marks. Rather, this distinction is functional to an historical-epistemological analysis of the term, such as the kind hereby being conducted. Henceforth the quotation marks to identify the 'Anthropocene' as theoretical entity, and boundary object.

This simple, yet scarcely acknowledged, terminological differentiation is at the core of much misunderstanding on the meaning(s) of, and claims on, the 'Anthropocene' both as conceptual entity and proposed time unit. That is the case with criticism toward the Anthropocene (as in geological time unit) as an anthropocentric concept.[41] This is an interesting line of argument, as the 'Age *of* Humans' (as it popularly translates) can be easily interpreted in the possessive genitive. Furthermore, as pointed out by posthumanist critics Astrida Neimanis, Cecilia Åsberg, and Johan Hedrén, naming a geological epoch after us "does not necessarily demonstrate the humility we may need to espouse" (Neimanis et al., 2015, p. 68). On the contrary, it might legitimize any techno-centered, managerial-like approaches (such as geoengineering, as commonly argued by humanists and social scientists) that ultimately express new forms of anthropocentrism. However, it is often unclear whether this criticism addresses the term, the idea, the time unit, the Earth System singularity, or the overall narrative associated with the 'Anthropocene.' Without proper clarification, criticism risks standing up a straw man.

An additional example of this confusion is an article published by *The Atlantic* on August 13, 2019, by Peter Brannen. The author made an interesting statement against the Anthropocene time unit, advocating that it should be considered an event rather than an epoch. His criticism toward the term went even further, arguing that an Anthropocene unit is "evidence of little more than our own species' astounding anthropocentrism," serving to "inflate humanity's legacy" by "promising eternal geological life to our creations" (Brannen, 2019a). Therefore, as his article's title clearly states, the Anthropocene is a 'joke.'

A quick response signed by AWG members (Wing et al., 2019) arguing how the Anthropocene is not hubris, but merely a recognition of facts, had Brannen changing his mind entirely. The AWG stressed the geologically deep mark left by humans especially on the biosphere, detouring the history of life on the planet by the action of a single species, over a very short (but yet to fully unravel) time span. This legacy will persist with or without us. Hence, Brannen's original article, which he retracted in a subsequent publication in *The Atlantic* published later the same year (Brannen, 2019b), confused the actual state of affairs that humans have caused, and that will persist in the future, with claims of anthropocentrism. The 'Age of Humans' does not make the 'Anthropocene' a state of affairs humans possess (i.e., the *of* is not possessive), but rather a state of affairs humans have left an imprint upon.

There are other examples supporting the necessity of linguistic clarity in Anthropocene Studies. However, in the context of the present research, this digression serves to illustrate the intrinsic polysemy that the term has assumed, and therefore the necessity of clarity in any given research about *which* facets of the 'Anthropocene' are being addressed. This is particularly necessary when distinguishing among different interpretations and variants of the broader 'Anthropocene' concept.

Linguistic and conceptual clarity is especially important in delineating the history of the concept. This research trend looks at the history of the concept, its conceptual roots, its evolution over time, and its present meaning. Generally, two positions are identifiable in terms of how a history of the 'Anthropocene' concept should be constructed, each approaching the 'Anthropocene' with different claims, intents, goals,

[41] In fact, even in this sentence it is hard to assess whether to use quotation marks or not, given that criticism often does not make explicit whether the *concept* or the *epoch* itself is anthropocentric.

and methodologies. These can be named *continuism* and *discontinuism*.[42] In the context of the present doctoral research, understanding the differences between these opposing views is important in framing the birthplace and time of the Anthropocene Hypothesis.

1.2.4.1 Continuism

The main argument of this position holds that the 'Anthropocene' has historical and conceptual precursors that date as far back as the late 18^{th} century.[43] This argument often derives the conclusion that the 'Anthropocene' is not a properly new nor utterly original idea, but rather a theoretical *revenant* under the guise of contemporary geological and Earth System scientific language (Syvitski, 2012).

Authors embracing this stance identify semantic continuities (hence '*continuism*') between past ideas resembling, anticipating, or informing the 'Anthropocene,' and they do so by adopting a genealogical method of analysis. Some authors (Autin & Holbrook, 2012; Bonneuil, 2015; Bonneuil & Fressoz, 2016; Lewis & Maslin, 2018a; Morrison, 2015) trace a genealogy to prove the existence of awareness and reflexivity on the impact of humans on the environment from a local to global scale (hence rejecting the idea of the 'Anthropocene' being a totally new concept). Others genealogical endeavors simply look at conceptual and historical predecessors to enrich the humanistic contribution to the debate, identifying possible theoretical continuities or differences between the 'Anthropocene' and supposed antecedents, or to strengthen the theoretical foundations of the new epoch (Horn & Bergthaller, 2020, pp. 35-44; Steffen et al., 2011a). In each case, *genealogy* plays a central role in assessing the history of the term.

But what does this method consist of? As a philosophical method, genealogy is a historical-hermeneutical form of analysis focusing on the relationship between discourse and language on the one hand, and structures of power on the other (Sax, 1989) in an attempt to understand the emergence – either contingent or necessary – of beliefs, ideas, and particularly moral values. The genealogical method has been widely popularized through the work of Friedrich Nietzsche, especially in his 1887 book *On the Genealogy of Morality*. Here, the German philosopher and philologist sets out to find the origin of "our moral prejudices," contraposing his theory of *ressentiment*[44] to the genealogical hypotheses of the "*English* kind"[45] (Nietzsche,

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[42] A comprehensive overview of these two opposing stances is provided by Horn and Bergthaller (2020, chap. 3). Horn (author of the chapter) refers to the continuist and discontinuist stances as, respectively, the 'historicizing' and the 'presentist' approach, generally identifying historians Christophe Bonneuil and Jean-Baptiste Fressoz with the former, and philosopher Clive Hamilton with the latter. Interestingly, she argues that in many ways this divide reflects C. P. Snow's 'two cultures,' in that it tends to polarize the role of the natural sciences and the humanities in conceptualizing the 'Anthropocene,' and thus in delineating its history.

[43] Horn (in Horn & Bergthaller, 2020) considers Georges-Louis Leclerc, Comte de Buffon's 1778 text *Epochs of Nature* to be, on a speculative level, the "first document of Anthropocene thought" (ibid., p. 39). Buffon is also considered by Lewis and Maslin (2015a, 2018a) as the earliest conceptual precursor of the term.

[44] On *ressentiment*, Nietzsche argues: "The continuing and predominant feeling of complete and fundamental superiority of a higher ruling kind in relation to a lower kind, to those 'below' – *that* is the origin of the antithesis 'good' and 'bad'" (p. 12). This is a central statement in defining his theory of history and his genealogical approach.

[45] Nietzsche is referring to the "English psychologists," namely, those of the English empiricist tradition, whom he considers to be "*actually interesting*" (p. 10) yet lacking "*historical spirit*" (p. 11).

2006, p. 4). In *Beyond Good and Evil*, published in 1886, Nietzsche also contraposes his genealogical method to the logical systems of deduction of values developed by Kant and Hegel. Consistent with the continental style of philosophical inquiry (and with his own trademark writing style), Nietzsche's genealogical analysis – whose primary focus is the genealogy of European moral values – should be understood as a unique hermeneutical approach to history based on a constellation of complex concepts that resonate throughout his entire work and personal life, rather than a strict analytical methodology.

Nietzsche's genealogical analysis became an object of interest of French philosophers during the second half of the 20th century, particularly Gilles Deleuze and Michel Foucault. In his 1962 book *Nietzsche and Philosophy*, Deleuze locates his considerations of Nietzsche's account of genealogy at the very beginning of the text, providing the reader with the following definition:

> Genealogy means both the value of origin and the origin of values. Genealogy is as opposed to absolute values as it is to relative or utilitarian ones. Genealogy signifies the differential element of values from which their value itself derives. Genealogy thus means origin or birth, but also difference or distance in the origin. Genealogy means nobility and baseness, nobility and vulgarity, nobility and decadence in the origin. The noble and the vulgar, the high and the low – this is the truly genealogical and critical element. (Deleuze, 1983)

Deleuze's idea of genealogy gravitates around two concepts, those of 'sign' and 'forces' (Pearson, 2007). To him, phenomena do not appear in the form of absolute values, nor are they dissolved into relativism. Phenomena or 'things' appear in the form of signs, which are interpreted by the existing interplay of forces that appropriate "the thing, which exploits it, which takes possession of it or is expressed in it" to the extent that the "history of a thing, in general, is the succession of forces which take possession of it" (Deleuze, 1983, p. 3). Therefore, the meaning – or, in Deleuze's terms, the 'sense' – of a thing can only be understood in the relation to the forces that appropriate that thing. Consequently, 'sense' is always a plurality, a complex network of coexisting meanings whose histories are unveiled by genealogy.

As for Nietzsche, it is not easy to frame a rigorous 'methodology' in Deleuze's account of genealogy. Likewise, Foucault's reading of Nietzsche and his genealogy takes a densely symbolical turn that escapes the common definition of 'method.' His definition of genealogy can be traced to his 1971 essay "Nietzsche, Genealogy, History," in which Foucault argues that

> Genealogy is *gray* [emphasis added], meticulous, and patiently documentary. It operates on a field of entangled and confused parchments, on documents that have been scratched over and recopied many times […] [Genealogy] must record the singularity of events outside of any monotonous finality; it must seek them in the most unpromising places, in what we tend to feel is without history – in sentiments, love, conscience, instincts; it must be sensitive to their recurrence, not in order to trace the gradual curve of their evolution, but to isolate the different scenes where they engaged in different roles. Finally, genealogy must define even those instances when they are absent, the moment when they remained unrealized (Plato, at Syracuse, did not become Mohammed). (Foucault, 1977)[46]

[46] The English translation was published in 1977 (see bibliography). However, the original French article was published in 1971 in *Hommage a Jean Hyppolite*, a book edited by Suzanne Bachelard.

The color gray, a metaphor which Foucault borrows from Nietzsche,[47] epitomizes clearly the fieldwork of genealogists. According to the French philosopher, genealogies – to be distinguished from 'histories' – do not aim at unveiling an ultimate origin containing an immanent truth actively transmitting its properties from past to present (and nor does history). On the contrary, they walk through the labyrinth of history, filled with accidents, dead-ends, details, and fragments, "to *dispel* the chimeras of the origin" (ibid. p. 5, emphasis added). Genealogy in its historical sense, namely in its being parodic (meaning offering alternative identities by venerating the past), dissociative (meaning dissolving a uniform historical identity into a heterogeneous plurality), and sacrificial (meaning possessing the danger of sacrificing the subject to the 'will to knowledge'), is to Foucault the "undermining of all forms of historically grounded truth claims" (Molina; Sax, 1989).

Dwelling on the meaning of genealogy between Nietzsche, Deleuze, and Foucault is well beyond the scope of this section, and outside the overall goal of the chapter.[48] For the present purpose, this digression is important to highlight the complex nature of genealogical research. What system of values must genealogical research be aware of when engaging with the 'Anthropocene' from a normative standpoint, and what system of values does it call for? What forces shaped precursors of the 'Anthropocene,' and to what degree have they changed, and are changing, the plurality of its sense? What parodic, dissociative, and sacrificial elements can be found in the genealogy of the 'Anthropocene'? These questions are crucial in the genealogical research of the 'Anthropocene,' and require additional research. Such is the task yet to be extensively tackled by philosophers and historians of ideas in Anthropocene Studies.

Research on conceptual precursors has been an endeavor conducted since the very first article that popularized the term 'Anthropocene' in contemporary debate, namely, Paul Crutzen and Eugene Stoermer's notorious *IGBP Newsletter* article published in May 2000 (Crutzen & Stoermer, 2000).[49] A short genealogy of the term is provided at the beginning of this brief article. George Perkins Marsh and Antonio Stoppani are considered pioneers in recognizing humans as a geological and morphological force during the 18th century – with Stoppani using the term 'Anthropozoic' to identify a human-induced geological time unit. The Russian geologist Vladimir Ivanovich Vernadsky, together the French philosophers Pierre Teilhard de Chardin and Édouard Le Roy, are often mentioned (e.g., Crutzen & Stoermer, 2000; Lewis & Maslin, 2015a; Steffen et al., 2011a) for using the term 'Noösphere' during the 1920s – a term stressing the role of humankind's brainpower in relation to its becoming a geological agent.

[47] "At any rate, I wanted to focus this sharp, unbiased eye in a better direction, the direction of a real *history of morality*, and to warn him, while there was still time, against such English hypothesis-mongering *into the blue*. It is quite clear which colour is a hundred times more important for a genealogist than blue: namely *grey*, which is to say, that which can be documented, which can actually be confirmed and has actually existed, in short, the whole, long, hard-to-decipher hieroglyphic script of man's moral past!" (Nietzsche, 2006, p. 8).
[48] On the differences between the two genealogical methods, see Sax, 1989.
[49] The term 'Anthropocene' seems to have first appeared on written records in English translations of Russian geology journals ("Paleontologicheskiy Zhurnal 1966, no. 1," 1966; Vinogradov et al., 1968). The term was informally used during classes by Eugene Stoermer, but was never given the weight it holds today.

The genealogical approach gained momentum, and in later years it developed into a discrete research trend within Anthropocene Studies. In 2011, together with Paul Crutzen, Jacques Grinevald (a French historian of science and AWG member), John McNeill, and Will Steffen published a research article entitled "The Anthropocene: Conceptual and Historical Perspectives" in which a seminal overview of the 'Anthropocene' genealogy was provided (Steffen et al., 2011a). This became the first of a series of dedicated genealogical analyses conducted in major publications in Anthropocene Studies that looked for historical, theoretical, and conceptual antecedents. Some examples are Lewis and Maslin's (2015a) *Nature* article "Defining the Anthropocene,"[50] and the introductory chapter of the AWG's latest scientific summary *The Anthropocene as a Geological Time Unit* (Zalasiewicz et al., 2019b). An interesting analysis conducted by Hermann Häusler traces a genealogical tree of the 'Anthropocene' in 19th- and early 20th-century Austrian–German geological literature, especially with the development of the discipline of 'anthropogeology' (Häusler, 2017), formed during the 1950s and later replaced by environmental geology.

So far, many names, events, and ideas have been considered as precursors of the 'Anthropocene,' from Alexander von Humboldt, Buffon, Thomas Jenkyn, George Perkins Marsh, Joseph Le Conte (who coined the term 'Psychozoic'), and Stoppani, to Vernadsky, Pierre Teilhard de Chardin, Édouard Le Roy, Aleksei Pavlov (who used the term 'Anthropogene' for the Quaternary), and Henry Bergson (Lewis & Maslin, 2015a; Steffen et al., 2011a). These names do not exhaust the list of past geologists, philosophers, and naturalists who seemingly foresaw the role of humankind as a geological and environmental agent. In more recent genealogies, precursors are found in events discussing humans' geological agency, such as the 1955 Princeton symposium Man's Role in Changing the Face of the Earth, or in linguistically similar terms, such as 'Anthropozoikum' (Ehlers & Krafft, 2006b, p. 5, quoting Markl, 1986) or 'Anthrocene' (Revkin, 1992).[51]

Providing a short genealogy of the term (i.e., historicizing the 'Anthropocene') has by now become a common – if not almost mandatory – practice in 'Anthropocene'-related publications, often introducing research articles, monographs, or even seeing entire dedicated book chapters. Master's and doctoral theses are part of the list too. This is certainly a valuable contribution – especially from the humanities – to Anthropocene Studies that provides a background of ideas and genealogies against which the 'Anthropocene' can be compared and discussed. However, the 'dominance' of the genealogical approach came at the expense of a more recently focused historical and epistemological analysis of the term. In addition, some scholars have questioned the validity and scope of this genealogical endeavor. This questioning is the starting point of the discontinuist stance.

[50] The article later turned into the first chapter of their 2018 book *The Human Planet* (Lewis & Maslin, 2018a).
[51] A useful visual illustration and comprehensive catalogue of important events, names, and conceptual precursors is provided by Sophie Yeo (2016) on her online exhibition *Anthropocene: Journey to a New Geological Epoch*, available online at https://www.carbonbrief.org/anthropocene-journey-to-new-geological-epoch (accessed on May 23, 2021).

1.2.4.2 Discontinuism

The underlying argument of 'discontinuism' holds that the 'Anthropocene' represents a theoretical singularity that has little or no semantic continuity with any past concepts, ideas, or narratives appearing to anticipate it in one way or another. Therefore, the continuist stance is wrong in identifying conceptual and theoretical antecedents in past ideas or narratives, for these are substantially different from that of the 'Anthropocene.'

Philosopher Clive Hamilton has been championing this criticism toward the genealogical approach since his 2015 article "Was the Anthropocene anticipated?" was published with Grinevald in *The Anthropocene Review* (Hamilton & Grinevald, 2015). His arguments against the continuist stance are multiple. First, he argues that the 'Anthropocene' emerged in the context of Earth System science, a recent and revolutionary approach in the study of the Earth merging a diversified spectrum of disciplines. As also outlined in 1.2.2, this approach incorporated system theory in studying the Earth's biogeochemical processes. This new set of methodologies and concepts engendered a new conceptual framework for assessing the impact of humans on the functioning of the Earth System. None of the proposed conceptual predecessors – especially those dating back to centuries ago – developed within this novel framework, which constitutes a distinctive feature of the 'Anthropocene.'

Second, the search for precursors is often misguided by what Hamilton and Grinevald see as a "deflationary move" (Hamilton & Grinevald, 2015, p. 2) – namely, the 'downsizing' of the importance of the 'Anthropocene' as an Earth System singularity and as a geological time unit. Whether unwittingly or intentionally, this move, they argue, does not reflect the epistemic novelty that the term entails, nor understands the scientific context informing it. Furthermore, as multiple normative claims have been attributed to the new epoch, diminishing its importance may implicitly detract from the call for action that much environmentalism has advanced in the past decades by reintroducing the logic of 'nature-as-usual.'

Third, continuists are motivated by a fundamental misunderstanding of the science informing the 'Anthropocene.' This argument follows from the first one, namely, the importance of Earth System science in defining the term. Hamilton argues that many scholars, including scientists, often misrepresent the 'Anthropocene' as the global impact of humans on the world's ecosystems, on its landscapes, or on the global environment (Hamilton, 2015, 2017). This is not what the 'Anthropocene' represents, as the terms 'environment' or 'world ecosystems' do not entirely represent its ontological reality and specificity. Rather, the concept reflects the human influence on the Earth as a system, which is reflected both on the alternation of its functioning and in the stratigraphic signature – among others. Hamilton considers these aspects as something more profound and meaningful than the oversimplified 'environmental impact' category that he sees often associated with the 'Anthropocene' concept.

Fourth, the quest for finding precursors is based on an epistemological fallacy not too rare in the history of scientific ideas – that is, confusing correlation with causation. To summarize this argument through the words of philosopher and historian of science Alexandre Koyré:

> We must not forget, moreover, that "influence" is not a simple, but on the contrary, a very complex, bilateral relation. We are not influenced by everything we read or learn. In one sense, and perhaps the deepest, we ourselves determine the influences we are submitting to; our intellectual ancestors are by no means given to, but are freely chosen by, us. (Koyré, 1957, pp. 5-6)

In addition to Hamilton's criticism, a fifth argument can be raised against continuism. It involves the terminological and semantic misuse of presumed theoretical precursors. This practice is often accompanied by misquotation among scholars in Anthropocene Studies generating historical anachronisms and inaccuracies. For instance, in a research paper by Hermann Häusler, the author states that the "geologist and priest Samuel Haughton (1821–1897) published a new Manual of Geology and introduced the Anthropocene as the epoch in which we live" (Häusler, 2017, p. 70). His bibliographical reference for this statement is Lewis and Maslin (2015a). Contrary to what is expressed by Häusler, Lewis and Maslin do not claim that Haughton introduced the term or the epoch, but rather that he "describes the *Anthropozoic* [emphasis added] as the 'epoch in which we live'" (ibid., p. 172). In his 1865 *Manual of Geology*, Haughton proposed new terms for James Dwight Dana's classification of geological time:

> Professor Dana proposed to divide the world into five ages, which might be called the age of Mollusks, the age of Fishes, the age of Reptiles, the age of Mammals, and the age of Man. / For These terms, I would substitute the following equivalents: The Malacozoic, Ichthyozoic, Saurozoic, Mastocoiz, and Anthropozoic Epochs. (Haughton, 1865, p. 138)

Despite the terminological similarity, Haughton's (as well as other authors adopting the term, including Antonio Stoppani[52]) Anthropozoic has a different meaning, time span, evidence, and conceptual framework than our present understanding of the Anthropocene proposed unit. Exchanging the two terms freely is a form of anachronism that should be avoided.

Another example of this form of anachronism can be found in philosopher Ian Angus's *Fossil Capitalism* (2016), where the author claims, "In 1922, the Soviet geologist Aleksei Petrovich Pavlov proposed *Anthropocene or Anthropogene* [emphasis added] as a name for the time since the first humans evolved about 160,000 years ago" (ibid., p. 27). Here, the anachronism is even more evident by explicitly taking the two terms as synonyms. In the foreword to Angus's book, John Bellamy Foster writes, "The appearance of Vernadsky's book corresponded to the first introduction of the term Anthropocene (together with Anthropogene) by his colleague, the Soviet geologist Aleksei Pavlov, who used it to refer to a new geological period in which humanity was the main driver of planetary geological change" (ibid., p. 11). Vernadsky's book in question is *The Biosphere,* published in 1926. It is around those years, incidentally the last of his life, that Pavlov "used to speak of the *anthropogenic era*, in which we now live" (Vernadsky, 2014,

[52] Antonio Stoppani was an Italian priest and geologist of the 19th century. His work (Stoppani, 1867, 1873) has been recently rediscovered throughout the genealogical research on the Anthropocene because of his use of the term 'Anthropozoic' (in Italian: 'Antropozoico'). A translated excerpt from his work largely cited in Anthropocene literature is provided by Federighi (2013). For an overview of Stoppani's contribution to the geosciences, see Lucchesi (2017). On Stoppani's life and work, see Zanoni (2014).

p. 80). However, no bibliographical reference is provided by Foster for the claim that Pavlov used both terms – simply because the Russian geologist never used the term 'Anthropocene' in first place. Contrary to what Foster argues, Pavlov only introduced and characterized the 'Anthropogene,' and in a substantially different fashion than that of the present characterization of the 'stratigraphic Anthropocene.'

Pavlov seems to have first introduced the term 'Anthropogene' in a 1922 article written in French for the geological section of the *Bulletin de la Société des naturalistes de Moscou*.[53] The article ("Epoques glaciares et intérglaciaires de l'Europe et leur rapport à l'histoire de l'homme fossile"[54]) was based on a speech previously held for the annual session of the Academy of Sciences of St. Petersburg on December 29, 1921. It discussed, as the title suggests, the alternate glacial and interglacial phases from the Pliocene to the present day. It is in the conclusive section of the text that the French term 'Anthropogène' appears in the context of a proposed tripartition of the Tertiary Era:

> Je termine cet essai par un vœu. Il serait temps de renoncer à la nomenclature instable incommode et contre-historienne de la dernière ère géologique. Le nom *tertiaire* conviendrait mieux pour désigner l'ère (et le groupe) et non pas la période. Cela correspondrait au développement historique de la science (Arduino). L'ère tertiaire pourrait être subdivisée en trois périodes: *Paléogène* – période des anciens genres des mammifères, *Néogène* – période des nouveaux genre des mammifères et *Anthropogène* – période du genre humain. (Pavlov, 1922, p. 76)[55]

In Pavlov's proposal, the Anthropogene replaces the quaternary (lowercase by Pavlov) as the last period of the Tertiary, itself replacing the Cenozoic Era (which has been reestablished in today's geological time scale). Whereas no (absolute) dating is provided along the text in terms of time range, Pavlov identifies the "période du genre humain" as commencing with alternate periods of glaciations, and the appearance of the first traces of humans in Europe. Notably, Pavlov cites stone tools, eoliths, and the Piltdown Man as proxies for the beginning of the quaternary/Anthropogene (ibid., pp. 72–73). All these proxies are deeply problematic, especially when a comparison between the Anthropogene and the Anthropocene is at stake. Already in 1905, skepticism toward the artificial nature of eoliths – flint mineral aggregates (i.e., 'nodules') believed to be ancient artifacts – begun to arise (Warren, 1905). The skepticism was confirmed during the 20th century, proving eoliths to occur naturally rather than being a product of ancient craftmanship (O'Connor, 2003). The Piltdown Man, supposedly the missing link between humans and apes discovered by Charles Dawson in 1912, was exposed as a scientific hoax in 1953 (Webb, 2016), and is now considered one of the greatest scientific forgeries in the history of British science (Bartlett, 2011).

The use of stone tools was a shared proxy for geological, paleontological, and archaeological communities in the 19th and early 20th centuries in separating the Stone Age from the Bronze Age.

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53 In English: *Bulletin of the Naturalist Society of Moscow*.

54 In English: "Glacial and interglacial epochs of Europe and their relationship with the history of human fossils."

55 In English: "I finish this essay with a wish. It is time to renounce to the inconvenient and counter-historically unstable nomenclature of the last geological era. The name *tertiary* would be better suited to designate the era (and the group) and not the period. This would correspond to the historical development of science (Arduino). The tertiary era could be subdivided into three periods: *Paleogene* – period of the old genera of mammals, *Neogene* – period of the new genera of mammals, and *Anthropogene* – period of the human genre." The emphasis in the French quote replaces letter spacing as occurring in the original text.

Nevertheless, an absence of established absolute dating techniques could not allow scientists to probe into the deep past – an issue that geologists were especially aware of. At the time Pavlov proposed a new distinction of the Tertiary, British geologist Arthur Holmes had just published his pioneering book *The Age of the Earth* in 1913, where he championed modern techniques of geochronology based on radioactive decay of elements. Pavlov was still part of the 'pre-radiometric dating' geological world, whose stratigraphy relied on relative dating techniques, and archaeological evidence (for the Quaternary). In fact, in addition to cycles of glacial and interglacial periods, much of what informs his Anthropogene is based on the prehistory of humanity: "[l]e progrès de l'étude des événements se rapportant aux derniers temps de l'histoire géologique et au commencement de la préhistoire de l'humanité présente un chapitre très interessant [*sic*] de l'histoire de la science"[56] (ibid., p. 23).

A further reason why 'Anthropocene' and 'Anthropogene' are sometimes interchanged, as just shown in Angus (2016) and Foster, is because the Russian term 'антропоген' had been translated (Shanster, 1973) as both 'Anthropocene' and 'Anthropogene' ("Paleontologicheskiy Zhurnal 1966, no. 1," 1966; Shanster, 1973; Vinogradov et al., 1968). This translation needs further clarification. The current Russian translation of 'Anthropo*cene*' is in fact 'антропоцен,' whilst now 'антропоген' translates only as 'Anthropo*gene*,' the proposed period substituting the Quaternary that was adopted following Pavlov's recommendations. This extremely thin line of distinction (a matter of one single letter) is important to stress. Contemporary geochronological classification uses the suffix *-gene* for Periods/Systems, whereas the suffix *-cene* is used for epochs/series. This naming protocol was not yet established in Soviet geochronological research. For instance, when E. V. Shanster authored the entry 'Anthropogenic System' for the second volume of the *Great Soviet Encyclopedia*, he equaled "Anthropogenic System" with "Anthropocene" because he adopted the same suffix for two Periods/Systems of the Cenozoic, namely the Paleocene (today Paleogene) and the Neocene (today Neogene). The translation was primarily a matter of terminological consistency. In our contemporary vocabulary, Shanster's Anthropocene should be translated as 'Anthropogene.' But as previously explained, this period was substantially different from the Anthropocene as currently being advanced by the AWG. Henceforth, instances of 'Anthropocene' in the Soviet literature should be considered as homonyms of the present Anthropocene: they mean different things through the same word.

The Anthropozoic, Anthropogene, or other terminological variants should not be so easily interchanged with the Anthropocene proposed unit. This is not a mere issue of nominalism. On the contrary, unruly equivalence between these two terms is exactly at the core of much misunderstanding within the genealogical approach, including the 'deflationary' move purposely or unwittingly put forward by it. It is also a general anachronistic mistake to overlap terms and concepts based on their semiotic and conceptual similarities. Research literature should consider these terms as separate instances of 'geological reflexivity,' as shall be explained later in this section.

[56] In English: "The progress concerning the study of the events relating to the last times of geological history and the beginning of the prehistory of humanity presents a very interesting chapter in the history of science."

Hamilton's 'radical' discontinuism, characterized by a rejection of the genealogical research *tout court*, has yet to be fully discussed in context of the history of ideas. That is because criticism on the meaning of 'genealogy,' as noted in 1.2.4.1, has not been extensively tackled yet either.[57] An interesting summary of the debate has been outlined by Horn, who sees these two opposing views as complementary rather than conflicting (Horn & Bergthaller, 2020). By her account, discontinuism (which she labels as 'presentists') focuses more on the present impact of humans through the lens of Earth System science, whereas continuism (the 'historicizing' understanding of the 'Anthropocene') looks at the historical roots of the 'Anthropocene' through culture to technology studies. Her preference toward continuism is made clear by addressing Hamilton's view as a "narrow conceptualization," an "extremely lean, epistemically homogeneous narrative" that excludes "any discourses that do not feed into the current [Earth System science] paradigm" (ibid., p. 37).

Whilst it is reasonable to consider the genealogical analysis useful in providing an interesting and evocative pre-history (or *paleo*-history) of the 'Anthropocene,' the 'Anthropocene' situates in a substantially different conceptual and linguistic – as well as historical – framework informing the term with a specific and unprecedented meaning. To advance a critique: the broader scope of Anthropocene Studies, harboring and welcoming interpretations and discourses from the natural sciences to the arts, should not be confused with the specific historical and epistemological task of reconstructing the birth of the 'Anthropocene' as a theoretical entity – an interpretative and descriptive task requiring much rigor and analyticity. This task is necessarily exclusive or 'sectorial,' especially considering the lack of a shared methodological framework in Anthropocene Studies. The risk of including "any discourse" is that of incurring the same issues already at the core of research on the 'Anthropocene' underscored in section 1.1.

At the core of Hamilton's account of the 'Anthropocene' as stand-alone concept is the novelty of the Earth System framework. In addition to this conceptual and historical base, a watershed separating the 'Anthropocene' from many presumed antecedents is the development of radiometric dating techniques in the early 20th century that set the foundation for modern absolute dating. These methods relied on radioactive decay, discovered by Henri Becquerel in 1896. Only a few years later, Ernest Rutherford and Frederick Soddy discovered in 1902 that radioactive elements decayed at specific rates, in fact delineating the concept of 'half-life' of chemical elements.[58] Already in 1904, Rutherford suggested the application of radiometric dating to measure geological time (Elias, 2015). In 1907, Bertram B. Boltwood, a pioneering figure in radiochemistry, suggested:

> If the quantity of the final product occurring with a known amount of its radio-active parent and the rate of disintegration of the parent substance are known, it becomes possible to calculate the

[57] This is clear evidence of the increasing number of question marks raised in the 'Anthropocene' debate arena, all requiring dedicated analysis through educational and research programs developing under the disciplinary category of Anthropocene Studies (section 1.1).

[58] In nuclear physics, the concept of half-life expresses the statistical amount of time required for the nuclei of an unstable atom to undergo radioactive decay. The concept is particularly relevant in radiometric dating, and for assessing the chemostratigraphic signature of the proposed Anthropocene unit, discussed later in section 3.1.2.5.

> length of time which would be required for the production of the former. Thus, knowing the rate of disintegration of uranium, it would be possible to calculate the time required for the production of the proportions of lead found in the different uranium minerals, or in other words the ages of the minerals. (Boltwood, 1907)

The rapid developments in physics and chemistry during the first half of the 20th century, from the development of mass spectrometers to the discovery of nuclear fission in 1938, saw the normalization of radiometric dating as *the* scientific method to probe into the geological deep past, finally providing an insight into the much-yearned-for absolute age of elements and setting the path for modern geochronology. This immensely important technique revolutionized the scientific world, particularly the geosciences, paleontology, and evolutionary biology. The development of radiocarbon dating (based on carbon-14) had also a remarkable impact on the human sciences as well, as in the case of archaeology. Humanity stepped out from a dark, inscrutable, and primarily Biblical understanding of time to a more and more precise characterization of geological time in absolute terms.

Earth System science, modern geochronology, and stratigraphy inform the language, practices, evidence, and methods that shape the 'Anthropocene' in the scientific discourse. Borrowing Foucault's (1970) popular terminology, they represent the *episteme* or conditions of possibility of the 'Anthropocene.'[59] Proposed conceptual equivalents of the 'Anthropocene,' such as Stoppani's 'Anthropozoic,' and authors whose thought supposedly anticipated the dawn of a human-driven epoch, are expressions of a different *episteme*. Rather, they hint of a general form of 'geological reflexivity.'[60] The example that could be provided, of interest in the history and philosophy of science, is that of Leucippus and his pupil Democritus. Their atomic theory of the universe, formulated around the 5th and 4th century BCE, has an outstanding resonance with our contemporary view on atoms as elementary constituents of reality. For this reason, it is not uncommon to consider them precursors of the modern conception of the atom, and mention them as such in high school of university textbooks. However, this is more a captivating move for readers than a claim of genealogical spirit. It would be unwise to argue that Leucippus and Democritus provided the episteme informing 19th-century particle physics, which is based on methods, techniques, a language, and also a social organization and production of knowledge radically different from that of ancient Greece. A genealogy of the kind is of valuable historical interest, but it expresses 'atomic reflexivity' only insofar as it is treated as a separate instance of atomic theory fundamentally different from our contemporary notion of 'atom.'

Therefore, discontinuism looks at correlations and similarities with a suspicious eye, grounding its understanding of the 'Anthropocene' into revolutionary scientific developments – that of Earth System science and modern geochronology – rather than genealogical ancestries. Consequently, the historical depth

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[59] On 'silent' revolutions that occurred during the 20th century with remarkable implications for the Earth sciences, see Allègre et al. (1999).

[60] While Bonneuil and Fressoz (2016) see the 'Anthropocene' as an instance of *ecological* reflexivity that has largely been anticipated during the 18th and 19th centuries, the 'Anthropocene' does not in itself entail ecological reflexivity, but rather *geological* reflexivity, a substantially different claim than recognition of human impact on the environment for its focus on humans as geological (rather than ecological) agents. A definition of 'geological reflexivity' is provided in 1.2.4.3.

of the term is truncated. Hamilton locates the starting point of the conceptual history of the 'Anthropocene' in the 1980s and 1990s, coinciding with the establishment of international research entities dedicated to the study of the Earth as a system. However, if we consider modern geochronology as another pillar of the Anthropocene Hypothesis, its pre-history could be traced to commence with the use of the term 'Anthropogene' in Soviet geological literature during the second half of the 20th century. This literature seems to have implemented the 'Anthropogene,' occasionally translated as 'Anthropocene' (Shanster, 1973), to identify the Quaternary period – as Pavlov originally suggested. A dedicated analysis on the Russian definition of 'Anthropogene' in the context of Soviet geological research has not yet been conducted. Nevertheless, given the present status of the geological time scale, it is possible that geological evidence supporting the Anthropogene in Russian research literature may differ substantially from present evidence informing the Anthropocene unit (see also Gerasimov, 1978 for usage of the term 'Anthropogene' in Soviet geology). It is also important to consider the social and historical context in which this science was being produced, namely, a Marxist ideology blended with science as one overarching state-narrative.[61]

Jai Syvitski (2012) identifies in 1990s Chinese geoscientific literature a research area anticipating the 'Anthropocene' in terms of formalizing scientifically the global impact of human activity. Such literature, gravitating around the Institute of Geology and Geophysics in Beijing – at that time under the direction of Chen Zhirong – made extensive use of the term 'Anthroposphere.' The literature systematically used the term 'Anthroposphere' in the context of Earth System science, considering it as an additional 'sphere' in the Earth's function (Zhirong, 1993, 1997, 2006).

Perhaps the closest terms preceding the modern 'Anthropocene' semantics are Hubert Markl's 'Anthropozoikum' (Ehlers & Krafft, 2006b; Markl, 1986), Andrew Revkin's 'Anthrocene' (Revkin, 1992, 2016) and Michael Samways's 'Homogenocene' (Samways, 1999). Coming from trained biologists, both terms 'Anthropozoikum' and 'Homogenocene' stressed the role of humankind as biological agents, scattering species across the globe and deeply affecting biodiversity. On the other hand, Revkin's 'Anthrocene' appears to come the closest to our modern understanding of 'Anthropocene' in terms of foreseeing possible research studying the impact of humankind in geological terms. He informally coined the Anthrocene as a new, post-Holocene age that future Earth scientists and geologists will recognize as defined by human actions (Revkin, 1992). Around seventeen years later, those Earth scientists and geologists concretized in the AWG.

[61] This point was discussed through private correspondence with the historian and philosopher of science Jacques Grinevald, also a member of the AWG. He agrees that the use of 'Anthropogene'/'Anthropocene' in early and middle Russian scientific literature is substantially different from the AWG's formulation, first and foremost because of its equivalence with the Quaternary, but also for its embeddedness in a deeply ideological science. The 'myth' of the Russian ancestorship was, according to him, launched by Marxist historian John Bellamy Foster in his preface to Ian Angus's book *Facing the Anthropocene* (Angus, 2016). However, mention of Pavlov already appeared a year prior to Angus's monograph in Lewis and Maslin's (2015a) highly debated "Defining the Anthropocene" article, published on *Nature*.

1.2.4.3 Solving the Dilemma

Continuism and discontinuism both have their strong and weak points. On the one hand, continuism enriches the historical and semantic background of the 'Anthropocene,' safeguarding the strength of its meaning and message against criticism of post-modernism or academic craftiness. However, in charting a history that extends hundreds of years, it risks losing the focus on the present defining qualities of the 'Anthropocene,' deflating or minimizing – either purposefully or unwittingly – its theoretical relevance. On the other hand, discontinuism grounds the present meaning of the term on recent but fundamental changes in science (i.e., Earth System science and modern geochronology) that inform a substantially different theoretical and research framework – one informing the present notion of 'Anthropocene.' However, by eliminating any connection with past concepts, discontinuism risks disregarding consolidated practices in the history of science and the history of ideas, thus depriving Anthropocene Studies of a large portion of historical research that has been, and can further be, conducted. Approaching the history of the 'Anthropocene,' and therefore understanding the Anthropocene, seems to pose a methodological dilemma: whether to consider it a *revenant*, or a theoretical singularity.

One way to tackle this dilemma is by looking at the 'Anthropocene' as well as any proposed conceptual precursors as historically and epistemologically *discrete instances of geological reflexivity*. Let 'geological reflexivity' be defined as a meta-historical epistemic category collecting and connecting each occurrence, either discursive or terminological, of descriptive and/or normative recognition of human impact on the Earth on a planetary scale. By subscribing to this meta-category of ideas and narratives highlighting the role of humans as geological agents (dating at least as far back as the late 18th century), the 'Anthropocene' idea still constitutes a theoretical entity with its own discrete history and epistemological status. Such status is granted by the unique context and theoretical framework it draws its scientific meaning from, namely, modern geochronology techniques and Earth System science. Considered this way, not all the 'Anthropocene' properties can be deduced (nor deflated) by merely looking at its connection to a broader trend of geological reflexivity, nor can the term be utterly separate from any recognition of human as geological agents. It is an idea produced within a specific episteme. In this sense, it is independent from any genealogical precursors. Studying its relationship with other instances of geological reflexivity (e.g., the Anthropozoic) is a different endeavor than researching its peculiar epistemological status, which requires an understanding of its epistemological context. An in-depth analysis of the contextual characteristics of the Anthropocene Hypothesis as a scientific hypothesis is provided throughout section 4.2.

Solving the dilemma this way seems to suggest that the genealogical approach is mistaken in interpreting the 'Anthropocene' as the direct product of the meta-historical category of 'geological reflexivity.' Once again, 'geological reflexivity' should be understood more as a historiographical category allowing existing research to locate instances of recognition of humans as geologically relevant entities with their own stratigraphic signature. One research trajectory within Anthropocene Studies has been identifying possible correlations and causations among these instances. Nevertheless, by implicitly or explicitly considering the 'Anthropocene' as the latest instance of geological reflexivity, the genealogical approach traces a fruitful and historically rich research landscape that should not be disregarded too quickly.

A second way to solve this dilemma is by differentiating between a *paleo-history*, *pre-history*, and *modern history* of the 'Anthropocene' (Figure 1.1). Anthropocene scholars (Zalasiewicz et al., 2019b) have already been labelling the corpus of literature preceding Crutzen's popularization of the term as 'prehistory' of the 'Anthropocene,' followed by its 'modern history.' This way, rather than being utterly rescinded from the 'Anthropocene,' the genealogical research promoted by continuists would then focus on the *paleo-history* – stretching from late 18th century (or prior) to the early 20th century – and *pre-history* of the term – from the application of radiometric dating in the early 20th century to the 1990s. Consistent with the revolutionary changes it brought about, radiometric dating constitutes the primary watershed between paleo-historical and pre-historical 'precursors' of the 'Anthropocene.' Such division would avoid any unwitting or voluntary dissolution of the 'Anthropocene' into past concepts.

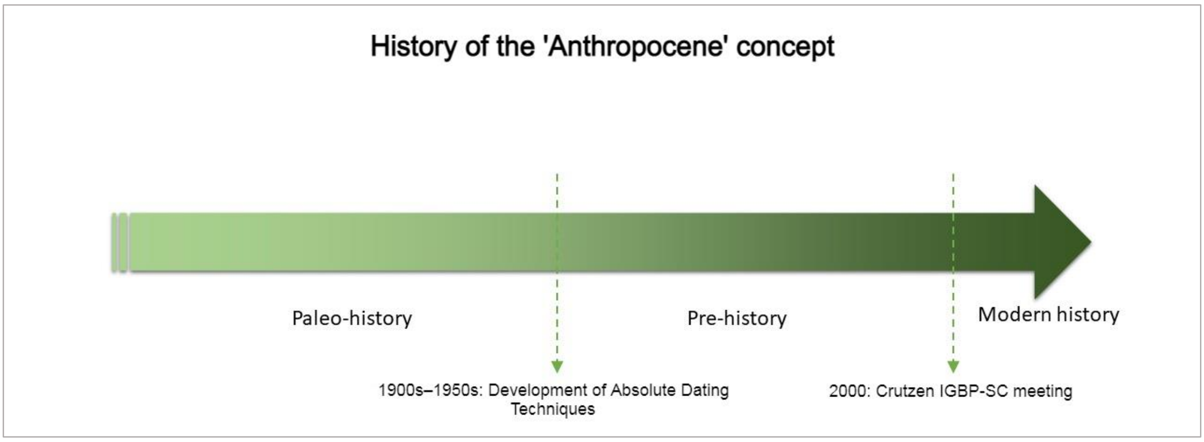


Figure 1.1. Threefold division of the history of the 'Anthropocene' concept. (Illustration by the author)

This approach would not solely highlight and discuss possible theoretical continuities, but also discontinuities between each instance – including the 'Anthropocene.' Reframing the genealogical debate in terms of geological reflexivity would preserve the uniqueness of the Anthropocene Hypothesis while acknowledging an extended tradition recognizing humans as geologically relevant agents on the Earth.

Once the paleo- and pre-history of the 'Anthropocene' are located, the 'modern' history could unequivocally be traced back to Crutzen's famous intervention at the International Geosphere-Biosphere Programme Science Committee meeting (or IGBP-SC) in February 2000. Indeed, this moment represent the genesis of the modern conception of 'Anthropocene,' and the starting point of the historical analysis conducted in the next chapter.

Crutzen's seminal intervention, and the 'Anthropocene' publications that ensued, prompted a discussion that slowly transformed the term from informal conjecture to a stratigraphic hypothesis. In 2009, the AWG was formed, and Chakrabarty published his seminal contribution "The Climate of History: Four Theses." These two defining moments – the establishment of the AWG, and Chakrabarty's *Four Theses* – could justify a further historical separation in the modern history of the 'Anthropocene' based on a pre- and post-AWG 'Anthropocene.' The years following the establishment of the AWG, and the inclusion of humanities in the 'Anthropocene' debate, saw a quantitatively documented surge in interest, culminating in documentaries, art exhibitions, and even songs and musical albums making use of the term. Christian Schwägerl (2014) reports that in 2003, Google would provide 413 results for the term 'Anthropocene.' In 2011, results increased to 450,000; in 2013, to 1,070,000. By September 2021, results totaled 5,350,000. One can also observe such discrepancy between the amount of literature produced between the 2000–2009 decade and the post-2009 years by also looking at research search engines such as ScienceDirect.com or Dimensions.ai – the latter providing for the year 2013 alone more than four times the amount of material provided between the 2000–2009 decade.[62]

The distinction between a pre- and post-AWG 'Anthropocene' is one of the fundamental premises of the research hereby conducted. Indeed, the establishment of the AWG delimits represents the upper limit of the *early research literature* on the 'Anthropocene,' which it explored in detail in the following chapter, as well as the "stratigraphic turn" (Davies, 2018, p. 64) – that is, the formulation of the geological 'Anthropocene' (i.e., the Anthropocene Hypothesis). It is argued that the first decade (2000–2009) of this recent history of the term has been largely overshadowed or often compressed in a handful publications and events. On the contrary, the following decade up to the present time has blossoming interest not just restricted to the work of the AWG. As illustrated in 1.1.1, the last decade witnessed the rise of dedicated 'Anthropocene' journals within and outside the academic niche. This large increase in public and academic perception is important to highlight because in its wake, it generated the many trends of debate and lines of criticism toward the notion. Controversy was virtually non-existent during the decade hereby under scrutiny, and the term, as illustrated in Chapter 2, was largely used by scientists rather than humanists or social scientists.

1.3 Defining the Anthropocene Hypothesis

The previous sections provided a critical overview of the major research trends, critical debates, and theoretical issues in Anthropocene Studies. This multidisciplinary network of research has gained momentum in the past ten years. The term 'Anthropocene' seems especially effective in providing a hub for discourses of an environmental nature, from increased rates of extinction and Earth System changes to

[62] Estimates drawn from https://app.dimensions.ai/discover/publication as of September 17, 2021. The total number of results for the 2000–2009 timeframe is 1,311, whereas the total number of results for the year 2013 alone is 6,062.

planetary thresholds of climate change, environmental justice, geological agency, and more. This is because, rather than focusing on isolated issues of an anthropogenic nature, the 'Anthropocene' represents "not a *problem*, but a *predicament*" (Thomas et al., 2020, p. 3). It is a state of affairs that, according to historian Julia Thomas (2019), no technical fixes can provide solutions for, but that we can only acknowledge and navigate. If so, the extent of this predicament lies beyond disciplinary domains – if not beyond traditional knowledge organizations of academic settings (Heikkurinen et al., 2016).

Yet, because of the novelty and sudden relative popularity the term benefitted from, more research on the philosophical and epistemological substrate of this notion needs to be conducted to assess its utility, validity, and legitimacy. Attempting to frame the multidimensional nature of the term into a single unifying definition seems to do no justice to the possible multiple meanings that it encompasses. This is even more pronounced with regard to how the 'Anthropocene' as a planetary phenomenon manifests itself in different modalities across human societies not just in geographical terms, but also in terms of race (Yusoff, 2019) and gender (Paulla & Anna, 2017) – as suggested by branches of humanistic scholarly research. This seems to add additional weight to the already existing burden of defining the 'Anthropocene' for multi- and transdisciplinary purposes.

Therefore, instead of conducting conceptual engineering over such a multidimensional and multidisciplinary term in order to extract a strictly defined, but unavoidably limited, definition of the 'Anthropocene,' a different object of research is considered. The object in question is the Anthropocene Hypothesis, namely, the scientific – and specifically stratigraphic – expression that emerged amidst the 'Anthropocene' debates. The Anthropocene Hypothesis is equivalent to what 'Anthropocene' scholars have occasionally addresses as 'geological Anthropocene' or 'stratigraphic Anthropocene.' Indeed, the Anthropocene Hypothesis represents the *stratigraphic variant* of the broader 'Anthropocene' concept. This scientific hypothesis of recent formulation has not yet been thoroughly scrutinized in philosophical terms – especially as an object of interest for the philosophy of science. Multiple reasons explain this research vacuum, some of which are outlined in section 1.3.3.

In order to consolidate a preliminary conceptual separation between the 'Anthropocene' and its stratigraphic variant, first a distinction between a descriptive and normative 'Anthropocene' is advanced. This distinction should help in delineating the theoretical boundaries of the Anthropocene Hypothesis in terms of aim, methods, and scope. Secondly, the Anthropocene Hypothesis is properly defined by locating three fundamental claims that characterize its scientific core, and distinguish it from the 'Anthropocene' concept. Lastly, section 1.3.3. discusses the methodologies adopted to study this scientific hypothesis. Because, as stated in the introductory remarks to this study, this work is set as an interdisciplinary effort, multiple methodologies of diverse disciplinary provenance are provided. Nevertheless, the main disciplinary matrix is considered to be the history and philosophy of science – itself a multidisciplinary effort.

1.3.1. The Descriptive and Normative 'Anthropocene'

To say anything about the world requires the use of verbal language, which allows us to express statements in different ways. Language statements can be analyzed by using many epistemic categories. One way to look at how statements are expressed is by categorizing them as *descriptive* or *normative*. Because of the way they are formulated, some statements seem to be either true or false (or approximately true or approximately false) – that is, they can be verified or falsified *sensu lato* by looking at their evidence, logical consistency, or other proofing methods. The sentences 'There are more than one billion human beings currently inhabiting planet Earth,' 'The Earth is 4.54 billion years old' and 'Dogs are reptiles' are examples of such sentences. They can be verified or falsified by looking at the real world and determining the truth of their claims. These statements tell how the world is (or how it approximately is) by merely describing it. Because of this, they could be classified as *descriptive statements*.

Other statements do not entail any degree of truth (or falsity) because they express value judgements about the world – that is, they express one's personal interpretation of a certain state of affairs. They do not describe how the world is, but rather how it ought (or ought not) to be. The claims 'The Earth is beautiful' and 'Humans should foster cooperation to create better societies' are examples of normative statements. Most, if not all, ethical claims could be considered normative statements: to claim that 'life has an intrinsic value' cannot be verified from a descriptive standpoint. It is based on the ethical and moral categories through which we attribute value to what we identify as life. Normative statements can be further classified not based on their syntax, but rather on their semantics (i.e., their content). Some statements deal with behavioral norms or the *ethos* one ought to observe in a given society (e.g., 'You should not steal'). This type represents *normative-ethical statements*. Other statements deal with expected predictions based on past background knowledge that is taken as a norm (e.g., 'It should be cold in February in Iceland'). This type represents *normative-functional statements*. A third class of statements deals with aesthetic judgements of a qualitative nature (e.g., 'The book *The Lord of the Rings* is better than the movie'). This type represents *normative-aesthetic statements*.[63] A fourth possible class of statements are prescriptive-procedural: they concern the established norms of executing any activity for whose performance those norms are (usually) implemented (e.g., 'Stratigraphy should follow the guidelines of the International Stratigraphy Guide'). This type represents *normative-methodological statements*.[64]

The distinction between descriptive and normative claims should not be taken too rigidly, as their boundaries are blurred and often intersect with one another (see Mylius, 2018, pp. 153-155). Mostly, the descriptive or normative nature of a statement is determined by its context. Claiming that 'the Earth gravitates around the Sun' in early 17th-century Europe may have been descriptive from our present

[63] The classification promoted here draws on the type of normative statements outlined in the online lecture "How to Build a Compelling Moral Argument," available at https://criticalthinkeracademy.com/courses/moral-arguments/lectures/655352 (accessed on March 2, 2021).

[64] The normative sentence types presented here do not exhaust the possible classification of normative statements. Legal, biological, moral, or medical statements may represent additional types of normative statements.

standpoint, despite the fact that it had tremendous political (viz. normative) implications during those times – as the Galileo affair bears witness. There is no logical nor linguistic property that can single-handedly classify language statements into sharply defined classes of sentences. Nevertheless, it seems feasible to distinguish some statements that, by virtue of how they are formulated and their context of formulation (e.g., the aim, the person stating the sentence, the historical time of utterance, etc.), entail either descriptive or normative claims about the world.

The research areas established by Anthropocene Studies include both descriptive and normative considerations about the 'Anthropocene,' so that the term entails both descriptive and normative meanings. Common descriptive proxies used to describe the 'Anthropocene' in extant literature are the increase in Earth System and socio-economic trends during the Great Acceleration (Steffen et al., 2015; Steffen et al., 2011b); the ongoing rates of extinction attributed to humans' niche-constructing activities (Boivin et al., 2016; Ellis, 2016b; Ersten et al., 2016) or hyper-dominance (Pena Rodrigues & Lira, 2019, p. 141); and the manifold types of stratigraphic evidence of anthropogenic sediments of present and future geological relevance (Waters et al., 2014a; Zalasiewicz et al., 2019b). This literature, surveyed throughout section 1.2, provides a descriptive snapshot of the ontology of the 'Anthropocene' generally (though not exclusively) based on the language of the natural sciences. '*Homo sapiens* is the plausible cause of the sixth mass extinction event' is either true or false regardless of one's normative consideration or personal feelings on the matter, and regardless of its political implications. In its descriptive sense, the 'Anthropocene' is not a label to mark a period of human history, but a term designating a set of identifiable characteristics. As the AWG (Zalasiewicz et al., 2019b, para. 1.1) argues, it is a phenomenon that happens to be driven by humans, and is inscribed in the Earth's geological history – even if humans were to disappear suddenly. Philosophically, this is a strong claim because it asserts that the Anthropocene (as a geological time unit) exists *independently* from us (which is not to say that we are not the cause). This is a *realist* stance toward the Anthropocene. It claims that what makes the Anthropocene such has as much of an ontological *raison d'être* as the Cretaceous-Paleogene meteor-driven extinction event, the Great Oxygenation event, or other episodes of the Earth's geological history – with the fundamental (and perhaps most important) difference that humans are both the observer and the cause of this event.

The social, political, artistic, or generally humanistic response to the 'Anthropocene,' either as a broader idea or as a proposed time unit or Earth System phase, informs the notion with *normative* value.[65]

[65] A Google search associates the designation 'normative Anthropocene' with environmental humanist and political ecologist Anne Fremaux. The search results redirect to an abstract of the second chapter of her 2019 book *After the Anthropocene*, entitled "A Critical Examination of the Naturalistic Narrative of the Anthropocene" (available at https://www.springerprofessional.de/en/a-critical-examination-of-the-naturalistic-narrative-of-the-anth/16574900, accessed on January 6, 2021). When asked about her theorizing of the normative–descriptive dualism of the 'Anthropocene' concept, Fremaux (personal communication, January 5, 2020) provided the following answer: "The normative Anthropocene refers to the ecomodernist narrative that uses the pseudo 'age of humans' to justify a further artificialization and capitalization of the planet (this is what I develop in Chap 4) while the descriptive anthropocene is the scientific narrative that tries to be as objective as possible as far as human transformation of planet earth is concerned (describing therefore the destruction that humankind has caused and the critical situation in which we are – scientific facts)." The distinction promoted in this section aligns with Fremaux's connotation of the normative and descriptive 'Anthropocene' – although additional types of normative statements are also recognized.

As a broader term framing the human–Earth relationship, the concept has been invested with normative significance ever since Crutzen's coinage of the term. Along with its descriptive content, the 'Anthropocene' has been implemented as a tool to broaden environmental discourse beyond the limits of climate change, biodiversity loss, or sustainability, by connecting the threads of these environmental narratives into one unifying framework. This literature – stemming especially from the environmental humanities, ecocriticism, or environmental and sustainability studies – tells what should be done in response to the ethical, political, social, and cultural challenges posed by the dawn of the 'Anthropocene.' It also stresses the plurality of diversified realities experienced by humans in facing this epoch. The epoch is not merely an analytical object of observation whose ontology is restricted by its scientific depiction: it also poses challenges to the very political, social, and economic means of subsistence of human societies. It asks for radical transformations, connecting a nexus of environmental narratives and at the same time extending beyond the limited yet dominant narrative of climate change (Crist, 2007; Thomas, 2019; Thomas et al., 2020).

A symbolic example of normative framing of the 'Anthropocene' discourse is the 'good Anthropocene' idea promoted by environmental scientist Erle C. Ellis (2011b) and later championed by environmental journalist Andrew Revkin (2014b, 2014c). For Ellis (2011), human resilience expressed in technological advancements will ensure "a good, or at least a better, Anthropocene is within our grasp" (p. 42). The idea – heavily criticized by philosopher Clive Hamilton (2014a; 2014b; see also Dalby, 2016) – is emblematic of normative attitudes toward the 'Anthropocene' as a state of affairs, but also as a conceptual framework for the present human–environment relationship.

It should once again be noted that the difference between normative and descriptive statements is difficult to delineate purely on a linguistic and conceptual level. This is especially the case if the 'Anthropocene' concept is understood as a *dual character concept* – that is, a class of concepts where both a normative and descriptive dimension are encoded that "are related but independent" (Reuter, 2019, p. 1) to one another.[66] Nevertheless, it seems useful to pose such a distinction to delineate the different research trajectories undertaken by disciplines engaged with the study of the 'Anthropocene' as a broader conceptual category, or as a phenomenon (or set of phenomena) with distinctive and observable features. This distinction underpins much of the theoretical outline hereby proposed to study the geological or stratigraphic variant of the 'Anthropocene' concept. It is shown throughout the following chapters that the core statements of this recent scientific hypothesis are fundamentally *descriptive*, meaning that the Anthropocene Hypothesis represents (in general terms) a descriptive statement about reality. However, it is also argued that the hypothesis also entails (1) *normative-functional* and (2) *normative-methodological* types of statements because (1) it contrasts with expected predictions within a Holocene framework (in stratigraphy, but also in Earth System science and biology), and (2) it challenges (directly and indirectly) in different ways

[66] Dual character concepts that have been recently investigated by philosophers, linguists, and cognitive scientists. For relevant literature, see Del Pinal and Reuter (2017), Knobe et al. (2013), and Leslie (2015).

traditional stratigraphic research.[67] Two examples may be useful in clarifying the ways in which the Anthropocene Hypothesis (tackled in the next section) entails normative statements.

Firstly, the AWG (Zalasiewicz et al., 2019b) has provided mineralogical evidence associated with the lithostratigraphic characteristic of the Anthropocene time unit (section 3.1.2.1). The group has been stressing the important of human-mediated mineral-like compounds as a seemingly global and synchronous marker of the Anthropocene. However, the International Mineralogical Association (IMA) Commission on New Minerals and Mineral Names (CNMMN) does not regard human-mediated mineral-like compounds as minerals – despite having virtually the same chemical and structural components of naturally produced minerals. As of 2017, only 208 types of human-mediated minerals have seen formal approval by the IMA. The CNMMN decreed that no future human-mediated chemical compounds will be considered as minerals, because minerals are only those that have "been formed as a result of geological processes" (Nickel, 1995, p. 689). To argue that human-mediated mineral-like compounds represent substantial mineralogical (and lithostratigraphic) evidence implies challenging the *norms* established by the IMA of what makes a mineral such.

Secondly, chemostratigraphy provides perhaps the most suitable primary marker for an Anthropocene to be placed around 1950 – that is, radionuclides fallout (section 3.1.2.5). However, chemostratigraphy is not formally recognized as an independent unit of stratigraphic classification, neither by the International Subcommission of Stratigraphic Classification (part of the ICS) nor by the North American Commission on Stratigraphic Nomenclature (NACSN). When asked why this is the case, the chemostratigrapher and geologist Muthuvairavasamy Ramkumar (personal communication, September 30, 2020) argued that "reasons for not having chemostratigraphy recognized yet may be 1. It is mostly used by a select group within petroleum exploration industry and fewer in academia, unlike sequence stratigraphy [and] 2. In order to push through the method to be recognized by NASC or international stratigraphic commission, a pressure group has to be formed and it is yet to take shape." Whether or not the AWG has been directly investing in the role of a 'pressure group' for recognizing chemostratigraphic units in either the ISG or the NACSN, promoting chemostratigraphic evidence as primary marker for the Anthropocene represents a major challenge to the *norms* for defining a geological time unit.

This theoretical clarification of the descriptive and normative scope of the hypothesis is important for framing the Anthropocene Hypothesis as a discrete theoretical entity, as well as for framing the limits of the present research.

[67] It should be noted that the AWG is not *directly* advocating for a restructuring of the epistemological foundations of stratigraphic classification to accommodate an Anthropocene Epoch. On the contrary, it is their aim to adhere to the standards and protocols of geochronological classification, and to promote a formal ratification within this framework. The epistemic challenges raised are rather a product of applying geochronological and stratigraphic methods and criteria to extremely recent geological times. These represents circumstances in stratigraphic research, as later observed in Chapter 4.

1.3.2. The 'Anthropocene' and the Anthropocene Hypothesis

What, then, is the Anthropocene Hypothesis?

Sections 1.1 and 1.2 provided an outline of the epistemological and ontological characterization of the 'Anthropocene' as boundary object – that is, an object "plastic enough to adapt to local needs and the constraints of the several parties employing [it], yet robust enough to maintain a common identity across sites," and with "different meanings in different social worlds" (Star & Griesemer, 1989, p. 393). It is not uncommon that scientific terms and ideas are embraced and readapted by the humanities, social sciences, and arts before their full acceptance by the scientific community. Darwin's theory of evolution through natural selection was shaped in a Marxist framework sooner than it was institutionalized into science, which only happened in the 20th century (Renn, 2020). Einstein's general relativity had initially more repercussions in the humanities and arts than in physics (Hacking, 2012). Terms and ideas are exchanged, borrowed, redefined, reshaped, and reformulated from their original meanings, occasionally to a point unrecognizable from their original use. The Kuhnian term 'paradigm' is perhaps most emblematic of this scholarly occurrence – a term Kuhn had to clarify virtually for the rest of his academic life.

The term 'Anthropocene' mostly developed and spread among scientific communities during its early phase (2000–2009). The term was mostly used informally, and had not yet received much attention from the humanities and social sciences. It was only after the formation of the AWG, and Chakrabarty's (2009) publication of "The Climate of History," that humanists and social scientists began to critically engage with the term. From 2009 onward, the 'Anthropocene' concept followed several different trajectories and purposes across the academic landscape as well as popular culture. One of these paths was the possibility of recognizing the Anthropocene as a distinct geological unit on the geological time scale. As detailed in Chapter 2, this research trajectory spurred from a few geologists interested in assessing the stratigraphic signature of *Homo sapiens*. This research trajectory developed throughout the years, accumulating research material and forging its own narrative and history – that is, the 'geological' or 'stratigraphic Anthropocene.' As stated by Waters et al. (2016), this research trajectory has developed by following two leading questions: "Have humans changed the Earth system to such an extent that recent and currently forming geological deposits include a signature that is distinct from those of the Holocene and earlier epochs, which will remain in the geological record? If so, when did this stratigraphic signal (not necessarily the first detectable anthropogenic change) become recognizable worldwide?" (p. 1). Answering these questions is the central scope of the AWG, and of the 'stratigraphic Anthropocene.'

Thus, to delimit the geological discourse on the stratigraphic nature of the Anthropocene, and to avoid the issue of defining a geology-exclusive 'Anthropocene,' a theoretical distinction between the 'Anthropocene' and the Anthropocene Hypothesis is advanced. The former constitutes the broader category or boundary object applied amongst different knowledge domains and investing different contextualized meanings. The latter specifically refers to the "stratigraphic Anthropocene" (Zalasiewicz et al., 2019b, p. 4), or the 'Anthropocene' as developed within geological – and more precisely stratigraphic –

research. The Anthropocene Hypothesis is the scientific belief by the multidisciplinary group of scientists (mostly geologists) working with and within the AWG that the Anthropocene may represent a discrete unit on the geological time scale. Hence, the object of the effort hereby conducted is not the 'Anthropocene,' but the Anthropocene Hypothesis as a *stratigraphic hypothesis*. The theoretical core of this hypothesis could be summarized in the following three claims:

> **Claim 1.** *Homo sapiens* has left a discernible stratigraphic signature of significant magnitude in recent geological history.
> **Claim 2.** The stratigraphic signature left by *Homo sapiens* could be translated into a geochronological and chronostratigraphic unit of time.
> **Claim 3.** The proper unit level reflecting the magnitude of the stratigraphic signature of *Homo sapiens* on the geological time scale and international chronostratigraphic chart is that of epoch/series.

Claim 1 is descriptive: it states that there exists such a thing as an observable stratigraphic record of an anthropogenic nature. Claims 2 and 3 are normative-methodological: the former acknowledges the possibility of formal recognition of an 'Anthropocene' geochronological and chronostratigraphic unit (the majority of the AWG also holds that formal recognition *should* be promoted); the latter suggests what hierarchical level should reflect the magnitude of this observed stratigraphic signature. The body of evidence, lines of reasonings, debates, and epistemology informing each of these claims is discussed over the course of the following chapters. In the present section, it is important to consider the several theoretical and linguistic benefits of distinguishing between the 'Anthropocene' and the 'Anthropocene Hypothesis.'

First, this conceptual separation overcomes the issue of definition by simply avoiding the impasse of providing an all-inclusive 'Anthropocene' concept. Whereas multidisciplinarity is also a constitutive feature of the Anthropocene Hypothesis, its aim is fundamentally restricted by the stratigraphic hypothesis of considering the Anthropocene as a discrete time unit. This implies that the focus given is on the epistemic actors, communities, and research material supporting or contesting the Anthropocene as a proposed geological time unit, and thus on the conceptual history, evidence, and epistemology of the Anthropocene Hypothesis.

Second, such delimitation avoids 'essentialist' arguments – that is, claims that the 'Anthropocene' means something defined exclusively by a particular knowledge domain. It seems practical to consider the 'Anthropocene' a fundamentally scientific term by considering its scientific (rather than humanistic) origins and spread across research communities (later illustrated in section 2.1.3). However, such a view is blind to the evolution of the concept. The widespread assimilation of the concept into humanistic scholarship seems a sufficient reason to now consider the term as belonging to the humanities and social sciences rather than the natural sciences. However, such a state of affairs does not seem to lay any solid foundation for a multifunctional use of the term. By postulating the Anthropocene Hypothesis as a separate theoretical entity, the issue of what the 'Anthropocene' *really* means is much easier to tackle because there is no *'real'* 'Anthropocene.' The Anthropocene Hypothesis simply identifies a particular variant of the 'Anthropocene' being discussed, and how this variant is best discussed. This is not the case, for instance, with the strategies of considering the 'original' or 'true meaning' of the Anthropocene.

Third, this separation transforms the Anthropocene Hypothesis into an object of interest for the philosophy of science. This philosophical domain in inquiry has been largely silent in discussing the scientific substrate of the hypothesis. In the 'Anthropocene' research landscape, the concept has been tackled mostly by humanists and social scientists from environmental history, literary criticism, ecocriticism, STS, or postcolonial studies. Philosophy of science has seen much criticism, if not an overall decline in practice due to the now more common historical and sociological approach to science (Zammito, 2004, 2011). Additionally, geology is a largely underrepresented disciplines in philosophical discourses, which have historically developed primarily around physics, and more recently around biology, medicine, AI, or cognitive sciences. This absence is considered unjustified from a theoretical viewpoint because the Anthropocene Hypothesis, as a scientific hypothesis of a highly contested nature, could and *should* represent an object worth philosophical commitment. Separating between the 'Anthropocene' and the Anthropocene Hypothesis is considered a step in this direction by delineating what object of analysis should primarily pertain philosophers of sciences in the 'Anthropocene' debates.

Fourth, the separation overcomes the 'undifferentiated *Anthropos* argument'[68] – that is, the argument that the 'Anthropocene' is an all-inclusive term blind to human differences and responsibilities in engendering this proposed epoch – by reassessing the epistemic purpose of '*Anthropos*' in the stratigraphic discourse. This is a particularly pressing line of criticism directed toward the 'Anthropocene' term (discussed in section 5.1.1). Beside the descriptive and functional-methodological nature of the Anthropocene Hypothesis, the epistemology of geochronology provides a sufficient reason for deflating the issue. In geochronology, most taxonomical units have historically been assigned names based on the location where their representing outcrops were first found – Devonian from Devon in England, Jurassic from the Jura Mountains, Permian from the Perm region in Russia, and so forth. Most of these 'labels' were products of 18th- and 19th-century British geology. This terminology has persisted without impinging on existing research, despite the major theoretical and methodological revolution caused by the application of radiometric techniques to derive absolute ages of rocks and strata. The nominalistic nature of geological taxonomy is largely pragmatic, and does not constitute a theoretical burden within the geochronological and stratigraphic domain. Problems within one knowledge domain (e.g., postcolonial studies, ecocriticism, environmental humanities) may not be such in another domain – as appears to be the case with the 'Anthropocene' term.

The more pressing issue in the history of geochronology had rather been developing an internationally shared and consistent geological time scale / chronostratigraphic chart to avoid the use of multiple time scales across global scientific communities; to eliminate gaps and overlaps among time units;

[68] Literature advancing this argument is explored in section 5.1.1.

and to establish a coherent and consistent language to facilitate effective communication among geoscientists. Institutionally, this was solved by the creation of dedicated entities, such as the International Subcommission on Stratigraphic Classification (formerly International Subcommission on Stratigraphic Terminology, founded in 1952 under the auspice of Hollis D. Hedberg, see Walsh et al., 2004), and textbooks like the *International Stratigraphic Guide* (and its abridged version). The aim of these entities and texts of "worldwide geographic spread" is to "promote international agreement on principles of stratigraphic classification and to develop an internationally acceptable stratigraphic terminology and rules of stratigraphic procedure—all in the interest of improved accuracy and precision in international communication, coordination, and understanding" (Murphy & Salvador, 2000, p. 232).

The aforementioned arguments aim at separating conceptually the nature of the Anthropocene Hypothesis from the broader discourse around the 'Anthropocene.' They provide a basis for claiming that the normative (viz. ethical, social, etc.) validity of the 'Anthropocene' (which is yet to be resolved by humanistic inquiry) is not an intrinsic aspect of the epistemology of the Anthropocene Hypothesis. The hypothesis primarily represents a descriptive hypothesis that, by virtue of its statements, also entails implicit types of normative-functional and normative-methodological statements. That is to say that, from a purely epistemological viewpoint, there is nothing descriptively good or bad about the fact that *Homo sapiens* is leaving a discernible stratigraphic signature in geological records of significant magnitude in recent geological history (Claim 1); that this signature could be translated into a unit of time on the geological time scale (Claim 2); and that the proper hierarchical level to reflect the magnitude of this stratigraphic signature is that of epoch/series (Claim 3).[69] They are descriptive statements about a certain state of affairs, and can either be true or false. Naturally, there are intrinsic normative implications in stating each of these claims, which translate into broader social and ethical calls. Furthermore, to claim that the Anthropocene Hypothesis does not entail some types of normative statements does not imply that its approval or rejection does not have broader normative importance. While the fate of the hypothesis has yet to be determined, it is reasonable to believe the term will persist in the activist and academic environmental vocabulary.

Once the descriptive nature of the Anthropocene Hypothesis is discerned and separated from its parental conceptual entity (i.e., the 'Anthropocene'), what remains is to assess *how* to approach this stratigraphic hypothesis in a way that is meaningful to understand its scientific core.

1.3.3. Approaching the Anthropocene Hypothesis

As a scientific idea, the Anthropocene Hypothesis can be investigated from multiple angles of analysis – from History and Philosophy of Science (HPS) and historical epistemology to Science and Technology Studies (STS), Sociology of Scientific Knowledge (SSK), epistemology, and philosophy of science. The

[69] A different set of meta-normative statements *about* the Anthropocene Hypothesis as a 'good' or 'bad' hypothesis (as in being useful or not) are ultimately part of the geological community's acceptance or rejection of the hypothesis.

relationship between these disciplines is uneasy, and often conflictual. Yet the present endeavor aims at borrowing elements from each of these fields, hence including historical (i.e., the history of the hypothesis; Chapter 2), sociological (i.e., the debate the hypothesis ignited; Chapter 5), and traditional epistemological features to delineate the birth and epistemology of the Anthropocene Hypothesis.

Nevertheless, the central line of analysis remains primarily philosophical. Scientific ideas are always part of a historical and social context that grant them the very conditions of possibility for their formulation, and are largely "influenced by values, motives, social interests, and political agendas" (Howard, 2009, p. 202). Within this context, philosophy of science is particularly keen on delineating the *epistemology* of scientific ideas – that is, the basic epistemic properties, such as empirical adequacy, logical consistency, explanatory power, or intelligibility, that make scientific knowledge particularly successful. Philosophy of science has always been concerned with the nature of science and scientific knowledge, with many of its questions overlapping with the field of epistemology (i.e., the study of the nature, structure, and value of knowledge), but also with metaphysics, philosophy of language, and philosophy of mind (Ladyman, 2019). The philosophical analysis of science can provide a useful conceptual toolkit to investigate the conceptual challenges and epistemic properties of the Anthropocene Hypothesis. This is not simply because the hypothesis represents a scientific idea with a specific set of epistemic properties that can be analyzed, but also because understanding its epistemology is paramount for developing a multidisciplinary framework and successful communication among disciplines in Anthropocene Studies.

This methodological driver is also a call for interest among philosophers of science in the 'Anthropocene' debate. Philosophy has been an active discipline within Anthropocene Studies. However, its focus has been primarily directed toward the normative-ethical, normative-moral, and normative-aesthetic aspects of the debate (Merchant, 2021; Polt & Wittrock, 2018; Raffnsøe, 2016; Zylinska, 2014). This has left a substantial gap in the more strictly philosophical analysis of the sciences engaged with the 'Anthropocene.' This is particularly true for the 'analytical' philosophy of geology – a much underrepresented subdiscipline within philosophy of science. Attempts to reconcile a prototypical philosophy of geology of a 'continental' fashion with Anthropocene Studies have been conducted under the theme of convergence between historical and geological time (Chakrabarty, 2009, 2015). Although geology overall has long "received little attention from the humanities" (Frodeman, 2014, p. 71), it seems that the 'Anthropocene' has been a hub for discourses between the natural sciences and the humanities, despite reproducing forms of academic antagonism (Riesch, 2014; Snow, 1959; Toivanen et al., 2017). Yet a thorough analysis from philosophy of science (viz. philosophy of geology) has been almost utterly nonexistent. As of August 2021, five articles result by keyword-searching 'anthropocene' (case-insensitive) in *Studies in History and Philosophy of Science Part A* (part B and C are dedicated, respectively, to modern physics, and biology and biomedical sciences). Only one article (Santana, 2019a) has been just recently published on the topic of the Anthropocene by *The British Journal of Philosophy of Science*. One result appears under 'anthropocene' in the journal *Philosophy of science* (Helgeson et al., 2021, the 'Anthropocene' is only mentioned once in the text), while no search results appear under 'anthropocene' in *Synthese*, *Journal for General Philosophy of Science*, or *Erkenntnis* – all well-established journals in philosophy of science.[70]

Why have philosophy of science and the 'analytical' philosophy of geology not engaged with the Anthropocene Hypothesis? Multiple reasons can be determined. One has to do with the most recent history and developments within philosophy of science as a discipline itself (Ladyman, 2019). The dawn of new approaches challenging the traditionally language- and logic-oriented problems formulated by philosophers of science, such as HPS or SSK, seemed to threaten the very foundations of philosophy of science. More importantly, philosophy of science mutated into philosophy of science*s* – abandoning the idea of a unified framework for all sciences and focusing on single disciplines, such as physics, biology, neuroscience, cognitive science, medicine, and so forth. Within this disciplinary rearrangement, geology – already a discipline largely overseen – did not gain substantial interest among philosophers of science. Consequently, the lack of a mature philosophy of geology resulted in the lack of commitment toward the philosophical study of the Anthropocene Hypothesis.

A second possible reason is that the 'Anthropocene' concept simply did not clearly resonate within philosophy of science. Standing at the epicenter of Anthropocene Studies, it is easy to have the impression that the 'Anthropocene' buzzword has been the most popular term in recent scholarship – especially among the humanities. However, once one's viewpoint is shifted outside the boundaries of Anthropocene Studies, the 'Anthropocene' becomes at best a word that has been 'heard of.'[71] Hence, it is feasible to assume that although they are probably aware of the existence of the term, philosophers of science have considered it a catalyst for environmental discourse rather than an object of scientific interest.

Another reason concerns the nature and use of the 'Anthropocene' concept. In the past decade, the term has been largely adopted and framed by environmental humanists and social scientists more than natural scientists (the latter mostly gravitating around the work of the AWG). This multidisciplinary appropriation transformed the term into an umbrella category framing many existing environmental narratives, leaving the impression that the term had few if any epistemic properties to be analyzed from a philosophy of science viewpoint. At best, philosophers engaged with normative aspects of the term – as later discussed in section 4.1. It is plausible that this multidisciplinary engagement – which saw the humanities and social sciences at the forefront in the past decade – had the 'Anthropocene' emerging as a social, political, and environmental message rather than a scientific hypothesis worth philosophical commitment (this is also consistent with criticism of the idea as a political statement; see section 5.2.3.3).

Yet scientific ideas could *also* be politically engaged without 'giving up the science' supporting them – meaning that being potentially political does not immediately preclude any idea from being an object of

[70] It should be noted that only English-speaking publishing platforms have been surveyed to assess the reach of the 'Anthropocene' debate in philosophy of science. However, as philosophy of science has been historically advanced predominantly by anglophone countries, this is feasibly a sign of overall lack of engagement on an international scale.
[71] Throughout formal and informal talks and email correspondence established with undergraduate, graduate, and doctoral students, and advanced academics of a multidisciplinary matrix, it became somewhat clear that the term 'Anthropocene' represents a popular concept only within specific academic niches close to environmental discourse. The term is either unknown or at most heard of (generally up to Edward Burtynsky's 2018 documentary *The Anthropocene*) in other disciplinary areas, and at different academic levels.

analysis within philosophy of science. However, as criticized by philosopher Don Howard (2009), most post-World War II philosophy of science disengaged with "the social and political concerns that shaped its earlier years" (p. 199). He notes that "by the end of the 1950s, thoughtful philosophical debate about the place of science in society had all but disappeared, replaced by a highly formalized philosophy of science pursued by a new generation of technically well trained young specialists whose inability to think carefully about science in context was disguised as disdain for irrelevant, non-technical questions" (p. 201). Without going deeper into this complex matter, is it feasible that this detachment may be one possible explanation for neglecting to investigate the broader 'Anthropocene' idea, and in turn the Anthropocene Hypothesis.

These and more explanations can account for the absence of philosophy of science, and particularly philosophy of geology, in Anthropocene Studies. This academic vacuum resulted in the theoretical difficulties in approaching the Anthropocene Hypothesis as a stratigraphic hypothesis. While this makes it impossible to build on preexisting philosophical literature, it also represents an opportunity to explore with the hypothesis in virtually unconstrained terms.

To summarize and conclude the chapter, the present work aims at conducting an epistemological analysis of the Anthropocene Hypothesis based on multidisciplinary techniques gravitating around philosophy of science. In what follows, the Anthropocene Hypothesis is treated as a separate theoretical entity from the 'Anthropocene.' It could also be rightfully argued that this theoretical separation minimizes the multidisciplinary nature of the Anthropocene – both as a geological time unit and broader boundary object. For instance, the very definition of 'geological Anthropocene' has been contested even after specifying its meaning and scope. Substantial criticism has pointed out that defining a 'geological Anthropocene' still requires going beyond the natural sciences, including insight from the social sciences (Ellis, 2016a) and liberal arts (Bostic & Howey, 2017) because geology *per se* is built on a language of dispossession as well as practices of extractivism and colonialism (Yusoff, 2019). This kind of criticism unveils a deeper problem – namely, how to establish methodologically sound interdisciplinarity between the geosciences on the one hand and the humanities and social sciences on the other. This remains an open question in the broader context of Anthropocene Studies.

A second point raised by this criticism concerns the blurred descriptive and normative nature of the 'Anthropocene'. Some disciplines involved in 'Anthropocene' Studies merely describe some state of affairs and apply the label 'Anthropocene' to highlight its anthropogenic nature. This is the case for Earth System science, evolutionary eco-biology, and the spectrum of disciplines included under geology and stratigraphy. Other disciplines, such as ethics, ecocriticism, and environmental humanities, have used the term to communicate messages of environmental awareness, responsibility, and stewardship, promoting action in a normative sense as a response to a certain state of affairs. The boundaries between normative and descriptive statements about the 'Anthropocene' are often blurred, and no universal formula to separate the two can be obtained. Yet this distinction is considered useful in delimiting the application and meaning of the 'Anthropocene' concept across different disciplines, and in the context of the present epistemological analysis.

CHAPTER 2

BIRTH OF THE ANTHROPOCENE HYPOTHESIS

I said that we were already in the Anthropocene.
My remark had a major impact on the audience.
First there was silence, then people started to discuss this.

—Paul Crutzen, *The Anthropocene: The Human Era and How It Shapes Our Planet*

In his landmark publication *The Structure of Scientific Revolutions*, Thomas Kuhn (2012) famously begins by reconsidering the role of history for the study of science. He writes: "History, if viewed as a repository for more than anecdote or chronology, could produce a decisive transformation in the image of science" (p. 1). He continues writing that, "[i]f science is the constellation of facts, theories, and methods collected in current texts, then scientists are the men [*sic*] who, successfully or not, have striven to contribute one or another element to that particular constellation" (p. 2). If the Anthropocene Hypothesis is to be treated as a *scientific* hypothesis, then it is paramount to locate that constellation of facts, theories, methods, scientists, and people that contributed to transforming the 'Anthropocene' from an informal designation to a scientific hypothesis. This is achieved by conducting a historical reconnaissance of those texts that implemented the term, and that enable a recognition of the Anthropocene Hypothesis as a scientific formulation. In particular, a chronology is attempted here of the events leading the 'Anthropocene' to evolve from an informal, spur-of-the-moment conjecture to a pivotal concept for research agendas, conferences, and a dedicated working group (i.e., the AWG).

Hence, section 2.1 explores the birth of the 'Anthropocene,' its spread, and its evolution across disciplines, fields of knowledge, and scholarly mediums. To do so, a corpus of literature of 670 texts using the term 'Anthropocene' and produced during the 2000–2009 decade is discussed from a quantitative as well as qualitative viewpoint. The quantitative approach dissects the corpus based on selected clusters representing properties of interest for analyzing the texts. The qualitative approach analyzes the corpus chronologically by surveying sample literature representing important sources in its process of dissemination and popularization, and epitomizing different uses of the term. The decade of analysis is considered vital in understanding the birth, survival, and evolution of the term in the scientific and academic world. The corpus provides an access point on texts as well as workshops, conferences, research initiatives, and personal insights from scientists that cumulatively shaped the early identity of the 'Anthropocene' – laying down the conditions of possibilities for the evolution of the 'Anthropocene' into a stratigraphic and geochronological hypothesis.

After probing into the early modern history of the 'Anthropocene,' section 2.2 then focuses on the birth and evolution of the Anthropocene Hypothesis based on the findings retrieved in section 2.1. Geological literature using the term 'Anthropocene' during the 2000–2009 period is considered indicative of the evolution of the 'geological Anthropocene,' which engendered the preconditions for the evolution of the 'Anthropocene' into the Anthropocene Hypothesis. Indeed, the chapter concludes by exploring the process of institutionalization of the hypothesis through the establishment of the AWG.

This chapter implements different methodologies to reconstruct the birth of the Anthropocene Hypothesis. Text mining techniques are deemed suitable means for reproducing how the term 'Anthropocene' was perceived, implemented, and shaped over time across disciplinary domains, fields of knowledge, and mediums. This content-analysis–oriented method is particularly valuable in deriving quantitative data concerning the birth, survival, and spread of the term in *academic* literature – the primary type of literature analyzed. As a complementary methodology, a discourse analysis of sample texts is conducted to reconstruct and discuss chronologically the history of the 'Anthropocene' concept. This method selects suitable textual samples that most represent how the term was implemented during the time frame considered. Lastly, the chapter also uses personal communication with the epistemic actors who used the term during its early research stages as a discrete and complementary source for reconstructing specific events or contextualizing material from the literature. This communication (primarily through email) is limited to recollection of the events and motives behind the use of the term by an epistemic actor, and it is considered (despite its theoretical and methodological limitations) as a valuable source for reconstructing the early history of the 'Anthropocene.'

2.1 The 'Anthropocene' in Early Research Literature

The Anthropocene Hypothesis represents a particular variant of the 'Anthropocene' – that is, the stratigraphic or geological variant. When this variant was formulated, the concept had already been circulating in academic literature, and specifically in scientific literature. Therefore, understanding the birth of the Anthropocene Hypothesis implies understanding the nature and evolution of the 'Anthropocene' concept across this literature. In turn, this means understanding the *modern history* of the 'Anthropocene' – a time period that laid the foundation for the stratigraphic interpretation of the term. This is achieved by probing into the very *early research literature* that pioneered use of the term 'Anthropocene' in the academic and public arena.

The designations 'modern history' and 'early research literature' play an important role in delineating the approach pursued in this chapter. Therefore, they require some preliminary remarks.

The term 'modern' delimits the time frame considered in exploring the history of the concept of 'Anthropocene.' Section 1.2.4 showed that one of the possible 'histories' of the 'Anthropocene' corresponds to its history as an idea and as a term. Existing research on the matter has become somewhat polarized between those advocating for a genealogical lineage that extends the semantic roots of the 'Anthropocene' to the late 18th century ('continuism'), holding that the concept is one among several instances of geological reflexivity coined in the past few centuries; and those considering it a theoretical singularity based on an unprecedented epistemological setting ('discontinuism'), holding that the genealogical approach fundamentally undermines and deflates the usefulness, importance, and uniqueness of the 'Anthropocene' concept. A proposed solution to this dilemma is to consider the 'Anthropocene' a discrete instance of geological reflexivity, and to divide its history into *paleohistory*, *prehistory*, and *modern history*. This conceptual framework allows us to fit the 'Anthropocene' within a meta-historical tradition ascribing geological agency to humanity, while at the same time acknowledging the particular conceptual history, development, semantics, social context, and usage that distinguishes the concept from past instances of geological reflexivity.

Adopting this framework steers us away from the genealogical analysis in order to study the modern history of the 'Anthropocene' and the Anthropocene Hypothesis. Genealogical approaches to the 'Anthropocene' are useful in identifying a general trend of geological reflexivity dating as far back as the 19th century, and to strengthen (or deflate, as argued by discontinuism) the conceptual ancestry of the term. However, they provide little insight into the particular *modern* history of the most recent 'Anthropocene' term. Instead, they develop a historical outlook on the *paleohistory* and *prehistory* of the term. The analysis hereby conducted locates the beginning of the *modern history* of the 'Anthropocene' – namely, the year 2000. This is virtually unanimously considered the cradle of the 'Anthropocene' as originally coined by Paul Crutzen during his popular IGBP-SC meeting intervention. Because scholarship around the 'Anthropocene' is still ongoing, its modern history extends from 2000 to the very present.

The year 2000 also defines the lower historical boundary of the *early research literature* analyzed in this section. Upward, this period is delimited by the establishment of the AWG, and by the publication of Chakrabarty's seminal article "The Climate of History: Four Theses" – both occurring in 2009, and both representing major turning points in Anthropocene Studies. Therefore, the early 'Anthropocene' research literature, or 'early modern history' of the 'Anthropocene,' comprises research material produced within the 2000–2009 decade. This is literature characterized by the earliest appearances of the term 'Anthropocene' in written sources. Early 'Anthropocene' research literature serves as a valuable witness to the birth, survival, spread, and evolution of the term across disciplines, fields of knowledge, and research institutions over time.

There are some drawbacks of a historical nature in the definition of *modern history* just provided. Most notably, the analysis hereby conducted excludes previous influences of crucial importance in understanding the conditions of possibility for the 'Anthropocene' to gain ground in the academic as well as public debate. Factors such as the dawn of the Earth System science approach through the late 1980s, the rise and institutionalization of environmental narratives and agendas, and the existence of genealogical precursors are intuitively key ingredients for a thorough historical epistemology (Feest & Sturm, 2011; Nasim, 2013; Renn, 1996; Sturm, 2011) of the 'Anthropocene' and the Anthropocene Hypothesis. Presumably, the 'Anthropocene' did not emerge from a cultural and intellectual framework that was not able to produce it. Some of these aspects were tackled in the previous chapter, but are not considered within the modern history of the term.

Nevertheless, there are some pragmatic reasons that justify the exclusion of pre-2000 social, cultural, historical, and genealogical factors. First, literature providing a detailed conceptual analysis of the prehistory (and birth) of the 'Anthropocene' is abundant (e.g., Bonneuil & Fressoz, 2016; Davies, 2018; Horn & Bergthaller, 2020; Lewis & Maslin, 2018b; Schwägerl, 2014; Steffen et al., 2011a; Thomas et al., 2020; Zalasiewicz et al., 2019b, para. 1.2).[72] To provide yet another narrative of the prehistory of the 'Anthropocene' would be redundant. Second, the methodology selected to explore the early research literature on the 'Anthropocene' focuses on literature produced within a specific time frame – that is, the 2000–2009 decade. This decade has largely remained unexplored in extant Anthropocene scholarship, despite being crucial in understanding the modern history of the 'Anthropocene' concept. The appearance of the term 'Anthropocene' in written academic contexts since 2000 grants the selected literature outstanding value and insight that cannot be equally deduced from earlier textual sources, genealogical precursors, or from the broader social and intellectual climate. Lastly, retracing the early modern history of the 'Anthropocene' is only useful in delineating the birth of the Anthropocene Hypothesis – the latter representing the main object of this overall research. Therefore, an exhaustive conceptual and historical analysis of the 'Anthropocene' is a different trajectory than the one hereby pursued.

[72] There are other examples of conceptual history beyond monographs and research articles. Perhaps emblematic is the research group 'Anthropocene Formations' developed by the Max Planck Institute for the History of Science under Department I (see https://www.mpiwg-berlin.mpg.de/project/knowledge-anthropocene, accessed on May 7, 2021) to study the history (both as in 'human history' and 'conceptual history') of the 'Anthropocene.'

The 2000–2009 decade represents a time period of great interest and value in the history of the Anthropocene Hypothesis and the 'Anthropocene' – not least because it represents the time when the term first appeared in research literature with its modern connotation.[73] Literature representing this time frame has often summarized it in a few crucial publications – namely, Crutzen and Stoermer's (2000) seminal IGBP article; Crutzen's (2002d) "Geology of Mankind"; *Nature*'s (2003) "Welcome to the Anthropocene"; Steffen et al. (2007) "The Anthropocene: Are Humans Now Overwhelming the Great Forces of Nature?"; Zalasiewicz et al. (2008b) "Are We Now Living in the Anthropocene?"; and lastly Chakrabarty's (2009) "The Climate of History: Four Theses." These represent crucial contributions in the history of the 'Anthropocene' and are often used as 'standard literature' epitomizing the early modern history of the term. Whilst undoubtedly valuable, these publications cannot fully epitomize nor appreciate the reception of the 'Anthropocene' among researchers and research communities. A more in-depth analysis is needed to understand the birth of the 'Anthropocene,' and thus of the birth of the Anthropocene Hypothesis.

The general trend in reconstructing the modern history of the 'Anthropocene' has been to summarize it through an exegesis of and commentary on the standard literature. A few examples of this trend are illustrated below.

In his second chapter of *The Birth of the Anthropocene*, Davies (2018) conducts an interpretative analysis of the 'Anthropocene' concept as portrayed in Crutzen's two landmark publications, namely, "The 'Anthropocene'" (2000) and "Geology of Mankind" (2002d). According to Davies, these texts provide archetypical versions of the Anthropocene which were foundational to later interpretations of the notion. Indeed, the chapter concludes with the "stratigraphic turn" (Davies, 2018, p. 64), consisting of the birth of the geological 'Anthropocene' with the establishment of the AWG, and the role of Chakrabarty's paper for setting a ground base for humanist versions of the 'Anthropocene.' However, Davies does not discuss the *very* texts where 'Anthropocene' was being implemented during its early stages, and thus how different disciplines perceived and used the term. He briefly notes that the 'Anthropocene' concept "began to appear in articles about human geography and geopolitics and in books for general audiences by environmental writers" (Davies, 2018, p. 44). However, no bibliographic references are provided for the articles, disciplines, and books he mentions, and no further historical analysis is conducted on the early research literature.

In his book *The Anthropocene: The Human Era and How It Shapes Our Planet*, Christian Schwägerl (2014) provides extensive valuable insights in terms of localizing the researchers, scholars, and general audience interested in the 'Anthropocene' by also narrating his first-hand experience with the process of institutionalization of the concept – especially in German scholarship. However, the history of the concept during its first decade of existence is summarized in roughly three pages (pp. 51–53), mentioning only a few publications of the 'standard literature' (i.e., Crutzen, 2002d; Crutzen & Stoermer, 2000; Steffen et al., 2007). Thereafter, the book primarily focuses on the 'state of affairs' of the Anthropocene – that is, its

[73] As noted in section 1.2.4.2, the term 'Anthropocene' appeared as a translation of the Russian term 'антропоген,' but its connotation is substantially different from the modern 'Anthropocene.'

underlying causes and political consequences from a social, technological, and environmental perspective. Again, a focused analysis of the 'Anthropocene' early research literature is absent.

A third account of the history of the 'Anthropocene' idea is provided in the first and ninth chapters of *The Human Planet: How We Created the Anthropocene*, by Lewis and Maslin (2018a). The monograph constitutes a landmark in Anthropocene Studies, delivering a clear explanatory narrative of the convergence of historical, evolutionary, and geological time, while at the same time providing a critical and highly discussed hypothesis on the onset of the Anthropocene as a geological unit (see sections 3.2.3.2 and 3.2.4.3). However, the history of the 'Anthropocene' idea is once again reduced to the quest of finding genealogical predecessors. Chapter 1 ("The Hidden History of the Anthropocene," pp. 19–41) recalls in just three pages (pp. 20–23) the "standard narrative" (p. 20) of the Anthropocene, condensing the 2000–2009 decade into Crutzen and Stoermer (2000), Crutzen (2002d), and Zalasiewicz et al. (2008).

A survey of the main existing monographs and research items (Bonneuil & Fressoz, 2016; Ellis, 2018; Hamilton, 2017; Hamilton et al., 2015a; Moore, 2016a; Zalasiewicz et al., 2019b) shows that they exhibit the same general pattern – that is, a preference for seeking genealogical precursors of the 'Anthropocene' rather than probing into its early research phase. Presumably, part of the reason behind this trend is the novelty of the term, especially in the context of the humanities and social sciences, which began to systematically engage with the term only after 2010. A second reason stems from the diversified areas of interest developed within Anthropocene Studies, some of which established primary focus areas at the expense of a conceptual history of the modern usage of the term.

Therefore, the central goal of this section is reconstructing the history of the 'Anthropocene' during its early research stage (i.e., 2000–2009), which in turn enables a reconstruction of the cultural and research premises that engendered the Anthropocene Hypothesis. To achieve this target, one must investigate the concept's birthplace and the context of its evolution by understanding how the term was used and by whom, and what research trajectories it undertook during its early appearance and spread among academic communities.

2.1.1 Methodology: A Quantitative and Qualitative Overlook

How, then, to reconstruct the early history of the modern 'Anthropocene'?

The methodology selected combines a quantitative keyword approach and text mining analysis of a selected corpus of literature with a qualitative discourse analysis of texts.[74] Choosing a keyword approach was rather intuitive: if the main target is assessing how the concept had been used during its early research stage, then surveying the appearance of the term 'Anthropocene' across the very first published sources using it provides a valuable means to this end. In particular, the relative frequency of the term

[74] This methodology is only restricted to the study of the 'Anthropocene' concept during its early stages (i.e., 2000-2009).

'Anthropocene' in published texts provides a useful proxy for authors' early engagement with the concept. Indeed, relative frequency is central in distinguishing between a qualitative and a quantitative approach to the identified corpus of literature – each discussed respectively in section 2.1.2 and section 2.1.3.

Whilst text mining (which includes word frequency) has been a historically intrinsic aspect of quantitative linguistics studies (Popescu, 2009), keyword approaches are not very common in historical research. Baron, Rayson, and Archer (2009) note that "there are relatively few studies of historical data that make use of the key words approach. Several of these [...] explore classic English literature, whilst others explore specific activity types such as the historical English courtroom [...] or specific topics such as swearing" (p. 7). This is also reflected in most historical and philosophical studies on science – with the notable exception of the field of scientometrics, the quantitative study of science and science communication through texts (Leydesdorff & Milojević, 2015). For the present research, this condition represents both an obstacle and an opportunity. As an obstacle, it means that the research hereby conducted cannot build on preexisting studies of a similar nature. No text mining analyses functional to the study of scientific hypotheses or concepts and their birth have been identified to draw on or borrow methodology from, making the foundations of this study necessarily less corroborated.[75] As an opportunity, it means that the method champions a novel approach – at least within Anthropocene Studies – to the study of the 'Anthropocene' concept. This method can be integrated with further in-depth analyses (e.g., sociological, bibliometrics, scientometrics, data science, etc.) of the mechanisms and modalities behind the spread of scientific ideas (e.g., Jiang et al., 2021; Morgan et al., 2018).

There are some identifiable epistemic benefits of choosing this unprecedented approach. The first benefits relate to its novelty. No quantitative analysis of this kind has so far been conducted in respect to the history of the 'Anthropocene' concept. As such, it provides a unique overview of a substantial corpus of literature that has been largely dwarfed by 'standard literature' narratives. A second related benefit concerns the literature discussed. As anticipated, much 'Anthropocene' scholarship has primarily focused on the genealogy of the 'Anthropocene' idea. This has left a significant vacuum concerning the role of early research literature in engendering the 'Anthropocene' concept and the Anthropocene Hypothesis. The approach hereby pursued reconsiders the epistemic, conceptual, and historical value of this literature, all of which has been largely overlooked. A third benefit concerns the research trajectory that this methodology generates. Such an approach opens the possibility for further quantitative studies in this direction – for instance, by systematically surveying the term in other languages. Feasibly, such an approach could also be used for retracing the history of other scientific concepts and ideas.

Conversely, this methodology necessarily has some limitations. Those relating to the technical aspects of the research (e.g., software accuracy, corpus completeness, etc.) are explained throughout the following subsections. As already stressed, one major limitation is that this method does not include within its range of analysis neither the paleohistory nor the prehistory of the 'Anthropocene' – that is, the historical,

[75] The only known exception in Anthropocene Studies is a linguistic study from Zottola and de Majo (forthcoming), who focus on use of the term 'Anthropocene' in newspapers between 2000 and 2018.

intellectual, and scientific contexts wherein the concept matured. However, this limitation is considered relevant only if a thorough conceptual history of the 'Anthropocene' is the primary target. Since this is not the case, the limitation is only partial. Another possible limitation is the applicability of this approach for longer time frames. The number of texts published using the word 'Anthropocene' during the 2000-2009 decade is vastly outweighed by those published during the 2010–2019 decade, during which the term saw a steep increase in academic and public appearance. A keyword search on the online research dataset Dimensions (accessed on September 17, 2021) provides 1,311 results for the 2000–2009 decade compared with 63,104 results for the 2010–2009 decade, showing a substantial difference in literature produced during the two decades. While the total number of results for the former decade makes text mining analysis feasible, this is not the case for the latter decade. This means that a comprehensive analysis of sources implementing the term 'Anthropocene' throughout *all* years since its coinage cannot be easily conducted (at least on an individual-scale project) with the methodology hereby chosen.

In the following subsections, the procedural steps to retrieve the early research literature and conduct a critical survey are outlined first. Then, section 2.1.1.2 explains the salient features of the corpus used in the analysis. Lastly, section 2.1.1.3 discusses the modality and purpose of retrieving the relative frequency of the term 'Anthropocene' in the textual corpus used to discuss the 'Anthropocene' in early research literature.

2.1.1.1 Procedure

The process leading from search and selection of literature to the organization and discussion of the corpus consisted of seven main steps, each discussed in the following paragraphs.

Step 1 – Defining Search Tools. The first step was selecting the tools for retrieving texts using the term 'Anthropocene' in the time period considered (i.e., 2000–2009). Given the recent production of the literature in question, almost all of the material was accessible online. This search has used three online search engines and bibliographic databases for scientific publications: ScienceDirect, WorldWideScience, and Dimensions. ScienceDirect is Elsevier's search engine for peer-reviewed literature, and covers a corpus of more than 18 million articles and book chapters from over 2,500 journals and 42,000 electronic books.[76] WorldWideScience is a federated-search–based[77] engine of multinational and multilingual reach released in 2007. Dimensions is the world's largest linked research information dataset, comprising 118 million publications and a network of 1.4 billion citations.[78] Google Scholar was also partially used for the search, but the overabundance of results makes it largely impractical to survey all results in a reasonable timescale.

[76] Fact sheet is available at https://www.elsevier.com/solutions/sciencedirect (accessed on May 10, 2021).
[77] For an explanation of federated searches, see https://blog.coveo.com/what-is-federated-search/ (accessed on May 10, 2021).
[78] Information available at https://www.dimensions.ai/# (accessed on May 10, 2021).

These represent easily accessible and easy-to-use search engines and databases available on the Internet, and they are particularly valuable for retrieving literature produced in recent times. No particular criteria were predefined for selecting these search engines and databases (among the more than fifty available on the Internet) other than preexisting knowledge and acquaintance with these. However, the selection of *multiple* search engines ensured greater exhaustiveness of the corpus, meaning that the final corpus should incorporate an exhaustive portion of all material published during the decade analyzed implementing the word 'Anthropocene' in anglophone literature.

Step 2 – Defining Search Criteria. Once the proper search engines were selected, keyword search was the next step to gather the corpus of literature. The search parameters were two: the keyword/unigram 'Anthropocene' (case-insensitive) in all texts, and the time range of interest (i.e., 2000–2009). English-language results was a third implicit parameter, considering that the keyword 'Anthropocene' is an English-born term. However, sample records from languages other than English were also considered in developing the corpus. Each of the search engines and databases provided highly variable results: only ~117 results through ScienceDirect, but ~1,258 results through WorldWideScience, and ~1,311 results through Dimensions. As anticipated, Google Scholar provided a much higher number of results at ~11,900, making an extensive review of single results practically unfeasible.[79] Intuitively, the algorithms delivering these results are not error-free. Indeed, scrutinizing the results showed multiple types of errors, such as multiple counting (i.e., same record in multiple results), incorrect time range, or missing keyword. Furthermore, search results may have excluded cases of misspelled variants (e.g., 'Anthropocenne,' 'Antropocene,' 'Athropocene'), meaning that the final corpus may exclude these occurrences (likely rare).

Step 3 – Defining the Corpus. A further step consisted of defining the criteria used to navigate the search results obtained from step 2. As mentioned, not all *results* could be immediately translated into individual cases, or *records*, of texts using the term 'Anthropocene' (i.e., the ~1,258 WorldWideScience search results are not equivalent to 1,258 unique records). This required a dedicated analysis of every individual result from the total combined results (approximately 2,700, excluding Google Scholar) among the selected search engines and databases. Intuitively, the main criterion to 'filter' results and convert them into working data (i.e., records) for the corpus was the appearance of the word 'Anthropocene' (case-insensitive) in texts. However, appearance alone was not considered sufficient for representing a valid corpus of literature. Thus, material where the unigram appeared only in the bibliography (for instance, as a title of a reference) was excluded. While this material witnesses the spread of the term across literature, it does not directly use the term, and therefore cannot be interpreted as proxy of early usage of the concept. Any result referring to the 'Anthropocene' either indirectly (e.g., the 'Age of Humans'), or as a 'meta-entity' (i.e., identifying the same object with different words) was also excluded because of the practical difficulties in retrieving this type of

[79] The approximation symbols reflect the fact that results may vary over time – for instance, because search engines are improved, and search queries provide more (or fewer) results. The results for each search engine and database mentioned are current as of May 10, 2021.

record. Results where the term appeared only as part of a project's name or acronym (e.g., SOPRAN, Surface Ocean Processes in the Anthropocene) mentioned in the text were also excluded, as these texts did not engage with the term *per se*. The selection criteria did not discriminate amongst results in terms of format. However, priority was given to *academic* records. Following this preference, the reception and appearance of the 'Anthropocene' across newspaper outlets is not exhaustive, and only a few newspaper articles are included in the corpus (see Zottola & de Majo, forthcoming, for a study dedicated to the reception of the 'Anthropocene' in news and media). Similarly, the selection criteria did not discriminate based on language. However, the anglophone origins and context of the 'Anthropocene' concept as well as the search engines used limit the analysis of the reception of the 'Anthropocene' in non-anglophone literature (especially in languages that do not use the Latin alphabet). Only a sample of the non-English reception of the term is considered.

Most of the material gathered was accessible for free. Material that was not readily available in online format (e.g., due to considerable monetary restrictions or other access limitations) was retrieved by contacting the authors, or through library access (mostly through the Bayerische Staatsbibliothek of Munich). After filtering all search results accordingly, the final corpus totaled 670 records. These records represent the basic working unit of the research conducted. They represent texts of various formats, languages, authorship, disciplinary provenance, and length, and define the corpus of the 'Anthropocene' early research literature.

Step 4 – Organizing the Corpus. Each of the 670 records was stored as a discrete entry on EndNote X8(.2). Because the main target is assessing *how* the concept of 'Anthropocene' was used in early research literature, some salient properties of the corpus were identified and used to label each record. These properties are *publication year*, *field of knowledge*, *discipline*, *language*, *format*, and *relative frequency* of the term 'Anthropocene.' These clusters represent the backbone upon which the quantitative analysis of the literature is conducted, and their selection and purpose are discussed separately in section 2.1.1.2.

Step 5 – Text Mining. An important cluster for organizing the corpus is the *relative frequency* (or *normalized frequency*) of the term 'Anthropocene' (case-insensitive) for each of the 670 records. Relative frequency is interpreted as a measure of authors' engagement with the term. Texts with higher normalized frequency are considered texts exhibiting higher engagement with the term. Conversely, texts with lower normalized frequency are considered texts exhibiting lower engagement with the term. The meaning and purpose of this numerical value requires a distinct analysis, conducted in section 2.1.1.3. The relative frequency of the term was determined by using the software Voyant Tools – an open source online software designed for text analysis.[80] This software was selected because of its focus on the digital humanities, because of its intuitive interface, and because it is open access. Text mining analysis required records to be readable as PDFs, and to have a software-readable text (i.e., scans of printed texts could not be readily mined by Voyant

[80] Information available at https://voyant-tools.org/docs/#!/guide/about (accessed on May 11, 2021).

Tools). Texts that did not initially correspond to this format and requirement were converted through Adobe Acrobat X Pro (version 10.1.16.13). After determining the relative frequency for each record, two clusters were used to divide the corpus based on a selected threshold value. This value allowed the literature to be divided into *central* and *peripheral* literature, and to explore the former through a more insightful historical and conceptual analysis.

Step 6 – Retrieving Findings. Approaching the corpus through the selected clusters revealed interesting information. From a quantitative viewpoint, several salient types of information could be retrieved, such as (1) the number of disciplines that have engaged with the term; (2) which disciplines used it the most (and least) among those engaging with it; (3) what field of knowledge saw the most interest; (4) the yearly increase in appearance in publication; (5) the main formats where the unigram appears; (6) which languages other than English engaged with the term; and (7) how much literature has a direct engagement with the term versus literature passively implementing it. These figures allow for a more thorough and qualitative discussion of the corpus.

Step 7 – Discussion. The last step was to discuss and contextualize the numerical findings from a qualitative viewpoint. The discussion also looks at those texts whose relative frequency shows a high degree of engagement with the concept in question. This literature is analyzed to assess how the concept was being conceived by early authors during the very first years of its existence. It is recognized that some disciplines played a pivotal role in engendering certain conceptions of the 'Anthropocene,' especially in scientific literature. Oceanography, hydrology, and limnology are an example of this, with much of the literature in the corpus gravitating around it during the concept's earliest years. Because a quantitative overlook can only get so far in delineating the early modern history of the 'Anthropocene,' a qualitative analysis is a necessary complementary effort.

2.1.1.2 The Clusters

Step 4 consisted of assigning to each of the 670 records defining the corpus specific 'labels' that represent some properties of interest in reconstructing the 'Anthropocene' in its early research phase. These labels form five main clusters – namely, *publication year*, *field of knowledge*, *discipline*, *format*, and *language* (Fig 2.1). *Relative frequency* is an additional property discussed separately in the next section. Each individual record was assigned one (in the case of publication year, language, format, and relative frequency) or more (in the case of discipline and field of knowledge) of these labels based on the record's specific attributes. Once all records were labelled accordingly, the resulting clusters provided informative insights into the corpus.

PUBLICATION YEAR (10)	FIELD OF KNOWLEDGE (5)	DISCIPLINE (39)	FORMAT (14)	LANGUAGE (6)
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009	Applied Sciences Formal Sciences Humanities Natural Sciences Social Sciences	Anthropology Archaeology Biology Economics Engineering Geology History Oceanography …	Abstract Book Book Review Book Section CFA Conference Paper Conference Proceedings Encyclopedia Journal Article Newspaper Article Pamphlet Report Thesis Web Page	Chinese English French German Italian Japanese

Figure 2.1. The five main clusters used to organize the corpus. Each cluster is defined by a certain number of corresponding 'labels' (ten for publication years, five for fields of knowledge, etc.). Every record in the corpus has at least one of each type of label.

Publication year reflects the year when a specific record was published. Intuitively, each record was assigned only one publication year.[81] The sum of all records published in a given year between 2000 and 2009 provides the *records per year* value (section 2.1.2.1). Records per year is an interesting quantitative measure, in that it provides information about the increase (or decrease) of the appearance of the term 'Anthropocene' over time. As such, records per year can be interpreted as a proxy for usage increase (as is indeed the case for the 'Anthropocene' concept), which in turns means increased interest in the term. Indeed, a key epistemic assumption behind this particular cluster is that an increase (or decrease) in the term's appearance in texts means an increase (or decrease) in interest.[82] Naturally, this is because authors interested in the term may have reasons to use it (conversely, authors disinterested in the term may have no reason to use it). Additionally, dissecting literature based on records per year aids the qualitative survey on the corpus by providing a chronological setting. As later discussed in section 2.1.3, some years saw a particularly visible increase in records per years that grounds a conventional partition of the history of the 'Anthropocene' in early research literature.

Field of knowledge represents the particular knowledge domain that a record belongs to. Traditional scholarship recognizes five main fields of knowledge that constitute higher education – namely, *humanities*, *social sciences*, *natural sciences*, *applied sciences*, and *formal sciences*. Fields of knowledge are supersets of disciplines. Each encompasses a number of disciplines that are diverse in their methods and objects of research. They serve primarily an organizational purpose rather than delimiting a strict epistemological demarcation between knowledge domains. For instance, universities commonly organize (e.g., financially, educationally,

[81] Equal records (e.g., exact same article) republished in different years are not considered.
[82] This assumption is also a reason why texts including the term 'Anthropocene' only as part of a project's name were excluded from the corpus (step 3), in that these do not provide valid data for interest in the term.

etc.) their faculties and departments through structures following this type of classification. Scholars and researchers locate themselves within disciplines that belong to one field of knowledge (or more, in the case of inter-/transdisciplinarity), so that terms such as 'humanist,' 'social scientist,' or 'natural scientist' express in a basic and loose way what methods, objects, or philosophies researchers endorse in pursuing their research interests.

The methodology hereby developed adopts this five-fold system of classification to determine what fields of knowledge were predominant in the 'Anthropocene' early research literature. Each record is assigned one or more fields of knowledge. Multiple fields of knowledge for the same record are assigned if the particular record engages in any form of multi-/inter-/transdisciplinarity – for instance, if it represents a study merging geology (i.e., natural sciences) with sociology (i.e., social sciences). *How* records are assigned a given field of knowledge depends on the particular discipline it is assigned. Each discipline corresponds to one and only one field of knowledge in the way represented in Figure 2.2. Consequently, assigning a discipline also implies assigning one more field(s) of knowledge to a record. The distribution of disciplines across fields of knowledge follows the outline of academic disciplines as illustrated by the respective Wikipedia page,[83] which provides a concise and useful organizational scheme of academic disciplines. The only major differences lie in the status of the disciplines of *history*, which is hereby considered part of the social sciences rather than the humanities, and *physical geography*, hereby classified as a natural science.

HUMANITIES (5)	SOCIAL SCIENCES (14)	NATURAL SCIENCES (15)	APPLIED SCIENCES (5)	FORMAL SCIENCES (0)
• Ecocriticism • Landscape Architecture • Law • Linguistics • Philosophy	• Anthropology • Archaeology • Economics • Environmental Studies • Gender studies • History • Human geography • International studies • Pedagogy • Political science • Psychology • Science and Technology studies • Sociology • Sustainability studies	• Arctic studies • Astronomy • Atmospheric science • Biology • Chemistry • Climatology • Earth System science • Ecology • Environmental science • Geology • Hydrology • Limnology • Oceanography • Physical geography • Soil science	• Engineering • Geoengineering • Medicine • Psychiatry • Resource management	n/a

Figure 2.2. Distribution of disciplines per field of knowledge. Notably, no discipline within the formal sciences using the term 'Anthropocene' has been located in the literature gathered.

[83] See the Wikipedia entry 'Outline of academic disciplines' (accessed on May 14, 2021. Last revision: May 6, 2021, 20:11 CET by Pfhorrest).

The *records per field of knowledge* represents the sum of all records for a given field of knowledge (section 2.1.2.2). Records per field of knowledge provides a coarse-grained overview of the knowledge domains that most engaged with the term 'Anthropocene' during its early research stage. Because records may be assigned two or more fields of knowledge, this type of clusterization also enables dividing the corpus into *multi-domain* and *single-domain* records. A multi-domain record is a record merging disciplines from two or more fields of knowledge (e.g., an Earth System science and political science record). Conversely, a single-domain record is defined by one or more disciplines within a single field of knowledge (e.g., a climatology and/or oceanography record). Multi-domain is not equivalent to multidisciplinarity – the latter describing a form of interaction among *disciplines* rather than *fields of knowledge*. Multi-domain and single-domain are salient properties because they help assess the degree to which the 'Anthropocene' represented an object whose conceptual history was confined to a single domain or multiple knowledge domains.

Discipline represents the particular disciplinary domain characterizing a record (e.g., geology, sociology, Earth System science, engineering, etc.). Disciplines are subcategories of fields of knowledge in a way illustrated in Figure 2.2, so that assigning one or more disciplines to a given record always implies assigning one or more field(s) of knowledge.[84] The sum of all records for a given discipline provides *records per discipline* (section 2.1.2.3). While records per field of knowledge provides a coarse-grained lens of analysis, records per discipline provides a fine-grained overview of which disciplines engaged with the term, and which engaged the most. This makes a discipline-based division one of the most informative properties of the corpus. Additionally, disciplinarity distribution provides a measure of *multidisciplinarity*. Terms such as 'multidisciplinarity,' 'transdisciplinarity,' and 'interdisciplinarity' define different ways of interaction and/or collaboration among disciplinary domains and fields of knowledge (for related literature, see Andersen, 2016; Darian-Smith & McCarty, 2016; Youngblood, 2007). In the present context, multidisciplinarity is defined in its broadest sense as the occurrence of multiple disciplines in characterizing the disciplinary content and/or provenience of a record. Each record that is assigned two or more disciplines is immediately labelled as multidisciplinary – regardless of the disciplines' respective fields of knowledge, or the particular type of interaction among disciplines.

The disciplines listed in Figure 2.2 represent *all* disciplines that characterize the corpus of literature. They were not selected based on a preestablished pool of an arbitrarily large number of disciplines (unlike fields of knowledge, which were drawn from the Wikipedia outline). Rather, their selection emerged organically from the organization of the corpus conducted between step 3 and step 4. Thus, disciplinary classification of the corpus is not applied to records *ex ante*, but rather is a product of the records themselves *ex post*. This represented a way to remain faithful to the disciplinary content and provenance of each of the records.

The main criterion used to assign each record one or more disciplines was crosschecking (whenever information was available) the record's title, summary/abstract/preface, publication platform (e.g., journal,

[84] For an overview of methods and systems of disciplinary classification, see https://education.stateuniversity.com/pages/1723/Academic-Disciplines.html (accessed on May 19, 2021).

publisher), and author's academic affiliation (e.g., 'Department of Geology' indicating *geology* as discipline) or background. Wherever crosschecking was not entirely possible or clear (a very minute portion of the corpus defined primarily by records of non-academic format), the record's title and author's affiliation or background were given priority in determining the discipline. To avoid proliferation of stand-alone disciplines (and thus clusters), a second criterion was to group specialized disciplines into their largest disciplinary domain (e.g., historical geology, petrology, and physical geology are grouped under 'geology'). In the case of disciplines resulting from the convergence of two or more disciplines, each of the converging disciplines is used to label the record rather than their converging product (e.g., a record recognizable as geochemistry is clustered under 'geology' and 'chemistry').

Assessing the disciplinary provenance of each record was perhaps the hardest property to detect. Major difficulties in inferring disciplinarity derived from (1) the specific formats of some records (e.g., pamphlets, web pages, newspaper articles), (2) the specialized disciplinary provenance of some records, (3) the extra- or non-disciplinary nature of some records, and/or (4) the mixed disciplinary matrixes of records (i.e., authors with different disciplinary backgrounds *x*, *y*, and *z*, publishing in a journal *p* about the topics *a*, *b*, and *c* – all placeholders representing different disciplinary areas). These represented some of the major challenges in assigning disciplinarity to records in a way that would be faithful to the nature of the record itself. Each challenge was tackled respectively by (1) considering the content of the format in addition to crosschecking general information, (2) grouping specialized disciplines into their larger disciplinary area, (3) assigning a discipline based on content-proximity by analyzing the text, and (4) ascribing different disciplines to records of a multidisciplinary nature.

Format represents the particular type of literature characterizing a record. Any type of format was included in the definition of the corpus conducted during step 3, meaning that the corpus is comprised of a variety of records of different formats (listed in Figure 2.1 above). However, primary attention was given to academic literature over non-academic literature (especially newspapers and websites, which are intrinsically difficult to track through the search engines used, and thus may not have been exhaustively accounted for in the final corpus). Similar to the selection of disciplines, the fourteen types of recognized formats emerged organically from the nature of the records themselves. Indeed, the very selection of *format* as a cluster mirrors the diversity among textual sources engendering the corpus. Format is an informative cluster for three main reasons. First, by assigning each record one (and only one) format, it is possible to assess what means of publishing the 'Anthropocene' concept spread most through. This assessment can be integrated with studies on science communication concerning what formats provide more visibility, or which are more effective in strengthening the scientificity or institutionalization process of scientific ideas.[85] Second, the existence of multiple formats witnesses the methods of propagation of the 'Anthropocene' across and beyond academic scholarship. This is a salient feature of the history of the concept that is to be drawn.

[85] The clusters used do not probe into the specific subtypes of formats – i.e., original research, short reports, and review articles (rather than book reviews) published in journals are all grouped under 'journal articles.'

Lastly, each record is assigned one (and only one) *language* representing the specific language of the record. As anticipated, English has been the primary language of the 'Anthropocene' by an outstanding margin. This is not solely connected to the extant status of English as the language of international scientific communication, but also because it represents the mother language of the term itself.[86] Accordingly, the tools used in step 1 and 2 were mostly English-focused databases and search engines, and the keyword search itself has been conducted by using the English unigram 'Anthropocene.' Therefore, the vast majority of records are in English.

Despite these parameters, a few records in European (French, German, Italian) and non-European (Chinese, Japanese) languages are nevertheless included in the corpus. This literature emerged independently from cross-surveying search engines and databases. It is plausible that each language-cluster is not utterly indicative of the type of scholarship that a specific linguistic community was pursuing during the first decade of existence of the 'Anthropocene' (e.g., Chinese records cannot be confidently used as proxies for Chinese research on the 'Anthropocene' during its early phase). However, records in languages other than English are extremely informative in that they provide a condensed snapshot of the way the term was being received in the international scholarly audience,[87] and they witness the reach of the term beyond linguistic and geographical confines. These are important aspects taken into consideration in the qualitative assessment of the 'Anthropocene.'

Once each record is assigned each of these types of labels, the clusters generated provide different numerical and visual proxies forming the basis for a quantitative analysis of the 'Anthropocene' in early research literature. Using these clusters also provides crucial insights in reconstructing the history and evolution of the 'Anthropocene' concept during its early phase. Notably, these selected clusters do not exhaust the spectrum of possible properties observable across the corpus. Author-focused analysis, word cloud analysis, social network analysis, inter-/trans-/multidisciplinary analysis, and more, could represent additional lenses of analysis for clustering the corpus. Delimiting the scope of the present analysis through the selected clusters only follows pragmatic and organizational motives.

[86] This is true only for the modern history of the 'Anthropocene.' When its paleo- and pre-history are considered, one could make the case that the term 'Anthropocene' first appeared in the Russian language, although the canonical translation from Shanster (1973) could be contested. See section 1.2.4.2.

[87] A linguistic barrier with some of the languages identified does not allow for a deep analysis of all the non-English records – especially for Chinese and Japanese literature.

2.1.1.3 Relative Frequency

An additional salient property retrieved from each record is the *relative frequency* of the term 'Anthropocene.' Relative frequency is a measure commonly used in linguistics to compare texts or corpora of different sizes. Its numerical value is expressed according to the following formula:

$$F_n = F_o \frac{10^6}{T}$$

Where F_n is the normalized or relative frequency (to a million, 10^6, and expressed in real numbers, ≥ 0), F_o is the observed frequency (i.e., total *n*-gram counts in a text), and T is text size (i.e., word count).

An example may better illustrate the meaning of relative frequency. Suppose a text A has 50 occurrences of the word 'Anthropocene,' whereas a second text B has 25 occurrences – so that $F_o(A) = 50$, and $F_o(B) = 25$. The observed frequency of 'Anthropocene' in text A is higher than that of text B. However, suppose A has a word count of 10,000, whereas B is only 2,500 words long – so that T(A) = 10,000, and T(B) = 2,500. In this case, the observed frequency alone will be insufficient to compare the texts because they have different text sizes. Therefore, it is necessary to normalize their frequencies by a common factor (i.e., a million), so that, according to the formula above, $F_n(A) = 50 \cdot (10^6/10{,}000) = 5{,}000$, and $F_n(B) = 25 \cdot (10^6/2{,}500) = 10{,}000$. While the term 'Anthropocene' appears twice as many times in text A than text B, the relative frequency of the term is half of that of text B – meaning that the term 'Anthropocene' is actually twice as frequent in B than A.

The F_n for each record was retrieved by using the open source software Voyant Tools (step 5). Texts were individually uploaded as readable PDF files, and the relative frequency for each was automatically measured by the software through the above formula. This process requires a few methodological remarks.

A first remark concerns one type of material uploaded for text mining. Edited volumes (labelled as 'book section') with multiple authors were not uploaded in their entirety. Only those chapters from distinct authors where the term 'Anthropocene' appears were mined for obtaining the relative frequency. This criterion ensured that each record was faithful to its textual content, and the relative frequency was consistent with the text analyzed. The criterion also implied considering multiple sections in the same edited volume as discrete records in the corpus. The same criterion did not apply to monographs authored by one or more authors, where all text is representative of the author or authors' engagement with the term.

A second set of remarks concerns some methodological limitations related to the accuracy of the software implemented.

The software mines the text in its entirety, meaning that each word in the text is counted regardless of the specific place in the text where a word appears (e.g., footer, header, bibliography, keywords, etc.). For example, the software counted each occurrence of 'Anthropocene' in the header or footer of a given text where the header or footer includes the publication's title on each page (or every other page). This resulted in several occurrences of the word as a product of the publishing layout of a journal or book section (or any other similar format) rather than the text's engagement with the term. Similarly, relative frequency accounts for the occurrence of the term in the bibliography section of a text (consistent with the search criteria defined in step 3, texts selected for the corpus must not occur exclusively in bibliography). However, a quick survey of each entry during the text mining step reveals that such occurrences are rare, and occurring in texts with low relative frequency.

Additionally, the software often recognized numbers, DOIs, dates, URLs, HTTPs, or other written linguistic expressions of various types as 'words,' hence retrieving a total word count that did not entirely correspond to the exact total word count of texts – 'exact' implying that a (written) 'word' is understood as a single linguistic entity with meaning.[88] However, because these represent a very minor set of written expressions compared to the main body of the texts, their impact on the total word count (and thus for the relative frequency) for each record is negligible.

A similar software-related reading error related to the accuracy of distinguishing words in a way that affected the total word count (i.e., T). The software was not always able to distinguish all individual words as different words, occasionally merging (and thus counting) two words as one (e.g., 'the humanimpact,' 'Theanthropocene,' 'anthropocenebegan'). This too represented a minor issue throughout the corpus (it only affected T, with a negligible effect on F_n), which was only relevant when F_o of 'Anthropocene' needed to be assessed. In this case, the text mining conducted by Voyant Tools was crosschecked by a simple Ctrl-F search on the PDF of the text in question. If a higher F_o value was retrieved through the Ctrl-F search, then F_n was adjusted manually.

Lastly, another software-related type of error in retrieving relative frequency derived from the misreading of words split at page end (i.e., An–thropocene, Anthro–pocene, Anthropo–cene, Anthropoce–ne). These instances were not recognized by the software as occurrences of the word 'Anthropocene.' This error (very limited in the corpus) was corrected by first keywording various components of the word (e.g., 'cene,' 'anthr,' etc.) to locate possible word splits, then adding the corrected errors to the total observed frequency of the term 'Anthropocene' obtained by the software, and lastly implementing the relative frequency formula to obtain manually the desired value (rounded up).

The central idea behind implementing relative frequency for reconstructing the history of the 'Anthropocene' in early research literature is that it represents a valid proxy for assessing each record's particular engagement with the term. Intuitively, not all texts using the term 'Anthropocene' have the same type and degree of engagement with it. Texts where the term appears on multiple occasions are usually texts that actively engage with the term – for instance, by discussing its meaning, its implications, its usefulness, or more. Conversely, records with low relative frequency are typically texts where the term 'Anthropocene' is primarily a 'background' notion – meaning that the texts do not probe into its semantic, but merely mention it marginally, or use it as an introductory or conclusive metaphorical device. If relative frequency

[88] This definition is only pragmatic. As argued by the linguist Martin Haspelmath (2011), "we do not have a good answer to the question of how to define the notion of word in a clear and consistent way that accords with our intuitions and with conventional practice" (p. 32).

is a proxy for textual engagement with the term, then those texts with higher relative frequency represent the main sources of historical value for reconstructing the history the 'Anthropocene.'

Indeed, relative frequency is particularly relevant in distinguishing between *central* and *peripheral* literature. This is a key conceptual distinction in the methodology and discussion conducted throughout section 2.1. The central literature includes all records whose text *actively engages* with the term – for instance, by critically discussing it, or using it as an epistemic tool. The peripheral literature includes all records whose texts *passively engage* with the term – for instance, by marginally tackling, mentioning, or using the term as a 'background' notion. Assessing each record's *degree of engagement* (i.e., assessing whether a record belongs to the central or peripheral literature) is determined by the relative frequency value assigned for each record locating above (central literature) or below (peripheral literature) an arbitrarily selected value. The value chosen for this study was 2000, so that all records belonging to the central literature have $F_n \geq 2000$, whilst all records belonging to the peripheral literature have $F_n < 2000$. This number reflects (1) a point of increase visualizable from the curve of all F_n values for each record (see Figure 2.10); (2) a value including all texts of the 'standard literature' in terms of relative frequency – namely, namely, F_n(Crutzen and Stoermer, 2000) = 2307, F_n(Crutzen, 2002) = 5800, F_n(Nature, 2003) = 5649, F_n(Steffen et al., 2007) = 2810, F_n(Zalasiewicz et al., 2008) = 2397, and F_n(Chakrabarty, 2009) = 2570;[89] and (3) a round value of practical utility.

The distinction between central and peripheral literature based on F_n should not be taken too literally. It is feasible that texts that substantially engaged with the term without frequently mentioning it may have also had a central role in shaping the history of the 'Anthropocene' and the Anthropocene Hypothesis. Indeed, the qualitative analysis of the corpus (section 2.1.3) uses sample peripheral literature considered interesting for reasons beyond the relative frequency value of those particular records. Similarly, some texts may have had a propagating role due to their status in the social network of academic scholarship rather than their engagement with the term. Research using author-based or journal-based citation metrics (e.g., *h*-index, Journal Impact Factor, CiteScore, etc.) may easily complement the present analysis by showing which texts and publication platforms in particular had broader reach.

Assigning a particular record to the peripheral literature does not diminish its importance in reconstructing the history of the 'Anthropocene.' On the contrary, the quantitative approach hereby conducted attributes outstanding value to textual sources previously unknown to Anthropocene scholarship. The distinction simply follows the pragmatic necessity of selecting some texts out of 670 for a

[89] Given their historical as well as methodological importance, F_n values for some texts (i.e., those with particular publishing layouts) exemplifying the 'standard literature' have been adjusted manually to provide more accurate F_n values. F_n(Crutzen, 2000) has been adjusted by copy–pasting relevant text into a Word document due to the software's omission of the title in the F_o count, and because the page layout of the published text includes words from an unrelated article (it also excludes the bibliography from T, which was erroneously printed on page 16 of the full Newsletter issue; the bibliography is included in F_n). F_n(Crutzen, 2002) has also been adjusted manually due to the software's misreading of two occurrences of 'Theanthropocene' rather than two distinct linguistic units (i.e., 'The' 'Anthropocene'). F_n(Nature, 2003) was adjusted by copy–pasting relevant text into a Word document due to the layout of the text, which includes words (substantially affecting T) from another distinct article published on the same page. F_n(Chakrabarty, 2009) gave F_o = 31 through a Ctrl-F search compared to F_o = 25 (+2 misreading of 'Anthropocene') through Voyant Tools. The disparity was adjusted accordingly.

qualitative analysis. The relative frequency approach provides the selection criteria to enforce this distinction.

2.1.2 Exploring the Early Research Literature: A Quantitative Overlook

The literature used to reconstruct the early (modern) history of the 'Anthropocene' concept represents a corpus of 670 records published between 2000 and 2009. These are predominantly English texts of various formats and disciplinary provenance, and exhibiting different degrees of engagement with the term. The relative size and composition of the corpus enables a quantitative approach to retrieving relevant information for reconstructing the history of the 'Anthropocene' and of the Anthropocene Hypothesis. All records and their respective properties are listed in the Appendix at the end of this research.

A preliminary question is whether the corpus is representative of the research material that was published during the decade of analysis in terms of (a) *completeness* and (b) *content*. These aspects arise from considering (a) the exhaustiveness of the corpus in respect to the literature using the term during the decade of analysis, and (b) the salient properties that make the corpus interesting (beyond the mere appearance of the term). Both conditions (i.e., completeness and content) need to be satisfied for the corpus to represent a valid pool of information.

As previously explained, the corpus is a product of a cross-survey between three main databases and search engines for academic publications (plus Google Scholar, only partially used for cross-surveying). Using multiple databases ensures that the final corpus is *semi-complete* – that it, the corpus encompasses *in principle* all literature produced between 2000 and 2009 that is available to the public.[90] This is 'in principle' because the completeness of the corpus cannot be verified (neither inductively nor deductively) with certainty. The corpus may have omitted literature that did not appear through search engines, especially since format-related restrictions are not applied (as is the case for the present approach). Furthermore, it might also be the case that some sources that used the term during the decade scrutinized are no longer available (e.g., webpages in particular[91]), resulting in missing records.

However, it is unlikely that a significant number of records is omitted from the corpus of analysis such that it would not faithfully embody the early research literature, and the modern history of the 'Anthropocene.' This is because (1) cross-surveying among *different* search engines and databases provides some warrants for the semi-completeness of the corpus; (2) the term had then been recently coined, meaning that its initial spread in literature is expected to be somewhat slow, and thus would exhibit a relatively low number of records per year (which is, in fact, consistent with the findings); (3) as an English-born concept developed within a predominantly English-speaking context, it is reasonable to assume that

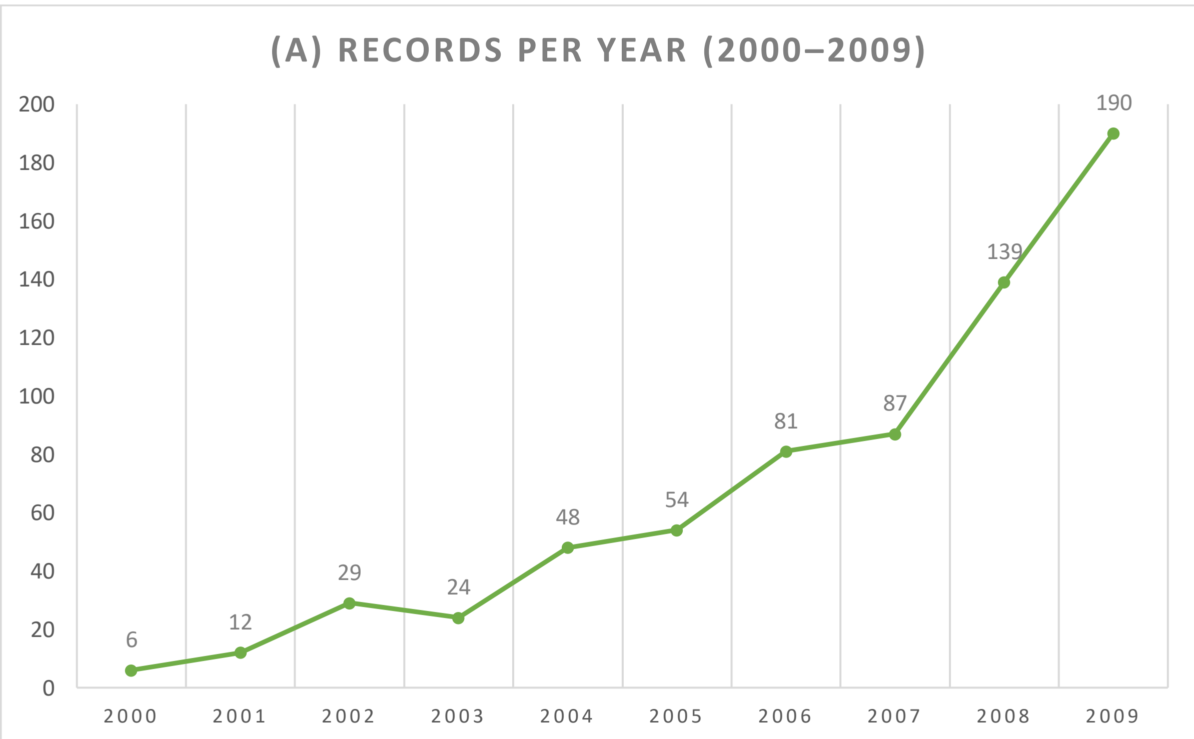
[90] Internal records (e.g., from organizations, institutions, etc.) using the term 'Anthropocene' are not accounted for in the corpus.
[91] See for instance Chakrabarty (2009), footnote 27. The original source from *The Australian* provided by the author is no longer an active link. No results are provided by searching for the article "Humans Creating New 'Geological Age'" on *The Australian* (https://www.theaustralian.com.au/, accessed on May 27, 2021).

the term did not spread faster in other languages beyond English, and thus no substantial non-English literature is expected to be missing; and (4) a survey of the bibliography of records (whenever available) does not point to any record that is not included in the corpus. Thus, if the corpus is semi-complete, then it exhaustively represents the (research) literature in a way that is faithful to the history of the 'Anthropocene' and the Anthropocene Hypothesis. If so, then the (a) *completeness* parameter is satisfied.

Intuitively, a quantitative analysis of a corpus of 670 records cannot be sustained based exclusively on the appearance of the term in literature. This number would be empty without considering the various salient properties that make this corpus interesting. These properties are analyzed through clusters as delineated in section 2.1.1.2. As shown in the following subsections, the selected clusters allow us to probe deep enough into the corpus to retrieve information of great value in understanding, on a *macrolevel*, the conceptual history of the 'Anthropocene.' Ultimately, this information is necessary to understand the context in which the Anthropocene Hypothesis came to be. If the selected clusters succeed in retrieving valuable information, then the selected corpus is faithful (content-wise) to the history of the concept during its early research stages. If so, then the (b) *content* parameter is satisfied.

2.1.2.1 Records per Year

The first property of interest for analyzing the corpus is records per year. This cluster reflects the number of texts published in a given year between 2000 and 2009 where the term 'Anthropocene' appears. Figure 2.3 provides a visual cue and starting point for the analysis.



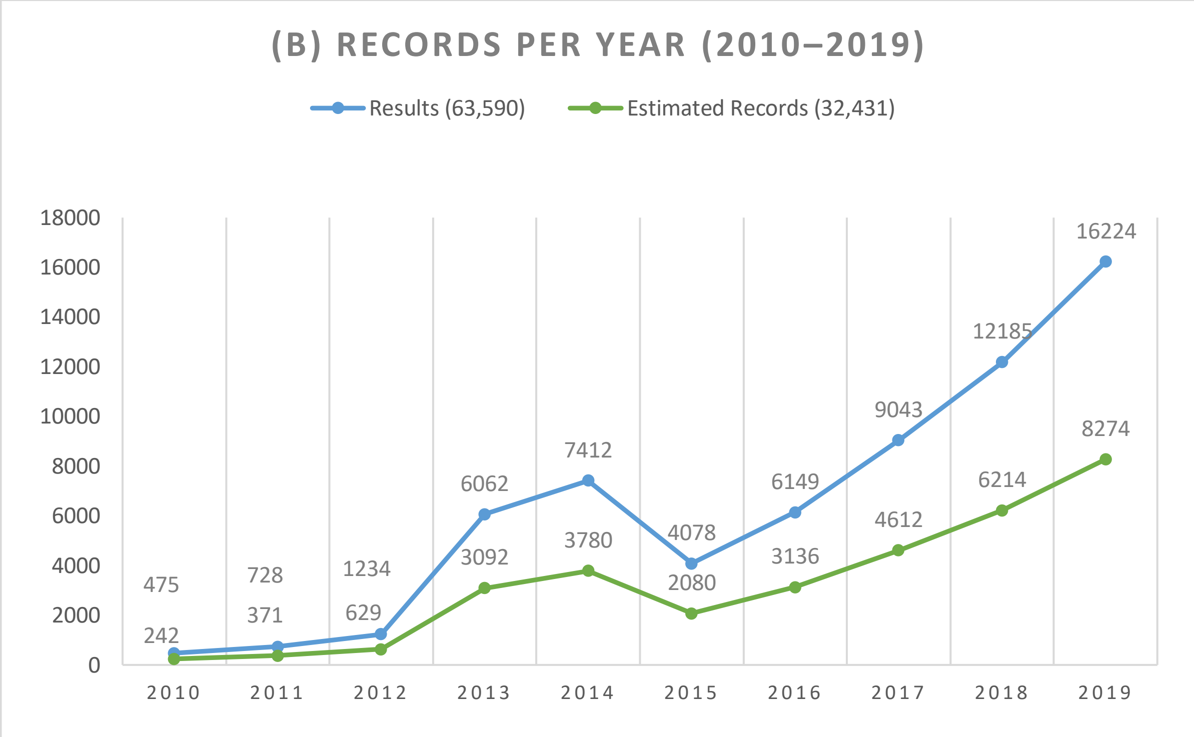


Figure 2.3. Graph (A) shows the number of records for the 2000–2009 decade, totaling 670 records. Graph (B) shows the number of results by keywording 'Anthropocene' (case-insensitive) between 2010 and 2019 through the search engine Dimensions (as of September 19, 2021), totaling 63,590 results (blue line); and the total amount of estimated records (green line). (NB: *records* and *results* are distinct entities that do not allow direct comparison. To compare between records during the two time frames, one could multiply the 2010–2019 results by a factor of 0.51 for each year, which is the ratio between records (670) and search results (1,311) for the 2000–2009 decade (via Dimensions.ai), and an estimate of ~32,431 records for the 2010–2019 decade. This is a practical solution to what would otherwise require surveying 63,590 total results from Dimensions.ai only).

The initial frequency of the word across literature in relation to time was low if compared both to similar studies on the lifecycle and propagation of neologisms (Altmann et al., 2013; Jiang et al., 2021),[92] and to the late spread of the term during the 2010–2019 decade (Figure 2.3B). In fact, the term only propagates slowly in academic discourses, reaching more than 100 records per year only by 2008. It was only after 2009 – coinciding with the establishment of the AWG, and the publication of Chakrabarty's (2009) seminal paper – that the 'Anthropocene' really witnessed a surge in interest across media outlets and diverse fields of academic inquiry. To place it in perspective: the totality of records representing the 2000–2009 literature amounts to 670. For the 2010–2019 decade, a (conservative) minimum of ~32,000 records are estimated. These sheer numbers suggest that the term did not immediately resonate across research communities, but took around ten years before it began to substantially appear in academic literature and other non-academic sources. If higher records and/or results implies higher interest (either positive or negative) among

[92] These studies should only be considered as inspirational for the present purposes. Comparisons with quantitative analysis of corpora for Internet neologisms are intuitively not one and the same as studies on the birth and evolution of scientific ideas.

epistemic actors, then publications per year provides a faithful proxy for assessing yearly increase (or decrease, e.g., between 2014 and 2015) in interest in the 'Anthropocene.'

Many combined forces may have contributed to the post-2009 increase in interest, in addition to the formation of the AWG and the publication of Chakrabarty (2009). Reasonably, a central force was the transformation of the 'Anthropocene' concept into a vector and hub for environmental discourses. In the last decade, the inclusion of environmental-oriented humanities and social sciences into the shaping of Anthropocene Studies has mutated the term from a descriptive category within a primary matrix of Earth System science and the geosciences to a normative category. The term has been placed at the forefront of environmental agendas promoted by think tanks, environmental movements, research institutions, and international organizations, all of which have seen the 'Anthropocene' as a communicative means for change.

The original slow propagation of the term may have been due to the restricted academic niche where the term saw initial spread. Crutzen's status as a Nobel laureate as well as one of the most-cited scientists by the 2000s (Schwägerl, 2014) was a central factor in the early survival as well as the later success of the 'Anthropocene.' However, the term remained a neologism of a technical nature and restricted to a specific circle of disciplines, organizations, and epistemic actors during its first years of existence. Crutzen's influence remained limited to disseminating the term primarily within the Earth System science community, whilst the term only sporadically appeared in neighboring disciplines. Although the term has always had an implicit normative overtone (see Dalby, 2016), it was only after the humanities and social sciences began a systematic engagement with the term that it transformed into a broader category for environmental communication and change. Prior to this 'environmental turn,' the term had been used primarily in the geosciences and Earth System science as an informal time designation marking the dawn of global-scale anthropogenic impact on the Earth System. The 'Anthropocene' mirrored global change, and "[t]he extent to which human activities are influencing or even dominating many aspects of Earth's environment and its functioning" (Steffen et al., 2004c, p. 14).

Records per year is a useful property for dissecting the corpus, providing a snapshot of the spread of the term over time. However, it should be noted that records per year does not account for the time difference between the writing, submission, and publication of a record. Academic publishing is a process that may vary from months to several years, depending on a series of factors such as format, the publisher's editorial timeframe, the peer-review process, and more. For instance, a record published in 2006 may have been submitted for publication in 2003, meaning that three years elapsed between submitting the manuscript and publishing that given record. Records per year is a value indicative solely of the number of records *published* in a given year, and not those *submitted*. Therefore, records per year as a time-sensitive proxy for the spread of the term is necessarily lagged, meaning that it cannot represent the *exact* timing of the spread of the term. While this does not represent an obstacle for the methodology hereby developed, it is important to stress the purpose and function of records per year as a meaningful property of the corpus.

2.1.2.2 Records per Field of Knowledge

Another interesting property for dissecting the corpus is records per field of knowledge – that is, what fields of knowledge mostly characterize the corpus. As outlined in the methodology section, records may be assigned one or more fields of knowledge (i.e., applied sciences, formal sciences, humanities, natural sciences, social sciences) depending on the particular disciplines it is assigned. This means that field of knowledge is a derivative property – that is, it is assigned only *after* a record is assigned a property, and as a consequence of the discipline assigned.

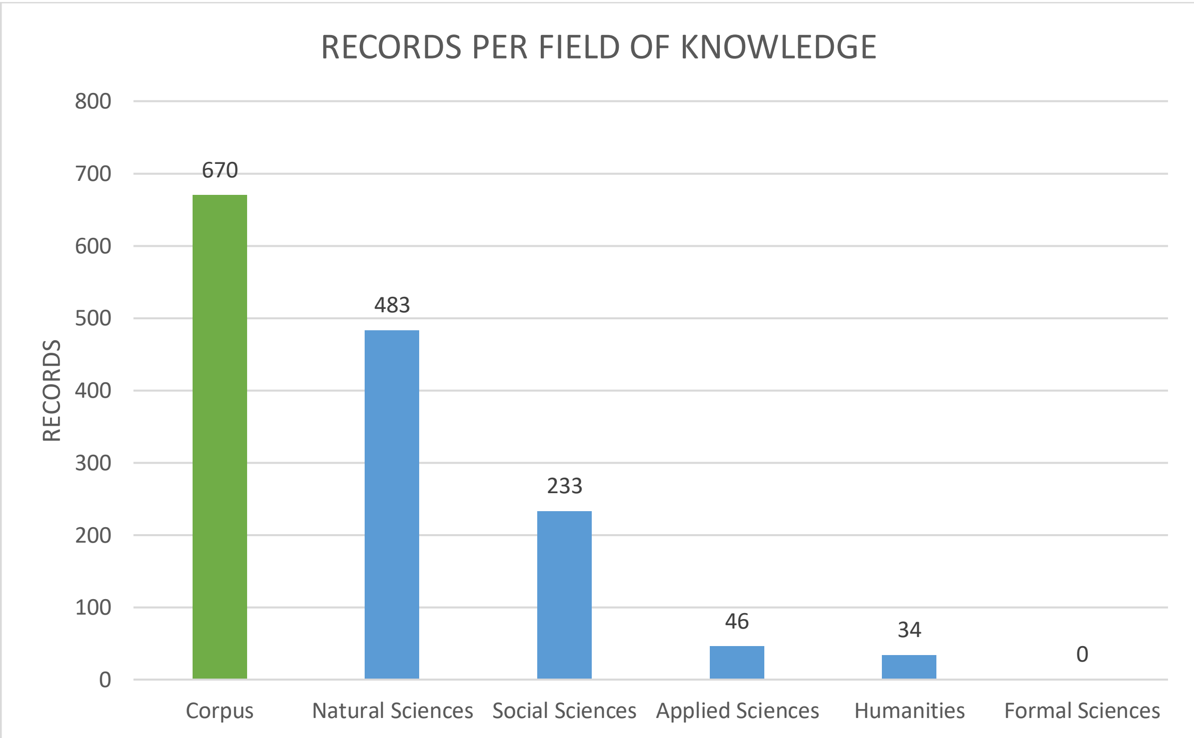


Figure 2.4. Number of records for each field of knowledge (in blue). To exemplify: 233 occurrences of 'social sciences' means that there are 233 records labelled as social sciences, although some of these records may also be labelled as natural sciences, applied sciences, or humanities if their respective disciplines fall within other fields of knowledge.

Figure 2.4 shows the total number of records per field of knowledge. High occurrence of records in a particular field of knowledge implies high reception of the term 'Anthropocene' within that knowledge domain.

A central characteristic of the early history of the 'Anthropocene' is that the literature implementing the term mostly stemmed from the natural sciences. Out of the 670 records composing the corpus, 483 records are recognized (at least) as natural sciences records. This represents almost three-quarters (72.1%) of the corpus. The second highest occurring field of knowledge is the social sciences, with 233 records recognized within this knowledge domain (34.8%), followed by the applied sciences with 46 records (6.8%)

and the humanities with 34 records (5.1%). No record was assigned a discipline representing the formal sciences (e.g., mathematics, logic, programming, AI, etc.). Presumably, this is because the concept was either irrelevant to the communities representing this particular knowledge domain, or its reach simply did not extend enough during the term's early stages.

The predominance of the natural sciences as primary field of knowledge can be correlated to the seminal influences of the original birthplace of the 'Anthropocene' – that is, the International Geosphere-Biosphere Programme (IGBP), and the Earth System science community (see section 1.2.2). The IGBP was a research program that ran from 1987 to 2015. Its primary research focus was the study of the Earth System and its interaction with human systems with the intention "to provide essential scientific leadership and knowledge of the Earth system to help guide society onto a sustainable pathway during rapid global change" (IGBP, 2015a, para. 1). The IGBP connected researchers of different scientific provenance, from geoscientists, oceanographers, and marine scientists to chemists, atmospheric scientists, climatologists, and more. This science-oriented context was crucial in defining the early identity of the 'Anthropocene.' It was during a *scientific* committee meeting of the IGBP that Crutzen famously coined the term, and through *scientific* outlets (e.g., *Nature*, the IGBP *Newsletter*, *Science*, *Scientia Marina*, geosciences journals, etc.) that the term began to gradually appear and spread via publications authored predominantly by *natural scientists*. The prevalence of the natural sciences in characterizing the 'Anthropocene' early research literature is paramount in understanding the premises engendering the evolution of the 'Anthropocene' into the Anthropocene Hypothesis. Indeed, the 'Anthropocene' concept was already embedded into a scientific context which invested it with an original scientific connotation – in addition to its scientific utility (a point later discussed in section 2.2.1). Arguably, the absence of this preliminary condition would not have equally prompted the formation of a research group (i.e., the AWG) and the hypothesis it has been promoting since 2009. This is also confirmed by the fact that a similar term proposed by Andrew Revkin in 1992 – the "Anthrocene" (Revkin, 1992) – did not equally resonate across scientific communities.[93]

The IGBP (and the Earth System science community) was not exclusively concerned with the science behind the functioning of the Earth System. Its aim was to provide leadership and knowledge for the benefit of society overall in the face of increasing anthropogenic pressures on the Earth System. This aim required the research program to include scholars from the social sciences and the humanities into the conversation. This is presumably a central reason behind the social sciences characterizing roughly a third (233) of all records of the corpus. This literature pioneered early social science approaches to the 'Anthropocene,' engendering later research trajectories regarding the utility and meaning of the concept in the broader public discourse on the human–environment relationship. This was particularly vivid in literature linking the term with central questions of sustainability and global change that informed much of the environmentally oriented scholarship from the social sciences. Beside the pioneering role of the IGBP, the term 'Anthropocene' had a very early conceptual link with historical questions concerning the beginning

[93] Other factors may have played a role in the lack of spread of the 'Anthrocene,' including Crutzen's higher academic prestige as a Nobel laureate and often-cited scientist, the proliferation of media outlets by the early 2000s, and the reach in relation to the publication format where the term appeared.

of the epoch. Historical periods such as the Industrial Revolution or the Great Acceleration were structural aspects in shaping the semantic identity of the 'Anthropocene' concept during its early research stages.

Only a small portion (34) of the records fall under the humanities – a value lower (albeit marginally) than the applied sciences (46), which include fields such as engineering and resource management. Systematic engagement from humanistic disciplines only occurred after the term acquired broader popularity, during the second decade of the term's existence. The humanities brought critical perspectives on the connotations and rhetoric of the 'Anthropocene.' This type of criticism was generally absent during the early research phase of the concept since the term had also yet to develop a 'narrative' clear and distinct enough to be an object of criticism.

As stated, records composing the corpus may belong to one or more fields of knowledge. A record whose disciplinary provenance entails two or more fields of knowledge is considered a *multi-domain* record, whereas a record with one or more disciplines within the same field of knowledge is defined as a *single-domain* record. Consequently, records can either be multi-domain or single-domain, but not both. Figure 2.5 illustrates how single-domain and multi-domain records compose the corpus.

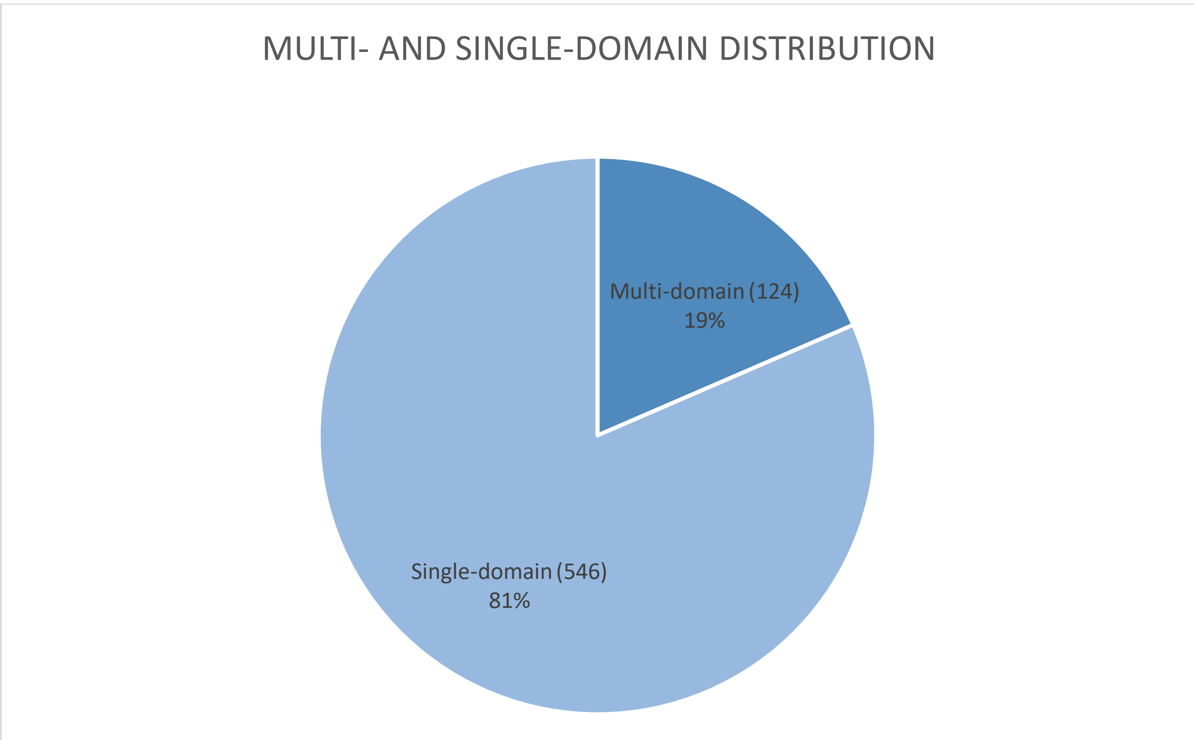


Figure 2.5. Percentage distribution of the corpus based on single-domain records and multi-domain records.

Dividing the corpus into single-domain and multi-domain records is a quantitative proxy to assess to what extent the 'Anthropocene' spread and evolved across fields of knowledge. Findings show that most records fall within the natural sciences, followed by social sciences, applied sciences, and humanities. Most records

(546) appear to be characterized by one of these domains rather than multiples – the latter representing almost a fifth (124 records) of the corpus. It is hard to assess whether these numbers provide any insight into the multi-domain nature of the 'Anthropocene' without a measure of comparison. Nevertheless, the chart above seems to suggest that most records engaged with the concept within the limits of their respective field of knowledge. This is not to say that the term did not have a multidisciplinary matrix, since multi-domain is not equal to multidisciplinarity – as previously stated. Presumably, the fact that most records are single-domain can be correlated to the large majority of records being from the natural sciences. If the term was a *scientific* neologism, then it is expected that the natural sciences were primarily (and individually) using the term without the necessity of multi-domain interaction.

Dissecting the literature through fields of knowledge reveals that the natural sciences was the primary field of knowledge where the term 'Anthropocene' spread and construed its identity. This is an important finding because it tells that the 'Anthropocene' was coined within a scientific context, and its early history could be treated as the history of a scientific concept. Ultimately, this is an important step in reconstructing the birth of the Anthropocene Hypothesis as the stratigraphic 'variant' of the broader 'Anthropocene' object. The absence of the humanities as a field of knowledge substantially engaging with the term reflects the absence of that trademark critical thinking that distinguishes humanistic disciplines. This is consistent with the fact that the 'Anthropocene' concept and discourse was mostly unproblematic during its early history. Debate over the meaning, discourse, and hidden nuances of the 'Anthropocene' only began to appear systematically after 2009, when the term began to spread at a more rapid pace across fields of knowledge.

2.1.2.3 Records per Discipline

Records per field of knowledge provides a coarse-grained proxy to assess what fields of knowledge most engaged with the term 'Anthropocene' during its early history. A finer-grain analysis is provided by records per discipline. Thirty-nine disciplines were identified according to the criteria defined in section 2.1.1.2. Figure 2.6 shows the number of records retrieved for each discipline.

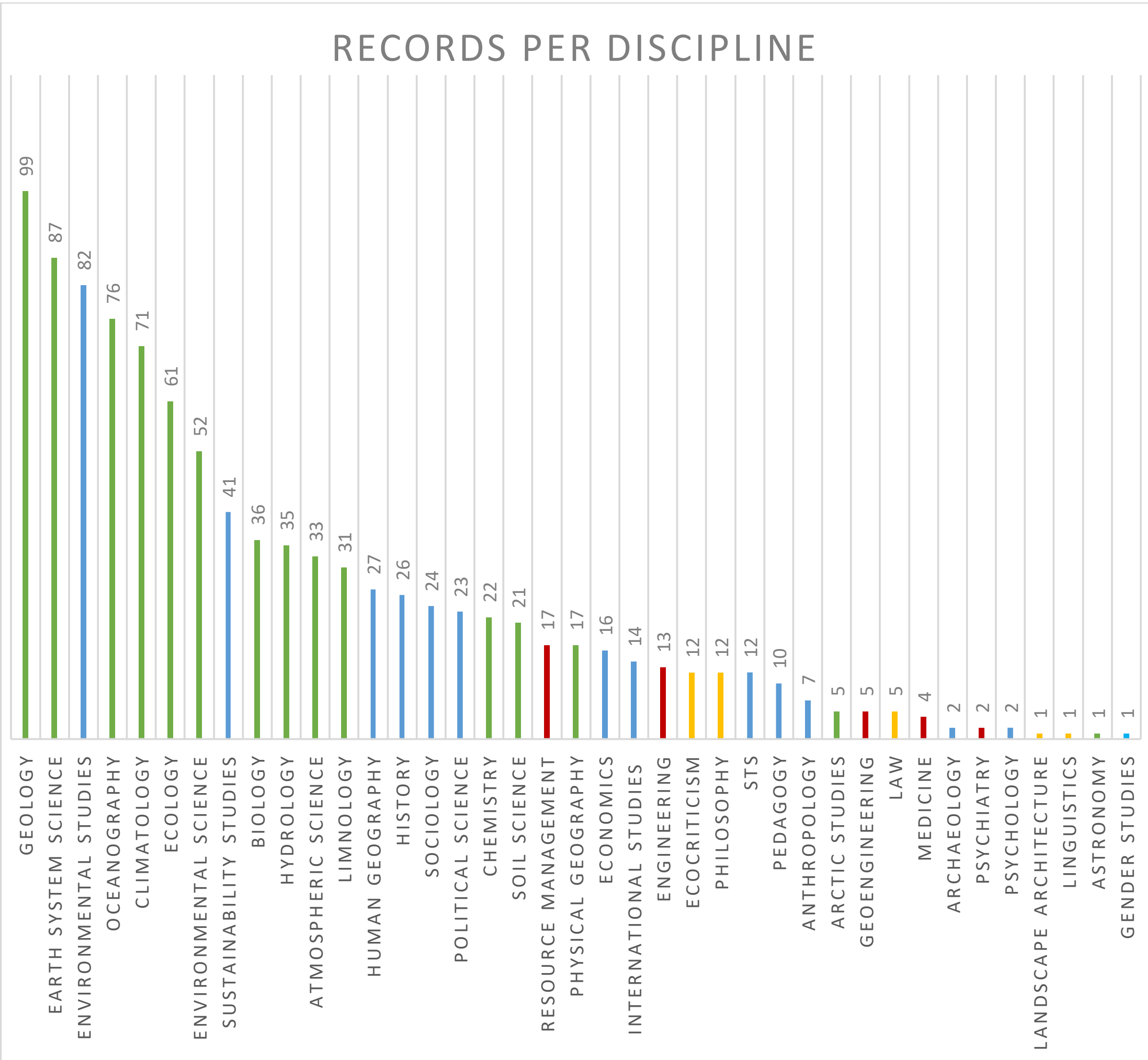


Figure 2.6. Total number of records for each discipline. Assigning one or more disciplines to a record followed the criteria delineated in section 2.1.1.2. Each color represents the field of knowledge each discipline belongs to (green for natural sciences, blue for social sciences, red for applied sciences, and orange for humanities; no records were retrieved for the formal sciences).

Findings based on records per discipline are consistent with those related to records per field of knowledge, in that the disciplines with highest records value fall within the natural sciences – with the exception of environmental studies (82), which is considered a social science. At the top end of the natural sciences, geology represents the discipline with the highest number of records (99),[94] followed by Earth System science (87), oceanography (76), climatology (71), ecology (61), and environmental science (52). At the bottom end, Arctic studies (5) and astronomy (1) have the lowest records value among the natural sciences.

Visibly, none of the disciplines with high records value stands out in terms of being exceedingly predominant (i.e., having double or triple the records of a following or preceding discipline). Indeed, geology precedes Earth System science only by a margin of twelve records. This means that no discipline was either predominantly or single-handedly using the 'Anthropocene' concept in a way indicating that the term belonged to a specific disciplinary domain. On the contrary, findings suggest that the concept was shared among a spectrum of scientific disciplines that used it interchangeably, and as an informal concept (as later discussed in section 2.1.2.6). This is further confirmed by the fact that 'geology' represents a pool of different subdiscipline (e.g., Quaternary science, Holocene science, historical geology, geomorphology, etc.), meaning that the term did not belong to a specialized disciplinary domain, but was a shared boundary object across the natural sciences – particularly the geosciences.

This is an important finding: it tells that, while the 'Anthropocene' was mostly a scientific idea/neologism, it was not confined to a discipline-based area, and thus to a delimited epistemic use. While Earth System science has often been portrayed as the conceptual cradle of the 'Anthropocene' (e.g., Steffen, 2021; Steffen et al., 2011a; Steffen et al., 2020; Zalasiewicz et al., 2021), and therefore as the original disciplinary domain of the term, early research literature is mostly characterized by a variety of scientific disciplines engaging with the concept. This is not to say that the Earth System science community did not play a key role in engendering future discussions on the Anthropocene. Indeed, it is exactly the *multidisciplinary* nature of Earth System science that allowed the term not to become technical jargon restricted to a single disciplinary domain. Nevertheless, a quantitative outlook based on records per discipline shows that Earth System science did not stand out as the discipline that most engaged with the term.

In fact, geology is the discipline exhibiting the highest number of records. Feasibly, two major reasons behind geology being the top-ranked discipline are attributable to the nature of the word itself, whose suffix '-cene' immediately distinguishes its geochronological denotation, and whose geological connotation was originally given to it when it was first formulated in a published medium.[95] These are perhaps more relevant reasons (although not sufficient, as later explained in section 2.2.1) than the source where the term originally appeared (the *IGBP Newsletter*), or the authors' provenance (Paul Crutzen, a chemist, and Eugene Stoermer, a marine biologist). From a quantitative viewpoint, it seems reasonable to

[94] Under 'geology' are grouped records that could also be represented under 'Earth science' or 'geosciences.' The terminological choice is only pragmatic.

[95] Crutzen and Stoermer (2000) wrote: "Considering these and many other major and still growing impacts of human activities on earth and atmosphere, and at all, including global, scales, it seems to us more than appropriate to emphasize the central role of mankind in geology and ecology by proposing to use the term 'anthropocene' for the current geological epoch" (p. 17). While the proposal was unofficial and informal, it represents the very first instance where the modern 'Anthropocene' is thought of as a possible geological epoch.

correlate the number of geology records with the interest that geologists and stratigraphers developed, by the later part of the decade, in the 'Anthropocene' as a possible geological time unit (Zalasiewicz et al., 2018; Zalasiewicz et al., 2008b). If the relative number of records means relative interest (either positive or negative) in the term within a specific disciplinary domain, then the pre-existence of a discrete body of geological literature implementing the term may be interpreted as a historical precondition for the development of the Anthropocene Hypothesis. One could infer that if early research literature was not characterized by geology records, the 'Anthropocene' might not have resonated among geologists, and the Anthropocene Hypothesis would not have developed to its current state (or not developed at all) – although such counterfactual reasoning is purely speculative. The reception of the 'Anthropocene' in geological literature is considered an important ingredient for the birth of the Anthropocene Hypothesis, and is separately discussed in section 2.2.1.

Records values for disciplines within the social sciences provide further interesting insights. Environmental studies (82) stands as the highest occurring discipline among records in the social sciences, followed by sustainability studies (41), human geography (27), history (26), sociology (24), and political science (23). At the bottom end, anthropology (7), psychology (2), archaeology (2), and gender studies (1) have the lowest records values among the social sciences.

Unlike geology in the natural sciences, records in environmental studies stand out from other disciplines in the social sciences with more than twice the records of the second-highest–ranking discipline (sustainability studies).[96] The reverse argument applies here: whereas the 'Anthropocene' in early research literature was somewhat equally shared among those disciplines most engaging with the term, the 'Anthropocene' was primarily an object of interest of environmental studies among the social sciences. This is an interesting finding because it suggests that the term had already begun to be used for framing socially oriented environmental narratives portraying the present human–environment relationship. The term was more than technical jargon of a geological provenance: it was a conceptual tool to understand the temporal and spatial scale of anthropogenic modifications of the Earth.

Findings related to the social sciences are particularly interesting for two disciplines – namely, history and archaeology. Notably, the records value for history (26) is relatively low. This may seem surprising, given the central role that history has played in forging a historical conception of the 'Anthropocene,' and in advancing arguments against the seemingly ahistorical nature of the scientific 'Anthropocene' (see section 1.2.3 and 5.1.3). The main historical impulse began after Chakrabarty's (2009) seminal paper, which ignited interest in the 'Anthropocene' among environmental historians. Prior to that, focused historical contributions to the 'Anthropocene' were only limited, and the term only appeared sporadically, although with discernible relative engagement across historical literature (as later discussed in

[96] It is not easy to define environmental studies as a discrete discipline, mostly because its inter- and multidisciplinary nature encompasses a range of disciplines within and outside the social sciences. As a pragmatic choice, this discipline was defined to include all texts whose content explicitly address one or more aspects of the human–environment relationship (in a strict sense) – in addition to the criteria defined in section 2.1.1.2. In these terms, environmental studies differs from sustainability studies (a seemingly overlapping discipline) because its primary object of interest is not necessarily sustainability *per se*.

section 2.1.2.6). A remarkably low records value occurs for archaeology, with only two records appearing in the corpus. Archaeology has been a central discipline in post-2009 debates on the Anthropocene Hypothesis, and has provided evidence for and against the formal recognition of the Anthropocene as a geological time unit (see section 3.1.3 and 5.2.2). However, it seems that the term did not resonate within archaeological research during the early history of the 'Anthropocene.'

Resource management (17) and engineering (13) have the highest records values among the applied sciences, representing almost two-thirds of the total records in their field of knowledge. Geoengineering – a discipline at the center stage of many extant debates on climate solutions (see Anshelm & Hansson, 2014; Vaughan & Lenton, 2011) – has a records value of only five, hinting that the 'Anthropocene' debate did not initially resonate within this specific discourse on mitigations of anthropogenic climate change. Nevertheless, the existence of a portion of literature from resource management and engineering hints that technically oriented solutions to anthropogenic environmental pressures were already considering the term as a valid reference framework for describing the present human–environment relationship. The term was not technical term exclusively restricted to the natural sciences: it denotated a state of affairs requiring practical solutions from the applied sciences too. Illustrative of the 'practical' dimension of the 'Anthropocene' is the fact that, despite having only a handful of records, applied sciences such as medicine (4) and psychiatry (2) also took marginal note of the existence of this term.

Lastly, an interesting finding is the remarkably low records value for disciplines in the humanities. Ecocriticism (12) and philosophy (12) are the top-ranked disciplines in their field of knowledge, followed by law (5), linguistics (1), and landscape architecture (1). Notably, the records value for disciplines with most records in the humanities (i.e., ecocriticism and philosophy) is extremely low when compared to the records value for disciplines in other fields of knowledge (except formal sciences). While this is only marginal compared to applied science (12 versus 17 records from resource management), it is substantial when compared to the social sciences (12 versus 82 records from environmental studies) and the natural sciences (12 versus 99 from geology). Especially compared to the latter, all the disciplines in the natural sciences except for Arctic studies (5) and astronomy (1) have higher records values than ecocriticism/philosophy.

Two observations can be deduced from these findings. First, the fact that precisely *ecocriticism* and *philosophy* have the highest records values in the humanities signals an early interest in the term as a category of environmental, philosophical, and literary interest. Whilst philosophy of science has remained largely oblivious to both the 'Anthropocene' and the Anthropocene Hypothesis, philosophical questions of an ethical drive (e.g., Raffnsøe, 2016; Schmidt et al., 2016; Zylinska, 2014) have been central in the post-2009 'Anthropocene' debate. Equally, insights from ecocriticism have been crucial in critically dissecting the rhetoric of the 'Anthropocene' portrayed by the natural sciences (e.g., Clark, 2015; Crist, 2013; Merchant, 2021; Neimanis et al., 2015). A second connected reason is that the absence of a substantial body of early humanistic literature mirrors the absence of that critical inquiry that typically distinguishes humanistic disciplines – philosophy in particular. This implies that, during the early research phase, the term

'Anthropocene' was largely unproblematized – meaning that questions about its rhetoric, assumptions, discourses, and implications were yet to be raised.[97]

Findings related to records per discipline are interesting because they are indicative of which disciplines most engaged with the 'Anthropocene' across fields of knowledge in terms of total numbers of records. This information can be used as additional proxy to reconstruct the history of the 'Anthropocene' based on the disciplinary trajectory undertaken by the term, anticipating many of the extant research hubs gravitating around it. Most importantly for the present research, the fact that geology represents the discipline with the highest records signals early interest in and use of the 'Anthropocene' as a geologically useful term. As discussed in section 2.2, this is a key factor in the birth of the Anthropocene Hypothesis.

Lastly, another interesting finding concerns the multidisciplinary origins of the 'Anthropocene' concept. The methodology outlined in section 2.1.1 allows records to represent one or more disciplines depending on several factors. Records representing one or more disciplines are considered multidisciplinary records. Conversely, records representing only one discipline are considered disciplinary records. Figure 2.7 illustrates the division of the corpus based on multidisciplinarity and disciplinarity.

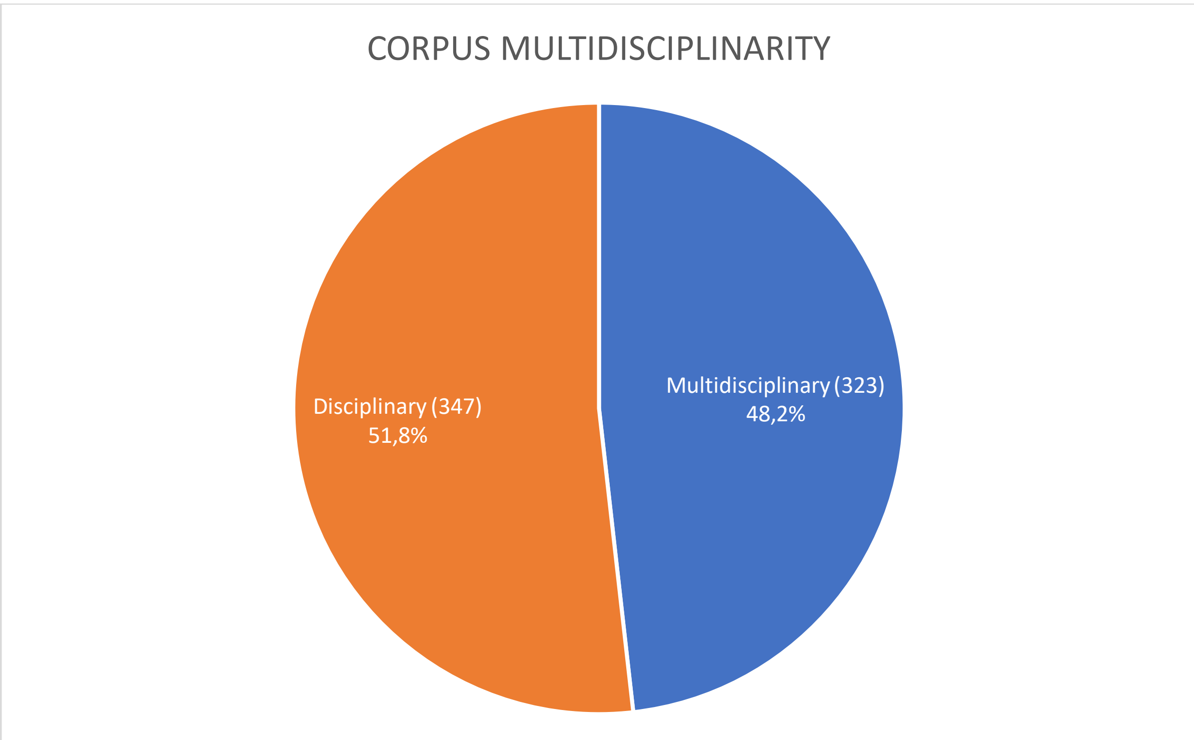


Figure 2.7. Division of the corpus based on multidisciplinary and disciplinary records.

[97] This aspect could also be attributed to the term's novelty, as it required time to develop identifiable narratives and discernible underlying assumptions.

The pie chart above shows that the records are almost equally divided between multidisciplinary and disciplinary records – the latter being higher by only a small margin. Whilst the concept was predominantly a single-domain one (see section 2.1.2.2), the 'Anthropocene' was multidisciplinary almost as equally as it was discipline based. First, this finding corroborates the idea that the term originally had a multidisciplinary impetus. While maintaining domain-specific applications, the term was not restricted to a single discipline. Second, this finding suggests that, if the natural sciences were the predominant field of knowledge engaging with the term, then it was primarily disciplines within the natural sciences that exhibited forms of multidisciplinarity.

2.1.2.4 Records per Format

Records differ in terms of publishing format. This is an interesting aspect of the corpus to analyze because it indicates which published mediums the 'Anthropocene' navigated as a concept during its early research phase, and which mediums most characterized its spread. Figure 2.8 illustrates the corpus divided by the formats.

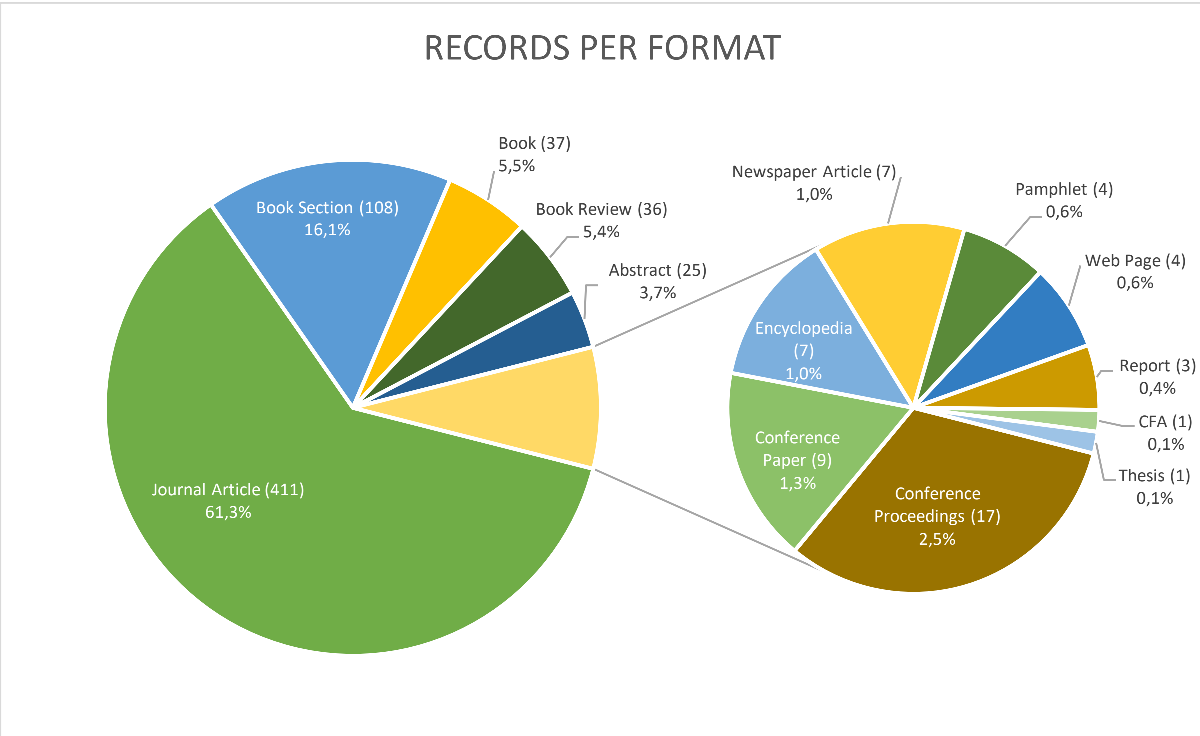


Figure 2.8. Division of all records composing the corpus based on the format retrieved. Percentage expresses the portion of the corpus, whereas the number in brackets is the number of records per format.

Findings show that the primary textual format propagating the 'Anthropocene' was journal article (411), representing almost two-thirds of the overall corpus, followed by book section (108), book (37), book review (36), and abstract (25).[98] Minor formats included conference proceedings (17), conference papers (9), encyclopedias (7), newspaper articles (7), and other formats with negligible records values.

Journals have played a central role in academia since their beginning in the 17th century (Tenopir et al., 2011). With the advent of the World Wide Web, e-journals have proliferated, making access to resources and knowledge much easier than ever before. Today, academics spend an increasing amount of time reading journal articles,[99] and "[o]ver a million articles are published each year in over twenty thousand peer reviewed journals" (p. 19) – making journal articles crucial to write and cite across all disciplines for "writing grant proposals, grant reports, and articles" (p. 4). Journals articles may be considered the primary medium of academic communication – considering also that they require less time to write (for the authors) and read (for the readers) than books. This enables ideas propagated mostly through journal articles to have higher reach (and impact) than those relying on other mediums, such as books, conference papers, etc. In turn, this means that if the 'Anthropocene' managed to spread widely during its early research stage, it is because its medium was primarily that of journal articles. Indeed, this is also confirmed by the high bibliometrics score of early journal articles such as Crutzen and Stoermer (2000), Sanderson et al. (2002), Crutzen (2002d),[100] or Sabine et al. (2004). Combined with the fact that no discipline was overwhelmingly predominant in using the concept, it is reasonable to conclude that journal articles diversified across disciplines (especially natural sciences), enabling the concept to roam around different fields of knowledge, and thus to survive as a neologism and scientific idea.

Books, book sections, and book reviews of an academic nature played a secondary role in propagating the concept of the 'Anthropocene' during its early stages. Together, these comprise 27.2% of the corpus – slightly more than a quarter of all records. It is hard to overstate the importance of books as a cultural, religious, academic, social, and political medium in the history of the human enterprise. However, recent scholarship has begun reconsidering the status of printed books in the era of digital electronic mediums (Chu et al., 2004; Noam, 1998; Seiler, 1992). While book publishing is often an academic requirement in academic career paths, it is intuitively a more time-consuming task for scholars who write and read books, and often necessitates hard-to-obtain funding to support a lengthy writing process.

Other literary mediums that aided the propagation of the term in academia are related to conferences – either proceedings or presentations. Conferences are important and resourceful mediums for oral transmission of ideas in the academic world. Tracking the oral transmission of the 'Anthropocene'

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[98] The majority of abstracts present in the corpus are abstracts for presentations or posters held for annual American Geophysical Union (AGU) Meetings. Some of these abstracts are discussed in section 2.1.3.

[99] For dedicated literature on the impact and importance of e-articles and journal publishing, see the work of Carol Tenopir and Donald W. King.

[100] For instance, bibliometric information regarding Crutzen (2002) is tracked through the Altmetric Attention Score, which is a metrics that "provides an indicator of the amount of attention that it [an article] has received. The score is derived from an automated algorithm, and represents a weighted count of the amount of attention we've picked up for a research output" (https://nature.altmetric.com/details/101691537, "About this Attention Score," accessed on June 13, 2021).

across epistemic actors requires a different methodological setting than analyzing textual sources. Nevertheless, the existence of papers, abstracts, and proceedings associated with conferences witnesses the existence of additional, unpublished mediums that aided the survival, propagation, and evolution of the 'Anthropocene' as a scientific and academic idea.

2.1.2.5 Records per Language

A fifth property of interest is the language of records. This property can be interpreted in terms of the geographical reach of the term as well as the primary linguistic framework wherein the concept took shape. Records per language are illustrated in Figure 2.9.

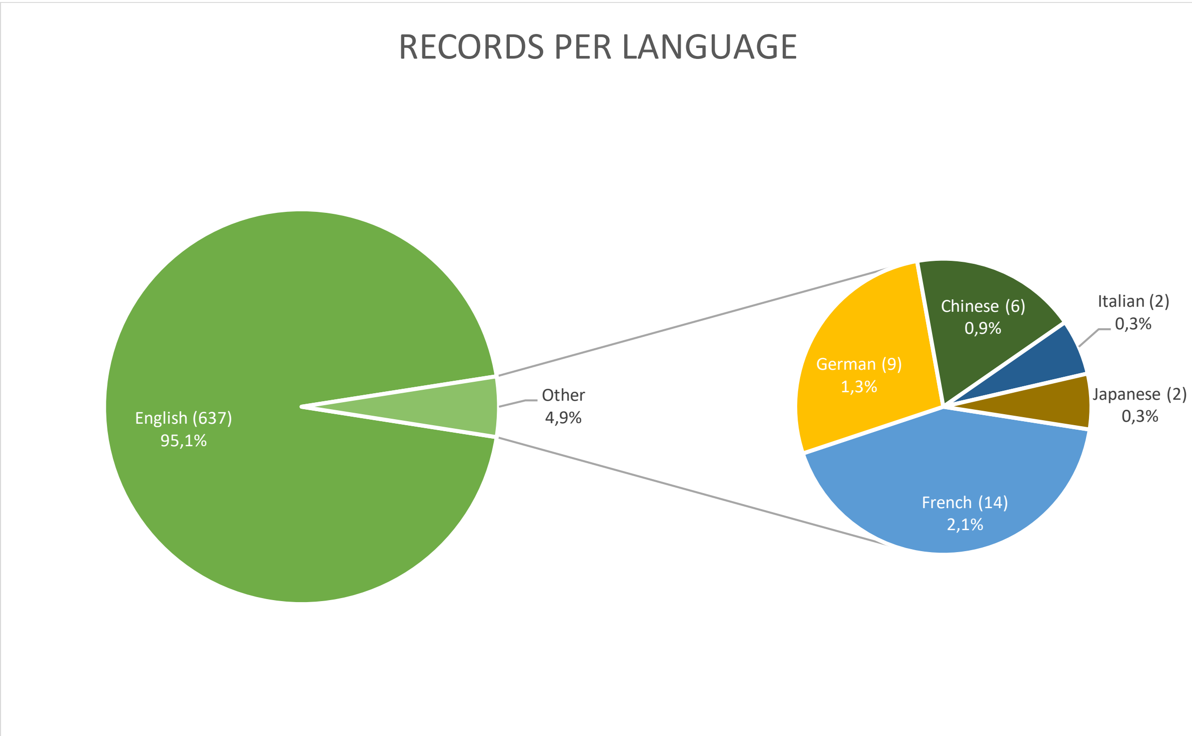

Figure 2.9. Pie chart showing the distribution of records per language. Six languages were identified using the term 'Anthropocene' (or an equivalent linguistic expression) during the 2000–2009 decade. Numbers in brackets represent the records for each language, while percentage expresses the records in respect to the entire corpus.

As anticipated in section 2.1.1.1, three factors determined the predominantly English-language matrix of the corpus analyzed – namely, the English provenance of databases and search engines used for step 1; the status of the English language as the language of international communication; and the anglophone nature of both the original context and coinage of the term 'Anthropocene.' Combined, these three factors are sufficient to explain the huge disparity between English-written records (637), amounting to 95.1% of the corpus, and non-English records (33), amounting to only 4.9%. These numbers cast no doubts that, while the corpus does not exhaust nor summarize the non-English literature produced during the 2000–2009 decade, the 'Anthropocene' is an English-born, and English-based concept.

A first interesting finding is which non-English literature received the term. French and German literature have the highest values for records per language among non-English records. This witnesses an early interest in the term for both linguistic contexts which developed into different local initiatives. For instance, in the case of Germany, this interest was cultivated through the years through the production of museum exhibitions such as *Welcome to the Anthropocene*, held at the Deutsches Museum between 2014 and 2016, and the joint Haus der Kulturen der Welt – Max Planck Institute for the History for Science initiative *Anthropocene Curriculum* (see also section 1.1.1). This is indicative of the term's reach beyond the anglophone intellectual landscape, foreshadowing a growing interest in the 'Anthropocene' as an object and phenomenon of global as well as local interest.

Another interesting finding related to records per language is the presence of non–Indo-European languages – that is, Japanese and Chinese. This shows the geographical reach of the term which, while predominantly spreading in literature in English, was received in Japanese and Chinese literature alike. This aspect is further tackled in section 2.1.3, where the texts themselves are analyzed.

Dissecting the corpus through language is only a minor property analyzed. Reasonably, tracing the reception and assimilation of the 'Anthropocene' among specific national academic cultures would require different criteria from those delineated in this research. Furthermore, the fact that the majority of records are in English does not imply that their reach did not extend beyond the anglophone world. A large portion of non-native English-speaking authors published material in English that was circulated among country-specific communities – most notably Germany and Sweden (where the IGBP Secretariat resided). It is very likely that non-native English-speaking authors approaching the 'Anthropocene' were an important factor in the geographical spread of the term, and in introducing the concept to their respective academic cultures.

2.1.2.6 Central and Peripheral Literature

A central property of interest regarding the corpus is the relative frequency (F_n) of the term 'Anthropocene' in the texts analyzed. This property reflects each record's particular engagement with the term. Each record has a F_n value that determines whether it belongs to the 'central' or 'peripheral' literature. For a record to belong to one or the other supercluster depends on whether $F_n < 2000$ or $F_n \geq 2000$. The selection of this threshold value has been justified in section 2.1.1.3. Figure 2.10 shows the curve (blue line) showing all records composing the corpus in terms of their F_n value. Records with $F_n \geq 2000$ (i.e., central literature) are interpreted as records whose texts exhibit high engagement with the term, whilst records with $F_n < 2000$ (i.e., peripheral literature) are interpreted as records whose texts exhibit low engagement with the term.

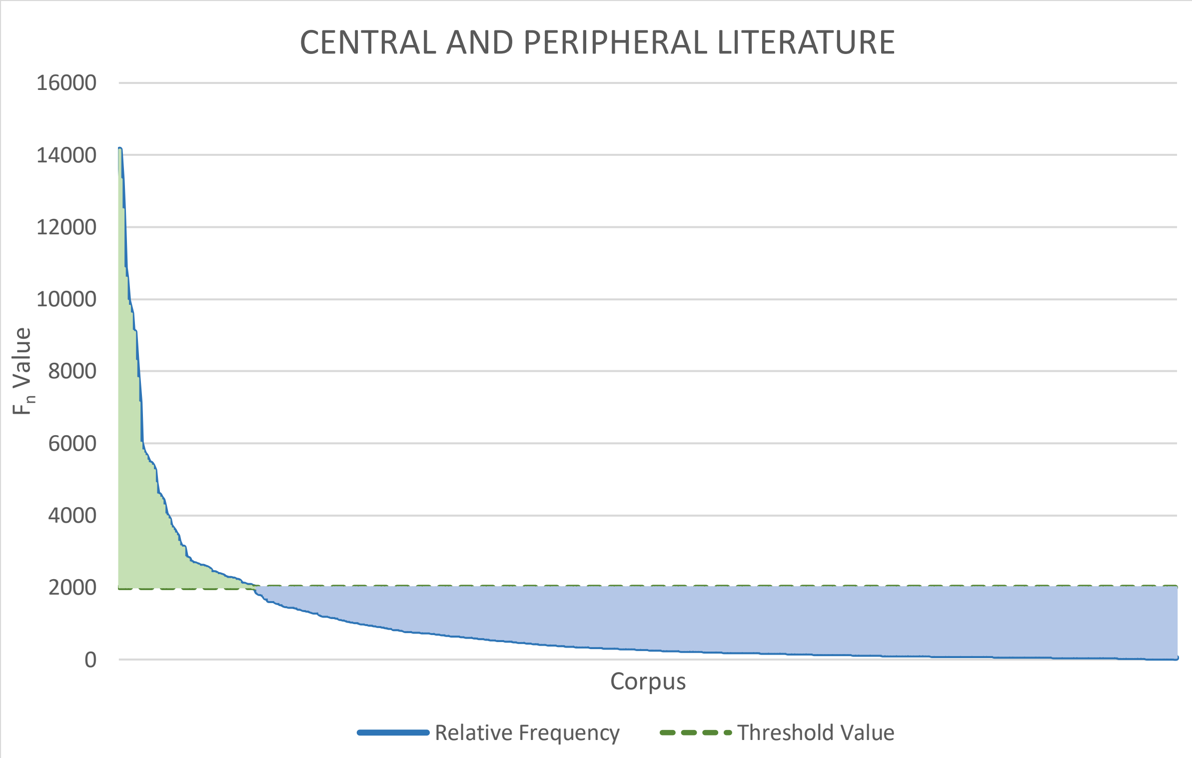

Figure 2.10. Graph showing the corpus of analysis based on F_n (normalized or relative frequency). The blue line represents all values for each record of the corpus. The dashed green line represents the arbitrarily selected threshold value, which distinguishes between central (light green) and peripheral (light blue) literature. The total records for the central literature are 83, whilst the total records for the peripheral literature are 587.

The graph above shows that the vast majority (87.6%) of records belong to the peripheral literature (587), whilst only 12.4% of records belong to the central literature (83). These initial values suggest that the term was mostly 'passively' received across early research literature. Only a reduced amount of text engaged with the term 'Anthropocene' in an 'active' way – that is, by exploring its semantics or using it systematically. While these numbers would require a measure of comparison (e.g., with the spread of other scientific or academic ideas), it is reasonable to consider the spread of the 'Anthropocene' to diffuse following this pattern – namely, appearing predominantly in literature with less direct engagement with the term rather than higher engagement. Presumably, this is because peripheral literature 'grounds' upon central literature which provides the concept with an initial, plastic identity; and because not every record's author(s) is either requested or willing to probe into semantic analysis of the term. The latter point is also corroborated by the later history of the 'Anthropocene' concept (i.e., 2010–2019) – witnessing a rise in articles and books with 'Anthropocene' in the title but not necessarily reflecting the analysis of the 'Anthropocene' concept as the primary object of inquiry.[101]

[101] It should be noted that this is not a form of criticism. Rather, it is a common practice in academic scholarship to borrow keyword terms with certain popularity to increase visibility, or to simply frame the context of a given research or subject matter. This is also consistent with the vast semantic reach and popularity that the 'Anthropocene' concept has acquired over the last decade.

Values related to central and peripheral literature are coarse-grained, and serve to define from a macro-perspective which records exhibit a high F_n value (and thus higher engagement) above or below the selected threshold value. This is of particular importance for selecting and analyzing literature for the qualitative analysis as well as for framing the literature in terms of total engagement. A more insightful property can be derived by integrating values from records per discipline to obtain the *normalized engagement factor per discipline* ($E_n(D)$). This is an informative property because it tells which disciplines mostly engaged with the concept not solely in terms of sheer numbers of records, but also in terms of the relative number of records with $F_n \geq 2000$ (i.e., belonging to the central literature) per discipline. This is because disciplines with high records values are not necessarily disciplines whose records exhibit a noticeable engagement with the term. For instance, the fact that environmental studies has higher records per discipline value (82) than environmental science (52) does neither entail that it has the highest *observed engagement factor* ($E_o(D)$) nor that it has the highest $E_n(D)$. In other words, $E_n(D)$ tells which disciplines have the most records whose texts exhibit high engagement; or, simplified, which disciplines are most representative of the central literature.

To retrieve the normalized engagement factor for each discipline, the following formula can be applied:

$$E_n(D) = E_o(D)\frac{10}{R(D)}$$

Where R(D) is the records per discipline value (defined for each discipline in section 2.1.2.3).[102] For instance, $E_n(D)$ for geology is 2.12, derived from an observed engagement ($E_o(D)$) of 21,[103] and from a records value (R(D)) of 99. By applying the formula above to all thirty-nine disciplines composing the corpus, their respective $E_n(D)$ values can be retrieved. The following table lists the obtained values.

[102] The formula is mathematically similar to the normative frequency formula described in section 2.1.1.3, but it should not be confused with it. The latter concerns the normative frequency of a *word* among *texts* of different sizes, whilst the normalized engagement factor per discipline concerns the frequency of a *record* with a specific normalized frequency value (i.e., ≥ 2000) among *disciplines*.
[103] The value 21 represents the number of 'geology' records with $F_n \geq 2000$ (see Appendix).

DISCIPLINE	R(D)	$E_o(D)$	$E_n(D)$
Anthropology	7	0	0.00
Archaeology	2	0	0.00
Arctic Studies	5	1	**2.00**
Astronomy	1	0	0.00
Atmospheric Science	33	1	0.30
Biology	36	2	0.56
Chemistry	22	3	**1.36**
Climatology	71	8	**1.13**
Earth System Science	87	15	**1.72**
Ecocriticism	12	4	**3.33**
Ecology	61	6	0.98
Economics	16	1	0.63
Engineering	13	1	0.77
Environmental Science	52	8	**1.54**
Environmental Studies	82	7	0.85
Gender Studies	1	0	0.00
Geoengineering	5	1	**2.00**
Geology	99	21	**2.12**
History	26	3	**1.15**
Human Geography	27	3	**1.11**
Hydrology	35	3	0.85
International Studies	14	2	**1.43**
Landscape Architecture	1	1	**10.00**
Law	5	0	0.00
Limnology	31	1	0.32
Linguistics	1	1	**10.00**
Medicine	4	1	**2.50**
Oceanography	76	9	**1.18**
Pedagogy	10	1	**1.00**
Philosophy	12	3	**2.50**
Physical Geography	17	0	0.00
Political Science	23	3	**1.30**
Psychiatry	2	0	0.00
Psychology	2	0	0.00
Resource Management	17	2	**1.17**
Sociology	24	2	0.83
Soil Science	21	3	**1.43**
STS	12	2	**1.67**
Sustainability Studies	41	1	0.24

Figure 2.11. Table showing the records per discipline (R(D)), observed engagement factor per discipline ($E_o(D)$), and normalized engagement factor per discipline ($E_n(D)$) for each of the disciplines representing the corpus. Values highlighted in bold black are disciplines with $E_n(D) \geq 1.00$, whereas values highlighted in bold red are disciplines with $E_n(D) \geq 1.00$ *and* $R(D) \leq 20$. (NB: because a record may belong to more than one discipline, the sum of all $E_o(D)$ (i.e., 119) is not equal to the number of records recognized as central literature (i.e., 83). This also implies that $E_o(D)$ may include the same record with $E_n \geq 2000$ for different disciplines. However, what appears as double counting does not constitute a fallacy because $E_n(D)$ is retrieved for each discipline, and the same record is not counted twice for retrieving single $E_n(D)$ values).

Two arbitrarily defined parameters were set to consider any given $E_n(D)$ value significant:

p1. R(D) value must be ≥ 20.

p2. $E_n(D)$ value must be ≥ 1.00.[104]

Disciplines with $E_n(D)$ values highlighted in red do not satisfy *p1* because their R(D) is too low for their $E_n(D)$ value to be considered representative of the central literature. For instance, landscape architecture ($E_n(D)$ = 10.00) and linguistics ($E_n(D)$ = 10.00) both have the highest normalized engagement value among disciplines by an outstanding margin. However, both disciplines have only one record in the entire corpus (i.e., R(D) = 1). Hence, they cannot be considered faithful representatives of the central literature. Similarly, philosophy ($E_n(D)$ = 2.50) and ecocriticism ($E_n(D)$ = 3.33) have higher $E_n(D)$ value than disciplines such as geology ($E_n(D)$ = 2.12) or Earth System science ($E_n(D)$ = 1.72), but their respective R(D) value (12) is too low according to *p1*. While these disciplines represent a valuable aspect of the corpus and of the early disciplinary engagement with the 'Anthropocene,' they cannot be used to epitomize the central literature because they exhibit low normalized engagement with the term.[105]

Disciplines neither highlighted in red nor in bold in Figure 2.11 do not satisfy *p2*, meaning that their $E_n(D)$ is too low for the discipline to be considered representative of the central literature. For instance, atmospheric science has an $E_n(D)$ value of 0.00. This means that no records in atmospheric science belong to the central literature, and thus the discipline is not representative of the central literature at all – despite satisfying *p1*. Similarly, biology satisfies *p1* because R(D) = 36, but it only has two records with E_n value ≥ 2000, resulting in $E_n(D)$ < 1.00. This means that neither atmospheric science nor biology can be considered among those disciplines most engaging with the 'Anthropocene' concept during its early research stage.

Ten disciplines satisfy both *p1* and *p2* – namely, geology ($E_n(D)$ = 2.12), Earth System science ($E_n(D)$ = 1.72), environmental science (($E_n(D)$ = 1.54), soil science ($E_n(D)$ = 1.43), chemistry ($E_n(D)$ = 1.36), political science ($E_n(D)$ = 1.30), oceanography ($E_n(D)$ = 1.18), history ($E_n(D)$ = 1.15), climatology ($E_n(D)$ = 1.13), and human geography ($E_n(D)$ = 1.11). The fact that geology represents the discipline with the highest normalized engagement factor supports the findings concerning records per discipline highlighted in section 2.1.2.3. Geology was not solely the discipline that saw most engagement with the 'Anthropocene' in terms of total records implementing the term, but also in terms of the relative number of records actively engaging with it. This is an important insight because, as previously noted, a high R(D) value does not necessarily imply a high $E_n(D)$ value. Such a finding can be considered as another

[104] The value R(D) = 20 for *p1* is based on lowering the mean average of the sum of all records per disciplines (approximately 24.7). Similarly, the value $E_n(D)$ ≥ 1.00 is retrieved through lowering the mean average of the sum of all $E_n(D)$ values (approximately 1.5). Lowering the value in both instances is a conservative approach to allow more disciplines to be considered as representative of the central literature.

[105] It should be noted that this parameter does not say that the *texts per se* have little engagement with the term. The parameter only applies to *disciplines* rather than the particular engagement that a text exhibits.

precondition for the subsequent evolution of the ‘Anthropocene’ into a discrete scientific hypothesis developed by a dedicated research group (i.e., the AWG).

Findings concerning the relative engagement factor are also consistent with the scientific origins of the ‘Anthropocene’ concept so far highlighted. Natural sciences have the highest records per field of knowledge, meaning that most early literature using the term ‘Anthropocene’ spurred from the natural sciences. This is an early sign that the ‘Anthropocene’ was primarily (although not exclusively) a scientific neologism and idea. Records per discipline (section 2.1.2.3) corroborated this early finding, showing indeed that most disciplines with a high R(D) value are disciplines within the natural sciences. By analyzing the records engagement through (1) selecting records with $F_n \geq 2000$, (2) selecting records based on *p1* and *p2*, and (3) by using the $E_n(D)$ formula, results illustrate that seven of the ten disciplines most representative of the early research literature are disciplines within the natural sciences, with the top four disciplines based on engagement factor being natural sciences (i.e., geology, Earth System science, chemistry, and environmental science). This is a third sign further corroborating the claim that the ‘Anthropocene’ in the early research literature represented a scientific idea.

Findings concerning the disciplines’ engagement factor also provide valuable insight concerning the social sciences. Indeed, three out of ten disciplines exhibiting the highest $E_n(D)$ value are disciplines within the social sciences – namely, political science, history, and human geography. This finding is also consistent with previous findings concerning both records per field of knowledge and records per discipline. While the R(D) value of each of these disciplines remains relatively low (despite satisfying the parameters set), the fact that political science, history, and human geography exhibit a discernible engagement factor signals an early interest from the social sciences in the ‘Anthropocene’ as a concept beyond the boundaries of the natural sciences. Presumably, this early engagement was seminal in pioneering later approaches to the ‘Anthropocene’ as a historical and political object of analysis.

2.1.3 Exploring the Early Research Literature: A Qualitative Overlook

The previous section discussed salient properties and findings identified by exploring the early research literature from a *macrolevel*, quantitative viewpoint. A *microlevel*, qualitative analysis requires engaging with the actual texts that represent the literature composing the corpus of analysis. This is achieved by exploring (1) the contexts of use of the term, (2) the connotations and places the term is given in texts, and (3) the concept’s particular uses and applications in written sources.

Intuitively, this analysis cannot be thoroughly conducted for *all* of the 670 records. A practical solution to exploring the corpus is selecting a certain portion of literature and discussing it based on the particular properties being analyzed (e.g., publication year, discipline, field of knowledge, etc.). The main criterion defining the selection of this sample literature is based on the distinction between central and peripheral literature.

As anticipated in section 2.1.1.3, this frequency-based distinction is implemented as a proxy for each record's engagement with the concept. Central literature represents 12.4% of the corpus (83 records), and has primary value in reconstructing the early history of the 'Anthropocene' and the Anthropocene Hypothesis. Central literature witnesses how the term was shaped by those epistemic actors engaging *directly* with the term. This type of engagement manifests in various ways – for instance, by providing a definition of the term, probing into the semantics of the concept, using the term as an epistemic concept for achieving certain research targets, or representing a pivotal concept for research proposals or a research program. The sections ahead will be particularly attentive toward this type of literature, shedding light on how the term evolved across mediums and contexts, and how such literature initiated archetypal research trajectories in Anthropocene Studies.

Peripheral literature represents 87.6% of the corpus (587 records). Because of its size, only a minor portion of this literature can be analyzed through selected samples of interest. Notably, the fact that, by definition, peripheral literature includes all records exhibiting relatively low engagement does not diminish the individual importance and role these records played in the birth, spread, and evolution of the 'Anthropocene' and the Anthropocene Hypothesis. Indeed, this literature was crucial in the spread and survival of the 'Anthropocene' during its early existence as a neologism and scientific idea, and is therefore extremely valuable in reconstructing the history of the 'Anthropocene' and its stratigraphic variant. In these terms, peripheral literature is just as important as central literature in reconstructing the early history of the term. The following sections will utilize samples of peripheral literature based on factors beyond relative engagement – such as context of use, epistemic actor, discipline, or format.

The distinction between central and peripheral literature is a key parameter in selecting sample literature. However, this distinction tells little *per se* concerning the *history* of the 'Anthropocene' concept during its early research stages. This is primarily because F_n values are unrelated to time (i.e., publication year). If reconstructing the history of the 'Anthropocene' and the Anthropocene Hypothesis means reconstructing a meaningful *chronology* of certain salient events, then selected literature is best surveyed chronologically – that is, from the year 2000 (when the term was coined) to the conceptual turning point occurring between 2008 and 2009. Therefore, the following sections discuss sample literature from a chronological viewpoint, using publication year (as well as month and day when deemed necessary and available) as a primary tool for a chronological reconstruction. As shown, this method consistently integrates the findings obtained from the quantitative analysis as well as discussing the texts in light of the salient properties identified.[106] What emerged is a history rich of events, actors, places, initiatives, and publications engendering the history of the 'Anthropocene' concept, and laying down the intellectual and historical condition of possibilities for the formulation of the Anthropocene Hypothesis.

[106] It should be noted that this chronological approach as a proxy for the spread and evolution of the 'Anthropocene' concept necessarily has a margin of 'delay.' This is due to the difference between the time elapsed since any author (1) encounters the 'Anthropocene' concept, (2) writes about the concept, and (3) publishes writings using the concept.

2.1.3.1 2000: Birth of an Idea

In its modern connotation, the term 'Anthropocene' first saw light during the 15th International Geosphere-Biosphere Programme Scientific Committee (IGBP-SC) meeting held at the Maximiliano y Carlota Hotel (today Mission Grand Cuernavaca Hotel) in Cuernavaca, Mexico, between February 22 and 23, 2000.[107]

The Scientific Committee was a central body of the IGBP. It represented the main decision-making entity of the program, and its annual meetings decided upon future research trajectories and policies of the overall IGBP organization. Central figures participated in the meetings, including the chairs of the IGBP's core projects, the executive directors, key stakeholders, and people appointed by the International Council for Science (ICSU, the sponsor of the IGBP).[108] Among the members of the Scientific Committee was chemist and atmospheric scientist Paul Crutzen (1933–2021), then vice chair of the IGBP and director of the Max Planck Institute for Chemistry (since 1980); chemist Will Steffen, then executive director of the IGBP organization; and geochemist and limnologist Michel Meybeck, then a member of the scientific committee for BAHC (Biosphere Aspects of the Hydrological Cycle), and working on the GWSP (Global Water System Project).[109]

The events leading Crutzen to coin the term are reported by Steffen (2013), who narrates that during a presentation from scientists of the IGBP's paleoenvironmental core project (i.e., Past Global Changes, or PAGES), Crutzen was becoming "visibly agitated" (p. 486) about the use of the term 'Holocene' to frame the context of their latest research. In a spur-of-the-moment exclamation, Crutzen reportedly said, "Stop using the word Holocene. We're not in the Holocene anymore. We're in the … the … the … (searching for the right word) … the Anthropocene!" (ibid.). As recounted by Crutzen in Schwägerl (2014), his remark "had a major impact on the audience. First there was silence, then people started to discuss this" (p. 9). A less 'animated' version of the episode is also recounted by Meybeck (personal communication, June 25, 2021), who recalls that

> Crutzen took the floor at the end of a presentation, or added one sentence after his intervention, remarking that: "I think we should no longer refer to the Holocene era, considering how Humans have influenced the earth system. I would suggest the term Anthropocene" (I cannot quote his exact words). I instantaneously made a small sketch about the Anthropocene in my notebook.

[107] An insightful and inspiring reconstruction of the Cuernavaca meeting and the years following it has been written by historian of science and AWG member Jacques Grinevald (2020), who considers Crutzen's intervention a 'Eureka!' moment.

[108] See http://www.igbp.net/about/organisation.4.2709bddb12c08a79de780001044.html (accessed on June 20, 2021) for information concerning the organization of the IGBP.

[109] The BAHC was a phase one core project of the IGBP that lasted from 1991 to 2003. Meybeck was a member of its scientific committee between 1995 and 2000. The GWSP was a core project of the Earth System Science Partnership (ESSP), and a joint phase two project for the IGBP. It officially launched in 2004 under the collaboration of the International Human Dimensions of Global Environmental Change Programme (IHDP), DIVERSITAS, the IGBP, and the World Climate Research Programme (WCRP).

Histories of the 'Anthropocene' concept state that the term first appeared in print in the popular *IGBP Newsletter* article published in May 2000. However, the term had already appeared a couple of months before in a much less-known outlet – the ASLO (Association for the Sciences of Limnology and Oceanography, formerly American Society of Limnology and Oceanography) *Limnology and Oceanography Bulletin*, formerly known as the *ASLO Bulletin*. The term appeared in Volume 9, Issue 1 of the bulletin, published in March, in the candidate statement for ASLO presidency of Hugh W. Ducklow (2000), an American marine scientist researching bacterioplankton and their role in the ocean carbon cycle. Ducklow had been an IGBP Scientific Committee member between 2000 and 2003, and was present during Crutzen's intervention in Cuernavaca. As he recalls (Ducklow, personal communication, August 7, 2019), "I was invited to run for the ASLO Presidency shortly after I attended the IGBP Meeting at which committee member Paul Crutzen argued for naming the present era Anthropocene. So it [the 'Anthropocene'] was on my mind." In his candidate statement, Ducklow (2000) wrote:

> In the post-Kyoto era, CO_2 from fossil fuels permeates the depths of the ocean and threatens unprecedented rates of climate change, and the hydrological cycle is dominated globally by human activity. Recently I heard Nobel Laureate Paul Crutzen declare that Earth has passed from the Holocene into the Anthropocene Era – recognizing the dominance of *H. sapiens* in planetary dynamics. These issues indicate the rightness and great need of ASLO's transition to a scientific society more engaged in earth system science, local, national and regional environmental policy issues. (p. 3)

It is interesting how the 'Anthropocene' concept plays a role in his candidate statement. On the one hand, the term stresses the dominance of *Homo sapiens* in planetary dynamics, and as such it is invested with a descriptive meaning with an implicit normative overtone. On the other hand, the concept has a key role in the advocated transitioning of ASLO into a new research framework of closer proximity to Earth System science as well as policymaking. These connotations provided the 'Anthropocene' concept with an identifiable epistemic function – that is, as an entity describing a specific state of affairs requiring a transition from traditional epistemologies of sciences to include *Homo sapiens* as a central epistemic factor. While this is only marginally tackled in the text, such usage of the term is recurrent in central literature during the early research stages of the 'Anthropocene.'

The article cannot be compared to Crutzen and Stoermer (2000) in terms of weight in determining the future history of the 'Anthropocene' concept. Ducklow himself (personal communication, August 7, 2019) states that the circumstances leading to his usage of the term were "just a coincidence." Nevertheless, in addition to being the earliest written record of the modern 'Anthropocene,' the short article is also the earliest signal of interest among the oceanographic, hydrologic, and limnologic community that grew significantly throughout the early years of existence of the 'Anthropocene.' Indeed, the combined records per discipline value for oceanography (76), hydrology (35), and limnology (31) is 142, with a significant portion of records stemming from oceanography. Ducklow (2000) witnesses an early (if not the earliest) interest among scientists (in a particular disciplinary arena) in the social and epistemic potential of the term.

As a matter of fact, marine sciences were to become among the main disciplines using the term 'Anthropocene' during its early history.

In May 2000, the seminal article "The 'Anthropocene'," authored by Crutzen and Eugene Stoermer, was published in the 41st issue of the *IGBP Newsletter*. Crutzen contacted Stoermer immediately after realizing that Stoermer had been using the term for years, offering him to jointly publish the seminal article. Eugene 'Gene' Stoermer (1934–2012) was a limnologist, ecologist, and diatoms expert who had used the term independently from the 1980s during his classes. As he recalled, "I began using the term "anthropocene" in the 1980's, but never formalized it until Paul contacted me" (Grinevald, 2007b, p. 243). Oceanographer and AWG member Jaia Syvitski (2012) recalls a 1995 email exchange with Stoermer where he "described terrestrial and neritic oceanic production during the *Anthropocene*" (p. 14, box 1). A former doctoral student of Stoermer's at Colorado State University, geologist Sarah A. Spaulding (personal communication, June 7, 2020) provides first-hand experience with Stoermer's context of use of the term:

> I recall Gene Stoermer using the term Anthropocene, but in such a way that it did not even seem new, or even novel. It was another way that he expressed what he had observed for decades. For most of his career, Gene worked on the sediment cores of lakes, investigating change in diatom assemblages over time.
>
> Primarily his research concerned lakes in the US, from Lake Okoboji in Iowa where he did his doctoral research while at Iowa State University, to the Laurentian Great Lakes. But he also worked in other large lakes, including Lake Baikal in Siberia. Gene often talked and wrote about the human record in these lakes. One does not need to be a scientist to see the differences between a slide of microscopic diatoms that dates from pre-human settlement to after human settlement. From his earliest work on lake sediments, his understanding of the dramatic impact of human presence was made clear.
>
> He was always an iconoclast, and to me, his use of Anthropocene was stated because it was obvious.

An especially interesting aspect of Stoermer's contribution to the concept is his disciplinary background and context of work – once again, oceanography and limnology. Quite possibly, Stoermer, who was an authority in his field, informed generations of students and researchers who heard him using the term. He taught for many years an influential field course, Ecology and Systematics of Diatoms, at Iowa Lakeside Lab. As noted by Spaulding (personal communication, June 22, 2021), "Most people in North America, and many internationally, trace their educational lineage to Stoermer in some way." This could represent a major driver behind the concept's particularly successful history within the oceanographic and limnological community – as witnessed by the joint number of records for both disciplines.

Crutzen was already a well-established scientist by 2000. He was "one of the most cited natural scientists in the world" (Schwägerl, 2014, p. 10), and had been awarded the Nobel Prize for Chemistry (with Mario Molina and Frank Sherwood Rowland) five years before in 1995 for his contribution to understanding the formation and decomposition of atmospheric ozone. Considering that prestige is a determining factor in the spread and establishment of scientific ideas (Morgan et al., 2018), Crutzen's successful profile undoubtedly played a key role not simply in the future spread of the term, but also in its initial survival and acceptance. As also recognized by Trischler (2016), neither Crutzen nor Stoermer predicted that the term would have such long-term success. If they had, "they would surely not have published their proposal in an internal newsletter, but rather in a prominent scientific journal in order to better reach the global scientific community" (p. 310). The fact that the term proliferated throughout the scientific world despite the original outlet further confirms that Crutzen's established figure was a central force in the spread and adoption of the term in early research literature. Crutzen himself stated that "I think my impetus made it possible for the Anthropocene idea to take off in the public and scientific arena" (Möllers et al., 2015, p. 32). Indeed, his contributions in the following years through publications and presentations are a central thread to follow in reconstructing the early modern history of the 'Anthropocene.'

The *IGBP Newsletter* article is seminal in different regards. The most intuitive is the appearance in published form (and most of all in the title) of the 'Anthropocene' as a main object of research. In these terms, the two-page article represents the cradle of the "founding myth" (Trischler, 2016, p. 310) of the 'Anthropocene' – a myth that has its origins in the Earth System science community. The article provides the first ontology of the 'Anthropocene' as an (informal) geological epoch determined by the impact of human activities. This characterization stretches from the expansion of humankind "both in numbers and per capita exploitation of Earth's resources" (Crutzen & Stoermer, 2000, p. 17) and a tenfold increase in urbanization in the past century, to the release of large amounts of greenhouse gasses through fossil fuel combustion, the formation of the ozone hole in the Antarctic, and the anthropogenic impact on the biosphere. This impact, they argue, "will continue over long periods" (ibid.), hinting at the possible millennial-scale footprint that humans will leave in the future. The time depth of humans' legacy in the stratigraphic record would become a major point of conversation around the stratigraphic significance of the 'Anthropocene' as a geological time unit (see section 5.2.1).

After providing a preliminary ontology for a state of affairs seemingly requiring a new designation replacing the 'Holocene,' the authors gave their seminal definition of the newly introduced neologism:

> Considering these and many other major and still growing impacts of human activities on earth and atmosphere, and at all, including global, scales, it seems to us more than appropriate to emphasize the central role of mankind in geology and ecology by proposing to use the term "anthropocene" for the current geological epoch. (ibid.)

Notably, the definition stresses the role of humanity in *geology* and *ecology* rather than Earth System science (which is never mentioned throughout the text). However, this does not imply that the Earth System has not been impacted by human activities. In fact, the Earth System is more implicitly addressed throughout the text by using proxies most commonly representing it (e.g., carbon dioxide, methane, population increase, fisheries impact, etc.) – the same proxies later used by Steffen et al. (2004c) to visually represent the Great Acceleration.[110] Nevertheless, this seminal definition pioneered the earliest interest in the geological impact of humans, attributing to the 'Anthropocene' an original underlying geological connotation. The definition did not yet represent the formulation of a 'stratigraphic Anthropocene' (i.e., the Anthropocene Hypothesis), but set the foundations for later work to build upon this original and basic input.

Crutzen and Stoermer assigned a starting date to the 'Anthropocene': the latter part of the 18th century. This is the time period coinciding with the dawn of the Industrial Revolution in England. As they argued, "[t]his is the period when data retrieved from glacial ice cores show the beginning of a growth in the atmospheric concentrations of several 'greenhouse gases', in particular CO_2 and CH_4" (ibid.), and that also coincides with James Watt's invention of the steam engine in 1784. Interestingly, the two scientists anticipated future debate on the beginning of the Anthropocene by acknowledging "that alternative proposals can be made (some may even want to include the entire holocene)" (p. 17). This represents a rich aspect and ongoing debate that has spanned for over a decade, seeing scientists and researchers debating over methods, evidence, and meaning of selecting a starting date for the 'Anthropocene' (see section 3.2).

Furthermore, the article suggests that without a global-scale catastrophe affecting the whole of humanity, humankind will "remain a major *geological force* [emphasis added] for many millennia, maybe millions of years, to come" (p. 18). Assigning humanity the status of 'geological force' has been a recurrent *topos* in Anthropocene Studies to the point that the 'Anthropocene' has often been interpreted as the time when humans have become a force equal to other geological forces shaping the planet. This aspect is separately discussed in section 3.1.1, as it constitutes a central characteristic separating the 'Anthropocene' from the Anthropocene Hypothesis.

Lastly, Crutzen and Stoermer's seminal article has an explicit normative nuance. The article concludes by stating:

> To develop a world-wide accepted strategy leading to sustainability of ecosystems against human induced stresses will be one of the great future tasks of mankind, requiring intensive research efforts and wise application of the knowledge thus acquired in the noösphere, better known as knowledge or information society. An exciting, but also difficult and daunting task lies ahead of the global research and engineering community to guide mankind [*sic*] towards global, sustainable, environmental management. (ibid.)

This is an interesting remark because it signals that the 'Anthropocene' was not conceived solely as a technical term encapsulating a set of measurable properties (e.g., population increase, atmospheric CO_2 concentrations, etc.), but also as a normative warning against the challenges that this proposed epoch entailed. Indeed, it was Crutzen's intention that the word would serve as a "warning to the world" (Dalby, 2016, p. 40, quoting an email correspondence between journalist Elizabeth Kolbert and physicist and climate expert Joe Romm) rather than a descriptive category. At the very beginning of the history of the

[110] This also explains why Crutzen and Stoermer (2000) has been labelled as a record in Earth System science (see Appendix).

modern 'Anthropocene,' a dualism between the descriptive and normative 'Anthropocene' (see section 1.3.1) is already discernible, foreshadowing later developments in both trajectories. This dualism was reflected upon by Crutzen years later in an interview by Christian Schwägerl published in *Welcome to the Anthropocene: The Earth in Our Hands* (Möllers et al., 2015). When asked whether the 'Anthropocene' represented solely a scientific hypothesis, Crutzen acknowledged that the term "also develops into a metaphor about the relationship between nature and humankind, with the latter initially on the receiving end" (p. 34). The normative nuances of the 'Anthropocene' remained constant in Crutzen's formulations of the term throughout the years.

Visibly, many of the central themes later explored in Anthropocene Studies can be correlated to Crutzen and Stoermer's seminal article. While neither scientist could have predicted the long-lasting history of the 'Anthropocene' concept, their contribution ignited a series of debates, themes, and research trends and trajectories that substantially affected not solely the future history of the concept, but engendered the formation of a very discrete knowledge domain – namely, Anthropocene Studies. Yet, neither Crutzen nor Stoermer could have foreseen the long 'Anthropocene' history ahead of them.

On October 13, 2000, in Volume 290, Issue 5490 of *Science*, two more articles appeared mentioning the term 'Anthropocene.' The concept made its official debut in a scientific, peer-reviewed journal.

The first article (a review article under 'climate change'), entitled "The Global Carbon Cycle: A Test of Our Knowledge of Earth as a System" (Falkowski et al., 2000), was authored by a team of seventeen researchers close to the IGBP community, including oceanographer Paul Falkowski (the lead author), future IGBP Executive Director and oceanographer Sybil Seitzinger, and Will Steffen. The presence of oceanographers among the contributors is yet another sign of early interest among the marine sciences in the 'Anthropocene.' A second remark concerns the use of the term 'Anthropocene' in the text. The article addresses anthropogenic changes to climatological and biogeochemical processes affecting the global carbon cycle, discussing state-of-the-art research as well as knowledge of carbon cycle couplings and feedback systems in the Earth System. The term 'Anthropocene' is mentioned once in the conclusion of the article, where the necessity of integrating knowledge from different disciplines among earth sciences is advocated for. The authors write: "As we rapidly enter a new Earth system domain, the 'Anthropocene' Era, the debate about distinguishing human effects from natural variability will inevitably abate in the face of increased understanding of climate and biogeochemical cycles" (p. 295). The 'Anthropocene' is interpreted as a new Earth System domain characterized by the pressing presence of human activities as a structural component of Earth System functioning. This unprecedented state is fraught with uncertainties related to a lack of integrated information, especially on the long-term scale, of human pressures on the planet. Another remark concerns the 'Era' designation. While the capitalization of 'Era' may suggest a geological denotation (geological units are capitalized), the designation is informal and does not reflect the original designation by Crutzen and Stoermer (2000, to whom Falkowski et al. cite as a reference). Rather than representing a formal geological time unit, the 'Era' stresses the magnitude of the 'Anthropocene' as a transitional phase characterized by a pre-human and a post-human Earth System.

The second article, entitled "The Ascent of Atmospheric Sciences" (Crutzen & Ramanathan, 2000), is authored by Crutzen himself and Veerabhadran Ramanathan, an atmospheric scientist and presently a distinguished professor at Scripps Institution of Oceanography at the University of California, San Diego. The essay provides a short history of the establishment and development of atmospheric sciences since the 17th century, tackling central historical figures in chemistry and meteorology. The term 'Anthropocene' appears once in the conclusion, where future trajectories of climate change (especially in terms of the ozone layer, global warming, and possible alterations of El Niño) are hypothesized. The authors write: "It may well be argued that the environmental expansion of human activity has jolted Earth into a new geological era, the 'Anthropocene'" (p. 303). Presumably, it was Crutzen's suggestion to use the term, after he had used it some months before to define the present geological time. In the article, the 'Anthropocene' is an era intended not as much as a formal geological unit, but rather as the beginning of a new time period dictated by a significant shift in the state of affairs driven by a certain force – that is, the "environmental expansion of human activity" (ibid.). The article concludes by suggesting possible technical solutions (e.g., geoengineering) to this environmental expansion, without going deeper into the meaning and implications of the 'Anthropocene'.

Lastly, two abstracts appeared for two different presentations held on occasion of the American Geophysical Union (AGU) Fall Meeting, hosted at the Moscone Convention Center in San Francisco between December 15 and 19, 2008. The AGU is a geoscientific and space-oriented society of international reach established in 1919 and headquartered in Washington, D.C. It has a wide range of peer-reviewed journals, and it is well-known for its annual meetings (i.e., the Fall Meetings) where thousands to tens of thousands of scientists participate by attending, presenting, and sharing their work through a vast number of panels and sessions. It is divided into twenty-five macrosections, each dealing with a specific aspect of Earth and space (e.g., Atmospheric Sciences, Biogeosciences, Aeronomy, etc.). In Lassey et al. (2000) – an abstract for a presentation under the Atmospheric Sciences section – the term appears in the abstract's title "How has the Global Methane Source Inventory Evolved over the Anthropocene?", and the 'Anthropocene' is shortly defined as the anthropogenic era. In Moore (2000), the 'Anthropocene' is only hinted at once in relation to the necessity of developing an "international programme of Earth System Science" (p. 1.) to face the challenges posed by this novel geological epoch. Lassey et al. (2000) and Moore (2000) are the first in a series of abstracts that began to appear in the AGU meetings. Presumably, the term had already echoed (although limitedly) across scientific communities and epistemic actors – especially those around the Earth System sciences, and close to Crutzen himself.

These early approaches to the 'Anthropocene' drew on Crutzen's seminal suggestion, which provided an elegant and simple term to frame the state shift in the Earth System brought about by human activities. They also inaugurated a slow transition from the 'Anthropocene' as an *informal scientific neologism* to the 'Anthropocene' as an *informal epistemic category*.

2.1.3.2 2001–2003: First Steps

By the end of 2000, the 'Anthropocene' had reached a discrete academic audience. Besides the *IGBP Newsletter* article, the term had appeared only twice, and as a background concept, in a scientific peer-reviewed journal (i.e., *Science*). In 2001, twelve records appear to have used the term, followed by twenty-nine occurrences in 2002, and twenty-four in 2003. The vast majority of these early texts only marginally used the term, yet they provide valuable insight into how the term was received and interpreted across a spectrum of disciplines and epistemic actors. The 'Anthropocene' was beginning to take its first steps in the academic and scientific landscape as something more than a mere neologism.

Crutzen was a main driver in popularizing the term in the early years. After the *IGBP Newsletter* article, Crutzen authored a series of publications centered around the 'Anthropocene.' Most notably, on January 3, 2002, Crutzen published one of the most quoted and distinctive publications on the 'Anthropocene' – *Nature*'s popular article "Geology of Mankind" (Crutzen, 2002d). At that time, Crutzen was director of the Max Planck Institute for Chemistry, and held a professorship at the Scripps Institution of Oceanography at UC San Diego.[111] The article represents central literature as it engages directly with the 'Anthropocene,' its meaning, its conceptual roots, and its normative intent. Crutzen provides a short genealogy of the term, mentioning past concepts recognizing "[m]ankind's growing influence on the environment" (p. 23) such as Antonio Stoppani's 'anthropozoic' and Vernadsky and Teilhard de Chardin's 'noösphere.' Then, he proceeds by delineating the ontology of the 'Anthropocene' using proxies such as the growing human population, land surface exploitation, dam building and river diversion, primary production removal from fisheries, per-capita energy use, rates of fossil fuel emissions, and release of toxic substances in the Earth's environments. As in Crutzen and Stoermer (2000), Crutzen (2002d) locates the beginning of this post-Holocene epoch in the late 18th century, "when analyses of air trapped in polar ice showed the beginning of growing global concentrations of carbon dioxide and methane" (p. 23).

An interesting nuance within the article is a change in tone from the previous *IGBP Newsletter* article. In the latter, the authors state that "[w]ithout major catastrophes […] mankind will remain a major *geological force* [emphasis added] for many millennia, maybe millions of years, to come" (Crutzen & Stormer, 2000, p. 18). In "Geology of Mankind," Crutzen (2002) writes: "Unless there is a global catastrophe […] mankind will remain a major *environmental force* [emphasis added] for many millennia" (p. 23). The emphases highlight the *type* of natural force that humankind is invested with. In the former article, humans are described as a *geological* force, whereas in the latter they represent an *environmental* force. There may be several reasons behind this shift in tone – for instance, the fact that the term 'environmental' is a much more normative term than 'geological'; a retraction of considering human actions to be equal to geological forces;

[111] The fact that Crutzen was affiliated with one of the most important oceanographic institutions in the world may be considered as another vector behind the early success that the 'Anthropocene' had across the oceanographic, hydrologic, and limnologic communities.

or simply an editorial choice by the journal.[112] This is a subtle, yet important distinction for framing later debates about the geological and stratigraphic depth of humanity (section 5.2.1), and the type of claims entailed in the Anthropocene Hypothesis (section 3.1.1).

"Geology of Mankind" crystallized the 'Anthropocene' as a novel term in scientific literature, revisiting in a prestigious and more visible journal theses previously advanced in the *IGBP Newsletter* entry. As also observed by environmental scholar Jeremy Davies (2018), "[i]t is this article that best marks the emergence of the concept into widespread scientific awareness […] [the] *Nature* article is the canonical statement of the first version of the Anthropocene" (pp. 43–44). However, the article was not Crutzen's only attempt to solidify his original version of the 'Anthropocene.' In the same year, he also published two other articles: one in the French *Journal de Physique IV* in November (Crutzen, 2002a), and one in the *Journal of Environmental Science and Health, Part A* on December 11 (Crutzen, 2002c). Both articles are introductions to the journals' respective issues, and both include the term 'Anthropocene' in their title. Crutzen (2002a) – also entitled "The 'anthropocene'" – reiterates and amplifies the definition and ontology originally advanced in Crutzen and Stoermer (2000), whilst Crutzen (2002c) – entitled "The Effects of Industrial and Agricultural Practices on Atmospheric Chemistry and Climate during the Anthropocene" – reiterates the *environmental* (rather than geological) impact of human activities over the past two or three centuries in defining the 'Anthropocene' through the atmospheric mark of greenhouse gasses.

Still in 2002, Crutzen also authored a book chapter entitled "Atmospheric Chemistry in the 'Anthropocene'" (Crutzen, 2002b). The chapter is part of the IGBP's *Challenges of a Changing Earth*, a volume following plenary presentations from "Challenges of a Changing Earth, a Global Change Open Science Conference" held in Amsterdam between July 10 and 13, 2001. Besides the title (and bibliography), the term 'Anthropocene' only appears in the introductory paragraph to denote a transitional epoch distinguishing the past two centuries.

Another one of Crutzen's major contributions to developing the concept of 'Anthropocene' came in a short article co-authored with Will Steffen for *Climate Change*, published on December 1, 2003. The article (an editorial comment to the journal's issue), "How Long Have We Been in the Anthropocene Era?" (Crutzen & Steffen, 2003), reflects on the impact of human activities and on the unfolding of the 'Anthropocene.' The article is seminal in different respects. First, the authors provide a preliminary snapshot of the famous set of twenty-four graphs that later became the symbol of the Great Acceleration. The graphs appeared 'officially' just a year later in the IGBP synthesis *Global Change and the Earth System*, at that time still in press. Second, the authors address (as the title suggests) the question over the beginning of the 'Anthropocene.' They suggest that the epoch has unfolded in time through several steps. A first step came at the dawn of agriculture and domestication. A second major step occurred between the late 18th century and 1950, during and after the Industrial Revolution. A third step coincided with the acceleration of Earth System and socio-economic trends after 1950 – a period shortly thereafter named the 'Great

[112] While still possible, this last option seems less likely, given that Crutzen continued to address humans as an 'environmental force' rather than a 'geological force' in the following years in other journals – as noted in the next section.

Acceleration.' This *diachronous* understanding of the 'Anthropocene' sets the premises for an Earth System science interpretation of the 'Anthropocene' (Steffen et al., 2007; Steffen et al., 2011b), and foreshadows later debates over the implication of a time-transgressive 'Anthropocene.'

Lastly, the authors briefly comment on a research article published in the same issue of *Climate Change* authored by paleoclimatologist William Ruddiman (2003). The article, entitled "The Anthropogenic Greenhouse Era Began Thousands of Years Ago," argues for a much earlier beginning to the 'Anthropocene' – which Ruddiman originally located between 8,000 ka and 5,000 ka. The proposal represents the original expression of the Ruddiman Hypothesis (sometimes addressed as the 'Early Anthropocene Hypothesis' or 'Early Anthropogenic Hypothesis') – a hypothesis that the paleoclimatologist has developed for almost two decades, and one of the main contenders among 'Anthropocene' hypotheses in locating the (informal) beginning of the epoch. The hypothesis has had a central role in debates about the Anthropocene Hypothesis, and it is discussed separately in section 3.2.2.3.

Crutzen's work and prestigious aura was a central factor in the early survival and spread of the term. The fact that similar terminological alternatives, such as the Russian 'Anthropogene,' 'Anthrocene' (Revkin, 1992), and 'Quinternary'[113] (Berger & Loutre, 2001, 2002), did not survive in the academic and popular arena corroborates the idea that Crutzen's position among the 'high ranks' of academia was a determinant in the survival (and spread) of the 'Anthropocene.'

By the beginning of 2001, the term started attracting several authors and appeared sporadically across scientific literature gravitating around the work of the IGBP. The term is only mentioned in passing by atmospheric scientist and climatologist Hans J. Schellnhuber (2001) in his contribution (the chapter "Earth System Analysis and Management") to *Understanding the Earth System*, a volume edited by geographers Eckart Ehlers and Thomas Krafft. Ehlers and Kraft were pioneering figures in the German reception of the 'Anthropocene,' and later edited *Earth System Science in the Anthropocene* (Ehlers & Krafft, 2006a), one of the first books where the term 'Anthropocene' appears in the title.[114] In Schellnhuber (2001), the term only appears in the caption for Figure 7 (p. 27), where the coevolution and coexistence of the ecosphere and the anthroposphere is illustrated. Schellnhuber was chairman of the Global Analysis, Integration and Modeling (GAIM) working group of the IGBP from 2000 to 2004, and was among the participants during Crutzen's famous intervention at Cuernavaca.

Schellnhuber was also among the authors (including Will Steffen) of the 4th issue of the IGBP Science Series (a series of executive summaries meant for policymaking and stakeholders),[115] entitled *Global*

[113] The term 'Quinternary' was coined by French geologist and engineer Auguste Napoléon Parandier (1804–1901), and promoted in an article entitled "Notice géologique et paléontologique sur la nature des terrains traverses par le chemin de fer entre Dijon at Châlons-sur-Saône," published on *Bulletin de la Société géologique de France*, series 3, 19, 794-818. In its modern connotation, the term has been reproposed by André Berger and Marie-France Loutre (mentioned later in section 2.2.1) in 2001 to define a post-Quaternary period (rather than epoch) based on forecasting of the melting of Antarctica's and Greenland's ice sheets in the next millennia. In their proposal, the 'Anthropocene' correspond to the last epoch of the Quaternary.

[114] Ehlers went on to publish the German-language monograph *Das Anthropozän: die Erde im Zeitalter des Menschen* (Ehlers, 2008).

[115] The Science Series was a collection of five executive summaries meant for policymaking and stakeholders summarizing Earth System research conducted by the IGBP. For more information on the IGBP Science Series and

Change and the Earth System: A Planet Under Pressure (Jäger et al., 2001) – which later gave the title to one of the most comprehensive syntheses of the IGBP's work (Steffen et al., 2004b). In Jäger et al. (2001), the 'Anthropocene' appears in the title of the third contribution: "The Anthropocene Era." The four-page entry identifies the major anthropogenic drivers behind global change and the altering of the Earth System. The term 'Anthropocene' is only briefly mentioned in the introductory section of the contribution, and defined (based on Crutzen and Stoermer's article) as the era in which "human activities have become a significant force in the dynamics of the Earth System" (p. 11).

Using the 'Anthropocene' as a background concept is a notable characteristic of peripheral literature. An early example of such use outside Earth System science appears in an article by ecologist Magnus Nystro and economist and environmental scientist Carl Folke (Nyström & Folke, 2001) published in *Ecosystems* in August 2001 (but available as early as February 25, 2000). The article focuses on coral reef resilience to anthropogenic disturbances. The term only appears twice in the text, featuring in the introduction and in a section's title. The authors define the 'Anthropocene' as a post-Holocene "human-dominated biosphere" (p. 406), and use it to frame the challenges posed against "the capacity of coral reefs to perform a number of critical ecosystem-level functions and to alter their ability to cope with disturbance" (ibid.). Thus, the "Anthropocene Era" (p. 408) is a state where human activities have become major drivers not solely for disturbances and stresses to coral reefs, but also for changing "ecosystem dynamics and resilience" (p. 409). As anticipated, this type of use – namely, using the term as a *background notion* (primarily in the introduction of a text) – is a distinguishing pattern across the entirety of the literature, exemplifying the use made of the 'Anthropocene' concept across records with low engagement with the term. Indeed, Folke (2003a, 2003b) continued to use the term over the next years as a background or 'introductory' concept,[116] by defining the 'Anthropocene' as (on both occasions) the "era where most aspects of the structure and functioning of Earth's ecosystems cannot be understood without accounting for the strong influence of humanity" (Folke, 2003a, p. 2027).

Oceanography and neighboring disciplines (i.e., hydrology and limnology) also began to engage with the term. As anticipated, these disciplines showed an early interest in the 'Anthropocene' concept during its early existence, appearing in a substantial number of oceanographic texts between 2000 and 2009. Research material from geochemist and oceanographer Michel Meybeck (2001) witnesses this engagement. Meybeck had been a scientific advisor for the UN Global Environment Monitoring System for freshwater (GEMS/Water) between 1978 and 1998, and a member of IGBP scientific committees. The scientist notes (Meybeck, personal communication, June 24, 2021) that "the global hydrologists of IGBP were the first to use the Anthropocene concept in 4 or 5 papers." Since his earliest publications, which were based on

to access the issues, see http://www.igbp.net/publications/scienceseries.4.1b8ae20512db692f2a680001564.html (accessed on June 23, 2021).

116 A survey of the peripheral literature seems to show that most texts using the term 'Anthropocene' do so within the introductory or conclusive remarks. However, this observation is not definitive and should be confirmed by a finer degree of analysis.

previous work on global change of world rivers, Meybeck has been using the 'Anthropocene' concept as an integral concept of his work and his research community. As he recalls,

> (i) from the Cuernavaca meeting until now the Anthropocene concept has been used by our community to analyse the complex and evolving interactions between Humans and their environment, particularly well addressed in river systems, where river quality and river fluxes are well suited to qualify (Who, why, where, when?..) and quantify (How much, when, where, ?..) these interactions. (ii) The concept occurred at the right time, we were already describing the global impacts on rivers since one or two decades (on nitrogen, phosphorus, sulfate, chloride, sediments, water runoff ...), but we were lacking a simple word and a clear concept to qualify this evolution. The IGBP-BAHC project clearly used the Anthropocene in its synthesis (Kabat et al, 2004)[117], and the Global Water System Project as well (2004–201x..). (ii) The hydrosystems (term used at for the Holocene) should now be conceived as *socio-hydrosystems* at the Anthropocene which can be studied at nested scales, from the small stream or the agricultural plot, to the global scale and the land to oceans inputs. (ibid.)

This insight shows how particularly successful the concept of 'Anthropocene' has been for oceanographic, hydrologic, and limnologic research through the years. It also shows that the term immediately proved to be *useful* by providing to existing and developing research a timely and accurate term to describe a transitional state of rivers following anthropogenic impacts. This is valuable information for reconstructing the history of the 'Anthropocene' and the Anthropocene Hypothesis, especially viewed against the vivid debates across disciplines over the utility of the term that developed in the past two decades (see section 5.2.4). It shows that the term was adopted, first and foremost, because of its utility in particular disciplinary domains. It elegantly framed a state of affairs which was dominated by human activities, and which requested new methodological approaches.

One of the earliest contributions on the 'Anthropocene' by Meybeck is Chapter 17 of *Science and Integrated Coastal Management*, a volume edited by oceanographers Bodo von Bodungen and R. K. Turner. The volumed is based on the 85th meeting of the prestigious Dahlem Workshop Series held between December 12 and 17, 1999.[118] The 'Anthropocene' appears in the title of Meybeck's chapter, "River Basins under Anthropocene Conditions." As is recurrent in the peripheral literature, the term appears (besides the title) only in the introductory section of the chapter, providing a preliminary context for the study. The author addresses the 'Anthropocene' as "the current geological epoch when the growing impacts of human activities on the Earth system are equal to the natural forcing" (Meybeck, 2001, p. 276), referring to Crutzen and Stoermer (2000) in the bibliography. However, Meybeck also comments:

> Although these authors [Crutzen and Stoermer] assign Watts's invention of the steam engine (1784) as the starting point of the Anthropocene, I prefer to refer to 1950 as the key date for its full development, i.e., the point at which many indicators of human impacts (e.g., land use, dam constructions, urbanization, CO_2 increase, waste release) reached a global extension. (ibid.)

[117] Meybeck is referring to Meybeck et al. (2004) and Vörösmarty and Meybeck (2004).
[118] See section 1.2.2, footnote 37 for information on the Dahlem Workshop Series.

This is an interesting remark because it not only anticipates the date later selected by the AWG to locate the stratigraphic beginning of the 'Anthropocene,' but it also represents an early instance of alternative starting dates of the 'Anthropocene.' Indeed, the proxies Meybeck provides embody some of the Earth System and socio-economic trends representing the Great Acceleration (a term coined four years later in 2005; see section 1.2.2), whose graphs later became the iconic symbol of the 'Anthropocene' (Steffen et al., 2015).

While, in terms of relative frequency of the term 'Anthropocene,' Meybeck (2001) represents peripheral literature, the term 'Anthropocene' is given epistemic significance, encapsulating the set of conditions under which rivers, influenced by human activities, now operate. This state of affairs requires new typologies and modelling of river systems. Such epistemic use of the concept is reiterated in further publications by Meybeck. For instance, in a paper for the journal *Aquatic Sciences* entitled "Riverine quality at the Anthropocene: Propositions for global space and time analysis, illustrated by the Seine River," Meybeck (2002) writes in the introduction that "[t]he term Anthropocene has recently been used to qualify this fundamental change in the Earth's System, particularly regarding the climate" (p. 376). In a 2003 paper entitled "Global analysis of river systems: From Earth system controls to Anthropocene syndromes," Meybeck (2003) lists a series of 'syndromes' that characterize rivers' ontology under Anthropocene conditions, such as contamination, flood regulation, acidification, eutrophication, and more (Table 2, p. 1942). Both articles share common technical features, such as the inclusion of 'Anthropocene' as a selected keyword, the appearance of the term in the introductory section of the text, and the peculiar (from today's perspective) linguistic choice of the phrase '*at* the Anthropocene' rather than '*in* the Anthropocene.' However, they also share their use of the 'Anthropocene' as an epistemic category – that is, as a stage or 'era' where anthropogenic transformations in the ontology of river systems have occurred worldwide at least in the past fifty years. Used as such, the term is not solely an informal designation, but has epistemic utility, identifying a particular set of conditions under which 'Anthropocene' rivers operate and need to be (re)considered.

Meybeck was a central figure in championing the concept of 'Anthropocene,' not solely among the oceanographic, limnologic, and general water science community. He is among the authors who most used the 'Anthropocene' during (and after) the term's early history in written records. As such, he was a major driver in spreading the term across diverse communities united by the international operations of the IGBP and the Earth System science community. As he recalls (Meybeck, personal communication, June 28, 2021), "in the next 5 years following Cuernavaca I tried my best to apply and circulate the Anthropocene concept in all the fields that could be connected to rivers: global sedimentology (sediment trapping in dams), global hydrology (BAHC synthesis), geochemistry, carbon cycle, aquatic ecology, land use change (Seine basin), and more generally in aquatic sciences (GWSP)."

The 'Anthropocene' also had an early appearance in the title of a paper published in *Scientia Marina* in December 2001 by Codispoti et al. (2001) – namely, "The oceanic fixed nitrogen and nitrous oxide budgets: Moving targets as we enter the anthropocene?" While the paper shows a relative frequency value (i.e., 504) substantially below the selected threshold value, the paper seems to have had a remarkable reach. This is not only confirmed by its citation score,[119] but is visible upon surveying literature in oceanography and limnology as well related literature excluded from the corpus of analysis.[120] Consistently with the peripheral literature, the term appears in the article's introduction. However, the term also appears in central portions of the text, where key questions on the discussed themes (i.e., steady-state ocean hypothesis, ocean denitrification, ocean nitrogen budget) are raised. In particular, the 'Anthropocene' is implemented multiple times to identify a transitional phase in assessing the deficit in the oceanic nitrogen budget and the functioning of the nitrogen cycle, both traditionally modelled without accounting for the human factor:

> *Are we in a transition state as we enter the Anthropocene in which the deficit in the oceanic fixed N budget exceeds ~200 Tg N yr* $^{-1}$*, or are we significantly underestimating oceanic nitrogen fixation, or both?* […] *The large deficit (~200 Tg N yr* $^{-1}$*) in our revised oceanic fixed-N budget* […] *could also rise because all studies bearing on this subject have been made during the climate transition from the Holocene to the Anthropocene*. […] Trying to understand how the oceanic source term for N_2O may change as we enter the Anthropocene is of more than casual interest. (pp. 91, 100)

This epistemic use of the 'Anthropocene,' which the article hints to have commenced by the 1950s, is remarkably similar to the use of the concept by Meybeck (2001, 2002, 2003). It is a concept identifying a specific threshold in time (i.e., 1950) after which the ontology and epistemology of certain objects (i.e., rivers, oceans) need to be revised in light of escalating anthropogenic impacts on the Earth. Once again, this proves that the term was particularly useful in the oceanographic, limnologic, and hydrologic community – all disciplines playing a central role in spreading the term during its earliest years of existence.

The 'Anthropocene' concept took its first step as a background notion and as an epistemic category in scientific publications in Earth System science, oceanography, hydrology, and limnology. In particular, water and marine sciences played a pivotal role in absorbing the term and transforming it into a functional epistemic concept within their disciplinary domain. This is also confirmed by the appearance of workshops featuring 'Anthropocene' in their title – such as the LOICZ (Land-ocean interaction in the coastal zone, an IGBP core project) "Coastal Change and the Anthropocene" workshop, held between May 29 and June 1 at the Rosenstiel School for Oceanography, Miami (LOICZ, 2002; Talaue-McManus, 2004); or the theme "The Arctic in the Anthropocene: The North Atlantic Arctic in Focus," chosen for the Second International Symposium of the Nordic Arctic Research Programme held in May 2002 in Akureyri in northern Iceland (Saarnisto et al., 2002). Moreover, the 'Anthropocene' soon became a key term for framing research initiatives of an international scale – such as the Sustainability Geoscope.

The Sustainability Geoscope was a German-based proposal for a "global observation instrument and interpretation framework designed to meet the need for integrated natural scientific and socioeconomic data of a next-generation type and quality" (Lucht & Jaeger, 2001, p. 138). The idea was first championed

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[119] See https://badge.dimensions.ai/details/id/pub.1071806898 (accessed on June 24, 2021).

[120] The latter point refers to literature quoting the article, and thus appearing under the keyword search 'Anthropocene' because of the paper's title. Because of the parameters set in section 2.1.1.1, this literature is excluded from the corpus, and thus not taken into consideration for the present analysis.

by physicist and Earth System scientist Wolfgang Lucht, then a postdoc researcher at the Potsdam Institute of Climate Impact Research, PIK, and sustainability and climate change scientist Carlo C. Jaeger, also a researcher at PIK. The proposal appears in a report for the Nationalen Komitee für Global Change Forschung (NKGCF, National Committee on Global Change Research), a German advisory entity on global change research funded and co-sponsored by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) and the Bundesministerium für Bildung und Forschung (BMBF, Federal Ministry of Education and Research).[121] Jaeger was a member of the NKGCF, which organized a meeting at Bad Honnef near Bonn in January 2001 that brought together over a hundred scientists in the German global change community. The symposium produced a twenty-paper report entitled *Contributions to Global Change Research: A Report by the German National Committee on Global Change Research*.[122] Lucht and Jaeger (2001) appears on this report as the last of the twenty papers with a contribution entitled "The Sustainability Geoscope: A Proposal for a Global Observation Instrument for the Anthropocene."

The paper mentions the 'Anthropocene' several times during the text. The authors address it as "[t]he currently emerging state of the planet, where there are no longer distant places to refer to as 'fully natural'" (p. 139). This emergent state "is characterised by the fact that the human and the natural systems are inseparably intertwined in one earth system, in what may be called an emerging post-natural state" (ibid.). To observe and monitor this phenomenon, which interlinks human and natural processes in the functioning of the Earth System, an "observation system is to be constructed" (p. 140). This observatory system is the Sustainability Geoscope, meant "to be an instrument for observing the emerging anthropocene and the sustainability transition" (ibid.). Such an instrument would develop as a national and international effort, grounded on the theoretical and empirical work of Earth System programs such as the IGBP, IHDP, and ESSP (Earth System Science Partnership, see section 1.2.2). The 'Anthropocene' seems to play more than a background role in the proposal: it represents the very phenomenon that the Sustainability Geoscope means to observe. As such, it is a central epistemic object of the proposal.

Workshops on the Sustainability Geoscope proposal followed after the Bad Honnef meeting. On October 25 and 26, 2001, a workshop sponsored by NKGCF and PIK was held in Berlin at the Hotel Intercontinental – a venue towering between the city's zoological garden and the famous Großer Tiergarten. The workshop "aimed at introducing the idea of a Geoscope to the international global change community and preparing the ground for interdisciplinary research efforts for sustainability transitions" (Lotze-Campen, 2001, p. 3). High-profile organizations were represented at workshop, including the IGBP-DIS

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[121] The NKGCF was terminated in 2013 and replaced by the Komitee für Nachhaltigkeitsforschung (DKN, German Committee Future Earth).

[122] Thomas Krafft (previously mentioned) was among the editors of the report.

Earth System Atlas initiative,[123] GMES,[124] HELIO international,[125] and more. Besides a strong German-based presence, there were also participants from other European countries, the USA, the UK, Iceland, Pakistan, India, Cameroon, and more. The sessions and working groups were documented by agricultural economist Hermann Lotze-Campen (2001), who had just joined the PIK as a researcher. Lotze-Campen's report has only one direct mention of the 'Anthropocene' in relation to the opening statements for the working group (cancelled "due to lack of interest among workshop participants," p. 10), suggesting that the 'Anthropocene' was not a primary object of conversation among participants during panels and sessions. Nevertheless, it is feasible that participants discussed the terms outside formal events, in that the term was already being actively used by some of the participants – including Thomas Krafft and Hans J. Schellnhuber, both of whom had already encountered and approached the term 'Anthropocene.' Considering the central role of the 'Anthropocene' in the previous proposals (as well as in the Sustainability Geoscope website), it is further likely that the 'Anthropocene' could have been a topic of conversation among participants, thus extending the reach of the term in the academic landscape.

The 'Anthropocene' appeared in three further documents related to the Sustainability Geoscope initiative. The first document is an interim report submitted in January 2002 to NKGCF (Jaeger et al., 2002). The report stresses again the aim of the Geoscope as "an observation instrument for the anthropocene" (p. 1) in the first paragraph of the document, where the 'Anthropocene' (appearing only once throughout the text) is defined as "the era which humankind has just entered and where the tight interlinkages between human and natural environment have become obvious and are taken into consideration in an integrated worldview" (ibid.). The second document is a pre-circulated paper authored by Lotze-Campen, Lucht, and Jaeger (2002) meant for the Fifth Annual Conference for Global Economic Analysis, hosted in Taipei between June 5 and 7, 2002. The 'Anthropocene' is again mentioned once, borrowing the same definition given in Jaeger et al. (2002). The same use is reiterated in the last document retrieved on the Sustainability Geoscope initiative where the 'Anthropocene' appears. The document is a paper authored by Lotze-Campen and Lucht (2002) on occasion of the Conference on the Human Dimensions of Global Environmental Change, held in Berlin on December 6 and 7, 2002. In all three documents, the 'Anthropocene' plays a background role, identifying a state of affairs on which the Sustainability Geoscope focuses.

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[123] The IGBP Data and Information Systems (DIS) was formed in 1993 "as a framework activity to improve the supply, management, and use of the data and information needed to attain IGBP's scientific goals" (IGBP, 2015b). Earth System Atlas was the initial project launched by IGBP-DIS, and was later taken over by GAIM (Global Analysis, Integration and Modelling, one of the IGBP core projects) when IGBP-DIS was terminated at the end of 2001.

[124] The Global Monitoring of Environment and Security (GMES) was founded on May 19, 1998 (at that time with the name of Global Monitoring for Environmental Security) by the joint initiative of the European Commission and European space industry representatives, during a meeting held at Baveno, Italy. The day established the adoption by interested parties of the Baveno Manifesto, which promoted the creation of a European-based Earth monitoring and observation program. In December 2012, GMES changed its name to Copernicus. More information on the history of Copernicus is available at https://insitu.copernicus.eu/news/the-copernicus-in-situ-component-since-the-baveno-manifesto#FTN2 (accessed on June 27, 2021), and on the respective Wikipedia page.

[125] HELIO (Hydro, Eolien, Light, Insulation, Organomasse) International was a French-based NGO comprising an international network of environment- and energy-oriented economists and experts, running from 1997 to 2015. More information on the initiative is available at http://helio-international.org/ (accessed on June 27, 2021).

The Geoscope initiative did not launch, despite the reports and series of workshops held to promote the idea. Nevertheless, the initiative is one of the earliest implementations of the term 'Anthropocene' in research-related projects. The 'Anthropocene' was the center of gravity of the initiative, representing the object or phenomenon of analysis the Geoscope was to analyze. This proves that the 'Anthropocene,' despite being then only a newborn neologism, was fraught with epistemic potential.

The echoing of the term across leading research institutions and initiatives, renowned researchers, journal articles, and other academic sources across a spectrum of scientific disciplines is a vertical and horizontal measure of the academic interest that the term ignited. In turn, this signals the epistemic potential that the term was immediately invested with, establishing itself as an informal, geologically charged designation for the time when humans became a significant planetary force. It was a boundary object that, while retaining central characteristics, was plastic enough to be readapted across disciplines (Braje & Lauer, 2020; Star & Griesemer, 1989) – particularly areas of knowledge related to the environment. As early as 2002, the term even appeared in study manuals. For instance, a terrestrial ecology textbook – meant to "introduce the science of ecosystem ecology to advanced undergraduate students, beginning graduate students, and practicing scientists from a wide array of disciplines" (Chapin III et al., 2002) – references the 'Anthropocene' as a post-Holocene epoch defined by humans. In the third edition of *Toxicological Chemistry and Biochemistry* (Manahan, 2003), the 'Anthropocene' is mentioned in relation to the anthroposphere and green chemistry, and it appears in the "Questions and Problems" exercise section for students.[126] Interestingly, the term even appeared in the doctoral dissertation *Inequality and Sustainability* by Colin David Butler (2002) – co-founder of BODHI (Benevolent Organisation for Development, Health and Insight) – where he defined the 'Anthropocene' as the "period, roughly coincident with the Holocene, marked by extensive human caused environmental change, global in scale" (p. 419).[127] Apparently, the 'Anthropocene' was already beginning to be considered as something worth teaching to new generations of students, and as a suitable framework notion for postgraduate research.

Moreover, the term slowly began to attract interest beyond the borders of the anglophone world, appearing in German environmental literature (Biermann, 2002; Ehlers, 2004; Fabian, 2002; Luhmann, 2004) as 'Anthropozän'; in early French publications (Caesau, 2002a, 2002b; Ramstein et al., 2004) as 'Anthropocène'; in Chinese literature (Tung Sheng, 2004; Zhu, 2001) as '人类世'; and shortly after in Japanese texts (Koji, 2004; Murakami et al., 2004) as '人新世.' This shows the degree of interest the term ignited across the global environmental and scientific community. The 'Anthropocene' took its first steps

[126] The questions asked are "What is the anthropocene? Is Earth now experiencing the anthropocene? How will humans know if the anthropocene develops?" (Manahan, 2003, p. 58).

[127] This equation between 'Anthropocene' and Holocene is based on McMichael (2001, quoted in Butler, 2002). It is possible that Butler misunderstood McMichael's claim that "[t]he foreseeable future of this planet will be human-dominated. The Holocene is rapidly becoming the 'Anthropocene'" (p. 344). McMichael did not equate the Holocene to the 'Anthropocene,' considering that he also cites Crutzen and Stoermer (2000) as a bibliographic reference. Rather, McMichael was stressing that the Holocene *is transitioning* to the 'Anthropocene.' It is relevant to stress that Butler did not (willingly) anticipate later debates on the beginning of the 'Anthropocene' (see section 3.2 for a relevant discussion) by proposing a Holocene/Anthropocene boundary.

predominantly within the boundaries of the anglophone world. Its voice, however, echoed beyond those geographical and linguistic boundaries.

The early years of the 'Anthropocene' show that the term was perceived and interpreted as more than a generic neologism doomed to a predetermined short lifecycle. On the contrary, it was the most suitable term for describing in a single and concise word the relationship between humans and the various components of the Earth System; it brought together existing research from various disciplinary areas by focusing the impact of human activities into a single semantic unit of practical as well as theoretical value; and it described a new phenomenon (or set of phenomena) requiring a revision of existing models and theories investigating humans as distinct entities from natural processes. The 'Anthropocene' was, to paraphrase historian John McNeill (2000), a term giving a name to *that* something which was new under the sun. The *Nature* (2003) editorial famously welcomed it in a short commentary published on August 14, 2003, during an unusually warm summer. The scientific community, and later the broader academic world, also began to welcome the 'Anthropocene' as an emerging scientific concept.

2.1.3.3 2004–2007: Spreading of the Term

The year 2004 saw a discernible increase in records – up to forty-eight, compared to twenty-nine in the previous year. This increase could be used to establish a boundary between two phases in the history of the 'Anthropocene': a phase when the 'Anthropocene' took its first steps across the academic and scientific landscape, and a phase characterized by a more rapid spread across fields of knowledge, disciplines, and formats. Records per year increase to fifty-four in 2005, eighty-one in 2006, and eighty-seven in 2007. As a consequence, this phase also demarcates an increasing engagement with the term from authors, witnessed by the emergence of more thorough analyses of the semantics of the 'Anthropocene' as well as an increasing appearance of the term in titles.

Crutzen maintained his role as primary driver for the diffusion of the term across the natural sciences. He published abundantly in different venues (and languages), including a newspaper article for *The New York Times* (Wallström et al., 2004, para. 11) published on January 20, 2004; a book written in Italian (curated by Andrea Parlangeli) published by Mondadori in 2005 (Crutzen, 2005a), representing one the first books on the 'Anthropocene' meant for the public audience; and a 2007 French article for *Ecologie and politique* entitled "La géologie de l'humanité: l'Anthropocène" (Crutzen, 2007). Publishing was not his sole means of spreading the term. He also organized and attended workshops and conferences where he further solidified the 'Anthropocene' in academic contexts.

A notable example is a workshop he attended in Vatican City, organized by geochemist and Director and Scientific Member at the Max Planck Institute for Chemistry Meinrat O. Andreae jointly with the Pontifical Academy of Sciences (PAS),[128] between October 31 and November 2, 2004, under the theme

[128] Crutzen had been a member of PAS since 1996.

“Interactions between Global Change and Human Health.”[129] The primary aim of the workshop was to analyze the feedback and interactions among “three issues related to our well-being [that] figure prominently in the public concern: Socio-economic development, adverse changes in the environment, and human and animal health” (Crutzen, 2006c, p. xi). The workshop was overseen by Marcelo Sánchez Sorondo, Chancellor of the Pontifical Academy of Sciences since 1998. Many important figures in the scientific world were invited – including economist David E. Bloom (Chair of the Department of Population and International Health, Harvard University), Carlo Jaeger (PIK), Anthony J. McMichael (Director of the National Centre for Epidemiology and Population Health, Australian National University), and epidemiologist David L. Heymann (representative of the Director-General for the Polio Eradication Campaign, World Health Organization). Important figures in the early history of the ‘Anthropocene’ were also invited – notably, Will Steffen, Michel Meybeck, and William F. Ruddiman.

From the written report of the workshop, the ‘Anthropocene’ seems only to appear as a background term. Steffen and Lambin (2006) mention the ‘Anthropocene’ only in their title, framing their discussion around the impact of humans on the functioning of the Earth System. Meybeck (2006) tackles the term briefly, defining it as “the new geologic era following the Holocene (the last 10,000 years), in which human control on Earth Systems dynamics, particularly climate, is now equal to or exceeds the natural forcing” (p. 62). Lastly, the term is only once mentioned by Andreae et al. (2006) in relation to global environmental change.

Only a few days after the PAS workshop, Crutzen also attended a plenary session entitled “Paths to Discovery,” held in the same venue in Vatican City between November 5 and 8, 2004. The aim of the plenary session (also organized by PAS) was to discuss and share strategies, methods, and experiences of scientific discovery from a theoretical, practical, and existential viewpoint. This event too included important figures in the academic, scientific, and ecclesiastic world – including particle physicist Nicola Cabibbo (President of the Pontifical Academy of Sciences), Cardinal Joseph Ratzinger (later elected Pope Benedict XVI on April 5, 2005), and Rita Levi-Montalcini, neurobiologist and Nobel laureate in medicine. Here, Crutzen gave a talk in the afternoon session of November 6, entitled “The ‘Anthropocene’: The Present Era Influenced by Human Activity.” The corresponding paper was published in the conference proceedings under the title “The Anthropocene: The Current Human-Dominated Geological Era” (Crutzen, 2006b). The paper discusses “the consequences of human activities on the earth’s atmosphere and climate during the ‘Anthropocene’” (p. 201) by using the twenty-four socio-economic and Earth System graphs then recently developed by the IGBP (Steffen et al., 2004b; discussed later in this section) – which he notes are probably already the “most cited diagrams on the consequences of human activities on the atmosphere” (ibid.).

[129] When asked about why choosing to organize the workshop with PAS in Vatican City, Andreae (personal communication, October 2, 2021) stated that “[t]here were several reasons. One is that it is an extremely attractive and “exotic” venue, which is important if you want to attract prominent and busy participants, who have to make choices what meetings to attend. Second, it provides a secluded and relaxed atmosphere, which is conducive to intensive exchange. Third, the Academy provides funding for the participants. Finally, they have been producing a nice book series where the outcome could be published.”

The 'Anthropocene' appeared as a background term during both events. However, the high-profile nature of the workshop and attendees witnesses the vertical reach that the term had already gained among the high ranks of international academia and scientific research – as early as 2005. The 'Anthropocene' was no longer to be treated as an informal designation, but as an epistemically useful term to frame a particularly discernible (and problematic) state of affairs. It was maturing into a discrete scientific concept identifying a discrete set of relevant problems. This is particularly confirmed by the plenary sessions, whose aim was for scientists to share their experiences in scientific discovery. Notably, Crutzen presented on the 'Anthropocene,' thus considering it a *scientific* idea charged with epistemic potential. This is an important characteristic in identifying the original semantics of the term, and in reconstructing the future trajectory of the Anthropocene Hypothesis.

Crutzen's academic activity scattered across countries, institutions, programs, and academic publishing outlets – witnessing the geographical and academic extent of his production. He contributed (as an editor, program advisor, and writer) to *Earth System Analysis for Sustainability*, the report of the 91st Dahlem Workshop held in Berlin between May 25 and 30, 2003 which the atmospheric scientist co-organized. His contributions appear in three different chapters of the report. In the opening chapter, Crutzen – together with sustainability scientists and ecologists William C. Clark and Hans J. Schellnhuber (Clark et al., 2004) – places the 'Anthropocene' at the very beginning of the report, providing a history of the idea, its meaning for Earth System science, and a prognosis for the future. With an incisive tone, the 'Anthropocene' is defined as "a new geologic epoch in which humankind has emerged as a globally significant – and potentially intelligent – force capable of reshaping the face of the planet" (p. 1). Beside Crutzen's personal influence on the term's use, positioning the 'Anthropocene' in the very first section of the opening chapter signals the importance the term carried in framing the status of the Earth System. In Chapter 14, Crutzen and Ramanathan (2004) further develop themes on the role of chemistry and atmospheric science in the 'Anthropocene' originally advanced in Crutzen (2002b).[130] It also expands on the 'Anthropocene' concept in an appendix (section 14.1) delineating the major anthropogenic factors (e.g., population increase, fossil fuel consumption, land conversion, etc.) engendering this new era. Lastly, Crutzen appears among the contributors to Chapter 16 (a group report by Steffen et al., 2004a), where the idea of a non-analogue state of the Earth System is reinforced by that of the 'Anthropocene' – so that the 'Anthropocene' *is* the non-analogue state the Earth has entered.

By emphasizing climate change and global change in the Earth System, Crutzen was also one of the leading researchers in juxtaposing pressing issues of societal relevance with the notion of the 'Anthropocene.' By the dawn of the 21st century, environmental narratives and international proactive and reactive efforts had their major focus on greenhouse gas emissions, global warming, and climate change – still today major hotspots for environmental debates. Inevitably, the 'Anthropocene' became enmeshed

[130] Notably, Crutzen (2002b) is entitled "Atmospheric Chemistry in the 'Anthropocene,'" whilst Crutzen and Ramanathan (2004) adds 'climate' (and a subtitle) to its title: "Atmospheric Chemistry and Climate in the Anthropocene: Where Are We Heading?" Other than reflecting the themes tackled in the chapter, this choice also reflects the strong climate-oriented connotations given to the 'Anthropocene' in Earth System literature.

(though not yet publicly) with these preexisting narratives, especially through the work of the IGBP and the work by Crutzen. Indeed, a large portion of his work focuses on the role of greenhouse gasses emissions and their impact on the climate. For instance, in a 2005 article published by *New Perspectives Quarterly* – a journal (ceased in 2020) "that consistently engages the best minds and most authoritative voices in cutting-edge debate on current affairs" (Gardels, 2021) – Crutzen (2005b) states:

> For the past three centuries, the effects of humans on the global environment have escalated. Because of *anthropogenic emissions of carbon dioxide*, *global climate* [emphasis added] may depart significantly from natural behavior for many millennia to come. It seems appropriate to assign the term "Anthropocene" to the present, in many ways a human-dominated, geological epoch. (p. 14)[131]

Likewise, in his early geoengineering proposals he noted that "reductions in CO_2 and other greenhouse gas emissions are clearly the main priorities" (Crutzen, 2006a, p. 217) in coping with the increasing "non-analogue condition of the Anthropocene" (ibid.). Placing the 'Anthropocene' into a politically sensible context may have contributed to the success of the 'Anthropocene' and its popularity in the Earth System sciences (perhaps at the expense of other more focalized disciplines such as oceanography, hydrology, and limnology, whose interest and contribution to the history of the 'Anthropocene' had not been thoroughly recognized).

Crutzen was also among the attendees of the 96th Dahlem Workshop "Integrated History and future Of People on Earth (IHOPE)." This was an influential workshop organized by ecological economist Robert Costanza (who was lead author of an often-cited article entitled "The value of the world's ecosystem services and natural capital"; see Costanza et al., 1997) held between June 12 and 17, 2005. Among the participants were also Will Steffen, and historian John McNeill, who later became an AWG member. The workshop's results are summarized in the popular report *Sustainability or Collapse? An Integrated History and Future of People on Earth* (Costanza et al., 2007).

The Dahlem workshop was influential for two main reasons. The first is related to the very aim of the workshop – that is, inaugurating "the first steps in developing a fully integrated history of humans and the rest of nature and thus [serving] as a foundation for the ongoing Integrated History and future Of People on Earth (IHOPE) project" (p. 4). The IHOPE project was reportedly launched by Robert Costanza during the 3rd IGBP Congress "Connectivities in the Earth System," organized in Banff between June 19 and 24, 2003.[132] Its primary goal was (before its digitalization) to deliver a "rich understanding of the interactions between environmental and human processes over the past hundred or so millennia on Earth" (IGBP, 2010, p. 1). IHOPE promoted the creation of an integrated framework to accomplish this goal:

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[131] Visibly, this article reiterates the status of humans as an "environmental force" (2005b, p. 16) rather than a 'geological force,' as originally stated in Crutzen and Stoermer (2000). This seems to corroborate a voluntary shift in tone (rather than an editorial choice) in Crutzen's notorious "Geology of Mankind," as previously anticipated.

[132] See also https://ihopenet.org/what-is-ihope/ (accessed on July 6, 2021) and the IGBP Report No. 59 (IGBP, 2010) for more information on the historical roots of IHOPE.

> To achieve this ambitious goal, new and existing data sources [will be used] to produce an integrated historical account of changes in climate, atmospheric chemistry and composition, ecosystem distribution, material and water cycles, species extinctions, land-use systems, human settlement patterns, technologies, patterns of disease, patterns of language and institutions, conflicts and alliances, and other variables. To achieve this ambitious goal, it will be necessary to create a framework that can be used to integrate perspectives, theories, tools and knowledge from a variety of disciplines spanning the full spectrum of social and natural sciences and the humanities. (ibid.)

The project was consolidated through the 96th Dahlem Workshop, and it became a project of interest shared among IGBP core projects as well as IHDP, while remaining under the administration of the IGBP's core project AIMES (Analysis, Integration and Modeling of the Earth System) until the program's dissolution. IHOPE was originally hosted by the US National Center for Climate Research (NCAR) from 2003 to 2009; by the Stockholm Resilience Center from 2009 to 2011; and then by Uppsala University's Department of Archaeology and Ancient History from 2011 to 2018. The project became part of Future Earth when the IGBP and IHDP dissolved in 2015, and is currently hosted online.[133]

The second major outcome of the workshop was related to the term 'Great Acceleration,' coined by John McNeill during the event. The designation provided yet another semantic piece to the 'puzzle' of the 'Anthropocene' by giving a name to the post-1950 surge in socio-economic and Earth System trends that the IGBP had only recently (and so elegantly) illustrated. Indeed, the designation later became the title of a very popular book in environmental history that McNeil published (together with historian and energy expert Peter Engelke) in 2014 – namely, *The Great Acceleration: An Environmental History of the Anthropocene since 1945* (McNeill & Engelke, 2014). Combined, the IGBP diagrams and the 'Great Acceleration' provided the 'Anthropocene' concept with a strong theoretical foundation. They integrated history, Earth System science, and the environmental research as intrinsic aspects of the 'Anthropocene' as a new phase of humanity. This had enormous repercussions for later debates (either historical, stratigraphic, or environmental) on the temporal nature of the 'Anthropocene.'

The respective experience and expertise of Crutzen, Steffen, and McNeill converged in one of the most popular publications in Anthropocene Studies – indeed, one often represented the 'standard narrative' of the early history of the Anthropocene. In December 2007, the journal *Ambio* published "The Anthropocene: Are Humans Now Overwhelming the Great Forces of Nature?" (Steffen et al., 2007). The article stemmed from the 2005 Dahlem workshop, and "marked the emergence of many key features of the Anthropocene concept in the peer-reviewed literature" (Steffen, 2021, p. 1).

The authors explore the onset and development of the 'Anthropocene' by using atmospheric CO_2 as their primary proxy to track this development. They begin by considering the earliest impacts of the *Homo* genus on the planet, from the discovery of fire through the Late Pleistocene megafauna extinctions to the dawn of agriculture. These pre-Anthropocene events influenced and greatly shaped the Earth's environments and biota. However, the authors argue that the impact of these events "remained largely local and transitory, well within the bounds of the natural variability of the environment" (p. 615). A fundamental

[133] See https://ihopenet.org/ (accessed on July 6, 2021).

transition "in the history of humankind, potentially of similar importance in the history of the Earth itself, was the onset of industrialization" (p. 616). This transition, with its roots in 18th-century England, represents Stage 1 of the 'Anthropocene' (ca. 1800–1945), characterized by "the enormous expansion in the use of fossil fuels, first coal and then oil and gas as well" (ibid.) associated with a six-fold population growth, fifty-fold economic growth, and forty-fold energy use. It is during the Industrial Revolution that atmospheric CO_2 concentrations reached and surpassed the natural variability of the Holocene. This signal is used as a proxy by the authors to locate the beginning of the 'Anthropocene' at 1800 (see also section 3.2.3.3). Stage 2 (ca. 1945–2015) coincides with the post-WWII Great Acceleration. The global population increased at an unprecedented rate, as did energy consumption, land conversion to agriculture, water use, and more aspects related to ever-growing and ever-demanding human societies. This period also witnessed an outstanding increase in atmospheric CO_2 concentrations, outpacing any prior increase in human history. Lastly, Stage 3 (2015–onward) relates to future scenarios of the 'Anthropocene,' mainly reliant on humans' ability to develop strategies for developing sustainable means of living (e.g., through mitigation efforts or geoengineering options). The authors conclude by stating that "[w]hatever unfolds, the next few decades will surely be a tipping point in the evolution of the Anthropocene" (p. 620).

The article encapsulates the meaning of the 'Anthropocene' in Earth System science, highlighting the transgressive onset of the epoch by dividing it into three main stages. Furthermore, it also provides a historical signpost for the status of the term at that time. By 2007, many environmentally oriented researchers worldwide (and not solely those close to the IGBP) had become aware of the term 'Anthropocene,' which was more and more used either as a background term or an environmental category with normative in addition to descriptive significance. The term became entangled with politically, socially, and scientifically dense terms such as 'sustainability,' 'global change,' 'climate change,' and 'global warming.' This semantic network was crucial in shaping future trajectories of the 'Anthropocene' as a concept depicting the human–Earth relationship in recent times, and as a dual normative and descriptive concept. The article was also crucial in inserting the viewpoint of historians into understanding the social and historical mechanisms behind the 'Anthropocene.' But these research trajectories had yet to fully develop outside the natural sciences.

If Crutzen was the main voice behind the spread of the 'Anthropocene,' the IGBP was the reverberant means through which the 'Anthropocene' echoed across researchers and institutions. Indeed, the IGBP remained a central vector in the spread of the 'Anthropocene' concept during this propagating phase. On April 11, 2004, the program published its landmark *Global Change and the Earth System: A Planet Under Pressure*, edited by Will Steffen and Hans J. Schellnhuber among others. The book synthesizes the research conducted by the IGBP during Phase One (i.e., 1987–2003), providing a 336-page snapshot of the present state of the Earth System and the pressure it faces under anthropogenic forcings. The 'Anthropocene' has a special place in Chapter 3, "The Anthropocene Era: How Humans are Changing the Earth System." Here, the concept is given a clear and distinguished Earth System connotation: "the Earth System is now in a no-analogue situation, best referred to as a new era in the geological history of Earth, the Anthropocene" (Steffen et al., 2004b, p. 81). While maintaining the original geological nuance attributed by Crutzen, the chapter discusses and characterizes the 'Anthropocene' in light of the anthropogenic drivers behind the altering of the Earth System during the past two hundred years, and their worldwide extent. Notoriously, these are illustrated through the famous set of twenty-four graphs, appearing for the first time – besides Crutzen and Steffen (2003) – in this synthesis. The 'Anthropocene' (appearing twice in the chapter's title and abstract) sees humans as a force "approaching or exceeding in *magnitude* some of the great forces of nature," operating "on much faster time scales than *rates* of natural variability, often by an order of magnitude" (Steffen et al., 2004b, p. 134). The resulting impact on the Earth System, generating a singularity or a no-analogue state, is the distinctive trait of the 'Anthropocene' from an Earth System viewpoint. The executive summary (Steffen et al., 2004c) provides a condensed ontology of the 'Anthropocene,' described in the following excerpt:

- In the last 150 years humankind has exhausted 40% of the known oil reserves that took several hundred million years to generate;
- Nearly 50% of the land surface has been transformed by direct human action, with significant consequences for biodiversity, nutrient cycling, soil structure, soil biology, and climate;
- More nitrogen is now fixed synthetically for fertilisers and through fossil fuel combustion than is fixed naturally in all terrestrial ecosystems;
- More than half of all accessible freshwater is appropriated for human purposes, and underground water resources are being depleted rapidly in many areas;
- The concentrations of several climatically important greenhouse gases, in addition to CO_2 and CH_4, have substantially increased in the atmosphere;
- Coastal and marine habitats are being dramatically altered; 50% of mangroves have been removed and wetlands have shrunk by one-half;
- About 22% of recognised marine fisheries are overexploited or already depleted, and 44% more are at their limit of exploitation;
- Extinction rates are increasing sharply in marine and terrestrial ecosystems around the world; the Earth is now in the midst of its first great extinction event caused by the activities of a single biological species (humankind). (p. 14)

The 'Anthropocene' was already embedded in an Earth System context that forged its original identity. However, because of the broader importance that *Global Change and the Earth System* invested in recollecting and summarizing over a decade of research from the IGBP, the book can be considered a seminal contribution to the development of an Earth System science 'Anthropocene.' Indeed, the synthesis solidified a research trajectory seeing the 'Anthropocene' mutate from loose concept to Earth System concept invested with a specific ontology and purpose – that is, to epitomize the state of the *Earth System* (rather than any other particular object or aspect of the Earth), and the main drivers of its functioning over the past few centuries. This is an important step in the history of the 'Anthropocene,' in that it represented among the first instances when the term 'Anthropocene' acquired a discipline-based meaning, transitioning from loose neologism to actively implemented epistemic category.

Global Change and the Earth System was not the only contribution stemming from the IGBP where the term gained relevance. The water science community gravitating around the organization, and particularly the contributions of Meybeck, strengthened the inclusion of water-related issues in the semantics of the 'Anthropocene' as an epistemic category. In 2004, another publication of the IGBP Book Series appeared – namely, *Vegetation, Water, Humans and the Climate: A New Perspective on an Interactive System* (Kabat et al., 2004). Meybeck was among the editors and contributors of the book, which synthetizes the work of BAHC by reporting "more than a decade-long research and findings of a large number of scientists studying the Earth system in terms of the connection between the terrestrial biosphere, the hydrologic cycle and the potential anthropogenic influences" (p. v). The term is only mentioned once in the introduction of Chapter D.4 (Vörösmarty & Meybeck, 2004), but is given more attention in Chapter D.8, and particularly in section D.8.5, entitled "Continental Aquatic Systems and Emergence of the Anthropocene" (Meybeck et al., 2004). The authors define the 'Anthropocene' as the period since the 1950s where "anthropogenic influence has exceeded natural forcings in many parts of the world" (p. 456), emphasizing water-related aspects and consequences of global anthropogenic forcings. They illustrate the "progressive development in time and space of human pressures leading to the Anthropocene" (p. 462) through working hypotheses "on the occurrence of some major pressures on continental aquatic systems at the global scale and related environmental remediation responses" (p. 463, Figure D.98). These hypotheses were further developed by Meybeck (2005b) in a chapter for the edited volume *Soil Erosion and Carbon Dynamics*, published the year after in 2005. Lastly, Meybeck et al. (2004) observe the gap in present knowledge over fluvial systems under 'Anthropocene' conditions, and how possible modelling strategies coupled with Earth System dynamics should be considered to fully understand the ontology of rivers and coastal zones in the 'Anthropocene.'

Oceanography, limnology, and hydrology maintained their interest in the term, which became a regular background concept framing anthropogenic impacts on rivers, seas, oceans, and water bodies in general. The 'Anthropocene' momentum in water sciences was kept alive by the work of the IGBP – the center of gravity of much water-related work using the term. In particular, Meybeck continued his efforts in stressing the importance of water sciences within the Earth System framework by emphasizing water-related aspects of the 'Anthropocene.'

For instance, in April 2004, he published an article in *Water Science and Technology* (a journal of IWA Publishing, a publisher specialized in knowledge about water) analyzing the dominant activities impacting continental aquatic systems (Meybeck, 2004). He defined the 'Anthropocene' as a new era "where continental aquatic systems are no longer controlled by earth systems processes but by human activities" (p. 73), illustrating the factors contributing to the shift from the Holocene to the 'Anthropocene' in continental aquatic systems. As in Meybeck (2001), the starting date for this transitional phase (and thus the 'Anthropocene') in continental aquatic systems is located at 1950 – a beginning consistent with the stratigraphic beginning currently assigned by the Anthropocene Hypothesis.

In early 2005, Meybeck and Vörösmarty (2005) published in Volume 337 of *Comptes Rendus Geoscience* (a journal of the French Academy of Sciences) an article entitled "Fluvial filtering of land-to-ocean fluxes: From natural Holocene variations to Anthropocene." The article explores the evolution of river systems and fluxes over two time scales: the last 18,000 years (at the end of the Last Glacial Maximum), and over the last 50 to 200 years – the latter being the 'Anthropocene.' The authors explore the state-shift in river systems brought about by human activities, observing that

> [a]t the Anthropocene, land use and water use as well as wastes inputs or leaks generated by human pressures are deeply changing the production of river-borne material and its transfer across fluvial systems […] Increase in concentrations and fluxes is general: at the finest scale, most major biogeochemical cycles are accelerated (erosion, N_2 fixation, metal transfers). […] Most natural filters are either removed or greatly reduced in their functionality by human pressures. […] [R]eservoir construction and expansion of modern irrigation works have been very rapid. […] Both reservoirs and irrigated areas should be explicitly considered in river flux modeling as they are very efficient filters for particulate matter and biogeochemical reactors. (p. 114, 116)

This is a clear example of 'epistemic use' of the 'Anthropocene' in central literature. The term is not merely mentioned as a background notion, but it is actively used to identify a time period determined by a transition from natural variability of fluvial systems into a human-dominated state; and a state-shift requiring new methods to assess the state of river and aquatic systems under 'Anthropocene' conditions. It has ontological significance (i.e., concerning the set of properties of fluvial systems) as well as epistemic significance (i.e., concerning knowledge of fluvial systems), providing a concept that easily encapsulates the changes river systems have undergone during the recent past and may undergo in the near future. As such, the term is not just *intelligible* (i.e., it is easy to comprehend its semantics), but also *useful* for *explaining* the particular state-shift in river systems occurring in the past century. As tackled throughout section 4.2, *intelligibility* and *explanatory power* are epistemic virtues vital in assessing the epistemic legitimacy of the 'Anthropocene' as a *scientific* hypothesis. The fact that the term seemingly had these virtues as early as 2005 in a given disciplinary context is an important finding for reconstructing the evolution of the 'Anthropocene' as a scientific idea.

Further publications adopted the term as background notion, defined mostly in terms of anthropogenic impacts on water systems. In the invited commentary section of an article published by *Hydrological Process* on February 15, 2005, Meybeck (2005a) states that "[h]uman influences on aquatic systems have now equalled or exceeded the natural controls, thus defining a new epoch: the Anthropocene" (p. 337). Similarly, in a coauthored paper published by *Global Biogeochemical Cycles* in December 2005, the authors (Dürr et al., 2005) define the 'Anthropocene' as a time when "changes in fluxes now match or exceed the natural fluxes particularly those to the atmosphere and the river systems" (p. 19). These papers contributed to the assimilation and use of the 'Anthropocene' in the water sciences, while maintaining the term's inner Earth System connotation. They also exemplify a body of literature in a particular disciplinary domain that used the term (primarily as a background term) to frame present and future trajectories of oceans, river systems, and water bodies in the non-analogue state of the 'Anthropocene.' Most importantly, literature in the oceanographic, hydrological, and limnological communities acknowledge the importance of using the 'Anthropocene' category to recognize this state shift when studying water bodies and their role in the Earth System – for instance, in assessing the oceanic sink of anthropogenic CO_2 (Sabine et al., 2004), or in developing new transdisciplinary frameworks for approaching this non-analogue state (Zalewski, 2007).

Literature was not the only mean through which the 'Anthropocene' concept grounded into water sciences. Research projects emphasizing the term were also emerging. A notable example is the SOPRAN (Surface Ocean Processes in the Anthropocene) project, a German-based initiative launched in February 2007 as a contribution to the Surface Ocean – Lower Atmosphere Study (SOLAS) international research project (Bange, 2015). SOPRAN aimed at understanding "how changing atmospheric composition (e.g. increased CO2, dust) affects the surface ocean ecosystem; how climate-related changes in surface ocean processes (upwelling, mixing, light, biology) alter oceanic emissions to the atmosphere; [and] the mechanisms and rates of ocean-atmosphere material exchanges" (SOPRAN, n.d.). The final SOPRAN meeting took place in Kiel on September 7, 2015, and the project ended in 2016.

These spectrum of contributions, from research articles to projects, witness the spread of the term 'Anthropocene' among water science communities, and particularly oceanography. They suggest that the term had a central role in encapsulating a certain state of affair. As noted by oceanographer and microbiologist David M. Karl (2007) in a review article for *Trends in Microbiology*, "we must remain vigilant about the sea around us as we enter the Anthropocene era" (p. 416).

Other disciplines besides Earth System science and the water sciences began to take interest and engage with the term, and in doing so, they contributed to its spread. An interesting example is soil science, where the term seems to have appeared for the first time in a *Journal of Soils and Sediments* article published on June 1, 2004 by soil biologist and forest scientist Winfried E. H. Blum (among the editors of the journal for the section on soil and landscape ecology) and soil scientist Hariharan Eswaran.

Both Blum and Eswaran were already established authorities in the international soil science community. Eswaran was a prominent figure in the American soil conservation landscape. He had been National Leader for World Soil Resources, USDA–NRCS (United States Department of Agriculture, Natural Resources Conservation Service), until his retirement in 2010. He was Fellow of the Soil Science Society of America in 1993, and was awarded the Guy Smith Medal for Soil Classification in 2012 for his contributions to the field. Blum had taught at BOKU (University of Natural Resources and Life Sciences, Vienna) from October 1979 until 2009, and held several important positions throughout his career – including a twelve-year mandate as Secretary-General of IUSS (International Union of Soil Sciences). He was awarded multiple prizes and decorations conferred by Austrian as well as international authorities.[134] Presumably, both Blum and Eswaran aroused interest in the 'Anthropocene' within the soil science community once they approached the term. Perhaps not by coincidence, soil science later became an important contributor to the empirical aspect of the Anthropocene Hypothesis.

In their one-page editorial comment, Blum and Eswaran (2004) define the 'Anthropocene' as the "epoch when the impact of human activities on ecosystems has exceeded that resulting from natural forces"

[134] An overview of Blum's roles, awards, and decoration throughout his lifetime is available at https://forschung.boku.ac.at/fis/suchen.person_uebersicht?sprache_in=deandmenue_id_in=101andid_in=23 (accessed on June 30, 2021).

(p. 71), adding that, from a soil science perspective, the 'Anthropocene' "can be described as an epoch of land and soil degradation, including desertification, leading to sedimentation and the creation of sediments" (ibid.). Moreover, the authors note that a framework was developed for understanding the 'Anthropocene' – that is, the DPSIR approach (Driver-Pressure-State-Impact-Response). This is a framework originally developed by the Dutch National Institute for Public Health and the Environment (Rijksinstituut voor Volksgezondheid en Milieu, or RIVM) during the late 1990s for the European Environment Agency, which has been using it ever since for modelling the interaction between the environment and human societies as well as reporting and enabling feedback from policymakers (see Kristensen, 2004 for further information on DPSIR). While Blum and Eswaran (2004) is a short contribution, the 'Anthropocene' has a noticeable role in it. It represents a new transition state where soils (among other aspects of the Earth System) are being heavily affected and determined by human actions. Similarly to Crutzen's originally proposal, Blum and Eswaran (2004) observe that locating the beginning of the 'Anthropocene' by the 18th century "is certainly adequate, because the last three centuries have documented information on changes of the land and of the ecology in general" (p. 71).

Blum did not seem to further engage with the 'Anthropocene' concept during the following years, except for in another editorial comment (Blum, 2008) for the *Journal of Soils and Sediments* published in February 2008. But the discipline of soil science did continue to engage with the term. In fact, all publications from the soil sciences retrieved in the corpus began to appear after 2004, witnessing a growing interest among researchers in this new, seemingly promising term. Soil scientists dealing with anthropogenic forcings on soils began to quote Crutzen's popular "Geology of Mankind" (e.g., Blum, 2008; Janzen, 2004; Richter, 2007; Scalenghe & Certini, 2006),[135] and to use the 'Anthropocene' primarily as a framework notion to locate the current status of soil sciences and of soils worldwide. The term gained significance in the soil science community, paving its way to the 18th World Congress of Soil Science, held in Philadelphia between July 9 and 15, 2006. Here, the term was used (and misspelled) to name the oral session 1.0b "Soil Change in Anthropocence [*sic*]," held on the morning of July 11. The session was chaired by soil scientist and geographer Victor Targulian, then an IUSS officer, and convened by Hariharan Eswaran, who had published his seminal article a year before with Blum. The three-panel session focused on past and present anthropogenic impacts on soils. One of the panels (number 27.2), held by a group of Russian researchers (Lyuri et al., 2006), was entitled "Self-Restoration of Post-Agrogenic Soils: Recent Process of Late Antropocene [*sic*]." Russian scientists were accustomed to using the 'Anthropocene'/Anthropogene as a geological unit, which had been used primarily during Soviet research (see section 1.2.4.2). In their presentation (only an abstract is available), the authors discuss the process of self-restoration in previously agricultural lands by using the European part of Russia as a case study. No specific time coordinates are provided to define the 'Late Anthropocene,' although the authors seem to suggest that the Anthropocene

[135] Notably among these, soil scientists Riccardo Scalenghe and Giacomo Certini (2006) later published articles (Certini & Scalenghe, 2011, 2021) advocating for a soil-based marker for the 'Anthropocene' as a geological time unit. Their proposal is discussed as an Early Anthropocene hypothesis in section 3.2.2.5. Soil scientist Daniel D. Richter, whose use of the term dates back to 2007, became an AWG member in 2012.

commenced in the 1950s (not in keeping with the original Soviet definition of 'Anthropocene'/Anthropogene).

Journal articles, abstracts, and conference presentations were not the only mediums acting as vectors for the spread of the 'Anthropocene.' The concept carved its way through encyclopedias as well. The term appears in the second edition of the *Encyclopedia of Soil Science* (Arnold, 2005) under the entry "Future of Soil Science: Role of Soils." The term only appears once in the introductory paragraph, reiterating the background function of the term common across peripheral literature. The term also appears under the "Pedosphere" entry in the *Encyclopedia of Ecology* (Targulian & Arnold, 2008), coauthored by Victor Targulian (who had chaired an 'Anthropocene' session during the 18th World Congress of Soil Science). Here, the term is given more relevance, identifying a period of "extensive exploitation of soils by humans during the last two centuries" (p. 2670). What particularly stands out from this encyclopedia entry is the use of the term. Throughout the text, the 'Anthropocene' is considered as a geological time unit as if it was already established. Unlike in most peripheral literature, the authors do not address it as a 'proposed' or 'suggested' epoch or era, but simply assume it as a time period identifying a qualitative shift in anthropogenic impacts on soils over the past two centuries. This is a remarkable use of the term, considering the importance of the format where it is being used. Another encyclopedia appearance is in the *Encyclopedia of Ecology*, under the entries "Paleoecology" (Birks, 2008) and "Noosphere" (Jaeger, 2008) – the latter edited by Carlo Jaeger, discussed in the previous section for his role in the Sustainability Geoscope initiative.

While the 'Anthropocene' took its first steps primarily within the natural sciences, by 2004 the concept had begun to be received, slowly and gradually, by disciplines within other fields of knowledge. Social sciences took an interest in the term, most notably environmental and sustainability studies (generally represented by texts of a multidisciplinary nature), but so did political science (e.g., Dalby, 2007a; Lange & Schimank, 2004), human geography (e.g., Ehlers, 2004; James & Marcus, 2006; Turner II & McCandless, 2004; Turner II et al., 2004), and history (e.g., Grinevald, 2007a; Grinevald, 2007b; Kennedy, 2006; Periman, 2006; Robin & Steffen, 2007; D. P. Turner, 2005) – among others. Despite the relatively low number of history records (i.e., 26), the discipline was particularly successful in establishing an early partnership with the Earth System science community, becoming a valuable contributor in venturing into the historical mechanisms that engendered the 'Anthropocene.' The IHOPE project (previously mentioned) is an example of this partnership.

By coupling human and Earth systems into an integrated historical and biophysical system over the past millennia, IHOPE intended to draft a *global history* of humanity in light of the Earth System. Intuitively, such global history necessarily required the discipline of history as a key ingredient for achieving this ambitious project, but it also needed the cooperation of other disciplines. As historian Libby Robin wrote with Earth System scientist Will Steffen in a seminal article published by *History Compass* on July 11, 2007, "[g]lobal history has become the business of more than just historians" (Robin & Steffen, 2007, p. 1694). That is because "[t]he Anthropocene defines the momentous and *historical* change in circumstances whereby the biophysical systems of the world are now no longer independent of the actions of people" (p.

1699), and therefore "[t]he idea of the Anthropocene demands an integration of biophysical and human history" (ibid.). This early perception of the role of history in studying the 'Anthropocene' anticipated many discussions of a historical nature that matured in the following decade – discussions that saw history among the most engaged disciplines in analyzing (and also criticizing) the 'Anthropocene.'

Among the applied sciences, the term surfaced around 2006 – seeing only one mention in 2004 by environmental scientist Braden Allenby (2004) in an article entitled "Infrastructure in the Anthropocene: Example of Information and Communication Technology," published by the *Journal of Infrastructure Systems*. Allenby had been Environment, Health, and Safety Vice President for AT&T from 1997 to 2004, before moving to Arizona State University as President's Professor and Lincoln Professor of Engineering and Ethics, School of Sustainable Engineering and the Built Environment. He made a significant number of contributions implementing the term 'Anthropocene' between 2006 and 2009. Most interestingly, these contributions spanned across disparate fields of knowledge, connecting environmental education and ethics to infrastructures, sustainable engineering, and Earth System science. Ethics and technology play a particular role in his writings. For instance, Allenby (2006) discusses the urgency of creating "macroethical" systems to face "the emergent behaviors and inherent unpredictability of the integrated natural/human/built complex adaptive systems of the Anthropocene" (p. 13). In particular, technology is crucial in the emergence of these complex adaptive systems, so that "perhaps the essence of the Anthropocene is technology" (p. 8). This a philosophically dense statement that, incidentally, also epitomizes the earliest instances of philosophical interest in the 'Anthropocene.' Indeed, philosophical (in a broad sense) texts implementing the term only began to appear in the later part of the decade.

Humanities too took notice of the 'Anthropocene' during this stage of the concept. As early as 2007, sociologist Eileen Crist (2007) expressed skepticism of the evolving rhetoric of the 'Anthropocene,' writing (in a section of the article entitled "Against the Anthropocene") that "[t]he linguistic ushering in of the Anthropocene conceptually hardens modern humanity's perceived entitlements, thereby reinforcing how human beings act within the biosphere" (p. 53). As such, "declaring the advent of the Anthropocene and the end of the Holocene is arrogant and premature, and it should be unmasked for what it is: enshrining humanity's domination over the planet or, at best, capitulating to fatalism" (ibid.). This early criticism foreshadowed much of the critique that developed within the humanities and social sciences in the following decade – which is thoroughly discussed in Chapter 5. Questions of environmental ethics were framed in a new light shed by the 'Anthropocene' – a concept that "puts us indeed at a hinge point of history" (Rolston III, 2007, p. 3) where an "Anthropocene Ethics" (Dalby, 2007b) seems necessary.

The literature, researchers, and events surveyed were combined vectors for the spread of the term across scientific communities in the middle of the 2000–2009 decade. Prestigious figures and institutions in the scientific world began to notice and engage with the term, which also became an object of discussions across workshops and conferences centered on the impact of humans on aspects of the Earth System. This increasing engagement exemplifies the 'epistemic growth' of the 'Anthropocene' – that is, from simple background concept and spur-of-the-moment neologism to epistemic category for identifying new ontologies and new epistemologies mirroring the human–Earth relationship in recent centuries.

2.1.3.4 2008–2009: The Double Turn

The year 2008 marked the beginning of an ongoing multidisciplinary and multi-domain surge in interest in the 'Anthropocene' – witnessed by the corpus as an increase from eighty-seven records in 2007 to 139 records in 2008, and 190 records in 2009. Multiple disciplines from all fields of knowledge (except formal sciences) began using the term as an informal designation for the present, in many ways human-influenced, stage of the Earth System. Following this explosion in interest, the sheer number of records reached four-digit figures during the next decade, and five-digit figures in 2020.[136] The total records for the 2008–2009 period almost equals the sum of all records for all previous years combined. This also means that almost half of the corpus is literature published at the end of the decade. As with the previous stages of the modern history of the 'Anthropocene' concept, this surge too can be used conventionally to delimit another stage. The substantial amount of literature produced during this time period makes navigating such literature (and thus the figures and events around it) a daunting task. Therefore, only a few selected publications are discussed, each providing a snapshot of the uses of the 'Anthropocene' across disciplines and fields of knowledge. The selected records do not fully epitomize the different trajectories the term was beginning to undertake. Nevertheless, they provide a practical snapshot of approaches to the 'Anthropocene' concept at the end of the first decade of the century.

Additionally, this brief period at the end of the decade is also defined by a turning point in the history of the 'Anthropocene' and the Anthropocene Hypothesis – that is, the establishment of the AWG, and the publication of the seminal paper "The Climate of History: Four Theses" by environmental historian Dipesh Chakrabarty. Both events occurred in 2009, crystallizing a 'double turn' of the 'Anthropocene' concept – namely, a *stratigraphic turn* and a *humanistic turn*. These events are of crucial importance in subsequent developments and a surge of interest in the 'Anthropocene.' The former defines the moment of 'detachment' of the 'geological Anthropocene' (i.e., the Anthropocene Hypothesis) from the 'Anthropocene' boundary object. This is traceable to the original case made by a group of authors in the seminal article published in February 2008 by *GSA Today* (the journal of the Geological Society of America), "Are we now living in the Anthropocene?" (Zalasiewicz et al., 2008b). The article (and the formation of the AWG that followed in 2009) was a central driver in the surge of interest that followed in later years. A thorough examination of the stratigraphic turn is conducted separately in section 2.2, whilst the humanistic turn is considered later in this section.

Most literature produced between 2008 and 2009 exhibits the same pattern identified in previous peripheral literature – namely, implementing the 'Anthropocene' as a background time category for the past

[136] Estimates based on https://www.dimensions.ai/ (accessed on July 19, 2021). See also Figure 2.3(B) above.

200 to 50 years framing localized studies on reactions of fauna and flora to anthropogenic pressures. However, a distinct characteristic of literature from late in the decade is that several texts *assumed* the 'Anthropocene' to be a commonly understood notion. The concept became shorthand for anthropogenically driven global environmental change (over the past 200 to 50 years) across a spectrum of disciplines – primarily those gravitating around Earth System science, but also environmentally oriented disciplines in the humanities, social sciences, and applied sciences. The 'Anthropocene' centralized previously disconnected and/or independent discourses into a simple and elegant conceptual unit. This is a very interesting finding, in that it tells precisely when and how the term transitioned from informal neologism to a shared boundary object, and into a functional scientific concept. The network of texts 'assuming' the existence of the 'Anthropocene' had yet to fully mature into its present state, where the term has fairly wide recognition across academia. Nevertheless, it seems around 2008–2009 that the line between epistemic use and background use of the 'Anthropocene' blurred: an epistemic use of the term was implicit in its background use.

As observed so far, Crutzen was a major force in spreading and popularizing the term throughout much of the 2000–2009 decade. Four records feature his name among 2008–2009 records. In 2008, he co-authored an abstract (Steffen et al., 2008) for a presentation held at the AGU Fall Meeting in 2008,[137] together with Will Steffen, John McNeill, and terrestrial ecologist Kathy Hibbard. The 2008 Fall Meeting was held in San Francisco between December 15 and 19, and hosted more than 11,000 participants and 15,800 presentations (Johnson, 2008). Steffen et al. (2008) was part of the "Earth System Science and Education for the Anthropocene II" session, one among plenty of sessions under the Global Environmental Change macrosection of the AGU. Geologist and paleobiologist Jan Zalasiewicz (who later became Chair of the AWG), paleoclimatologist Alan Haywood, and ecologist Erle Ellis (who became an AWG member) were conveners of the sessions. The presentation held by Crutzen and his colleagues restated much of what the authors had already advanced a year before in their popular *Ambio* article (Steffen et al., 2007). The session was preceded by a poster session entitled "Earth System Science and Education for the Anthropocene I." Here, the term 'Anthropocene' appeared in the title of four abstracts or presentations (out of fourteen total) – namely, "Holocene = Anthropocene? The HYDE database for integrated global change research over the past 12,000 years" (Goldewijk, 2008), "Stratigraphy of the Anthropocene" (Zalasiewicz et al., 2008a), "Warming of the Continents in the Anthropocene" (Davis & Chapman, 2008), and "Organic Chemostratigraphic Markers Characteristic of the (Informally Designated) Anthropocene Epoch" (Kruge, 2008). The term also appeared in other sessions under different macrocategories.[138]

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[137] The abstract is available online at https://ui.adsabs.harvard.edu/abs/2008AGUFMGC22B..01S/abstract (accessed on July 18, 2021).

[138] Davis (2011) observes that "[a]t its December 2008 Fall meeting in San Francisco, California, the American Geophysical Union (AGU) included *nine sessions* [emphasis added] with Anthropocene in the title, including 'Stratigraphy of the Anthropocene' and 'Stages Anthropocene: assessing the human impact on the Earth system'" (p. 78). However, a search on the AGU Abstract Browser (https://abstractsearch.agu.org/about/, accessed on July 18, 2021) finds only *two* sessions including 'Anthropocene' in the title (both in the Global Environmental Change section) – namely, the aforementioned "Earth System Science and Education for the Anthropocene I" and "Earth System

The 'Anthropocene' had already appeared in previous AGU meetings as early as December 2000 (see section 2.1.3.1). Presumably, the AGU had become another vector in the spread and popularization of the term across scientific discourse throughout the following years. A quick search on the AGU Abstract Browser reveals 308 search results for the keyword 'Anthropocene' across all abstracts submitted for the meetings.[139] Despite being relatively low when compared to the number of abstracts submitted for AGU Fall Meetings, it still witnesses an increasing interest in and spread of the term through another major scientific organization. Most importantly, the AGU became a vector for popularizing the 'Anthropocene' as a *geological* concept, not just an Earth System concept. Indeed, by the end of 2008, the 'Anthropocene' as a possible formal geological unit was beginning to take shape.

Crutzen continued his prolific scientific career by publishing and coauthoring important papers, such as a study on the impact of N_2O (nitrous oxide) release from biofuel on global warming reduction published in *Atmospheric Chemistry and Physics* (Crutzen et al., 2008; the 'Anthropocene' is not mentioned here), and the popular *Nature* article "A safe operating space for humanity" (Rockström et al., 2009a), coauthored with prominent researchers in the Earth System science community including Johan Rockström, Hans Schellnhuber, Will Steffen, Robert Costanza, and more. In the latter article, the term 'Anthropocene' appears in the introduction as a background term – defined as the era "in which human actions have become the main driver of global environmental change" (p. 472) – and in relation to biodiversity loss. While the term is mostly marginal, the fact that it is used in a pioneering study is crucial. Indeed, the 'Anthropocene' represents that state toward which the Earth is transitioning due to human actions. This transition is signaled by overstepping natural 'planetary boundaries' – a central concept promoted by the authors to "define the safe operating space for humanity with respect to the Earth system" (ibid.). Exiting this safe operating space (i.e., exceeding planetary boundaries) means entering the 'Anthropocene.' Therefore, the concept of 'Anthropocene' found itself interlinked with the concepts of 'Earth System,' 'sustainability,' 'mass extinction,' and now 'planetary boundary' – increasing its semantic and epistemic value in framing the most recent ontology of the human–Earth relationship.

The Dutch chemist undoubtedly maintained his role in disseminating the 'Anthropocene' concept throughout the years. However, by 2008 the concept had acquired its own momentum, appearing in disciplines as disparate as medicine, ecocriticism, economics, biology, pedagogy, political science, and more. Mostly, the term was implemented by disciplines for time reference purposes. For instance, an article (Plant et al., 2008) published by *Mineralogical Magazine* in February 2008 refers to the "late Anthropocene" (p. 487)

Science and Education for the Anthropocene II." Presumably, Davis is using the term 'session' to mean 'abstract' or 'panel.' In this case, eight abstracts or panels with 'Anthropocene' in the title appear rather the nine (i.e., Davis & Chapman, 2008; Goldewijk, 2008; Joo & Lerman, 2008; Kruge, 2008; Mortyn et al., 2008; Schertzer, 2008; Steffen et al., 2008; Zalasiewicz et al., 2008a). The ninth session (i.e., Alpers et al., 2008) alluded by Davis only mentions the 'Anthropocene' in the abstract, but the term does not appear in the title. The original bibliographic reference provided by Davis (https://www.agu.org/cgi-bin/SFgate/SFgate) is no longer available. The sessions are discussed later in section 2.2.2.

[139] Search results (for all years since 2000) retrieved from https://abstractsearch.agu.org/dbsearch.php?q%5B%5D=anthropoceneandfield%5B%5D=all (accessed on July 18, 2021).

as the second half of the 20th century while discussing the health hazards of endocrine disrupting substances. The idea that the 'Anthropocene' could have begun earlier than the Industrial Revolution had already been circulating before the Anthropocene Hypothesis was formulated.

In biology, the term saw light as a background notion to frame localized studies on biota. More interestingly, the term also became associated with discourses surrounding a possible sixth major extinction event. For example, a research article (Wooldridge, 2008) for the Discussions section of *Biogeosciences* published in June 2008 refers to an "an impending Anthropocene extinction event" (p. 2414) as a possibility associated with current CO_2 emissions. In Jackson (2008) – an article published by *PNAS* in August 2008 – the author writes in the abstract that "the synergistic effects of human impacts are laying the groundwork for a comparably great Anthropocene mass extinction in the oceans with unknown ecological and evolutionary consequences" (p. 11458). In November 2009, conservationist and ecologist Rodolfo Dirzo (2009) stated that that "the Anthropocene is a planetary experiment of sorts, and the experiment is providing ample evidence that the human enterprise is an omnipresent driver of contemporary evolution" (p. 3041). Indeed, the evolutionary consequences of the 'Anthropocene' later became a major discursive hub in Anthropocene Studies as well as a marker for stratigraphic research (section 3.1.2.4). This is an important finding: the 'Anthropocene' was often associated with discourses on anthropogenically driven extinctions of biota, and later with research on the anthropogenic sixth mass extinction event. This use of the term added another piece to the 'semantic puzzle' of the 'Anthropocene,' expanding its semantic horizon in a way that soon became useful for encapsulating the extent of human impact over the past 50 to 200 years.

The conceptual link between anthropogenically driven extinction and the 'Anthropocene' was a gateway for the concept beyond the boundaries of the natural sciences. The humanities began to absorb the concept and critically dissect it. Ecocriticism is an example of this, expressing most of its interest during these final years of the decade (ten out of twelve records under ecocriticism are published between 2008 and 2009). In April 2008, environmental humanist Deborah B. Rose published a short piece in *The Australian Journal of Anthropology* entitled "Love in the Time of Extinctions" (Rose, 2008), where she argues that "[a] key idea to emerge from the Anthropocene concept is the need for the ecological humanities: we need both science and humanities in dealing with the challenges of our time" (p. 82). This remark foreshadowed a systematic engagement from the environmental humanities with the 'Anthropocene' that emerged in the following years – often in the form of critique of its scientific rhetoric. Rose also contributed to Issue 47 of the *Australian Humanities Review* (published in November 2009), introducing the special issue *Writing in the Anthropocene* for the Ecological Humanities section (Rose, 2009). Beside the editors' introduction (Rooney & Smith, 2009), the term appears only marginally in Bastian (2009) and Ryan (2009), but has a central role in Rigby (2009). The environmental humanist writes in the opening lines of her contribution:

> Two words haunt any ecologically attuned consideration of the historical hour in which our increasingly globalised world currently finds itself: one, which heads this special issue of the Ecological Humanities,

> is 'anthropocene'; the other, lurking as a grim potential, or even an unfolding reality, within the notion of the anthropocene is 'ecocide'. The former term implicates us all in a call to responsibility: the future of Earth, understood as a diverse collectivity of more-than-human life and the conditions in which such life either thrives or fails, we are told, now lies in our human, all-too-human hands. Awesome, and certainly burdensome, though the responsibility connoted by this word may be, the latter term is more troubling, implicating us, and some considerably more than others, as perpetrators of a crime against our Earth others that is at once historically unprecedented and morally unforgivable, and by which we too are now imperiled. (p. 173)

The 'Anthropocene' represents a challenge "not only for philosophy, but also for literature and other forms of art" (p. 176). This challenge is particularly vivid in the relationship humans have established with more-than-human and other-than-human life; a relationship expressed by increasing rates of anthropogenically induced extinctions – the 'ecocide.'

Philosophy integrated the 'Anthropocene' concept into ethical discourses. Allenby (2009) observes that emerging "built/human/natural systems of extraordinary complexity" will require an augmentation of traditional ethical frameworks, which are currently inadequate to grasp and tackle the degree of complexity the 'Anthropocene' poses. This reassessment should be conducted on three levels: the personal, the institutional, and the macroethical. Although few in number, some writings on environmental ethics found marginal use in the term. Botanist Matthew Hal states that "the turn away from arbitrary killing of plants helps foster the long-term relationships of care for nonhumans which are needed to counter the human appropriation of the Earth in the anthropocene" (p. 181). Indeed, the 'Anthropocene' became a key notion in subsequent discourses on how to confront ethical dilemmas and challenges posed by the 'Anthropocene' (e.g., Raffnsøe, 2016; Schmidt et al., 2016; Zylinska, 2014) – especially in the context of an increasing conflict between human presence and other living beings (particularly wildlife).

This type of humanistic engagement began transforming the 'Anthropocene' into an ethical, social, and political category, *de facto* initiating the 'humanistic turn' of the concept. Overall, this turn saw humanists and social scientists engaging with the 'Anthropocene' as a cultural category. For environmental historians in particular, much extant work developed after the seminal contribution of Dipesh Chakrabarty (2009).[140] Published by *Critical Inquiry* in Winter 2009, the article has been considered "a primary text for understanding the problematic nature of the Anthropocene as a cultural category, one that describes a

[140] Asked about his first encounters with the concept of 'Anthropocene,' and the choice of using the term in his seminal publication, Chakrabarty (personal communication, September 6, 2021) recalls: "I was part of several conversations at once in the period c. 2003/4 - 2007: with my Australian friends re their unusually prolonged drought and water-shortage in the first decade of this century, the like of which I had never seen before in my long relationship with Australia since the 1970s; about the 2003 wildfires that destroyed a lot of Canberra and its environs; about the natural history of "bushfires" in Australia; reading Tim Flannery's The Future Eaters in that context and hearing a lot about climate change in the Australian media and observing how it became a key political issue in their 2007 national elections; and an Indian geologist friend directing me to the article "Are we now living in the Anthropocene?" published by the American GSA Newsletter in 2008. What had the biggest intellectual impact on me was the point then made by many geologists/earth system scientists that humanity had become a geological force changing the climatic system of the planet as a whole with devastating impacts on what we regarded as human civilization and freedoms. It made me rethink the idea of "human agency" that had, until then, remained a key category in the Anglophone social, cultural, and political history that constituted the core of my academic life and training. My first article emerged from this set of encounters and was a reflection on how these encounters challenged many of the conceptions that undergirded the intellectual traditions within which I worked."

collective, if unintended, human project whose implications extend far beyond geological inquiries about stratigraphic dating" (Emmett & Lekan, 2016, p. 7). It develops four theses based on the idea that the divide between human history and natural history (or between human time and geological time) has collapsed with the dawn of the 'Anthropocene.' The concept appears in the statement of Chakrabarty's second and third theses – namely, "The idea of the Anthropocene, the new geological epoch when humans exist as a geological force, severely qualifies humanist histories of modernity/globalization" (Chakrabarty, 2009, p. 207), and "The geological hypothesis regarding the Anthropocene requires us to put global histories of capital in conversation with the species history of humans" (p. 212). In the former, the author discusses the notion of 'freedom' in light of humans' geological agency, asking whether the 'Anthropocene' poses fundamental boundaries to the 'modern,' post-Enlightenment conception of freedom. In the latter, the author asks how (if any) the category of the 'human species' used in the geological 'Anthropocene' may relate to postcolonial theory – a field of inquiry notoriously skeptical of universal categories.[141] Notably, Chakrabarty is addressing the "geological hypothesis regarding the Anthropocene" – that is, the Anthropocene Hypothesis. Such word choice implicitly signals the existence of the stratigraphic variant as an entity loosely *independent* from the broader 'Anthropocene' boundary object. This seems to be confirmed by the parallel interest in the 'Anthropocene' that humanists were developing by the end of the decade, forging a notion of broader reach than Earth System science or geology.

Chakrabarty's paper is situated at the advent of an increasing interest from the humanities in the 'Anthropocene.' It heralded much of the discourse developed within this field of knowledge – from the convergence of human and geological history, to the tension between *Anthropos* (as a cultural being) and *Homo sapiens* (as a biological being), to the role of faith in rationality and science in postcolonial historiography. As such, it can be conventionally used as signpost marking the beginning of an ongoing interest among humanists in the meaning of the 'Anthropocene,' and the predicament it entails.

By the end of the decade, the 'Anthropocene' had journeyed vertically and horizontally across a spectrum of disciplines, organizations, conferences, journals, workshops, and newspapers. Crutzen's original impetus – propelled by publications or prestigious venues where the term was shared and propagated – ensured the 'Anthropocene' neologism survived its earliest stages. The IGBP also played a crucial role in vitalizing the term, attributing it its original Earth System science connotation. Once the term had reached a discrete audience of academically established scholars, these main drivers – Crutzen and the IGBP – were no longer necessary for the term to survive and preserve its own momentum. This is also confirmed by the fact that the term's popularity continued to rise after the end of the IGBP initiative. The wide news coverage of Paul Crutzen's death on January 28, 2021 is likely to have further spread the 'Anthropocene' into the popular and academic discourse. The strengthening of global warming and climate change narratives in the past two decades further fueled the environmental and social nuances the term entailed since its original coinage at the seminal Cuernavaca IGBP-SC meeting. What followed in the 2010–

[141] The 'species-talk' has been a major point of criticism of the rhetoric of the 'Anthropocene,' according to several environmental humanists. This type of criticism is discussed in section 5.1.1.

2019 decade was an unprecedented growth of interest in the term, witnessed by the range of initiatives and publications bearing the ‘in the Anthropocene’ designation in their title. In the present context, this early history is crucial in framing the historical context from which the Anthropocene Hypothesis originated and evolved into its current status. Its particular history is discussed in the following section.

2.2 The Geological ‘Anthropocene’

The analysis conducted in section 2.1 provided some resourceful quantitative and qualitative insights concerning the historical and conceptual context that preceded and influenced the birth of the Anthropocene Hypothesis. The most relevant findings concerning the early modern history of the ‘Anthropocene’ are:

(1) The term did not immediately spread at a rapid pace during its first decade of existence; rather, it emerged gradually through different stages.
(2) The appearance of the term in records primarily belonging to the natural sciences suggests a fundamental scientific characterization of the term, complemented by a multidisciplinary interest developed by the end of the decade.
(3) The term had remarkable vertical as well as horizontal reach, appearing in high-profile academic events and publications across a wide spectrum of disciplines within the natural sciences, social sciences, applied sciences, and humanities.
(4) Crutzen, the IGBP, and the water science community (i.e., oceanography, hydrology, and limnology) were among the main drivers in the survival, spread, and popularization of the term during its early research stages.
(5) The discipline with most records using the term ‘Anthropocene’ is geology, which is also the discipline with the highest normalized engagement factor per discipline.

Findings (2), (3), and (5) are particularly interesting in assessing the status of the ‘Anthropocene’ concept in geological literature before its stratigraphic formulation.

Finding (2) shows that the ‘Anthropocene’ was originally conceived within a scientific context. The term was deployed in literature mostly as a background notion framing local as well as global studies on anthropogenic forcings. However, central literature shows how the term assumed an epistemic function by (a) locating a time threshold for a significant shift in the functioning of the Earth System; (b) defining a post-Holocene state where fauna and flora has been altered to an unprecedented degree; (c) bringing together previously disconnected scientific discourses on human impacts; and (d) stimulating an integration of the ‘human factor’ in extant epistemological frameworks for scientific disciplines, thus dispelling the human-nature epistemic divide and considering humans as a natural force or agent. These uses of the term show that the ‘Anthropocene’ had a particular function in scientific literature, and should therefore be treated as a scientific informal (in the literal sense of not being formally defined by any particular discipline) category. Only by the end of the decade did the term begin to attract substantial interest from other disciplinary domains, complementing the body of literature that was already developing within the natural sciences. The scientific origins of the ‘Anthropocene’ are considered a central historical factor in the evolution of the Anthropocene Hypothesis.

Finding (3) shows that the term was not a technical one restricted to a particular scientific niche, nor to a particular field of knowledge. While natural sciences deployed the concept more than other knowledge domains by a substantial margin, the spectrum of disciplines using the term is remarkable, making it a boundary object worthy of different angles of analysis. More importantly, the term was perceived as something worth using (either marginally or actively) across the top end of the academic hierarchy. Its appearance in high-profile events such as the AGU Fall Meeting, the Dahlem Workshops, and the Pontifical Academy of Sciences meetings, as well as in prestigious and high-visibility journals such as *Nature*, *Science*, *PNAS*, and more, shows that the term was almost immediately welcomed among the ‘peaks’ of academia – a circumstance inevitably linked to Crutzen’s own contributions to the term. The ‘prestigious status’ that the term had already acquired during its early history is considered another factor behind the birth of the Anthropocene Hypothesis.

Lastly, finding (5) shows that dissecting the corpus into records per discipline results in a total of 99 records for the discipline of geology. Among these, 21 have a relative frequency (F_n) ≥ 2000. This implies a normalized engagement factor per discipline ($E_n(D)$) of 2.12 – the highest value among disciplines within the parameters defined in section 2.1.2.6 (see also Figure 2.11). The margin between geology and other high-ranked disciplines (e.g., Earth System science, environmental studies, oceanography, etc.) is not wide enough to consider geology as a ‘dominant’ discipline in implementing the ‘Anthropocene’ in texts. Furthermore, the label ‘geology’ construed for the present research incorporates several subdisciplines of the geosciences that are diverse enough to render ‘geology’ a fundamentally vague category – a shortcoming offset by the practical value of using such a label. Nevertheless, because geology is the top ranked discipline in terms of records *and* the discipline with the highest engagement factor, it is worth dedicating a circumscribed analysis to this cluster of literature. Indeed, early literature from geology is recognized as foreshadowing the question of the utility and meaning of formalizing the ‘Anthropocene’ by showing indeed how the term was being used prior to the establishment of the AWG and the Anthropocene Hypothesis. The question of the *utility* of the ‘Anthropocene’ as a geological time unit is a pressing one, and is tackled again in sections 4.2.3 and 5.2.4.

Thus, section 2.2.1 starts from this body of literature from geology to reconstruct the pre-history of the Anthropocene Hypothesis. After this literature has been thoroughly explored, section 2.2.2 frames the social and epistemic context wherefrom the Anthropocene Hypothesis stemmed, emphasizing the role that the Stratigraphy Commission of the Geological Society of London played in the formulation of the stratigraphic variant of the 'Anthropocene.' Lastly, section 2.2.3 reconstructs the birth of the AWG, and summarizes its core activities during its mandate. The AWG represents the main body upholding the Anthropocene Hypothesis, and it is therefore a primary source in reconstructing the birth and formulation the hypothesis in question.

2.2.1 The 'Anthropocene' in Early Geology Literature

Section 2.1.2.3 advanced two main reasons behind geology being the discipline with the highest number of records – namely, (1) the geological nature of the term itself implicit in the suffix '-cene,' and (2) the original connotation given by Crutzen as a possible (informal) *geological epoch*. Yet neither is sufficient to explain why any geologist would consider using the term. The appearance of a geological neologism does not immediately translate into interest in, nor usefulness of, the term in relevant research. If the term was being used, it is because it was generally considered *suitable* and/or *useful* for a given purpose – e.g., framing a particular research topic, providing some time coordinates, or circumscribing a particular state of affairs. The literature surveyed in this section aims at demonstrating this point, showing also how some major themes in extant 'Anthropocene' research emerged organically from the nature of the concept itself. (e.g., its beginning, its hierarchical level, etc.).

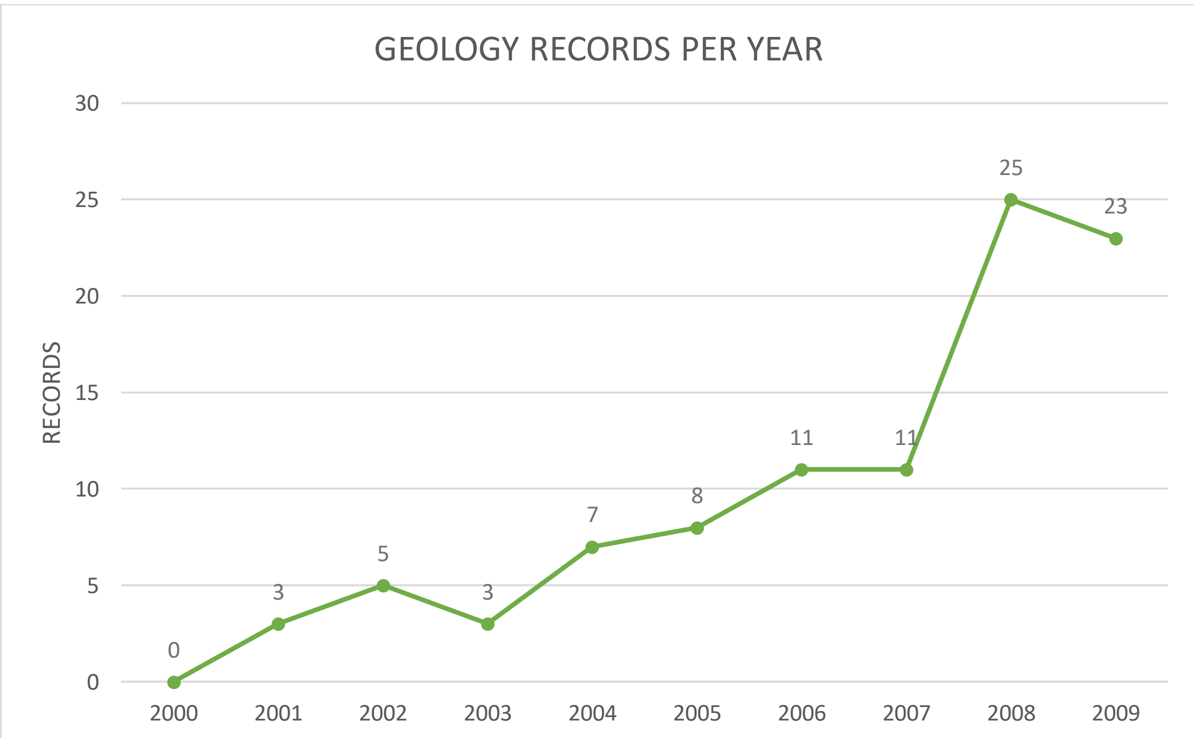

Figure 2.12. Geology records per year. This curve can be compared to Figure 2.3(A) to assess its consistency with the spread of the term across all disciplines considered.

Besides a slight decreasing trend by 2009, the appearance of the term in geological literature mirrors the pace of the term's appearance in 'Anthropocene' early research literature (Figure 2.12). The term gradually appeared in a handful of publications during the first half of the decade, while occurring more substantially in the second half, especially in 2008 and 2009.

The earliest geology records implementing the 'Anthropocene' appear in 2001. Notably, this implies that Crutzen and Stoermer's (2000) seminal article is not defined as a geology record. Indeed, while the article is credited as the conceptual cradle of the modern history of the 'Anthropocene' – presenting for the first time the conjecture that the "the current geological epoch" (p. 17) could be renamed 'Anthropocene' – its overtone and content as well as its publishing source and context are profoundly interrelated with the Earth System science framework. The *IGBP Newsletter* was the newsletter of an Earth System science community rather than a stratigraphic community. The article was a product of an informal intervention held during an IGBP-SC meeting, where scholars from the Earth System science community attended and participated. The proxies used by the authors to delineate a prototypical ontology of the 'Anthropocene' share more with the Earth System and socio-economic trends of the Great Acceleration (Steffen et al., 2015) than the stratigraphic properties distinguishing the Anthropocene Hypothesis (surveyed in the following chapter), or any other geological time unit. These facts corroborate the hypothesis that Crutzen's original formulation cannot be considered a formal request for stratigraphic recognition addressed to the international stratigraphic community. Rather, the suggestion was an informal call for scientists in the Earth System science community to address the past 200–250 years as the 'Anthropocene' in order to stress the magnitude and extent of human activities. As seen throughout section 2.1.3, the community responded positively to this call.

One of the few geology records from 2001 using the term 'Anthropocene' is a conference paper presented for the joint conference V Reunião do Quaternário Ibérico (REQUI, Fifth meeting of the Iberian Quaternary) and I Congresso do Quaternário de Países de Línguas Ibéricas (CQPLI, First Quaternary Congress of Iberian Language Countries)[142] hosted in Lisbon between July 23 and 27, 2001. The paper was authored by climatologists André Berger and Marie-France Loutre (currently the executive director of PAGES), at that time both researchers at the Georges Lemaître Centre for Earth and Climate Research (TECLIM) of the Catholic University of Louvain, Belgium. The paper (which analyzes the long-term impact of anthropogenic greenhouse gas emissions on climate variability, especially in terms of variability in the Quaternary glacial–interglacial cycles) only mentions the 'Anthropocene' once in the subtitle – "The past and future climate at the astronomical time scale: The anthropocene, a transition between the Quaternary and the Quinternary." The term is only used as a background concept. However, the paper provides results concerning "the modelling experiments using different CO_2 scenarios both at the geological and human

[142] Both REQUI and CQPLI are Portuguese-based Quaternary events organized by Iberian geological organizations such as the Geological Society of Portugal (Sociedade Geológica de Portugal), the Portuguese Working Group for the Study of the Quaternary (Grupo de Trabalho Português para o Estudo do Quaternário) and the Spanish Association for the Study of the Quaternary (Asociación Española para el Estudio del Cuaternario).

time scale" (p. 6), suggesting that at least 40 ka will be "required for the climate system to be no longer sensitive to what could happen over the next few centuries" (p. 9). This is an interesting observation because it provides early research on the possible *geological* impact of humans. The human geological legacy has become a central topic among scientific debates over the Anthropocene Hypothesis,[143] and represents one of the aspects distinguishing the hypothesis from the broader 'Anthropocene' concept.

Berger and Loutre also published another paper in 2003 (Berger et al., 2003) suggesting that the 'Anthropocene' could be a period-level transition "between the Quaternary and the next geological period – the Quinternary? – if the Greenland and west Antarctic ice sheets would disappear totally" (p. 135). Within this proposal, the 'Anthropocene' would represent the last epoch of the Quaternary Period, preceding the transition to the Quinternary as a new period of geological time.

The 'Anthropocene' also appears in Jones (2001), the third chapter of the edited volume *Geomorphological Processes and Landscape Change*. The geographer tackles the term only marginally, but anticipating (with remarkable foresight) one of the central questions concerning the 'Anthropocene' – that is, its beginning:

> Exactly when such an Anthropocene should be seen to replace a truncated Holocene is a matter of debate, depending on the criteria adopted. Some would undoubtedly advocate ad 1000, which roughly equates with the beginning of the industrial cycle of global population growth (Whitmore et al., 1990), while others would prefer c. ad 1500, so as to conform with what Roberts (1998) refers to as the culmination of the 'taming of nature' phase and the commencement of 'the modern era'. However, there is likely to be even greater support for c. ad 1750, approximately corresponding to the start of the Industrial Revolution, the commencement of anthropogenically enhanced greenhouse gas emissions and the beginning of the 'The Great Climacteric' (Burton and Kates, 1986),[144] an ongoing period which has seen fundamental changes in the interrelations between sociotechnical systems and the physical environmental systems, resulting in profound effects on the latter […]. Irrespective of the details or the terminology used, it is abundantly clear that a time-span as short as the last 1000 years involves consideration of surprisingly great changes in environmental conditions due to human activities. (p. 62)

Interestingly, the author does not quote nor cite Crutzen and Stoermer (2000), suggesting that the term was already circulating among geological communities as early as 2001. Another interesting aspect relates to the chosen starting date after which human activities began to substantially alter the global environment, dating at least to 1000 CE. Mentioning 'The Great Climacteric' as an ongoing post-industrial phase has an obvious similarity to the Great Acceleration, coined only a few years later – once again showing the remarkable prescience of this excerpt.

A major contribution to the pre-history of the 'geological Anthropocene' is undoubtedly Crutzen's (2002) "Geology of Mankind" (discussed in section 2.1.3.2). This is considered a record from geology in

[143] Section 5.2.1 reviews the debate over the geological significance of anthropogenic signals in rocks and strata.

[144] The references by Jones (2001) are (in order of appearance): Whitmore et al. (1990), "Long-term population change"; Turner et al. (eds.), *The Earth as Transformed by Human Action* (Cambridge: Cambridge University Press), 26–39; Robert (1998), *The Holocene*, 2nd ed. (Oxford: Blackwell); and Burton and Kates (1986), "The Great Climateric, 1748–2048: The transition to a just and sustainable human environment," in Kates and Burton (eds.), *Themes from the Work of Gilbert F. White* (Chicago: University of Chicago Press), 339–60.

addition to Earth System science. While the article reiterates and polishes some of the theses already advanced in the *IGBP Newsletter* article, stressing 'geology' in the title had a remarkable influence on later commentators who had used the *Nature* article as a bibliographic source.[145] Indeed, not by coincidence, the seminal 2008 article authored by members of the Stratigraphy Commission of the Geological Society of London (Zalasiewicz et al., 2008b) – a major step in the formulation of the Anthropocene Hypothesis – directly mentions Crutzen's *Nature* article rather than the IGBP piece, stating that "[i]n 2002, Paul Crutzen, the Nobel Prize-winning chemist, suggested that we had left the Holocene and had entered a new Epoch – the Anthropocene – because of the global environmental effects of increased human population and economic development" (p. 4). Crutzen's seminal 2002 article is also mentioned in the first newsletter of the AWG as the locus of the original suggestion of a new geological time interval (AWG, 2009). It was Crutzen (2002) rather than the *IGBP Newsletter* article that resonated among members of the Stratigraphy Commission of the Geological Society of London.

Geologists started using the 'Anthropocene' informally, and in different ways, but sharing the basic idea of a human-influenced period of time. For instance, in Higginson et al. (2004) – a study on geochemical evidence of changes in Arabian monsoons published in the journal *Geochimica et Cosmochimica Acta* in October 2004 – the 'Anthropocene' (appearing once in the abstract) represents a set of conditions under which climate operates under the late Holocene. The authors write: "The causes of abrupt change have significant implications for understanding future manifestations of similar forcings under late Holocene ('Anthropocene') boundary conditions" (p. 3807). Interestingly, the 'Anthropocene' seems to be equated to the later part of the Holocene rather than a truncation of it – suggesting an informal and implicit usage of the 'Anthropocene' as a 'sub-epoch' or 'age' of the Holocene. A similar connotation seems to be given to the concept by Zielhofer et al. (2004) in a study published by *The Holocene* in September 2004. The authors write: "The synthetic profile comprises late-Pleistocene to mid-Holocene, but not *late-Holocene, alluvial units, because – at least from antiquity on – distinct human impact (Anthropocene)* [emphasis added] on the Medjerda fluvial system has to be considered" (p. 852). Technical language aside, the author seems to consider the 'Anthropocene' as the late part of the Holocene, where a distinct human factor is discernible. Again, this witnesses a use of the 'Anthropocene' as an informal sub-unit of the Holocene (or simply a synonym of the Late Holocene).

What is important to highlight about these excerpts is not just the implicit hierarchical level attributed to the 'Anthropocene' unit, but the *utility* of the term in identifying a particular time period (distinct from the Early to Middle Holocene). In both studies, this period highlights the time when the 'human factor' has become an integral component in circumscribing a particular state of affairs or set of conditions – which the 'Anthropocene' embodies. In this sense, the concept is given a certain epistemic function: that of providing time coordinates for a state shift.

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[145] This is not to say that the *IGBP Newsletter* article was less frequently quoted or had less value, but that evidently the *Nature* article had a much wider reach than the former.

This sample literature embodies much of the informal use geologists and scientists had made of the 'Anthropocene' during its early research stages. By the end of the decade, some authors were using it as a customary term in geological literature. For instance, a 2008 study by De Vleeschouwer et al. (2008) published in the *Journal of the Chilean Chemical Society* states that "very few articles have investigated Holocene or anthropocene reconstruction derived from peat bog geochemistry" (p. 1640). The fact that the authors neither define the 'Anthropocene' nor provide a bibliographic reference suggests that the term was no longer a relatively unknown neologism, but rather a term widely understood within their community (i.e., geochemistry). Similarly, a 2008 research article by Gabrielli et al. (2008) for *Chemical Geology* reads: "In general there are a lack of studies aimed at evaluating the occurrence of anthropogenic Pt and Ir in the atmosphere during the current Anthropocene" (p. 79) – this time citing Crutzen and Stoermer (2000) as a bibliographic reference. A striking similarity between these two articles is that they both stress the necessity of strengthening Anthropocene-related research. In doing so, they are explicitly demarcating between a Holocene and an 'Anthropocene' state of affairs – the latter establishing a new regime where humans are the central factor.

The 'Anthropocene' also appeared in teaching mediums, confirming a sense of utility or suitability among researchers using the notion. The term occurs once in the second edition of *Introduction to Organic Geochemistry* (Killops & Killops, 2005) – a textbook for undergraduate and postgraduate students in organic geochemistry – in relation to increasing anthropogenic CO_2 and CH_4 concentrations in the atmosphere, where the authors write: "Such rapid changes over the past 200 years have led Nobel laureate Paul Crutzen to suggest that we are no longer in the Holocene epoch but the 'Anthropocene'" (p. 291). In *Tectonically Active Landscapes* (Bull, 2009) – a book on tectonic activity written for graduate students "with an interest in geomorphic processes, landscape evolution, and tectonics of plate boundaries" (p. ix) – the author mentions the 'Anthropocene' twice in the introduction, writing that "[b]oth the Pleistocene and Holocene styles of climate change are now history, having been replaced by the Anthropocene" (p. 3). While these textbooks may not have been major individual contributors to the spread of the term by themselves, they are a valuable witness of the process of assimilation of the term in geological research as well as science teaching (a phenomenon observed in other disciplines as well; see section 2.1.3.2). Once again, the term is used to identify a transition to a certain state of affairs, from the climate to atmospheric concentrations of greenhouse gasses, suggesting that the term had a certain utility as an informal designation.

Another noteworthy appearance of the term is in a 2008 book intended for a popular audience entitled *The Earth After Us*, authored by geologist and future AWG Chair Jan Zalasiewicz. The text (published unrelatedly only a year after Alan Weisman's *The World Without Us*) explores the human legacy in rock records from the viewpoint of a hypothetical future civilization.[146] The 'Anthropocene' is introduced at the end of Chapter 7. Here, the author also discusses the possible hierarchical level best representing the degree of changes brought about by human activities, commenting that

[146] The text is particularly important in the context of assessing the geological depth of the human footprint. This point has been a major hotspot for debate in extant stratigraphy debates on the impact of human activities, and it is discussed separately in section 5.2.1.

> one would lay odds, right now, on the Anthropocene attaining the status of, at the least, a geological period. For those who are not completely hung up on our everlasting immortality, a reasonable interim aim might be to try very, very hard for the Anthropocene to develop into something no greater than an epoch-scale event. That might, just, save a few billion human lives. (p 157)

The question of the hierarchical level of the 'Anthropocene' was beginning to take shape as a discrete research question, as later advanced by the seminal publication by members of the Geological Society of London (Zalasiewicz et al., 2008b). *The Earth Without Us* exemplifies the spectrum of mediums through which the 'Anthropocene' was navigating, transgressing the usual mediums of journal articles or newspapers to appear in science teaching and communication outlets.

The 'Anthropocene' also resonated across geological communities internationally, particularly in Europe, but also stretching to the Far East. An article mentioning the 'Anthropocene' in Chinese literature dates as early as August 2001 (Zhu, 2001), whilst a 2004 contribution in the Chinese journal *Quaternary Sciences* (Tung Sheng, 2004) advocates for dedicated 'Anthropocene' research – somewhat foreshadowing the subsequent development of Anthropocene Studies. In Japanese literature, the term appears in a report (Koji, 2004) of the XVI International Congress of the International Union for Quaternary Research hosted in Reno, Nevada, USA between July 23 and 30, 2003; and in a 2004 research article in the *Journal of the Geological Society of Japan* (Murakami et al., 2004) that considers spheroidal carbonaceous particles (SCPs) and charcoal analysis as "effective techniques for paleoenvironmental study during the era of the 'Anthropocene'" (p. 11). While this sample literature is not exhaustive of the reception of the 'Anthropocene' in Chinese or Japanese literature, they show the geographic extent of the spread of the term during its early research stages.

The geology records so far surveyed embody ways of using the 'Anthropocene' that all share a basic property: the term's utility. Studies on anthropogenic impacts of various types used the term in ways that stressed a state shift from previous, Holocene conditions, whether in terms of climate variability, atmospheric composition, or other Earth-related aspects. The term was considered useful in encapsulating this state shift in an elegant, simple way, simultaneously calling for new approaches in studying this state shift event. Being a *useful* category was a central factor in the assimilation and spread of the 'Anthropocene' across geological literature. Nevertheless, the term was never canonized in a sense that it was rigorously defined – not necessarily as a geological time unit, but as a *geological concept* in the first place. The 'Anthropocene' remained an informal designation for a period of time that ranged from decades (i.e., 50 years) to hundreds of years (i.e., 200–250 years) and even millennia (Ruddiman, 2003). Presumably, these two factors – namely, the term carrying some degree of *utility* in geological research and the lack of a *formal geological definition* of the 'Anthropocene' – were the implicit circumstances that led a group of geologists (the AWG) to consider the formalization of the Anthropocene as a geological time unit. The geological or stratigraphic variant of the 'Anthropocene' was about to take shape.

2.2.2 From the 'Anthropocene' to the Anthropocene Hypothesis

At what point in the history of the 'Anthropocene' did the concept evolve into its stratigraphic variant, the Anthropocene Hypothesis? The shaping and emergence of the geological variant of the 'Anthropocene' is a process that occurred over the span of approximately three years – from the middle of 2006 (when discussions of formal ratification began among British geologists) to late 2009 (when the AWG was formed).

A conventional date to delimit the birth of the Anthropocene Hypothesis may be set at a meeting of the Geological Society of London Stratigraphy Commission (GSSC) held on May 17, 2006, in the Council Room of the Burlington House, a Palladian-style building located at the heart of London and home to the five so-called Courtyard Societies of London[147] – including the Geological Society (located in the east wing of the building). The Stratigraphy Commission (SC) is a national body representing the "appropriate professional interests of all British geoscientists" (Geological Sociey of London, 2021, para. 1). It operates in close association with the IUGS, and its largest and oldest constituent body, the ICS. The May 17 meeting was one of the three yearly meetings of the GSSC, traditionally held in February, May, and October. These meetings discuss topics in stratigraphy and provide advice to the Geological Society on various matters, while also bringing forth and exploring new ideas. The 'Anthropocene' question emerged as an item in three GSSC meetings, the minutes of which are hereby used as primary source.

Among the twelve attendees of the May 17, 2006 meeting were Jan Zalasiewicz (then SC Chairman) and Colin Waters (SC Secretary). Zalasiewicz had taken interest in the term, having read Crutzen's *Nature* article, and had begun discussing the term informally with his colleagues as a topic of conversation during the Commission lunchtimes. As recalled by Colin Waters (personal communication, October 27, 2020), "Jan had asked for this [i.e., a possible 'Anthropocene' paper] to be put on the agenda having read the Crutzen work on the Anthropocene and thought it might make for an interesting paper by the GSSC." The 'Anthropocene' was one of the items on the meeting's agenda. The meeting minutes[148] provide a short recollection of the final stages of the meeting, when the 'Anthropocene' was discussed:

> 9.4 Anthropocene
>
> [A] raised the issue of overlap with archaeology and that the French had a term Poubellian (plastique et sans plastique). It was thought that this paper would be suitable for the Bicentenary celebrations of the GS. An alternative slant was proposed, that the term has been proposed, and the paper could concentrate on how we as geologists define the base of this epoch. [B] said [they] would circulate a paper in press about the definition of the Holocene, where a similar problem of many different indicators and the need to fix upon the most suitable.

[147] The five societies are the Geological Society of London, the Linnean Society of London, the Royal Astronomical Society, the Society of Antiquaries of London, and the Royal Society of Chemistry.

[148] The minutes of the GSSC meetings are not openly available. On request, the minutes discussed in this section were made available by the Stratigraphy Commission through the Secretary Colin Waters, and the authors have been anonymized by using placeholders (e.g., A, B, C, etc.).

What emerges from the meeting minutes is that there was nothing intrinsically 'special' about the meeting, nor about the proposal of writing an 'Anthropocene' paper. The concept was one topic among many items (numbered 1 to 10) that were discussed, ranging from membership and the website to the research affairs and publications. The paper suggested by Zalasiewicz (item 9.4) is the last of four publications discussed during the ninth item of the meeting, which dealt with GSSC publications. Zalasiewicz's suggestion to write a paper on the topic of the 'Anthropocene' was not discussed in detail, but only marginally. As acknowledged by Waters, "[t]he entry in the Minutes is far from inspiring, or suggesting it [i.e., the 'Anthropocene'] would develop to where we are today" (personal communication, October 27, 2020). However, what makes the event particularly important in identifying it as the birth of the Anthropocene Hypothesis is that it laid the foundations for the groundbreaking *GSA Today* article later published in 2008, which itself prompted the establishment of the AWG. The meeting suggested (although marginally and quickly) that the 'Anthropocene' could be treated and properly defined as a geological entity. Indeed, Waters observes that, "[g]iven that the publication led to Jan being invited to establish the AWG, it could be seen as the very earliest stratigraphical discussion of the topic that we are aware of" (ibid.). *Ex post*, the May 17, 2006 Burlington House meeting represents the birthplace of the geological 'Anthropocene' (Zalasiewicz et al., 2018).

By the following GSSC meeting on October 19, 2006, the draft of the *GSA Today* article had already circulated. The draft was discussed as item 6.2 on the meeting's agenda. The meeting minutes report the discussions and actions that ensued from the presentation of the first draft:

> 6.2 Anthropocene
>
> [A] considered the manuscript was unacceptable and wished to have [their] name removed from the authorship. Firstly, Anthropocene means "dawn of man" and so is an unsuitable term. The more accurate Anthropogene is a term already used by the Russians for the Pleistocene. [They] also felt that the paper overemphasised the significance of what to [them] will become simply a stratigraphical marker band. [C] felt the paper was important, if only to demonstrate the deleterious impact mankind is having on the planet. [D] felt that the paper needed to be more objective, whereas the abstract gave the impression we supported use of the term. [D] also considered it should include more references to how the term has been used in recent publications. [E] suggested that mention of the atomic testing in the abstract as a possible source for a GSSP should be removed.

There is a clear difference, documented both by the duration and content of the discussion, between the May and October meetings. The former only marginally anticipated the idea of drafting a paper on the 'Anthropocene.' The latter saw geologists debating the meaning and importance of a geological 'Anthropocene,' including [A]'s remarks of a terminological nature that foreshadowed one of the central lines of criticism against the Anthropocene Hypothesis (see section 5.2.3.1). [D]'s intervention anticipated a debate over the mandate and philosophy of the AWG, stressing the necessity of remaining 'neutral' in assessing the stratigraphic validity of the 'Anthropocene' as a geological time unit. A discussion over the beginning of the 'Anthropocene' was also on the table, including the possibility of using atomic bomb testing as a source for a GSSP (which [E] contested). These themes developed in the article published in 2008. Paleobiologist Mark Williams (personal communication, August 1, 2021) recalls: "I remember strong consent in the room for writing such a paper, and only one person not wishing to be involved." A distinct picture of an emerging concept of geological interest materializes from the October meeting, which represented another step toward the publishing of the *GSA Today* article.

The last and final step before the article was submitted for publication was the February 7, 2007 GSSC meeting. The 'Anthropocene' paper appears as item 6.2 on the agenda:

> 6.2 Anthropocene
>
> It was felt that with some modification the paper could be submitted to Geology. However, there was also scope for a significantly trimmed version to go to Nature or Science. Comments on how to reduce the text would be appreciated. [F] indicated that the revised text would need to include findings from the IPCC 2007 report. [E] suggested that it should also refer to the Stern report (2006) and [they] offered to have the figure drafted. [B] would wish to submit the paper before the May meeting of the GSSC.

The minutes detail the final actions and recommendations before submitting the article for publication. In particular, they recount the possible venues where the article could see light. Three journals were originally considered – namely, *Geology* (a journal of the Geological Society of America), *Nature*, and *Science*. Reportedly (Zalasiewicz, personal communication, August 9, 2021), the article was first submitted to *Geology*, which considered it to be too philosophical for the more empirical and technical style of the journal. *Nature* was also considered, but the GSSC members foresaw some difficulties in publishing in this journal, including the fact that the 'Anthropocene' might not have been an 'exciting' or news-worthy idea (Gibbard, personal communication, July 31, 2021). Ultimately, the *GSA Today* journal was selected due to its news-like approach, its broad reach, its focus on short articles, and for being open access (the latter feasibly a major factor in the article's success).

After editorial adjustments were made and a publisher was selected, the seminal four-page[149] article "Are We Now Living in the Anthropocene?" by the members of the GSSC saw light in early February 2008 in Volume 18, Issue 2 of *GSA Today*. The article denotes a turning point in the history of the 'Anthropocene,' initiating the *stratigraphic turn* from 'Anthropocene' to Anthropocene Hypothesis.[150] The authors crystallize the Anthropocene Hypothesis in its very first formulation, suggesting that a case could be made for the formal recognition of a post-Holocene geological unit – a unit determined by the stratigraphic footprint of human actions. The first few lines of the article exemplify this seminal formulation:

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[149] Five pages including the bibliography, and an advertisement of Meiji ML Series Polarizing Microscopes of Meiji Techno American.

[150] Davies (2018) has also used "Stratigraphic Turn" as the title of a section of his book *The Birth of the Anthropocene* (pp. 64–68), ascribing this turn to the establishment of the AWG in 2009. In the present approach, the publishing of Zalasiewicz et al. (2008) is considered the moment best representing the beginning of the stratigraphic turn of the 'Anthropocene.'

> The term *Anthropocene*, proposed and increasingly employed to denote the current interval of anthropogenic global environmental change, may be discussed on stratigraphic grounds. A case can be made for its consideration as a formal epoch in that, since the start of the Industrial Revolution, Earth has endured changes sufficient to leave a global stratigraphic signature distinct from that of the Holocene or of previous Pleistocene interglacial phases, encompassing novel biotic, sedimentary, and geochemical change. These changes, although likely only in their initial phases, are sufficiently distinct and robustly established for suggestions of a Holocene–Anthropocene boundary in the recent historical past to be geologically reasonable. (Zalasiewicz et al., 2008b, p. 4)

The are several aspects that make this article particularly important in the history of the 'Anthropocene' and its stratigraphic variant – that is, the Anthropocene Hypothesis.

First, there is the fact that the authors suggested that the 'Anthropocene' could be treated as a *stratigraphic concept*. As observed in section 2.2.1, geologists and researchers in the geosciences had used the term throughout the 2000–2009 decade. The term defined a recent time interval (i.e., generally the past 200–250 years) characterized by a remarkable anthropogenic impact on the Earth. However, there were no institutional attempts in the geoscientific community to provide a formal definition of the 'Anthropocene' – either as a geological time unit, an event, or a geologically relevant phenomenon. The geologists of the GSSC were the first to promote at an institutional level the possibility of approaching the 'Anthropocene' concept on stratigraphic grounds. Their claim was based on the stratigraphic significance of many of the anthropogenic forcings that were previously studied by the Earth System science international community and were now being translated into stratigraphic terms. Indeed, this claim became one of the three central claims of the Anthropocene Hypothesis delineated in section 1.3.2 – that is, Claim 1 ('*Homo sapiens* has left a discernible stratigraphic signature of significant magnitude in recent geological history'). An ontology of the stratigraphic 'Anthropocene' was provided in support of this claim, based on a range of signals including an increase in human numbers, anthropogenic erosion and denudation rates, perturbation of the carbon cycle, temperature rise, biotic changes associated with accelerated anthropogenic extinctions, and an increase in ocean levels. This range of stratigraphically significant signals "makes clear that we have entered a distinctive phase of Earth's evolution that satisfies geologists' criteria for its recognition as a distinctive stratigraphic unit" (p. 6).

Second, by advancing that the 'Anthropocene' could be treated as a stratigraphic concept, the geologists implied that *stratigraphic criteria* could be used to investigate the geological nature of the 'Anthropocene.' These criteria used to treat the 'Anthropocene' as a stratigraphic concept are the same criteria used to propose and formalize any geochronological and chronostratigraphic unit on the geological time scale. They require assigning a possible unit level to the proposed stratigraphic unit, and locating its beginning, or lower boundary, through either a Global Boundary Stratotype Section and Point (GSSP) or a Global Standard Stratigraphic Age (GSSA). These represent chronological methods for selecting the beginning of geological units. Methodological technicism aside (discussed separately in section 3.1.2.6), what is important to highlight here is the *type* of criteria originally discussed during the earliest stages of the Anthropocene Hypothesis. These criteria differed from previous and parallel versions of the

'Anthropocene,' in particular from the original Earth System variant of the concept. They delimitated the space of inquiry and semantic horizon of the geological 'Anthropocene,' thereafter laying the path for an ongoing research trajectory. In doing so, they contributed to the conceptual separation of the Anthropocene Hypothesis from the 'Anthropocene' boundary object, and from the variants that materialized in the following years.

A third related fact concerns the unit level that the 'Anthropocene' was originally ascribed by the geologists of the Stratigraphy Commission. In geological nomenclature, the suffix '-cene' is usually ascribed to *epochs* of the Cenozoic. Crutzen's original coinage of the 'Anthropo-cene' seemed to imply that the proposed unit should be already treated like an epoch-level unit – an aspect that has been criticized by some geoscientists (see section 5.2.3.1). The geologists of the GSSC embraced this unit level, arguing that "[w]e consider it most reasonable for this new unit to be considered at epoch level" (p. 6). While discussions over the unit level of the proposed geological unit followed in the next years, the AWG maintained (as of August 2021) its original stance, considering the epoch-level the most suitable one to represent the stratigraphic markers characteristic of the 'Anthropocene.'

A fourth aspect that made the *GSA Today* contribution particularly important is its resonance across the academic community as well as the public. The article made the news on several platforms such as *BBC News* (Pease, 2008), *New Scientist* (2008), *Live Science* (Britt, 2008), and *The Guardian* (Lewis, 2009), to name a few. Only a few days after the article was published, Zalasiewicz and Williams (also a GSSC member at the time) were hosts of a program on National Public Radio (Seabrook, 2008) in the US. The idea of a human-determined geological epoch found fertile ground in news and media amidst the increasing urgency of responding to anthropogenic environmental threats. Presumably, the article also resonated among humanists and social scientists.

The Anthropocene Hypothesis was beginning to take shape, and thereafter to pave its way through the academic landscape. At the December AGU meeting in San Francisco (previously mentioned), members of the Stratigraphy Commission of London organized two sessions entitled "Earth System Science and Education for the Anthropocene I" and "Earth System Science and Education for the Anthropocene II" – the former convened by Williams and Andrew C. Kerr along with geographer Navin Ramankutty; the later convened by Zalasiewicz, paleoclimatologist Alan Haywood, and geographer Erle C. Ellis (who later became an AWG member). Among the posters presented was one entitled "Stratigraphy of the Anthropocene," authored by GSSC members (except for Alan Haywood). In the abstract (Zalasiewicz et al., 2008a),[151] the authors promote the formation of an 'Anthropocene' Working Group to determine whether the 'Anthropocene' could be formalized as a geological time unit:

> *The Anthropocene is currently an informal unit referring to the current interval of anthropogenic global environmental change. Yet, it is being increasingly adopted in scientific literature, and has also attracted widespread public interest in underscoring the scale of contemporary environmental perturbation*. Possible eventual formalization is the

[151] The abstract is publicly available at https://abstractsearch.agu.org/meetings/2008/FM/GC11A-0664.html (accessed on July 29, 2021).

> responsibility of the International Commission on Stratigraphy (ICS) and would be preceded by formation of an Anthropocene Working Group, best attached to the Subcommission on Quaternary Stratigraphy. Consideration of evidence pro and con formalization would take several years, and would enter novel territory for such discussions, such as comparison of both deep-time and near-present stratigraphic record with evidence of ongoing environmental process, and likely also forward-modelling (of sea level, ocean/atmospheric chemistry, biotic composition and so on). Consideration of an effective boundary needs also be made, whether or not linked to a Global Stratigraphic Section and Point (GSSP), and also of the hierarchical scale of the unit. *We here ask the ICS to set up an Anthropocene Working Group, without prejudice to the eventual outcome.*[152] As in past determinations of formal chronostratigraphic boundaries, focussing scientific debate on this question would provide valuable data and insights to the wider scientific, and not just to the geological, community. (p. 2, emphases added)

The abstract stresses two connected points advanced at the end of section 2.2.1 – namely, the fact that the term was increasingly being used, implying that it was invested with some utility in the geological and scientific literature; and the fact that the term was still an informal designation, implying that a formal definition (as a geological time unit) would be beneficial for the geological and broader scientific community. Feasibly, these were epistemic preconditions that motivated geologists to formulate the stratigraphic variant of the 'Anthropocene.'

The *GSA Today* article, and the stratigraphic research that ensued, initiated the stratigraphic turn of the 'Anthropocene.' The short piece resonated across the public and academic circles, championing the hypothesis that humans might have left a stratigraphic mark in rocks and strata deep enough to define a new, post-Holocene unit of geological time. If this was the case, then a substantial amount of scientific research needed to be conducted to either corroborate or disprove the hypothesis. This task required the formation of a dedicated Working Group – the Anthropocene Working Group – within the Subcommission of Quaternary Stratigraphy (SQS).

2.2.3 The Anthropocene Working Group

Working Groups (or Task Groups, capitalized according to the ICS statute) are stratigraphic entities appointed within the seventeen Subcommissions of the ICS that primarily focus on locating, characterizing, and defining the lower boundaries of geochronological/chronostratigraphic units (see section 3.1.2.6). The establishment of a Working Group by a Subcommission follows the general statute compiled by the ICS, which provides guidelines for the role, meaning, organization, administration, and functioning of the overall organization. Section 7 of the 2017 statute summarizes the structure and purpose of Working Groups:

152 Technically, it is not a responsibility of the ICS to establish working groups on particular time units. The responsibility falls within the specific Subcommission – in the case of the 'Anthropocene' unit, the Subcommission of Quaternary Stratigraphy. However, the ICS statute (ICS, 2021) also states that "the Executive Committee also may appoint Task Groups for specific tasks that relate to its activities and responsibilities" (para. 7). This might explain why the abstract directly addresses the ICS for setting up an Anthropocene Working Group, although the AWG does not directly relate to the "activities and responsibilities" of the ICS.

> Task or Working Groups are organisational bodies for limited, short-term stratigraphic tasks. Task Groups are generally organised under individual Subcommissions, but the Executive Committee also may appoint Task Groups for specific tasks that relate to its activities and responsibilities. Commonly, a Task Group is created for the selection and definition of the lower boundaries of chronostratigraphical/geochronological units. Task Groups may also be created for the purpose of replacing and/or selecting new boundary definitions, stage units or other stratigraphical units. Each Task Group will have a single scientific task. (ICS, 2021, para. 7)

The "limited" duration of a Working Group is a four-year mandate that can be extended for an additional four years, making the usual lifecycle of such groups eight years. If additional time is needed, "the Task Group should be dissolved and then reconvened at the discretion of the Subcommission Chair" (para. 7.1). A Chairman (or leader) and, if needed, a Secretary are selected either by the ICS Executive Committee, or by the respective Subcommission, as *officers* of the Working Group. The number of *members* should "represent regional and/or methodological diversity in an appropriate manner" (para 7.2), and should not exceed forty. The terms for officers are four years, after which they can be re-elected and re-appointed for only one additional four-year term. Members also have four-year terms of office, which can be extended for two mandates of four years each (for a total of twelve years) (para. 9.1). Officers are elected by their respective Subcommission or Executive Committee through voting, whilst voting members "are elected by its executive, in consultation with existing voting members, and confirmed by the management or executive of the ICS body under which the Task Group resides" (para. 9.6). Decisions over scientific and organizational matters are made through internal voting, requiring "a sixty percent (60%) majority of delivered votes, provided that a quorum of 60% has been attained" (para. 9.7). Working Groups are dissolved once their task has been fulfilled (para. 7.5) – for instance, when a group successfully reaches formalization of a lower boundary of a geochronological/chronostratigraphic unit on the geological time scale.

The idea of forming a Task Group to research the 'Anthropocene' as a geological time unit was first suggested by Quaternary geologist and current ICS Secretary-General Philip Gibbard, a GSSC member and former SQS Chair between 2002 and 2012. Gibbard was not present during the seminal May, October, and February meetings, when the 'Anthropocene' paper and idea were discussed. However, he had discussed the idea of 'Anthropocene' with his long-standing friend Jan Zalasiewicz, suggesting (between meetings) that he convene a group of individuals to assess whether or not the 'Anthropocene' had any stratigraphic meaning and value.[153] Gibbard felt that the SQS should consider the stratigraphic status of the proposed unit, given that the 'Anthropocene' idea had gained substantial ground in scientific, and particularly geological, literature. As he states (Gibbard, personal communication, July 31, 2021), "if we are

[153] Gibbard could not convene the group himself, as his status as Chair of the SQS may have become a conflict of interest if he were to be appointed as an officer of the AWG. This is also the reason why Zalasiewicz stepped down as Chair of the AWG in 2020 upon being elected as Chair of SQS.

not going to do so, who will?", meaning that no other entity within the ICS (and possibly in the IUGS) other than the SQS could have raised the question concerning the 'Anthropocene' in stratigraphic terms.[154]

Formal approval to form an Anthropocene Working Group was granted in the summer of 2009 (ICS, 2009). The group initially consisted of only three individuals: Jan Zalasiewicz as Chairman of the group, Mark Williams as Secretary, and Philip Gibbard as voting member. Gibbard suggested that Zalasiewicz be appointed as Chairman of the group. This was a rather intuitive choice, since he pioneered the 'Anthropocene' idea in the Burlington House meetings and promoted the publication of the seminal *GSA Today* article. Williams was appointed as Secretary "for reasons including practical ones (having the office next door to JZ [Jan Zalasiewicz])" (AWG, 2009, p. 3).[155] The very limited size of the original group required Zalasiewicz and Williams to recruit new members. Williams (personal communication, August 1, 2021) recalls "many discussions with Jan about who to involve, and as secretary I sent out many of the email invitations asking people to join." By the end of 2009, the group grew to sixteen members, listed on the first newsletter of the newly established Task Group (AWG, 2009), published in December. The AWG, "the remit of which is to examine the status, hierarchical level and definition of the Anthropocene as a potential new formal division of the Geological Time Scale" (ibid.), had officially begun its operations.

What followed from the establishment of the AWG is more than a decade of stratigraphic and broader multidisciplinary research on the Anthropocene Hypothesis. The group has been the gravitational entity around which discourses on the geological 'Anthropocene' have revolved over the past decade. Its research has launched multidisciplinary and international interest and critical debates over the meaning and utility of an 'Anthropocene' geological unit for stratigraphy, for science, and for society overall. The number of members has grown substantially over the years, including a diversified pool of researchers from the natural sciences, humanities, and social sciences (Lundershausen, 2019). As of August 2021, the group has thirty-seven members, including the current Chair Colin Waters, who replaced former Chair Zalasiewicz in 2020, and Secretary Simon Turner, who succeeded Waters. Communication among members of the group has largely occurred through email.

The AWG has had six main meetings at different times and in different locations since its inception:

- Haus der Kulturen der Welt, Berlin, October 16–17, 2014.
- McDonald Institute for Archaeological Research, Cambridge University, November 24–25, 2015.
- Fridtjof Nansen Institute, Oslo, April 22–23, 2016.
- Max Planck Institute for Chemistry, Mainz, September 5–8, 2018.[156]
- Center for the Gulf South, Tulane University, New Orleans, November 8–9, 2019.
- Haus der Kulturen der Welt, Berlin, September 22, 2021.

[154] This is also because the 'Anthropocene' was already implicitly being considered as an epoch-level unit, and therefore under the responsibility of the SQS.
[155] Both Zalasiewicz and Williams were (and currently are) located at the University of Leicester.
[156] Another meeting at the MPI for Chemistry was held on March 16, 2017. However, only a few members of the AWG attended the meeting, which was organized by Paul Crutzen at his home institution (AWG, 2017).

During the latest AWG meeting in Berlin, at the Haus der Kulturen der Welt, researchers affiliated to the group presented preliminary and ongoing findings concerning valid GSSPs candidate for an Anthropocene chronostratigraphic unit.[157] The meeting (hosted in hybrid form due to the ongoing COVID-19 pandemics) preceded the "Anthropogenic Markers" workshop, organized jointly by the HKW and the Max Planck Institute for the History of Science, and held in September 23–24. A major outcome of the meeting will be a special publication, to be submitted to *Anthropocene Review* in 2022, summarizing the major anthropogenic markers and signals as well as challenges around each of the proposed Anthropocene GSSP. This will constitute a crucial step towards submitting a formal proposal.

The group activity – spanning longer than the normal eight-year lifecycle for Working Groups according to the ICS Statute – has produced a vast body of literature on the Anthropocene Hypothesis. Many publications, volumes, initiatives, and conferences have been organized by members of the group, and by researchers gravitating around it.[158] Recently, research exploring the organization and functioning of the AWG has also been conducted (Lundershausen, 2019; see also PhD research from Alexander Damianos and Fabienne Will), further corroborating the important position the AWG invests in the broader 'Anthropocene' debates.

The research history of the AWG may be condensed in a few landmark publications produce since the group's formation. On March 13, 2011, a volume of the Royal Society of London was published under the title "The Anthropocene: A new epoch of geological time?" (Zalasiewicz et al., 2011b), featuring thirteen papers focusing on the stratigraphic nature of the 'Anthropocene.' Two months later, on May 11, a meeting on the 'Anthropocene' convened by Mike Ellis, Jan Zalasiewicz, Mark Williams, and Alan Haywood, supported by the British Geological Survey, was hosted at the Burlington House. As reported by the AWG (2012) newsletters, "the meeting was widely regarded as a considerable success, and resulted in widespread publicity (including *Nature*, with a feature, an editorial and inclusion in their annual roundup of 'highlights of the year'." The meeting partially motivated the preparation of a special publication for the Geological Society of London (AWG, 2013), *A Stratigraphical Basis for the Anthropocene* (Waters et al., 2014a), published three years later in 2014. The volume provided the first extensive stratigraphic and scientific characterization of the Anthropocene Hypothesis, outlining the key stratigraphic signals that could ground a possible formal definition of the suggested 'Anthropocene' geological unit. More recently, the AWG published its latest comprehensive scientific summary of the Anthropocene Hypothesis, *The Anthropocene as a Geological Time Unit* (Zalasiewicz et al., 2019b). The book provides preliminary scientific evidence in support of the Anthropocene Hypothesis, which is discussed in the next chapter.

The constellation of activities launched by the AWG is beyond the limits of the inquiry conducted in this chapter, whose primary focus was to reconstruct the early modern history of the 'Anthropocene,' and to frame the theoretical preconditions and social processes behind the birth of the Anthropocene

[157] A map of the proposed locations for an Anthropocene GSSP is given later in section 3.1.2.6.
[158] An exhaustive account of events and publications connected to the work of the AWG, and to the broader scientific 'Anthropocene,' is available through the various AWG newsletters on the group's website (http://quaternary.stratigraphy.org/working-groups/anthropocene/, accessed on August 2, 2021).

Hypothesis. As such, a thorough investigation of the organization, structure, and operating methods of the AWG also falls beyond the reconstruction of the birth of the Anthropocene Hypothesis.

In the following chapters, the research emphasis is shifted from a historical reconnaissance to an investigation of the epistemological nature of the hypothesis. This is assessed based on the latest evidence provided by the AWG (Chapter 3), and by framing the epistemic virtues the hypothesis entails from a philosophical standpoint (Chapter 4). Lastly, the debate (Chapter 5) surrounding the 'Anthropocene' and the Anthropocene Hypothesis is framed.

CHAPTER 3

ANATOMY OF THE ANTHROPOCENE HYPOTHESIS

We have managed to confuse ourselves for years
with the jargon of lithostratigraphy, biostratigraphy, chronostratigraphy and the rest.
In fact it can well be argued that basically there are only two concepts – rocks and time –
with the rest just an obfuscation of the nomenclature.

—Derek Ager, *The Nature of the Stratigraphical Record*

A distinctive aspect of most scientific hypotheses is their empirical basis. Scientists formulate hypotheses based on available observations to explain a certain state of affairs or phenomenon. Observations that support a hypothesis attempting to explain a certain state of affairs or phenomenon are traditionally understood as *empirical evidence* for the hypothesis. Empirical evidence plays a central role in science, and it is often a major discriminant among scientific hypotheses competing to explain certain phenomena (because empirical evidence is never unequivocal) and distinguishes scientific from non-scientific hypotheses. It also involves a process of negotiation wherein a community of epistemic actors delimit what does, and what does not, constitute evidence for a given hypothesis. As such, 'evidence' is a deeply social category – in addition to being a philosophically dense concept.

If the Anthropocene Hypothesis represents a *scientific* hypothesis, then one should expect an empirical base for its central claims supported by a certain community. Because evidence does not necessarily confirm *one* hypothesis but multiple hypotheses with conflicting claims – a condition known in philosophy of science as 'contrastive underdetermination' (Stanford, 2017) –, alternative hypotheses competing with the Anthropocene Hypothesis in explaining a certain state of affairs (i.e., the beginning of a global anthropogenic stratigraphic signature) are expected. What is, then, the empirical body of this hypothesis? What other hypotheses compete with the Anthropocene Hypothesis, and in what ways?

This chapter seeks to answer these questions by exploring the evidence supporting the empirical structure of the Anthropocene Hypothesis, and alternative and competing hypotheses to the Anthropocene Hypothesis. Section 3.1 investigates the stratigraphic basis of the Anthropocene Hypothesis. The epistemic context of stratigraphic classification is illustrated, and the evidence gathered thus far (primarily by research revolving around the AWG) is discussed. This is accomplished by framing such evidence against the standards of stratigraphic classification defined by international guides and research protocols, and by surveying the different types of stratigraphic evidence supporting the claim for formal recognition of the Anthropocene as a geological time unit.

Subsequently, section 3.2 tackles one of the most discussed and important aspects of the Anthropocene Hypothesis, and perhaps of the overall 'Anthropocene' debate: the beginning of the Anthropocene as a geological time unit, and as a concept of scientific utility. While this aspect has been framed by humanists and social scientists in terms of its broader social, political, and ethical importance, determining the beginning of a time unit on the international chronostratigraphic chart (and geological time scale) represents a necessary epistemic requirement to the formalization of any chronostratigraphic and geochronological unit. As such, it follows strict stratigraphic guidelines and protocols – to which the Anthropocene Hypothesis must adhere in order to be considered a stratigraphic hypothesis. This aspect is tackled by conducting a critical survey of the proposed starting dates for the Anthropocene as a geological time unit. Each provides different methods and empirical evidence for promoting possible starting dates – some even challenging a chronostratigraphy-based definition of 'Anthropocene.'

The central scope of this chapter is not to determine whether the Anthropocene Hypothesis is true or false – that is, whether or not a lower boundary of an anthropogenic stratigraphic nature could be located around the 1950s; nor is it to determine whether or not the evidence gathered by extant research justifies formal recognition on the geological time scale. Rather, it seeks to show how the Anthropocene Hypothesis represents a *scientific* hypothesis based on the type of empirical evidence it advances. This requires conducting 'anatomical' work – that is, dissecting the body of empirical evidence that informs the Anthropocene as a geological time unit, and discussing those alternative hypotheses at the center stage of the Anthropocene Hypothesis debate.

3.1 Stratigraphy of the Anthropocene

Chapter 2 illustrated how the 'Anthropocene' idea transitioned from a loose scientific term to an overarching category for environmental discourses among the natural sciences, social sciences, humanities, and arts. One among the many research trajectories developed within Anthropocene Studies occurred within stratigraphy, or more precisely, within chronostratigraphy and geochronology – two interlinked branches of stratigraphy dealing (among others) with the reconstruction of geological time. The process leading to the formation of the AWG in 2009 provides a practical signpost delimiting the institutionalization of the Anthropocene Hypothesis, after which dedicated geological research has increasingly evolved into its present status.

The Anthropocene Hypothesis is one of many different formulations of the 'Anthropocene' within Anthropocene Studies. It is also one among different formulations within the natural sciences. In Earth System science – the disciplinary cradle of the 'Anthropocene' – the term reflects the increasing anthropogenic impact on Earth System functioning, from the steep increase in socio-economic and Earth System trends of the Great Acceleration (Steffen et al., 2015; Steffen et al., 2011b; Steffen et al., 2004c) to the planetary boundaries for sustainability (Rockström et al., 2009a; Rockström et al., 2009b). As seen, the IGBP played a crucial role in circulating the idea among multidisciplinary communities of scientists and, later, humanists and social scientists as well. In this context, the 'Anthropocene' represents a phase or stage of the Earth System, perhaps best represented by the surge in energy consumption across human societies since the Industrial Revolution and particularly since the Great Acceleration along with its implications for the Earth System (Syvitski et al., 2020). This multidisciplinary approach, stemming from the relatively new discipline of Earth System science, allows us to consider human societies as an integral part of the Earth System – breaching an already contested but longstanding dichotomy of humans *and* nature by representing humans *as part of* nature itself.

The 'Anthropocene' in Earth System science is very close to the stratigraphic Anthropocene. In fact, the AWG has argued that the "geological interpretation of the Anthropocene complements the ESS [Earth System science] interpretation" (Zalasiewicz et al., 2019a, p. 324). This is not simply because members of the Earth System science community often share results, research material, platforms, and institutions with researchers on the Anthropocene Hypothesis (e.g., Steffen et al., 2016). It is also because anthropogenic activities altering the function of the Earth System may translate into geologically significant evidence. The AWG has stressed that "the significance of the Anthropocene lies not so much in seeing within it the 'first traces of our species', but in the scale, significance and longevity of change to the Earth system" (Zalasiewicz et al., 2015b, p. 201). More recently (Zalasiewicz et al., 2019a), the group stated that "[t]he Anthropocene *as an ESS and a chronostratigraphic unit* [emphasis added] recognizes dramatic changes to the Earth System, using the same criteria that delineates any other previous epoch" (p. 326). Both excerpts suggest that, while also adopting the traditional standards of stratigraphic classification (illustrated throughout this chapter), the Earth System science evidence plays a central role in defining the Anthropocene as a *stratigraphic* unit. The abrupt changes in the functioning of the Earth System that have occurred over the past 250, and especially over the past 70 years, represent a marked event horizon that is unprecedented in human as well as geological history, and in the history of the Earth System. This horizon may be used to locate a boundary in the stratigraphic record reflecting these changes. This means that aspects of recent shifts in the Earth System are reflected in stratigraphic research, and vice versa – witnessing the close conceptual partnership between stratigraphy and Earth System science.

In evolutionary biology and ecology, the term has been widely associated with increasing extinction rates (Barnosky et al., 2011; Ceballos et al., 2015; Ceballos et al., 2017; Pimm et al., 1995), reportedly associated with increasing and global-scale human niche construction activities (Ellis, 2016b; Ersten et al., 2016; Fox et al., 2017; Kendal et al., 2011a, 2011b; Laland et al., 2001; Smith & Zeder, 2013). This literature suggests that evolutionary processes have been dramatically altered by the establishment of "new evolutionary pathways created by human hyper-dominance as a 'hyperkeystone' species" (Pena Rodrigues & Lira, 2019, p. 141). Understanding the contemporary biosphere is not possible without including the human factor as a structural component of the present status of life on Earth – although the human-biosphere-ecosystems represents a complex relationship that poses practical difficulties in modelling (Ellis & Ramankutty, 2008). While *Homo sapiens*, like any other organism, has been altering its environment throughout its existence as a species, it is only recently that its collective actions have become a driver for biological and ecological change. The first signs of anthropogenic influence on the biosphere can be dated to the extinction of the mammalian megafauna during the Late Pleistocene, between 50 to 12 thousand years ago (DeSantis et al., 2019; Doughty et al., 2010; Haynes, 2018). Forest clearance and land conversion to agriculture during the Neolithic Revolution further expanded human niche construction activities. With increasing population and energy demands over time, "[h]umans have fundamentally altered global patterns of biodiversity and ecosystem processes" (Ellis & Ramankutty, 2008, p. 439) and established new ecological domains that the environmental scientist (and AWG member) Erle Ellis and geographer Navin Ramankutty defined as 'anthropogenic biomes' or 'anthromes' (ibid.). As later discussed (section 3.1.1.4), the 'sixth extinction event' in the history of life (Kolbert, 2014) is relevant in the context of biostratigraphy – one of the types of stratigraphic records left by the human species.

There is a necessary connection between different knowledge domains within the natural sciences in approaching the 'Anthropocene.' This is a consequence of the ontological breadth of this concept, encompassing a range of phenomena that can be observed, elaborated, and formulated based on the specific disciplinary stance one is located within. However, to investigate the very evidence and epistemology of the Anthropocene Hypothesis, it is paramount to differentiate it from other similar or overlapping narratives from the natural sciences, or within Anthropocene Studies. One way of doing this is reiterating the argument that the Anthropocene Hypothesis represents specifically the stratigraphic formulation of the 'Anthropocene.' Alternative scientific interpretations of the 'Anthropocene,' such as those from Earth System science and evolutionary biology, are not bounded to the claim of recognition of the Anthropocene as a geological time unit in the same way the Anthropocene Hypothesis is. The fact that *Homo sapiens* has left a discernible *stratigraphic* footprint (Claim 1), and that this footprint may see *geological formalization* (Claim 2 and 3), are the central claims that distinguish the Anthropocene Hypothesis or stratigraphic Anthropocene from other scientific and non-scientific interpretations of the 'Anthropocene.'

Therefore, the following section delineates what evidence makes the Anthropocene Hypothesis a hypothesis of a stratigraphic nature. Rather than passively listing a collection of research material, the nature of the evidence so far advanced is also critically discussed. This analysis is particularly important for two reasons.

First, by providing an overview of the actual research material and types of evidence, it shows that the Anthropocene Hypothesis – regardless of one's personal position on it – is a scientific hypothesis worthy of philosophical, and especially epistemological, analysis. While this may seem trivial, the absence of a philosophy of science in Anthropocene Studies, and accusations of hidden political agendas (Finney & Edwards, 2016), make it necessary to stress this point. This analysis complements the theoretically oriented analysis later conducted in Chapter 4.

Second, if the stratigraphic 'Anthropocene' constitutes a discrete instance of geological reflexivity, then its defining content and structure should be exposed in a way that makes it unique and substantially distinguishable from genealogical precursors – such as the 'Anthropozoic' or the 'Noosphere.' The historical (Chapter 2), empirical, and theoretical (Chapter 4) context of the Anthropocene Hypothesis suggests that this is the case.

3.1.1 Geological Claim and Stratigraphic Claim

Before moving on to surveying the material and research context of the Anthropocene Hypothesis, a preliminary remark concerning the nature of its claims is considered necessary.

Two implicit and seemingly identical claims concerning the scope of the 'Anthropocene' have been formulated and adopted in Anthropocene Studies (whether in the natural sciences, social sciences, or the humanities). Let us identify them as the 'geological claim' and the 'stratigraphic claim,' and define them as such:

> **Geological Claim (GC):** Humans have become a significant geological force, equal in extent to the geological forces of nature, such as erosion, volcanism, seismic activity, or glaciation.[159]
>
> **Stratigraphic Claim (SC):** *Homo sapiens* has left (and is leaving) a discernible stratigraphic footprint that may be used to define the beginning of a new geological time unit.

[159] For examples of geological forces, see https://www.nps.gov/subjects/geology/geology-concepts.htm (accessed on August 8, 2021); and http://www.discovergrandteton.org/teton-geology/geologic-forces/ (accessed on March 24, 2021).

The first argument promoted here is that these two seemingly equivalent claims should be separated. Although they share a causal connection (SC is a consequence of GS), they mean different things. This has also been recognized by philosopher of science Carlos Santana, who argues that "[a]sking whether the Anthropocene should be designated a new epoch is not the same as asking whether humans are significant geological agents" (Santana, 2019a, p. 1075). Locating this subtle difference is difficult, especially since both claims often overlap or appear simultaneously in extant literature (Carrington, 2016; e.g. Crutzen & Stoermer, 2000; Steffen et al., 2007; Steffen et al., 2011a; Vaughan, 2016). SC is a consequence of GC because the stratigraphic footprint of *Homo sapiens* is a direct consequence of its geological action. In fact, most related literature has underscored that we have entered the Anthropocene *because* we have become a geological force – differing in opinion on *when* humans turned into a geological force. However, it seems they express different things about humans and their role on the Earth and in its history – GC interpreting human actions in terms of their broader geological significance, and SC interpreting human actions in terms of their specific stratigraphic magnitude.

The second argument promoted is that SC (rather than GC) is the explicit claim of the Anthropocene Hypothesis. This is consistent with Claim 1 of the Anthropocene Hypothesis – that is, '*Homo sapiens* has left a discernible stratigraphic signature of significant magnitude in recent geological history.' The Anthropocene Hypothesis does not directly advocate for GC, but rather considers GC as an empirical assumption to advance SC. In these terms, GC is a substantially different statement than observing that human activities are discernible on a stratigraphic (and particularly geochronological/chronostratigraphic) level because it centralizes the discussion over humans' *geological agency* rather than stratigraphic footprint (and its utility as a geological time unit). It requires a different line of reasoning and investigation, and is thus *assumed* in the Anthropocene Hypothesis. It seems intuitive to infer that, in order to leave a stratigraphic signature, a species must attain some sort of 'geological power' to imprint such a mark.[160] Yet, assessing whether a species holds geological agency is a different theoretical endeavor than defining its stratigraphic footprint in order to establish a geological time unit. Feasibly, a discrete discussion on the geological agency of *Homo sapiens* should be approached in terms of 'theoretical geology' – namely, by defining what represents a 'geological force.'

Because GC informs SC as an assumption, GC requires a few additional remarks.

GC is not an utterly new claim in the domain of geology. It had already seen light as early as the late 18th century, with the writings of Comte de Buffon. It saw early instances of recognition in the geological work of Thomas Jenkyn (Lewis & Maslin, 2015a) and Antonio Stoppani (Federighi, 2013), who both used the term 'Anthropozoic' during the 19th century. Within Anthropocene Studies, GC is rooted in Crutzen and Stoermer's seminal IGBP article, where the authors claimed that "mankind will remain a *major geological force* [emphasis added] for many millennia, maybe millions of years, to come" (Crutzen & Stoermer, 2000, p. 17). Crutzen further reiterated GC in later publications, writing that "[h]umankind is bound to remain a noticeable geological force, as long as it is not removed by diseases, wars, or continued serious

[160] This point may be inverted: that is, a species could be attributed geological agency *because* of its stratigraphic mark.

destruction of Earth's life support system" (Crutzen, 2002a, p. 4).[161] Together with Will Steffen and John R. McNeill, Crutzen wrote in 2007 that "[h]uman activities have become so pervasive and profound that they rival the great forces of Nature" (Steffen et al., 2007, p. 614). In his article "The Climate of History," Chakrabarty (2009) also addresses humans as a "geological force" (p. 206). Later, in a 2018 interview conducted by Shiraz Sidhva for the *UNESCO Courier*, the environmental historian claimed that "[w]e have somehow acquired the role of a *geological force* [emphasis added] − thanks to our pursuit of technology, population growth, and our capacity to spread ourselves all over the planet" (p. 12). The claim that humans have become a geological force has been by then largely and almost passively assumed as a cardinal tenet in Anthropocene Studies, and literature implementing this label is abundant. It is plausible that this linguistic label is more than a metaphorical device.

Is it true that humans parallel, if not exceed, the effects of geological forces? This statement seems quantitatively true, but it requires further considerations. Geological literature commonly recognizes plate tectonics, volcanism, erosion, glaciation, or heat from the Earth's interior as examples of *endogenous* geological forces (examples of *exogenous* forces are the Sun's radiation, gravity, or asteroid collisions). These are forces that have been operating on billion-year scales, and have shaped the life-hosting planet Earth as we know it. For instance, plate tectonics has been operating on the Earth's lithosphere for the past 3.3–3.5 Ga (Sobolev et al., 2019) and is the main force responsible for the creation of mountains and oceans, as well as being a crucial driver behind chemical cycles such as the carbon cycle (Poli, 2015). A strong link between plate tectonics and the origin of life has been suggested (O'Neill, 2016). Another example is volcanism, which has been operating even before the onset of plate tectonics. The action of volcanism led to modifications of soils, water, and the atmosphere that were crucial for the development of life, and its role in heat transfer from the Earth's inner core is necessary in maintaining Earth System stability. Lastly, life itself, primarily through photosynthesis, has been an active geological force that has been shaping the Earth's surface and atmosphere for billions of years. Without photosynthesis, most extant life would not be possible, meaning that life *overall* can be considered a geological force (Westbroek, 1991) – with some species, such as *Homo sapiens*, developing a more prominent, yet transient, role as geological actor.

Geological forces are those *structural* forces operating on a planetary level on billion-year timescales, and that have made the Earth the only planet observed so far to harbor complex life. Thus, there is an intrinsic link between geological forces and life. Planets with no or few geological forces harbor no life – they are dead planets. To claim that humans have become a geological force means that humans hold the

[161] As previously noted in section 2.1.3.2, Crutzen (2002b) wrote that "mankind will remain a major *environmental force* [emphasis added] for many millennia" (p. 23), switching the tone from 'geological' to 'environmental' in a seemingly equivalent fashion. This difference has also been noted by philosopher of science Jay Foster (2018), who similarly questions the status of humans as geological forces. However, the use of 'global environment' or other 'environment'-related terminology in association with the Anthropocene has been criticized by Hamilton (2015), who sees Crutzen's terms as open to possible misleading interpretations regarding the scope of the Anthropocene. However, Hamilton is not championing the geological nor the stratigraphic claim – his third view emphasizes the role of the Anthropocene in the Earth System framework. The reasons why Crutzen decided to use 'environmental force' rather than 'geological force' may be due to editorial choices, or a choice of reflecting the bigger environmental narrative – the latter being consistent with the normative content that Crutzen hoped to deliver with the new term (Dalby, 2016).

same ontological status as plate tectonics or volcanism. While this may appear to be the case from quantitative analysis (e.g. in terms of energy flow, see McNeill & Engelke, 2014; Syvitski et al., 2020), *Homo sapiens* does not have the same ontological significance as geological forces. The absence of plate tectonics, volcanism, glaciation, erosion, and so forth is not equal to an absence of *Homo sapiens*. Without 'traditional' geological forces, complex life – and thus the very existence of *Homo sapiens* – would not be possible. The Earth would very likely resemble other inhospitable planets of the Solar System. However, the same cannot be said of the absence of *Homo sapiens*. Although humans are agents of vast biological and evolutionary change, including the manipulation of genomes and human-induced speciation, they are (still) only a transient organism in the history of life on Earth. Therefore, to claim that humans equal and/or exceed the power of geological forces may be true only on a restricted time scale, and only where 'geological' implies an effect on the Earth System, and on the global environment. As a structural feature of the Earth, humans can hardly be considered a *structural* geological force. However, *Homo sapiens* could be considered as *part* of the geological force represented by biological life itself, and as a *transient* geological force capable of changing the direction of Earth's geological history.[162]

To claim that, strictly speaking, humans are not geological forces is not to say that humans are not geological/geomorphological *agents*, nor that they do not operate on the same scale as geological *processes* – a further distinction that needs to be made. The deliberate annual relocation of material by humans (570 megatons/year) exceeds ocean sedimentation processes by rivers (220 megatons/year) by a factor of three (Douglas & Lawson, 2001). Landscape-forming is now conditioned by both natural and anthropogenic processes in terms of impact and rate (Price et al., 2011). Human-induced erosion corresponds to "an amount ~10 times that imposed by glaciers, rivers, and other natural processes combined" (Wilkinson, 2005, p. 163), alongside significant rates of anthropogenic denudation mostly associated with agricultural practices (Wilkinson & McElroy, 2007). This data snapshot shows that humans in fact equal or exceed in quantitative measures the action of the geological forces that shape the Earth. Yet, because they are not an intrinsic driver of planetary changes on a billion-year scale, and thus are not necessary for life as such in the way some other geological forces are, humans should be considered geological *agents* rather than geological *forces*. Chakrabarty (2009) argues that "[t]o call ourselves geological agents is to attribute to us a force on the same scale as that released at other times when there has been a mass extinction of species" (p. 207). This attribution is quantitative, meaning that humans exhibit similarities to geological forces in the way they interact with the environment – as illustrated by the data above. However, the attribution is not qualitative, in the sense that humans are *the same as* geological forces.

While extant literature (including Chakrabarty, 2009) often interchanges 'agents' and 'forces' (mostly using these labels as rhetorical devices or metaphors to convey a normative message, rather than a descriptive analytical category), the theoretical impasse has been recognized by a few scholars. For instance, Clive Hamilton (2017) argues that "[h]umankind is perhaps better described not as a geological force but

[162] This argument may also be another reason why Crutzen (2002) decided to use the term 'environmental force' rather than 'geological force.').

as a geological power, because we have to consider its ability to make decisions as well as its ability to transform matter. Unlike forces of nature, it is a power that can be withheld as well as exercised" (p. 6). While he emphasizes the role of conscious agency, the attribution of geological agency hereby advanced is rather based on the ontological place of humans on the Earth, with particular regard to geological time. A similar distinction (aimed at tackling the question of causality in the Anthropocene) has also been advanced by Thomas et al. (2020), who distinguish between 'forcing' – a "perturbation in a system" that "does not suggest that there is will or intention behind the disruption" (p. 13) – and 'forces' – the normative and historically oriented category implying "happenstance, inevitability, *and* intention" (ibid.) – in analyzing the complex interplay of both in engendering the Anthropocene. This literature shows the epistemological advantages of delineating by means of conceptual clarity the ontological status of *Homo sapiens*. This is particularly useful to avoid criticism of ontological anthropocentrism, as shall be analyzed in section 5.1.2.[163]

There are further characteristics distinguishing GC from SC. To represent a geological force does not immediately translate into the domain of stratigraphy. Geological forces have been active underlying processes throughout most of the Earth's history (a theoretical postulate known in geology as the Uniformitarian Principle). They represent the cause of major global phenomena (e.g., massive volcanic eruptions, climate change, magnetism, migration of species, etc.) whose effects are left in the stratigraphic record. Ultimately, this record is used to divide geological time in a useful and meaningful way. Hence, geochronological/chronostratigraphical recognition is a different theoretical ground and endeavor than assessing what does or does not constitute a geological force. SC is mostly concerned with the stratigraphic basis of an Anthropocene time unit – namely, whether humans have left a substantial stratigraphic mark in geological records detectable by present or future geologists, and whether this mark should be represented on the geological time scale. Stratigraphy investigates a spectrum of several material and non-material properties of rocks and strata that can be correlated and used to reconstruct the Earth's geological history. It does not (at least directly) raise questions of humans' geological agency insofar as anthropogenic sediments represent the main object of analysis (i.e., there could be substantial anthropogenic sediments without ascribing humans the status of geological force).

Another aspect distinguishing SC from GC is the question concerning humans' geological legacy from a 'future geologist perspective.'[164] This is represented by a hypothetical scenario used to either validate or invalidate the Anthropocene Hypothesis by asking whether or not a future geologist (from hundreds to millions of years in the future) will detect a global and seemingly synchronous[165] anthropogenic stratigraphic signature. The idea that future geologists might detect a boundary horizon in the stratigraphic record by the 19th or 20th century is a recurrent argument in 'Anthropocene' literature. Yet this thought experiment does

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[163] The *descriptive* statement that humans are not geological forces, but rather geological agents, should not be confused with the *normative* 'No-Problem View' (Leinfelder, 2013) – that is, the stance that "[h]uman behavior is irrelevant because natural processes such as volcanoes and weather patterns are claimed to be stronger than any of the effects that human industry might have" (p. 17). This view has been overwhelmingly considered detrimental to social environmental responsibility, and thus reject by scientific as well as humanistic scholarship.
[164] This mental experiment is discussed thoroughly in section 5.2.1.
[165] Synchronicity (i.e., the approximate same age of a stratigraphic unit) is a requirement for determining a new chronostratigraphic unit by using a Global Boundary Stratotype Section and Point (GSSP; see section 3.1.2.6).

not ask whether a future geologist will consider *Homo sapiens* as a geological force.[166] Rather, it asks whether or not it is possible and plausible for a future observer to recognize a discrete and unique 'Human Stratum.'

One last note concerning SC may be due. The idea that humans may leave a stratigraphic footprint is also not completely new in geological literature. In the 19th century, geologists already used archaeological records as evidence for the latest strata of geological time (although they operated within a substantially different framework than present geological research). For instance, beer bottles and cans had been used by the American geologist Charles Butler Hunt (1906–1997) to date sediments in Western North American mining camps during the 1950s (his 1959 geology text goes by the title *Dating of Mining Camps with Tin Cans and Bottles*). As recalled by Ager (1973), a humorous French classification of the upper Holocene distinguished between an Upper Dustbinian (with plastic) and a Lower Dustbinian (without plastic).[167] Anthropogenic material constitutes a substantial portion of the evidence supporting the Anthropocene Hypothesis. This evidence builds a case for official recognition of the Anthropocene as a geochronological and chronostratigraphic time unit. It also delineates the epistemological profile of the Anthropocene Hypothesis – further corroborating the conceptual separation between the 'Anthropocene' and the Anthropocene Hypothesis. Additionally, new and 'unorthodox' evidence – that is, evidence of a very recent and unprecedented nature, such as new anthropogenic minerals – has been provided by members of or researchers affiliated with the AWG, evidence whose epistemology has been criticized both by humanists and scientists. This aspect too further corroborates the claim that the Anthropocene Hypothesis constitutes an object of interest for the philosophy of science, specifically the philosophy of geology.

The distinction between GC and SC is important in framing the purpose of the Anthropocene Hypothesis. The hypothesis does not seek to describe or explain whether or not *Homo sapiens* has become a geological force or agent, but rather if our species has left discernible and substantial stratigraphic evidence to locate the beginning of a new unit of geologic time. This is an important theoretical postulate to keep in mind when assessing the evidence gathered in support of the hypothesis.

3.1.2 Context and Evidence

The Anthropocene Hypothesis bases on a body of evidence defined within a certain disciplinary context. This epistemic context is represented by geochronology and stratigraphy. Like any other disciplinary domain, this context is characterized by rules, methods, and objects of research that, besides differentiating it from other epistemic contexts within and outside the natural sciences, also set the standards or 'paradigm' (Kuhn, 2012) for extant research. In the stratigraphic community, these standards are generally embodied

[166] If *Homo sapiens* will be extinct by the time of a future hypothetical observer, it will be unlikely that the observer will recognize our species as a geological force – given the definition and examples of geological forces previously outlined in the section. This does not imply that a future geologist will not detect any stratigraphic signals associated with *Homo sapiens*.

[167] In French, 'Poubellien supérieur (á plastique),' and 'Poubellien inférieur (sans plastique).'

by the *International Stratigraphic Guide* (ISG, or simply *Guide*), which functions as an international reference framework for stratigraphic classification, terminology, and procedures.

The first edition of the *Guide* was published in 1976 by the former International Subcommission on Stratigraphic Terminology (ISST, now the International Subcommission on Stratigraphic Classification, ISSC), and edited by the American geologist Hollis Dow Hedberg (1903–1988), a key figure in promoting a unified framework for international stratigraphy. A second edition edited by Amos Salvador (1923–2007) was published in 1994, including new sections and further strengthening the terminological and procedural framework. The principles provided in the *Guide* are implemented by the ICS and the IUGS, of which the ISSC is part of. As part of the ICS, the AWG adheres, among other things, to the guidelines advanced in the *Guide* to propose the ratification of a geologic time unit in the Geologic Time Scale. The goal of the *Guide* is briefly highlighted in its Chapter 1, section D:

> The Subcommission [on Stratigraphic Classification] offers its *International Stratigraphic Guide* as a recommended approach to stratigraphic classification, terminology, and procedure – not as a "code." Individuals, organizations, or nations should not feel compelled to follow it, or any part of it, unless convinced of its logic and value. Stratigraphic classification, terminology, and procedure should not be legislated. Real and lasting progress will be achieved only as geoscientists voluntarily agree on the validity and desirability of certain principles, procedures, and terms. The purpose of the *Guide* is to inform, to suggest, and to recommend; it must continually evolve in keeping with the growth of geologic knowledge. (Salvador, 1994, p. 4)

The *Guide* does not constitute a binding protocol, but is rather the outcome of long-sought efforts to create a coherent and consistent set of guidelines across geological communities worldwide. Because of its central role in creating a shared epistemology of stratigraphic research, the *Guide* (and its abridged version, Murphy & Salvador, 2000[168]) is hereby used as a first major source to investigate the epistemic context of the Anthropocene Hypothesis. Additionally, the definitions and principles stressed by the Guide have often been implemented both by supporters (Zalasiewicz et al., 2019b) and critics (e.g., Gibbard & Walker, 2014) of the hypothesis – corroborating the central epistemological function played by the *Guide*.

Alternative, nationally based guidelines exist among other scientific communities and nations. An example is the North American Commission on Stratigraphic Nomenclature (NACSN) – a second source used here to investigate the epistemology of the Anthropocene Hypothesis. Founded in 1946 (originally as the American Commission on Stratigraphic Nomenclature, renamed in 1978), the organization has adopted a Code (last revised in 2005) to promote terminological, classificatory, and procedural consistency specifically among North American geologists and stratigraphers. While generally consistent with the guidelines set by the *Guide*, the Code maintains some terminological differences, such as the use of the term 'geosol' in pedostratigraphy, the designation 'allostratigraphic unit' instead of 'synthem' in allostratigraphy (see note 27), or the naming of the Carboniferous Subsystems. The 2005 Code clearly states that a "guiding

[168] The abridged version of the 1994 *Guide*, edited by Michael Murphy and Amos Salvador, was published in 2000 to compensate for the lack of the *Guide*'s accessibility *Guide* for students and scholars internationally. It does not revise the original 1994 *Guide*, but only trims the text down to 36 pages.

principle in preparing this Code has been to make it as consistent as possible with the International Guide [i.e., the *Guide*], and at the same time to foster further innovations to meet the expanding and changing needs of earth scientists on the North American continent" (NACSN, 2005, p. 1556). Hence, while terminology, research methods, practices, and rules may differ among geologists and stratigraphers based on local customs and traditions, the fundamental principles and methods of geochronology and stratigraphy are embodied by the *Guide*.

The *Guide* and the Code represent two sources from which to derive the methodological context of the Anthropocene Hypothesis. A third major source used in this chapter is the AWG's (Zalasiewicz et al., 2019b) latest and most comprehensive monograph, *The Anthropocene as a Geological Time Unit*. This source summarizes a decade of work specifically oriented around the question of whether or not the Anthropocene could be recognized as a time unit. The monograph provides the very empirical backbone of the hypothesis, encompassing literature exploring the stratigraphic significance of human activities. Rather than a conclusive effort, the work represents preparation for a formal proposal to the SQS, the ICS, and finally to the IUGS. The work outlines the stratigraphic basis of an Anthropocene unit as currently (viz. March 2021) upheld by the vast majority of the AWG, *de facto* expressing the Anthropocene Hypothesis as a stratigraphic hypothesis.

But what does it mean for the Anthropocene Hypothesis to represent a *stratigraphic* hypothesis? Answering this question requires probing into the methods and purpose of stratigraphic research.

The *Guide* defines stratigraphy as the "descriptive science of rock strata" and "rock bodies forming the Earth's crust and their organization into distinctive, useful, mappable units based on their inherent properties or attributes" (Salvador, 1994, p. 13). Stratigraphy is crucial not simply for describing, classifying, naming, and correlating rock units across the globe, but also for providing base material for reconstructing the Earth's history by dividing it into meaningful taxonomical units (Figure 3.1).

A central idea in stratigraphic research is the concept of the 'stratigraphic unit.' Stratigraphic units represent bodies of rocks with distinct recognizable properties (e.g., color, texture, age, fossil presence, position, residual magnetism, etc.) used for classification of the Earth's rocks. Each stratigraphic unit is characterized by a set of unique properties that distinguishes it from others, and that allows correlation among synchronous but geographically distant sedimentary strata (i.e., strata of the same age may occur at distant locations as they were transported by action of plate tectonics). This uniqueness is due to the specific physical, biological, chemical, fossiliferous, or other properties that distinguish that unit. Multiple types of properties can be observed in a rock or strata, and based on which property is observed, a corresponding type of stratigraphic classification is used. For instance, lithological properties define and characterize lithostratigraphic units, biological properties define and characterize biostratigraphic units, and time-based properties define and characterize chronostratigraphic and geochronological (*sensu stricto*) units. Stratigraphic classification encompasses this diversified spectrum of material properties used to classify rocks and, together with radiometric dating techniques, to reconstruct geological time through meaningful time units.

I. MATERIAL CATEGORIES BASED ON CONTENT OR PHYSICAL LIMITS

LITHOSTRATIRGAPHIC	LITHODEMIC	MAGNETOPOLARITY	BIOSTRATIGRAPHIC	PEDOGRAPHIC	ALLOSTRATIGRAPHIC
Supergroup	Supersuite				
Group	Suite	Polarity Superzone			Allogroup
Formation	*Lithodeme*	*Polarity Zone*	*Biozone*	*Geosol*	*Alloformation*
Member		Polarity Subzone	Subbiozone		Allomember
Bed(s) or Flow(s)					

IIA. MATERIAL CATEGORIES USED TO DEFINE TEMPORAL SPANS

CHRONOSTRATIRGAPHIC	POLARITY CHRONOSTRATIGRAPHIC
Eonothem	Polarity Superchronozone
Erathem	
System	*Polarity Chronozone*
Series	
Stage	Polarity Subchronozone
Chronozone	

IIB. NON-MATERIAL CATEGORIES RELATED TO GEOLOGIC AGE

GEO-CHRONOLOGIC	POLARITY CHRONOLOGIC	DIACHRONIC	GEO-CHRONOMETRIC
Eon	Polarty Superchron		Eon
Era			Era
Period	*Polarity Chron*	*Episode*	*Period*
Epoch		Phase	Epoch
Age	Polarity Subchron	Span	Age
Chron		Cline	Chron

Figure 3.1. Types of stratigraphic classification listed by the NACSN Code. Table I shows all types of material-based stratigraphic units. Table IIA lists material, time-based units (polarity chronostratigraphic units are chronozones based on magnetic polarity). Table IIB illustrates non-material geochronological units. Units in IIB are not stratigraphic units, because only material units are part of stratigraphic classification. Italicized units are fundamental units according to the Code. The units listed by the Code have minor differences from the stratigraphic categories listed by the *Guide* (see Murphy & Salvador, 2000, p. 10, Table 1). (Readapted from the original source: NACSN, 2005)

Key concepts in stratigraphic classifications are those of *stratotype* (or *type section*) and *type locality*. A stratotype is a specific interval or point in a layered outcrop functioning as a standard for defining and characterizing a given stratigraphic unit. A type locality is the geographical locality of a stratigraphic unit (generally unlayered) or rock where that unit or rock was first identified, and that represents a standard of reference (e.g., Icelandite, a type of volcanic rock first found in Iceland). Stratotypes may be defined on a given boundary between two distinct stratigraphic units, in which case a *boundary-stratotype* is adopted as a standard of reference. The concept of boundary-stratotype – that is, a "specified sequence of rock strata in which a specific point is selected that serves as the standard for definition and recognition of a stratigraphic boundary" (p. 26) – is an important component in understanding chronostratigraphic units, and thus the GSSP method adopted by the AWG in locating the beginning of the Anthropocene. This aspect is discussed in section 3.1.2.6.

The Anthropocene Hypothesis argues that human activities are leaving (and have already left) a discernible stratigraphic signature in rocks. This signature can be represented as a discrete stratigraphic unit based on the unique properties these rocks exhibit. These properties differ substantially from the stratigraphic profile of the Holocene (Waters et al., 2016), suggesting that the Anthropocene is a stratigraphically distinct unit of time – thus the reason the hypothesis is *stratigraphic*.

To claim that the Anthropocene could be recognized as a discrete geologic time unit means that it could represent a *geochronological* and *chronostratigraphic* unit on the geological time scale. The *Guide* defines geochronology as "[t]he science of dating and determining the time sequence of events in the history of the Earth" (Salvador, 1994, p. 16), whereas chronostratigraphy is the discipline concerned with the study of the time of formation of rocks. Whilst the term 'geochronology' has only been used since around 1893 (Reiners et al., 2018, p. ix), systematic attempts to order and reconstruct time based on fossils, archaeological data, or rock layers can be traced at least as far back as the 17th century, when the Danish scientist and bishop Niels Steensen (commonly known as Nicolas Steno) delineated four fundamental principles (or laws) of stratigraphy.[169] For the most part, geochronological and chronostratigraphic dating had been *relative*, meaning that it assigned a sequential order to events based on rock or fossil records without necessarily providing a corresponding numerical date.[170] Critical theoretical and experimental developments during the 20th century allowed measurements of the absolute age of rocks with different degrees of precision and accuracy. Many of the already existing geological time units (most of British coinage) were gradually assembled and coherently unified in a geological time scale, providing an increasingly thorough description and hierarchical classification of the Earth's approximately 4.54 billion-year history (Dalrymple, 2001).

Hence, the Earth's history has been divided into chronostratigraphic and geochronological units dividing geological time in a meaningful and useful way. By arguing that a new division of time could be located in the Earth's most recent history (one determined by the stratigraphic footprint of *Homo sapiens*), the Anthropocene Hypothesis establishes itself as a *geochronological* and *chronostratigraphic* hypothesis.

[169] The four laws are those of superposition, original horizontality, cross-cutting relationships, and lateral continuity.

[170] Relative dating is still a useful and common practice in geology, especially in fieldwork. Most stratigraphic units are not *directly* defined by their numerical ages, but only by the specific physical, chemical, or fossil properties that characterize their boundaries. Absolute dating techniques (e.g., radioisotope dating) are only later applied to provide numerical dates to stratigraphic units.

1. **Definition, Characterization, and Description**
    a. Name
    b. Stratotypes and Other Standards of Reference
    c. Description of Unit at Stratotype or Type Locality
    d. Regional Aspects
    e. Geologic Age
    f. Correlation with Other Units
    g. Genesis
    h. References to the Literature
2. **Special Requirements for Establishing Subsurface Units**
    a. Designation of Well or Mine
    b. Geologic Logs
    c. Geophysical Logs and Profiles
    d. Depositories
3. **Naming of Stratigraphic Units**
    a. Geographic Component of Names of Stratigraphic Units
        I. Source
        II. Spelling of Geographic Names
        III. Changes in Geographic Names
        IV. Inappropriate Geographic Names
        V. Duplication of Geographic Names
        VI. Names of Subdivisions of Stratigraphic Units
    b. Unit-term Component of Names of Stratigraphic Units
    c. Relation of Names to Political Boundaries
    d. Reduction in Number of Names through Correlation
    e. Uncertainty in Assignment
    f. Abandoned Names
    g. Preservation of Traditional and Well-Established Names
4. **Publication**
    a. A Recognized Scientific Medium
    b. Priority
    c. Recommended Editorial Procedures
        I. Capitalization
        II. Hyphenation
        III. Repetition of Complete Name
5. **Revision or Redefinition of Previously Established Stratigraphic Units**

Figure 3.2. List of requirements for accepting the proposal of a new stratigraphic unit according to the *Guide* (based on Salvador, 1994).

If the Anthropocene does possess a distinct stratigraphic profile – as the AWG has been arguing (Waters et al., 2016; Waters et al., 2014a; Zalasiewicz et al., 2019b; Zalasiewicz et al., 2011a; Zalasiewicz et al., 2014c) – and if its stratigraphic signature is considered geologically important, then a case for its official recognition as a discrete geochronological/chronostratigraphic unit can be made. A formal proposal for official recognition of a unit can be forwarded by the unit-specific working group to their respective higher institutional bodies (in the case of the Anthropocene Hypothesis, the SQS), up to the ICS, and finally to the IUGS. The *Guide* highlights necessary steps to submit a formal proposal (summarized in figure 3.2). They cover several aspects of the proposal, from defining and characterizing a unit through the naming protocol, to the publication procedure advised (including editorial procedure). In principle, these guidelines apply to all types of proposed stratigraphic units – thus including an Anthropocene unit.

Requirements in (1) cover the definition, characterization, and description of the proposed unit. Murphy and Salvador (2000, p. 235) also provide functional definitions of the verbs 'to define' (to set "limits or boundaries to units in the classification," ibid.), 'to characterize' ("to state what is unique, thus, a characterization of a stratigraphic unit specifies its unique attributes or unique combination of attributes," ibid.), and 'to describe' ("to summarize the total content and relationships of the unit of the classification," ibid.). Defining, characterizing, and describing a new stratigraphic unit "should include a clear account of its boundaries, diagnostic properties, and attributes" (Salvador, 1994, p. 17). This should also include a name (consistent with the requirements in (3)), a designated type section or type locality, the complete stratigraphic properties of the unit, correlation with other units, and more. The same guidelines established in (1) apply as well to subsurface units (i.e., units not exposed in an outcrop), which are less common than outcrop sections.

Requirements in (3) concern the naming protocol for a proposed unit. This is an especially important point since, as previously stressed, the terminological choice of 'Anthropocene' has been contested by many, especially historians.[171] Usually, names of formal stratigraphic units should follow geographic designations followed by their respective kind and rank – e.g., the Permian System represents a succession of rocks named (by Roderick Murchison in 1841) after their region, Perm, in Russia. The naming protocol varies across the types of stratigraphic properties considered (e.g., lithostratigraphic, biostratigraphic, etc.). Some chronostratigraphic units do not follow the geographical clause, and preserve long-established names (e.g., Quaternary Period, originally coined by the Italian geologist Giovanni Arduino in 1759; see Gibbard & Walker, 2013). Notably, requirement 3g provides ground rules for the preservation of traditional and well-established names for stratigraphic units. The requirement states:

> Although it is strongly urged that all new stratigraphic units be named according to the recommendations of this *Guide*, it is realized that there are many well-established and traditionally used stratigraphic units, particularly lithostratigraphic units, of long historical standing for which exception should be made […] Such units should not be abandoned merely because they lack geographic names. Tolerance and flexibility are advised. (Salvador, 1994, pp. 22-23)

A 'conservative' understanding of this passage seems to suggest that this exception should only be allowed exclusively for well-established and official units with "long historical standing" – for instance, the Millstone Grit Group (also used as an example by the *Guide*), a lithological unit of the Carboniferous Period deriving its name from stones used in watermills rather than from a locality. Such units were established prior to the existence of international standards for stratigraphic nomenclature and classification, and their widespread recognition and use make terminological consistency superfluous. However, if the 'Anthropocene' term is to be considered well-established (as both critics and advocates agree) in terms of reception across the

[171] See sections 1.2.3 and 5.1.3.

geological (and broader scientific) literature, then the geographic designation may not represent a major violation of terminological praxis – as otherwise observed by some critics (LeCain, 2015; Scourse, 2016; Suckling, 2014; Walker et al., 2015). Ultimately, the degree of tolerance and flexibility toward the naming of a proposed unit is decided within the geological community based on the usefulness and meaning of the proposed unit (in addition to other epistemic and social determinants).

Requirements in (4) concern the 'sociological' aspects of proposing a time/rock unit – namely, the publication of a proposal in a recognized scientific medium, publication priority, and further editorial recommendations. Interestingly, the principle of priority outlined in 4b stresses that "[p]riority alone does not justify displacing a well-established name by one not well known or only occasionally used; nor should an inadequately established name be preserved merely on account of priority" (p. 23). This guideline may be useful in attributing a 'priority principle' to the 'Anthropocene' term against the array of terminological alternatives proposed by humanistic scholarship (assuming the term to be more popular than other variants across the scientific community). At the same time, 4b also ensures that terminological alternatives (consistent with the naming procedures set by the *Guide*) to the 'Anthropocene' may ultimately be adopted. This is an eventuality neither excluded nor rejected by the AWG.

Lastly, requirement (5) provides guidelines for revisions or redefinition of previously established units. Once ratified – a process requiring the approval of the specific working group, Subcommission, ICS, and lastly IUGS – the chosen boundary (i.e., beginning) of the proposed unit cannot be modified for at least ten years (Zalasiewicz et al., 2019b).

The guidelines offered by the *Guide* provide a starting point for understanding the requirements and procedure of the AWG in assessing in what terms an Anthropocene stratigraphic unit should be characterized – that is, if there are significant markers that make the Anthropocene a substantially different stratigraphic unit from the Holocene (or the Meghalayan, if its proposal is demoted from epoch/series to age/stage[172]); and *how* it should be characterized (i.e., its hierarchical level, its primary and secondary markers, its beginning, etc.). They also afford insight into the epistemological ground wherein the Anthropocene Hypothesis is located. But what does *characterize* the Anthropocene? What boundary *defines* it? What evidence *describes* it?

A range of scientific evidence has been gathered since the AWG began its operations (mostly unfunded) in 2009. This evidence ranges from evolutionary biology and ecology to Earth System science and geology. However, the primary evidence informing the Anthropocene Hypothesis is represented by stratigraphic evidence, embodied (in simplified terms) by core samples extracted by scientific research teams from several paleoenvironmental archives in several sites around the world, such as speleothems, ice, marine or freshwater anoxic basins, saline or cold lakes, delta or estuarine sediments, peat mires, and more (Zalasiewicz et al., 2019b, para 7.8.4). This type of evidence is based on observable properties of rocks (either sedimentary, igneous, or metamorphic) and strata, which include lithostratigraphy,

[172] As also shared by other members of the AWG, it is unlikely that the Anthropocene can see higher hierarchical recognition than the level of epoch/series.

magnetostratigraphy, pedostratigraphy, biostratigraphy, or chemostratigraphy, combined with chronostratigraphy (see figure 3.1). Each of these represents specific properties of stratigraphic significance used to characterize and define stratigraphic units. If the Anthropocene is to be recognized as a geological unit distinct from the Holocene, substantial evidence of its unique stratigraphic profile must be provided to justify its recognition as a geochronological/chronostratigraphic unit on the geological time scale. Thus, the following sections overview the stratigraphic evidence that the AWG has gathered so far by tackling each of these types of stratigraphic evidence.[173] It will be illustrated that, across the spectrum of anthropogenic markers for an Anthropocene unit, geochemical markers such as $\delta^{13}C$ or radionuclides (e.g., plutonium-239, carbon-14, caesium-137) associated to nuclear and thermonuclear bomb testing around the 1950s are the most resolved, widespread, and correlatable signals across core samples analyzed (Waters et al., 2018).[174]

3.1.2.1 Lithostratigraphic Evidence

Lithostratigraphy is the "element of stratigraphy that deals with the description and systematic organization of the rocks of the Earth's crust into distinctive named units based on the *lithologic* [emphasis added] character of the rocks and their stratigraphic relations" (Salvador, 1994, p. 31). Lithology is the description of the visible physical properties of rocks in an outcrop, such as color, grain, fabric, or texture. A lithostratigraphic unit is "[a] body of rocks that is defined and recognized on the basis of its observable and distinctive lithologic properties or combination of lithological properties and its stratigraphic relations" (p. 32). Lithostratigraphic units are temporally diachronous, meaning that they are defined exclusively based on their physical properties and "not by their inferred age, the time span they represent, inferred geologic history, or manner of formation" (ibid.). The hierarchical subdivision of formal lithostratigraphic units (from lowest to highest) consists of flow (used for volcanic units), bed, member, formation, and group.[175] Other terms may be used for igneous and metamorphic rocks (e.g., 'schist,' 'granite,' 'complex') due to the non-layered nature of these. The primary formal unit of lithostratigraphy used for geological mapping is the *formation*. Formations are the only formal units (with groups, which constitute two or more formations) represented in stratigraphic columns – that is, stratigraphic representations of geographical areas based on the vertical succession of rock sequences. Formations may vary from less than a meter to kilometers in thickness, and their formal recognition varies depending on the geological complexity and specificity of a region.

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173 The AWG (Syvitski et al., 2020) has also provided a list of sixteen examples focusing on anthropogenic energy consumption since ~1950 of significance from an Earth System perspective. Some of the examples overlap with stratigraphic evidence. However, as stated at the beginning of the chapter, the relationship between Earth System evidence and stratigraphic evidence is not directly discussed in the present chapter.

174 $\delta^{13}C$ expresses the ratio between the stable isotopes ^{13}C and ^{12}C reported in parts per thousand. It is an isotopic signature widely used in archeology, paleontology, and paleoecology.

175 Lithostratigraphic units are capitalized when associated with their respective designations, for example, Toroweap Formation or Supai Group.

There are several requirements for the establishment of lithostratigraphic units. One is the possibility of grounding a geological map of the region the unit seeks to describe – that is, it must cover a significant portion of the area laterally. Lithostratigraphic units should also conform to the law of superimposition (in a succession of undisturbed strata, younger layers or rocks lie on older layers or rocks) and the principle of lateral continuity (layers extend horizontally in all directions, all things being equal) – both additional methodological requirements for proposing lithological units (Ford et al., 2014). Like other stratigraphic units, a designated lithostratigraphic unit must be based on its respective type section (i.e., stratotypes) or type locality (Figure 3.2, req. 1b). The stratotype should also be accessible, clearly visible, and preservable through time. If a single type section is not available (for instance, in the case of non-layered rocks), locality or a 'complex'[176] may provide the stratotype for a lithostratigraphic unit. Units that do not surface in an outcrop are designated based on their lower and upper boundaries.

Studies on the physical characteristics of anthropogenic rocks and strata[177] have been conducted extensively in the past decades, and they inform much of the empirical basis of the Anthropocene Hypothesis. Zalasiewicz et al. (2011a) note that two main processes comprise anthropogenic modification of sedimentary patterns – namely, the modification of natural sediment patterns by damming, agriculture, trawling, or the modification of rivers and coastlines; and the creation of novel strata or novel sedimentary environments especially through built environments (e.g., construction of cities, excavation, transportation of geological material), where modified or new geological material forms layers up to several meters in depth and extends for as much as 90 km^2 (as documented for the English West Midlands or 'Black Country,' a mining center active throughout and after the Industrial Revolution). Whilst the built environment is mostly characteristic of terrestrial land, coastal zones and sea floor associated with oil platforms (and spills) or fluvial waste discharge also comprise distinct anthropogenic deposits.

Metal-enriched sediments and other anthropogenic sediments "from the Industrial Revolution onwards is a recurrent observation along […] industrialized areas of the world" (Irabien et al., 2015, p. 203), as suggested by a study on the chemostratigraphic and lithostratigraphic signatures of the Anthropocene on the eastern Cantabrian coast in northeastern Spain. A study by Wilkinson (2005) on the denudation[178] rate of natural processes in geological time compared to human-induced erosion of soils (from construction and agricultural practices) suggests that "human activity is many times the most important geomorphic agent acting on the surface of the modern Earth" (p. 163). This research seems further corroborated by a study from Douglas and Lawson (2001) showing how the deliberate anthropogenic flow of material (57,548 megatons/year in 1995) exceeds the natural material transport to the world's ocean by rivers (~22,000 Mt/year) by a factor of almost three. Like Wilkinson, the authors conclude that human activity "is the most

[176] A complex is defined as a "lithostratigraphic unit composed of diverse types of any class or classes or rocks (sedimentary, igneous, metamorphic) and characterized by irregularly mixed lithology or by highly complicated structural relations" (Murphy & Salvador, 2000, p. 242).

[177] Strata (plural of *stratum*) are layers of rocks distinguished by their lithologic properties. They are usually visible to the naked eye as horizontal sequences of layers of different colors and widths. Other properties, such as fossil remains or remanent magnetism, can be detected in strata.

[178] Denudation is the processes of reduction of the topographical relief or 'flattening' of the Earth's surface by the action of geological forces – for instance, by weathering or erosion through waves or wind.

efficient geological agent on the earth at present" (p. 24).[179] A third study of interest by Hooke and Martín-Duque (2012) stresses the extent of humans' land transformation, which the authors estimate to surpass 50% of the Earth's total land surface distributed unevenly between urban areas, industrial complexes, agricultural land, pasture, and other parameters of human activity.

Yet numerical expressions of humans' overwhelming presence and agency on the planet do not necessarily translate into a discrete lithostratigraphic unit. Specific and clearly recognizable anthropogenic rocks need to be identified as possible anthropogenic rock types for lithostratigraphic classification. The AWG (Zalasiewicz et al., 2019b, para. 2.1-2.6) has found in mineralogical research a step toward the characterization, definition, and description of anthropogenic rock types. Minerals are defined as naturally occurring elements or compounds with discernible internal structure and chemical characteristics. Aggregates of one or more minerals[180] compose rocks – the essential working unit of petrology and a structural component of geology and stratigraphy. A study by Hazen et al. (2008) divides the history of the Earth into ten stages based on the evolution and accretion of mineral species, grouped into three eras: the era of planetary accretion (4.56–4.55 Ga), the era of crust and mantle reworking (4.55 Ga to 2.5 Ga), and the era of bio-mediated mineralogy (2.5 Ga to present). According to the authors, while physical and chemical processes determined, respectively, the first and second eras of mineral evolution, the shift in the third and current era was determined by biologically induced mineral diversification mostly by atmospheric oxygenation through cyanobacteria photosynthesis – a process beginning at least in the Paleoproterozoic Era (2.5–1.6 Ga). The tenth and last stage of mineral evolution (< 0.542 Ga) is characterized by Phanerozoic mineralization, "when biology came to dominate the mineralogical diversification of Earth's surface" (p. 1709).

Hazen et al. (2017), Zalasiewicz et al. (2014a), and Zalasiewicz et al. (2019b, 2.1)[181] have advanced that a fourth new era or eleventh phase could be designated as "a time when mineral diversity is experiencing a punctuation event owing to the pervasive near-surface effects of human industrial society" (Hazen et al., 2017, p. 595). Three features of stratigraphic (and particularly lithostratigraphic) importance can be derived from this new mineralogical era/phase.

First, there is "the widespread occurrence of synthetic mineral-like materials" (p. 606), characterized by the production of approximately 180,000 inorganic crystalline (orderly structured) compounds – an event with unprecedented pace and scale in the entire solar system, vastly outweighing the biologically mediated rise of minerals during the Great Oxygenation Event (taking the total to approximately 5,700 minerals). These synthetic compounds are most pervasive in the built environment, and provide the basis for anthropogenic rock types of widespread spatial ramification such as concrete (cement), bricks, ceramics, or asphalt/bitumen (Zalasiewicz et al., 2019b).

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[179] Interesting to note is the wording used by Wilkinson as well as Douglas and Lawson to address humans as geological *agents* rather than *forces*, as suggested in section 3.1.1.

[180] As of July 2021, around 5,721 types of minerals have so far been recognized (see http://cnmnc.main.jp/IMA_Master_List_(2021-07).pdf, accessed on September 20, 2021), with as many as 50 new types introduced every year (Hazen et al., 2008).

[181] See also Essefi (2020) for further mineralogical research and additional evidence from geochemistry.

A second feature is represented by human bioturbation. Bioturbation is the disturbance of strata (mostly by burrowing) by living organisms. It is documented throughout the Phanerozoic Eon, and constitutes the primary marker for the Cambrian (and Phanerozoic) GSSP – represented by the burrowing of *Treptichnus pedum* in a stratotype at Fortune Head, Newfoundland, Canada. Researchers (Zalasiewicz et al., 2014b) have noted the unparalleled degree of bioturbation caused by humans, generally associated with mining, drilling, boreholes, or construction of subsurface storage facilities. These activities affect surface, shallow, and deep strata – the last being less exposed to erosion and weathering and thus "permanent on geological timescales" (p. 5).

Lastly, a third feature concerns human-mediated, global-scale redistribution of minerals. Anthropogenic actions have not simply created new mineral-like compounds, but also rearranged and redistributed naturally produced minerals in a way comparable to the action of natural forces.[182] This global redistribution of minerals is intrinsically linked to human modes of existence, such as the use of precious metals and stones, collections of mineral archives in museums, and other cultural, social, and industrial uses of minerals across human societies. The very collections housed in museums represent unique combinations of minerals that would not occur naturally and are thus in themselves culturally mediated assemblages of potential stratigraphic value.

It is not a matter of conducting field research to retrieve anthropogenic deposits – widely documented across terrestrial, coastal, and maritime land – in order to characterize an Anthropogene lithostratigraphic type-unit. As seen, anthropogenic deposits or human-mediated mineral-like compounds are widely scattered on the planet's surface. The more problematic issue is adhering to the formalisms of lithostratigraphic and mineralogical recognition. The International Mineralogical Association (IMA) Commission on New Minerals and Mineral Names (CNMMN) has defined 'mineral' as "an element or chemical compound that is normally crystalline and that has been formed as a result of geological processes" (Nickel, 1995, p. 689). The CNMMN has also considered anthropogenic substances or "synthetic equivalents" as "those produced by Man, and are not regarded as minerals" (p. 690). As of 2017, 208 types of human-mediated minerals with principally or exclusively anthropogenic origins have been approved (Hazen et al., 2017). These anthropogenic minerals (e.g., Laurium) were formed by the action of geological processes on anthropogenic substances. However, with the scarcely countable multitude of anthropogenic substances possibly interacting with geological processes and forming new mineral-like compounds, the CNMMN decreed that no future chemical compounds of the kind will be considered as minerals (while still retaining the mineral status of previous human-mediated minerals). Hence, the great majority of newly produced anthropogenic mineral-like compounds are not officially recognized by the IMA, and are likely not to fall under the extant regulations.

This formal blockade generates a dilemma: that is, whether or not a change in characterization of minerals should be promoted. On the one side, one could consider whether the IMA classification and

[182] This comparison has led researchers to often compare humans to geological forces, as previously discussed in section 3.1.1.

taxonomical schemes should undergo structural or partial changes to accommodate the extent of mineral-like compounds and human-mediated compounds of anthropogenic origin – most sharing properties with, and having longevity equal to, naturally occurring minerals. On the other side, it may be simply sufficient to consider mineralogical markers as auxiliary evidence for the Anthropocene Hypothesis, without requesting their consideration as the basis for a discrete Anthropocene lithostratigraphic unit. An effort in the first direction has been conducted by Hazen et al. (2017) by providing an interpretative and prototypical taxonomy of human-mediated mineral-like compounds divided into anthropogenic compounds that are either indirectly produced or directly synthetized for industrial purposes. Interestingly, this division implements *intentionality* as a demarcation criterion between human-mediated mineral-like compounds – an unusual (and philosophically dense) epistemic parameter when seen in the context of traditional stratigraphic classification.

The implicit demarcation postulated by the IMA between naturally occurring geological processes and human activities is philosophically interesting. As seen, this separation serves to discern minerals from human-mediated mineral-like compounds. If humans have truly become a major geological and biogeochemical agent in the functioning of the Earth System, then this epistemic division seems epistemically unwarranted. However, on a more practical level, the inclusion of anthropogenic 'minerals' would require a substantial revision and restructuring that would not be restricted to extant organizational schemes (taxonomy and classification), but would extend also to include the whole body of mineralogy (and adjacent disciplines), from textbooks to methods of research. In Kuhnian terms, it would consist of a paradigm shift. If sciences exhibit conservative responses toward structural changes, as Kuhn has noted, then 'negotiating' human-mediated 'minerals' for a structural disciplinary revision is perhaps not a bargain most scientists would be willing to take. Maintaining the human/nature divide is a practical choice, more than a strictly ontological and epistemological statement about the role and agency of *Homo sapiens*.

This mineralogical issue is related to lithostratigraphy as well. This is because minerals form the basic 'elements' of rocks and strata, and characterize many of the lithological properties used to define lithological units. Consequently, researchers (Edgeworth et al., 2015; Ford et al., 2014) have noted that traditional standards and taxonomies in lithostratigraphy may no longer be capable of translating the level of anthropogenic deposits that have been sedimenting and layering across the Earth into lithostratigraphic units. An epistemic revision is required to accommodate the lithostratigraphic novelty characterizing the Anthropocene. For instance, Ford et al. (2014) argue that "the stratigraphy of such deposits [anthropogenic deposits of a lithological character] is not readily described by existing classification schemes, which do not differentiate separate phases or lithologically distinct deposits beyond a local scale" (p. 55). The request for the formalization of such classification schemes may encourage future research to dissolve the human/nature boundary in mineralogical, and thereafter lithostratigraphic, classification.

In addition to the difficulties related to the nature of lithostratigraphic anthropogenic units, current lithostratigraphic hierarchies (group, formation, member, bed, flow) do not accommodate anthropogenic deposits. This is because anthropogenic deposits are characterized by an array of different lithological properties (often concentrated in the same deposit) that do not generally seem to match the language and method of lithostratigraphic classification – mostly because of the novelty of implementing a lithostratigraphic approach to anthropogenic sediments. Hence, Edgeworth et al. (2015) consider it necessary that "the archaeosphere should be recognized as a single lithostratigraphic unit (made up of multiple smaller units)" (p. 22). Similarly, Ford et al. (2014) consider it either "necessary to argue that lithostratigraphy needs to evolve as a classification scheme to consider the unique circumstances of artificial deposits, not currently considered in any scheme, or it be argued that lithostratigraphic definitions are fixed and cannot be modified to incorporate the vagaries of man-made stratigraphy" (Ford et al., 2014, p. 81).

Although anthropogenic deposits seem to satisfy to different degrees the various lithostratigraphic criteria set by the geological community, recognition of anthropogenic sediments in traditional taxonomies (either stratigraphy or mineralogy) is ultimately a decision to be taken by the appropriate scientific bodies, and thus by scientific communities.[183] Furthermore, the lithological and lithostratigraphic properties of anthropogenic deposits seem to suggest a diachronous onset of the Anthropocene – one defying a chronostratigraphic-based definition of the epoch (Edgeworth et al., 2019).[184]

3.1.2.2 Magnetostratigraphic Evidence

Magnetostratigraphy is the "element of stratigraphy that deals with the magnetic characteristics of rock bodies" (Salvador, 1994, p. 70). Due to their magnetic mineral compositions, some rocks have measurable magnetic properties. The most common property in stratigraphic research is "the change in the direction of the remanent magnetization of the rocks, caused by reversals in the polarity of the Earth's magnetic field" (p. 69). The natural remanent magnetization (NRM) of rocks represents the 'trace' left by the geomagnetic field at the time of their formation, and can be used to determine the history of the Earth's axial dipole magnetic field in terms of direction and intensity as well as the movements of rocks across tectonic plates (and thus their place of origin). Types of NRM are thermoremanent magnetization (acquired during the cooling of magnetic minerals below Curie temperature, the threshold value of 570°C above which materials lose their permanent magnetic properties), chemical remanent magnetization (acquired by ferromagnetic minerals through chemical processes under certain conditions), viscous remanent magnetization (acquired by long exposure to a magnetic field, generally the geomagnetic field), and primary or characteristic remanent magnetization (acquired naturally during the formation of the rock).[185] Since types of NRM may overprint or be superimposed over the history of a rock's magnetism, NRM is usually

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183 Japanese geological research has been using the term 'Jinji Unconformity' to demarcate the boundary between artificial and natural deposits (Nirei et al., 2012).

184 This is true only insofar as one equates anthropogenic deposits (as a lithostratigraphic unit) with the Anthropocene (as a geochronological/chronostratigraphic unit). The AWG has stressed that anthropogenic impacts should not be considered the same as the signals used to mark the beginning of the Anthropocene at ~1950s (Zalasiewicz et al., 2017b; Zalasiewicz et al., 2021).

185 For a concise summary of different types of remanent magnetization, see https://cse.umn.edu/irm/6-types-remanence (accessed on August 8, 2021).

considered the vector sum of all the different magnetic components (i.e., all the magnetization acquired in different ways throughout a rock's history).

Among the types of NRM, primary or characteristic remanent magnetization is especially important because it records magnetic polarity of the geomagnetic field at the time of a rock's formation. Polarity (i.e., the existence of magnetic poles) is a property of all magnetic fields. In the case of the geomagnetic field (generated by electric currents from the Earth's outer core, made of a mixture of molten iron and nickel), polarity is the direction of the geomagnetic field in respect to the magnetic north pole and magnetic south pole. At apparently random intervals, the Earth undergoes geomagnetic reversals, and magnetic north and south are inverted (the last reversal, the Brunhes–Matuyama transition, occurred around 781,000 years ago). A change in intensity and pole orientation in the geomagnetic field that is not associated with a reversal is known as an 'excursion' (e.g., the Laschamp excursion, ~41 ka). Reversals are recorded by rocks globally and synchronously because of the global extent of the geomagnetic field. Periods of alternate 'normal' or 'reverse' polarity are called *chrons* in geochronology, and *chronozones* in chronostratigraphy (currently, we are situated in the Brunhes Normal Chron). In magnetostratigraphy, they are equivalent to the *polarity zones* (or subzone and superzone) of rock bodies. Polarity zones are the basic unit of magnetostratigraphic polarity classification. They are defined by the magnetic polarity of rock bodies traceable to their remanent magnetism. Together with marine magnetic anomalies, the magnetostratigraphic record enables the reconstruction of the geomagnetic polarity time scales (GPTS) – an important addition to the reconstruction of the Earth's history.[186]

Since the geomagnetic field is independent (so far) of human influence (Zalasiewicz et al., 2019b), no human-induced disruption nor polarity reversal can be used as a magnetostratigraphic marker for an Anthropocene unit. However, magnetism is still a relevant aspect of anthropogenic sediments and mineral-like compounds. Artificial materials heated at high temperatures acquire thermoremanent magnetization when they cool below the Curie temperature, providing archaeomagnetic evidence. This means that anthropogenic rocks or human-induced mineral-like compounds may preserve (if undisturbed) remanent magnetism for geologically significant periods of time in the future because, as for other rock types, they record the Earth's geomagnetic field direction. More importantly, mineral magnetism "responds directly to anthropogenic impacts on the environment and so does provide a potential marker for the Anthropocene" (p. 81). This is because changes in magnetic properties associated with anthropogenic activities will be recorded in magnetic minerals, providing an anthropogenic signature of a global extent. In this respect, the most significant anthropogenic modifications of the Earth's surface documented in magnetic records are land use and the burning of fossil fuels (Snowball et al., 2014).

Instances of high concentration of magnetic minerals associated with land use have been documented in Europe at least since 2.6 ka (Zalasiewicz et al., 2019b, para. 2.6.2), with the largest signatures beginning around 1100 CE. They can be attributed to anthropogenic deforestation, water catchment, and

[186] Only a portion of the Earth's magnetism has been recorded in the GPTS, which 'only' extends as far back as 160 million years ago (Langereis et al., 2010). Due to difficulties in finding NRM in increasingly older rocks and establishing correlations among them, only scattered GPTSs or punctuated data is currently available for older time scales.

soil erosion. These changes in land use transferred and concentrated iron oxide (Fe-oxide) sediments in lacustrine and riverine systems as well as peat bogs. The concentration of iron oxides in aquatic systems have been used as proxies of environmental change by Holocene mineral magnetic studies because of their sensitivity to changes in soil (Snowball et al., 2014). Since the late 1970s, the study of the properties of magnetism in relation to both anthropogenic and natural pollution, climate change, and sedimentation has been the object of the field of environmental magnetism.

A second source of mineral-magnetic signatures is from atmospheric pollution associated with the burning of biomass and fossil fuels (Zalasiewicz et al., 2019b, para. 2.6.3). The combustion of hydrocarbons (the basic chemical compound of coal, petroleum, and natural gasses) has been considered as a potential marker for the Anthropocene, providing auxiliary evidence of stratigraphical value to the Anthropocene Hypothesis. This marker is represented by the release of fly ash such as spheroidal carbonaceous particles (SCPs) containing iron oxides from oil burning, or magnetic inorganic ash spheres (IASs) from fossil fuel burning as well as iron and other metal manufacturing and smelting. Different techniques can be implemented to assess the magnetic properties (e.g., remanent magnetization) of these particles, which can be correlated among deposits worldwide to provide seemingly isochronous mineral magnetic pollution events.

Magnetostratigraphy provides a pool of auxiliary evidence in support of the Anthropocene Hypothesis. However, such evidence does not constitute the primary marker for the Anthropocene. Magnetic markers have seen wide application in Cenozoic stratigraphy (< 66 Ma), especially for defining the base of the several series within the Neogene. The Gauss-Matuyama reversal (2.58 Ma) is also used as a defining marker for the Gelasian Age/Stage, and for the higher Quaternary Period/System. No magnetic reversal or excursion of equal magnitude has been recorded in recent times, nor has any anthropogenic activity been documented to substantially affect reversal or excursions of the geomagnetic field. Nevertheless, magnetic events of anthropogenic origin have been recorded. Snowball, Hounslow, and Nilsson (2014) have suggested that the 1890–1900 CE interval represents a mineral magnetic pollution event that is well recorded in mineralogical and magnetostratigraphic evidence, and that could provide an additional marker for the Anthropocene.

Magnetostratigraphic research shows that not all functions of the Earth System are affected by human activities. The Earth's geomagnetic field, and se the magnetosphere it produces, is largely independent of human forcings, and its reversals and excursions are related to the Earth's inner composition and dynamics as well to its axial rotation.[187] Nevertheless, magnetic properties of rock unrestricted to the polarity record are documented and provide additional data for an anthropogenic stratigraphic signature in rock records.

[187] For a short explanation of the causes of geomagnetic reversals, see Glatzmaier (1999).

3.1.2.3 Pedological and Pedostratigraphic Evidence

Pedology is a subdiscipline of soil science studying the formation and properties of natural soils. The discipline studying the relationship and stratigraphic properties of buried soils is *pedostratigraphy*. The concept of soil has different technical meanings depending on the discipline engaging with it. In pedological research, soil represents "the unconsolidated mineral matter on the surface of the Earth that has been subjected to the influence of genetic and environmental factors" (Chesworth, 2008, pp. 616-617), and is often represented as a 'natural body' or 'organism.' Soils are composed of different layers or *soil horizons* (usually identified with the letters O (organic), A (surface), B (subsoil), C (substratum), and R (bedrock/rockhead)) that are parallel to the surface, each having distinct properties (e.g., chemical, physical) that separate them from one another. The description of recognizable soil horizons is a necessary step for defining a pedostratigraphic unit.

The North American Commission on Stratigraphic Nomenclature (NACSN) has formally recognized pedostratigraphic units in 1961 (Zalasiewicz et al., 2019b, para. 2.7.3), and has since provided terminological guidelines. The 2005 version of the North American Stratigraphic Guide does not attribute any stratigraphical significance to the term 'soil.' The term *geosol* has been instead proposed as the only fundamental unit of pedostratigraphic stratification (NACSN, 2005, Article 56). The definition of pedostratigraphic units provided by NACNS differs from that provided by the International Union for Quaternary Research (INQUA)[188] – an international organization founded in 1928 that studies climatic and environmental changes during the Quaternary Period (2.58 Ma). The SQS has been using the term 'paleosol' as the basis for a pedostratigraphic unit, claiming that the acceptance and utility of the term 'geosol' is not universal.[189] Nominalism aside, pedostratigraphic units have been recognized as additional time-transgressive stratigraphic markers because of the distinct analyzable properties of soils as fundamental constituents of the Earth (NACSN, 2005, Article 55g). Nevertheless, neither North American nor international stratigraphy have extensively described anthropogenic signals in pedological and pedostratigraphic terms – until only recently. Similarly, the *Guide* does not provide any methodological nor terminological directives for soils and pedostratigraphic units, stressing that "[t]he stratigraphic treatment of soils needs additional consideration before attempting to formalize principles and procedures and to incorporate soil-stratigraphic units into the *Guide*. These units may be subject to future discussion by the ISSC" (Salvador, 1994, p. 2).

Pedology endured major funding cuts among developed countries by the end of the 20th century (Basher, 1997). Recently, increasing anthropogenic modification of soils has caused pedology and pedostratigraphy to undergo new developments through attempts to integrate human actions into the study of soil formation and composition (Zalasiewicz et al., 2019b, para 2.7.1). Traditionally, pedology has been

[188] Pedostratigraphy has been especially valuable in Quaternary research because soils are better preserved than in pre-Quaternary geological times.
[189] See http://quaternary.stratigraphy.org/stratigraphic-guide/pedostratigraphy/ (accessed on April 14, 2021).

conceived as "the study of soils as *independent* [emphasis added] natural bodies" (Chesworth, 2008, p. 616). Eugene Woldemar Hilgard (1833–1916), a father of American soil science, saw the pedogenetic forces of 'virgin soils' as the only object of interest to pedology (Richter, 2007). Soils as independent bodies did not merely define the object of study of pedology as a distinct discipline, but also demarcated epistemologically 'natural' or 'virgin' soils from 'non-natural,' 'artificial,' or 'managed' soils (Zalasiewicz et al., 2019b, para. 2.7.1). Human actions had been considered disturbances rather than part of the natural processes of soil formation, and thus beyond the reach of pedology. Likewise, pedostratigraphic research has been conservative in integrating human forcings into the classification of pedostratigraphic units.

An expression of this conservative stance toward the integration of anthropogenic forcings on pedogenesis is the 'state factor theory.' The theory was originally proposed by pedologist Hans Jenny (1899–1992) in his 1941 textbook *Factors of Soil Formation: A System of Quantitative Pedology*. The model has been very influential in soil sciences and ecology. It provides a mathematical description of the functional relationship between soil properties and soil formation factors through the following equation:

$$s = f(cl, o, r, p, t, ***)$$

Where *s* represents soil type, *f* stands for 'function of,' *cl* local climate, *o* organisms (or biotic factor), *r* topography (or relief), *p* parent material, and *t* time (Jenny, 1941). The asterisks represent one or more unknown variables that may have to be included in the equation.

Notably, the human factor (definable as *h*-factor) is not immediately considered as an independent state variable. It is plausible that the *h*-factor in Jenny's account is either (1) excluded *a priori* because of the focus on natural or 'virgin' soil formation; (2) implicit among one or more of the five given variables (arguably in *o*); (3) or included in the group of unknown variables. Its epistemic exclusion seems a feasible sociological factor, given that traditional pedology and pedostratigraphy has largely focused on the formation of non-human-altered soils. Jenny too notes that human interference has constituted a problem (rather than a variable) for soil classification in North American soils (p. 191). However, the scientist is fully aware of the extent of human impacts on soils, suggesting that human impact could be treated as an independent variable. For instance, he writes:

> Lands in all parts of the world are plowed and are subjected to numerous cultural treatments. Stable manure is added to the soil wherever cattle are raised. Crops are harvested universally. Deforestation occurs on all continents, and burning is practiced whenever needs arise. In all these enterprises, man acts, as far as the soil is concerned, *as an independent variable or soil-forming factor* [emphasis added]. (p. 203)

A substantial overview of the human impact on soils is provided in Chapter 7, section C of his book. While the emphasis is placed on natural variables rather than anthropogenic forcings in soil formation processes, Jenny considers humans as no less soil-forming factors than natural ones. This seems to also exclude altogether both the possibility that humans represented, at his time, an unknown variable yet to be integrated into the state factor model, and that the *h*-factor is merely excluded *a priori* from consideration amongst soil formation variables.

Jenny distinguishes between *dependent* and *independent* variables in biotic soil-forming – the former being a variable *produced* by a given soil (i.e., the dependence of an organism on its soil), the latter being a variable that *produces* a given soil independently of the soil properties, and without changes in other soil-forming factors. He further postulates that "[*i*]*f organisms are to be included among the soil formers, they must possess the properties of an independent variable*" (p. 197). From the earlier excerpt, Jenny seems to attribute this status of independent variable or soil-forming factor to humans. However, despite the importance attributed to humans in soil formation and alteration, the fact that humans are considered "as an outstanding *biological* [emphasis added] soil-forming factor" (p. 232) leads ultimately to the conclusion that Jenny incorporates human activity into the *o*- (organism or biotic) factor.

The subsumption of the *h*-factor into the *o*-factor, and thus its exclusion as a clearly distinguishable human factor in the state factor model, has been contested over the second half of the 20th century (Richter, 2019). Proposals to fully integrate the human component into the state factor models have been developed (Dudal et al., 2002), also by Jenny himself (Amundson & Jenny, 1991, 1997). Some of these proposals emerged as research groups. For instance, a Soil Change Working Group was launched in 2009 as part of the Soil Science Society of America (SSSA) and in cooperation with the International Union of Soil Sciences (IUSS). The group (no longer operating) aimed at fostering "interdisciplinary collaboration on soil issues affected by human forcings" (Richter et al., 2011, p. 2081) by (1) encouraging the institutional and disciplinary recognition of anthropedology as the science of human-soil formation, (2) advancing networking initiatives to study and model global soil change, and (3) establishing communication pathways to stress the social relevance of human-soil research. A second example is the International Committee on Anthropogenic Soils (ICOMANTH), formed in 1988 with the goal of integrating anthropogenic soils into the official soil taxonomy. Its recommendations were ultimately accepted in 2014 (Richter, 2019).

As expressed by AWG member and soil scientist Daniel Richter (2007), many of these efforts spurred from the idea that "confining human influence within the biotic state-factor seems to underestimate humanity's reach over ecosystems and soils worldwide" because "humanity has outgrown the biotic factor of soil formation" (p. 961). Modelling humans as merely one among many possible biological complexes that fill the biotic factor in the equation does not reflect the unparalleled scale and extent of anthropogenic pedogenesis and soil disruption. That is, the *h*-factor should be included in the state factor equation *in addition to* the *o*-factor. However, Richter and Yaalon (2012) also note that the question of understanding the relationship between humans and soils, and the polygenetic nature of soils, extends beyond mathematical formalism and traditional pedology because "(i) Human forcings take us well outside our scientific experience with soil as a natural body; and (ii) Human forcings deepen and broaden the dialog of our science, necessitating new interactions not only with the social sciences and the humanities but with the public at large" (p. 767). An effort in the direction of understanding human forcings on soils, and the switch of soils from natural bodies to human-natural bodies, has been encouraged by the institutionalization of anthropedology and anthropedostratigraphy (Richter, 2007, 2019; Richter et al., 2015; Richter & Yaalon, 2012).

How is a discussion on the philosophy of pedology relevant to the Anthropocene Hypothesis? *Homo sapiens*, like any other terrestrial living organism, performs niche-constructing activities that inevitably change the Earth's soils. Since the Neolithic Revolution, the human impact on soils has been remarkable – to the extent that authors have considered the dawn of anthropogenic cultivated soils as a possible GSSP for an Anthropocene Epoch (Certini & Scalenghe, 2011, discussed in section 3.2.2.5). In its most recent history, the extent of land modification has reached more than half of the total land surface of the Earth. Considering that around 98.6% of surface land is covered by soils (Richter, 2019, quoting Buol & al., 2011), this data intuitively translates into possible pedological and pedostratigraphic evidence for an Anthropocene stratigraphic unit.

As seen, pedology connects with stratigraphy through pedostratigraphy. Reconsidering the epistemology of pedology by integrating the human factor has consequences in terms of characterizing and describing an anthropogenic signature in pedostratigraphic units. As also noted by Richter et al. (2015), NACSN requires pedostratigraphic units to rely on already formally defined lithostratigraphic or allostratigraphic units,[190] and the *Guide* does not treat pedostratigraphic units as independent stratigraphic units. Because of the issues inherent in formalizing Anthropocene lithostratigraphic units, this seems to rule out *ex ante* any recognition of anthropogenic pedostratigraphic units (or anthropedostratigraphic units). However, Richter et al. (2015) note that the impact of humans on global soil, or the pedosphere, is reflected in signals of lithostratigraphic, biostratigraphic, and chemostratigraphic nature. These signals reflect both a natural transition toward a new human-soil regime, and the epistemological transition toward anthropedostratigraphy. Equally to the issues encountered in most of traditional stratigraphy, scientific recognition of human forcings in traditional pedology and pedostratigraphy constitutes the major challenge in advancing (anthro-)pedostratigraphic evidence in support of the Anthropocene Hypothesis.

3.1.2.4 Biostratigraphic Evidence

Biostratigraphy is the "element of stratigraphy that deals with the distribution of fossils in the stratigraphic record and the organization of strata into units on the basis of their contained fossils" (Salvador, 1994, p. 55). Fossils play an important role in providing paleoecological, paleogeographic, and paleontological records of the past, and represent a distinctive lithological feature of rock strata. Fossil presence in rock

[190] Allostratigraphy is "a stratigraphical method that subdivides geological sequences based upon a hierarchical framework of bounding surfaces or discontinuities that serve to compartmentalize discrete packages of sediment or rock" (Lee, 2018, p. 407). The term 'allostratigraphic unit' is used by NACSN (2005), while the *Guide* refers to allostratigraphic units as 'unconformity-bounded units' or *synthem* – namely, a "body of rocks bounded above and below by specifically designated, significant and demonstrable discontinuities in the stratigraphic succession" (Salvador, 1994, p. 46).

strata is a precondition for biostratigraphic classification – namely, the "systematic subdivision and organization of the stratigraphic section into named units based on their fossil content" (ibid.).

The term 'fossil' encompasses a vast range of different types of entities. The AWG has adopted the definition of 'fossil' provided by the International Code for the Nomenclature of algae, fungi and plants (ICN).[191] This choice considers the ICN's definition "the most flexible and useful" (Zalasiewicz et al., 2019b, p. 110) because it distinguishes between fossils and non-fossils based on the *stratigraphic* relations of fossils with their sedimentary context. Most fossils preserved in sediments occur as trace fossils (or ichnofossils), namely, traces of organism activity (e.g., footprints, burrows, feces); or body fossils, namely, the decay-resistant skeletal or anatomical remains of a dead organism. A third kind is represented by chemofossils or biosignatures – that is, signatures of varying size and type that are preserved in nature suggesting evidence of life. Geological units throughout the Phanerozoic (< 541±1 Ma) are usually characterized by ichnofossils and body fossils, whereas signs of early life in Precambrian units are partly based on molecular biosignatures. Fossiliferous rocks are characterized by the presence of fossils of organisms that either originated and died in a particular site (biocoenosis), were brought together at the moment of their death (thanatocoenosis), or were relocated from their natural environment when alive.

Biostratigraphic units are called *biozones* – that is, intervals of rock strata defined by their characteristic fossil record. Contrary to lithostratigraphic units, biozones are not defined by the lithological properties of rock strata, but only by the presence and characteristics of fossils. A stratigraphic boundary marked by a distinctive and significant change in fossil character in a rock section is known as a biostratigraphic horizon or *biohorizon*. Common examples of biohorizons are the first occurrence (FO) and last occurrence (LO) of a given biological taxon in the rock record – identified respectively with the lower and upper biohorizon of a biozone. 'First' and 'last' occurrence are determined upward (following superimposition) in a rock section rather than downward (following the direction of drilling for sampling). The total evolutionary history of a given taxon is determined by its First Appearance Datum (FAD) and Last Appearance Datum (LAD). FO and LO delimit, and thus define, the biozone of a taxon in particular sample or locality, whereas FAD and LAD define the biochronozone[192] of a taxon (Saraswati & Srinivasan, 2016).

Biostratigraphic units differ from other types of stratigraphic units "in that the organisms whose fossil remains define them show evolutionary changes through geologic time that are not repeated in the stratigraphic record" (Salvador, 1994, p. 53). Because of the irreversibility of evolutionary changes, biostratigraphic units uniquely reflect the strata they correspond to, and greatly aid time correlation of strata – meaning that they are "more influenced by, and indicative of, geologic age" (p. 100). This is one of the reasons why biostratigraphic markers have been widely privileged as a primary marker for defining the base of geochronological/chronostratigraphic units.

[191] The ICN represents an internationally ratified set of rules and recommendations for botanical nomenclature.

[192] In chronostratigraphy, a chronozone is "the body of rocks formed anywhere during the time span of some designated stratigraphic unit or geologic feature" (Murphy & Salvador, 2000, p. 258). Accordingly, a biochronozone is the fossil taxa originating during a given time span.

Biozones are not numerical time units. They do not provide a numerical age for absolute time correlation. However, given the unidirectional process of evolution and the law of superposition (i.e., younger taxa are enclosed in higher strata), fossils also provide the relative age of enclosing strata (NACSN, 2005, Articles 48a). Application of radiometric dating to fossils (geochronometry) allows to obtain absolute numerical ages for fossils. In addition to their wide geological application – often being associated with other types of stratigraphic (especially chronostratigraphic), archaeological, or paleontological evidence to reconstruct planetary changes – biostratigraphic units or biozones are crucial for providing evidence of evolutionary change.

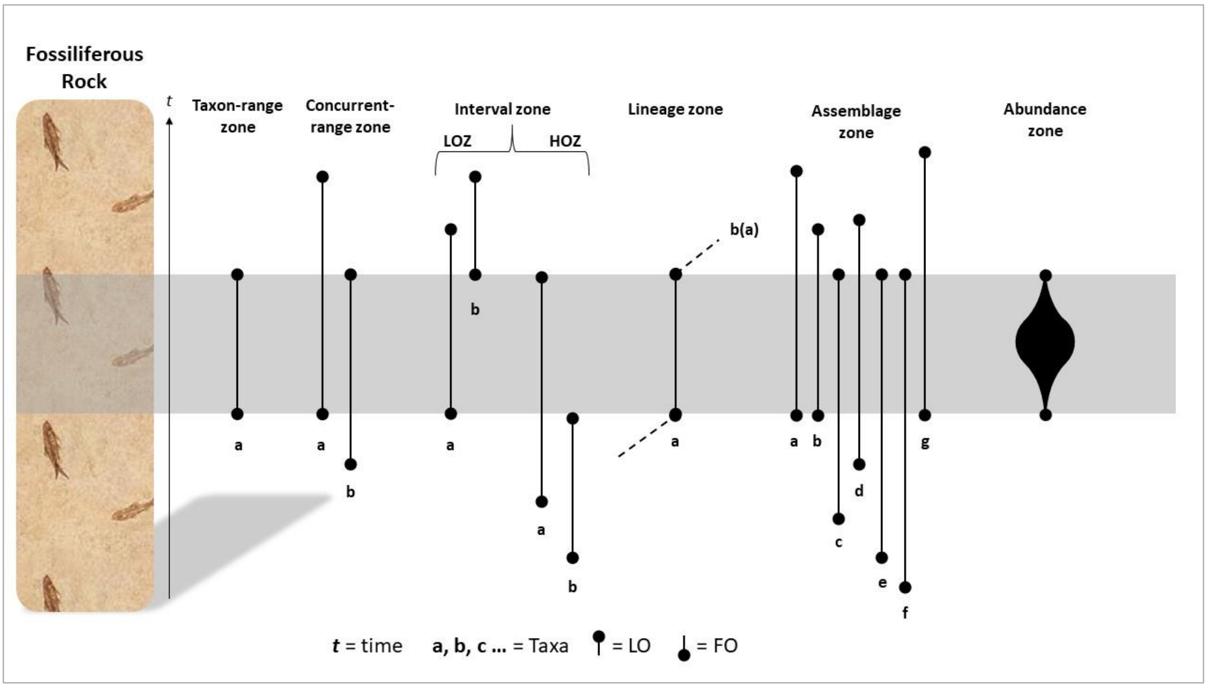

Figure 3.3. Simplified representation of the five common types of biozones used in biostratigraphy. (Illustration by the author)

Biostratigraphic research utilizes five common types of biostratigraphic units or biozones to distinguish strata based on their fossil content – namely, range zone, interval zone, lineage zone, assemblage zone, and abundance zone (Figure 3.3). These biozones allow biostratigraphers to date and correlate stratigraphic sequences (Saraswati & Srinivasan, 2016). Unlike lithostratigraphic or chronostratigraphic units, biozones are not hierarchical, meaning that a single stratigraphic section can be explored through different zones simultaneously.

- A *range zone* is defined as the "body of strata representing the known stratigraphic and geographic range of occurrence of a particular taxon or combination of two taxa of any rank" (Murphy & Salvador, 2000, p. 247). Range zones distinguish between *taxon-range zones* (boundaries defined by

FO and LO of a single selected taxon) and *concurrent-range zones* (boundaries defined by overlapping segments of range zones between two selected taxa).

- An *interval zone* is the "body of fossiliferous strata between two specified biohorizons […] defined and identified only on the basis of its bounding biohorizons" (p. 248). Its boundaries are arbitrarily selected biohorizons that do not necessarily coincide with the range zone of taxa (e.g., the highest-occurrence zone (HOZ) is defined by the LO of two taxa; conversely, the lowest-occurrence zone (LOZ) is defined by the FO of two taxa).
- A *lineage zone* is the "body of strata containing specimens representing a specific segment of an evolutionary lineage" (p. 250). It is determined by a selected segment in the evolutionary lineage of a taxon. Its boundaries are based on the biohorizons corresponding to the LO of successive phylogenetic taxa. Lineage zones are a unique type of biostratigraphic unit because "they require for their definition the reasonable assurance that the taxa chosen for their definition represent successive segments of an evolutionary lineage" (Salvador, 1994, p. 61). In most cases, this requires paleontological rather than biostratigraphic inference.
- An *assemblage zone* is the "body of strata characterized by an assemblage of three or more fossil taxa that, taken together, distinguishes it in biostratigraphic character from adjacent strata" (Murphy & Salvador, 2000, p. 250). Its boundaries are established based on the specific fossil composition of the assemblage by arbitrarily choosing (yet providing a sound justification for the choice) the LO and FO of determined taxa. Assemblage zones provide valuable proxies for the paleofauna and paleoflora of particular regions or areas, and thus are good indicators of past environments and geologic age.
- An *abundance zone* is the "body of strata in which the abundance of a particular taxon or specified group of taxa is significantly greater than is usual in the adjacent parts of the section" (p. 251). Its boundaries are determined by the notable (statistical) increase in abundance of one or more taxa.

The fossil record is a primary means for reconstructing the Earth's geohistory as well as the history of life. The vast majority of GSSPs used to define the lower boundary of geochronological/chronostratigraphic units make use of biostratigraphic evidence as a primary marker. Alternatively, biostratigraphic units can be implemented as secondary or auxiliary markers. For instance, all of the Cenozoic epochs (< 66 Ma) are characterized by paleontological distinctiveness – from the fifth major extinction event associated with the iridium anomaly resulting from an asteroid collision (i.e., the Alvarez Hypothesis) for the Cenozoic lower boundary, to the late Pleistocene megafauna extinction associated with the interstadial (i.e., warmer) period determining the beginning of the Holocene (11.7 ka). Consistently, a clearly distinguishable biostratigraphic marker should characterize the Anthropocene Epoch.

Anthropocene researchers have been discussing what types of biozone would best represent the biostratigraphic signature of the Anthropocene (Barnosky, 2014; Zalasiewicz et al., 2019b, para. 3.1). Besides the stratigraphic nature of the Anthropocene Hypothesis, these discussions stem from recent scholarship investigating the evolutionary impact of human niche-constructing activity (Boivin et al., 2016; Ellis, 2016b; Ellis & Ramankutty, 2008; Kendal et al., 2011a, 2011b; Laland et al., 2001; Odling-Smee et al., 2003; Pena Rodrigues & Lira, 2019; Zalasiewicz et al., 2011a). Such extensive multidisciplinary literature has analyzed the biological and ecological pressures of human activities on the Earth's biota, leading to the comparison between ongoing rates and magnitude of current extinctions and past mass extinction events, and to the conclusion that humans have triggered the Earth's sixth major extinction event (Barnosky et al., 2012; Barnosky et al., 2011; Ceballos et al., 2015; Ceballos et al., 2017; Dirzo, 2009; Dirzo & Raven, 2003; Kolbert, 2014). The presumed sixth mass extinction event represents an important biostratigraphic signal (or pool of signals) of an Anthropocene stratigraphic unit.

But what is a mass extinction event? And how are past and present extinctions measured? Different techniques are used to retrieve extinction rates, depending on whether one is calculating past extinction rates or future rates. Most of our knowledge of past extinction rates is based on "only two kingdoms,[193] plants and animals, over the past 600 million years" (May et al., 1995, p. 2). These are the most documented kingdoms in fossil records, during a time period (the so-called Cambrian Explosion) seeing the proliferation of multicellular and complex life.

The most common method to estimate future rates of extinction is the species-area relationship method, based on estimates of species (S) per area (A) and growth of expansion used inversely to deduce species decrease due to habitat loss (Smithsonian Insider, 2011), so that $S = cA^z$, where *c* and *z* are constants (Pimm et al., 1995).

Another technique involves comparing current rates of extinction against background extinction rates – namely, the expected rates of extinction during a timespan in the absence of human intervention on the Earth's biota. These rates are derived from fossil records and are commonly based on the average lifespans of species per million years, or extinction per million species years (E/MSY). For the past 66 million years (i.e., throughout the Cenozoic), background extinction rates have ranged from 0.1 to 1 species per million species per year (Dirzo & Raven, 2003), with species' average lifespan between 5 and 10 million years (May et al., 1995). Background extinction rates allow us to compare past extinctions with the ongoing sixth mass extinction event.

A third method uses the International Union for Conservation of Nature (IUCN) Red List of Threatened Species, or simply Red List, to assess how fast a species has 'climbed' the seven-category ladder of extinction threat.[194] The Red List provides a vast database on the conservation status of documented species, and can be used to infer the likeliness of future extinction rates based on how fast a species has moved from one status (e.g., Near Threatened) to another (e.g., Critically Endangered). Şengör, Atayman, and Özeren (2008) have also distinguished between magnitude, intensity, and greatness of an extinction

[193] The term *kingdom* identifies the second highest taxonomy rank. Traditionally, biological taxonomic ranks are (from highest to lowest) domain, kingdom, phylum, class, order, family, genus, and species. Other ranks are also used to identify sub- or super-ranks (e.g., subspecies, superfamily).

[194] The categories falling under 'adequate data' are Extinct (EX), Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), and Least Concern (LC). Because of lack of data, some taxa may also fall under the categories of Data Deficient (DD) or Not Evaluated (NE).

event. Magnitude (M) "is a scalar number signifying the number of taxa constituting the total diversity decline" (Şengör et al., 2008, p. 13737); intensity (I) "is the inverse of the duration of the time interval, expressed in millions of years (Ma), in which the taxa contained in the M number have disappeared" (ibid.); and greatness (G) is the product of the magnitude and intensity of an extinction event, so that $G = M \times I$. Whereas rate is not explicit in this equation, time is an implicit factor in I, so that rate and greatness are related, yet different, metrics for analyzing extinction events (Barnosky et al., 2011).

Comparisons between the ongoing human-induced extinction and past mass extinction events are problematic for several reasons, mostly related to the nature of fossil records (Barnosky, 2014; Jablonski, 1994). For instance, past extinction events are documented through fossils buried dozens to hundreds of millions of years in the past – primarily fossils of marine invertebrates. Conversely, present extinction rates are based mostly on terrestrial biota due to a substantial lack of knowledge of marine biodiversity (compared with terrestrial biodiversity). Paleontological databases tend to focus on "the more abundant, widespread, and geologically long-lived species, which will have the greatest total number of individuals and occur in the greatest number of localities and rock types" (Jablonski, 1994, p. 13). Modern rates of extinction based on loss of rarer species with limited geographical distribution may not be paleontologically or biostratigraphically detectable. Furthermore, modern rates of extinctions require different approaches than paleontological events – the former being assessed by the International Union for Conservation of Nature and its Red List, a different operating framework from paleontological studies on extinctions. Taxonomically, in these kinds of studies, fossils are usually analyzed at higher taxa than species (e.g., genus, family) because species-level fossils are very incomplete and "subject to sampling and preservational bias" (p. 11), whereas modern extinction rates are monitored on the species (i.e., phylogenetic species concept) taxon level. Barnosky et al. (2011) have highlighted these differences, suggesting possible comparative solutions such as "to examine regions or biomes where both fossil and modern data exist […] to use taxa best known in both fossil and modern records […] to standardize extinction counts by number of species known per time interval of interest," or "to scale proportional extinction relative to the time interval over which extinction is measured" (p. 52).

Despite methodological issues for comparative analyses, it has been suggested that the Anthropocene extinction event should be considered a major extinction event because current extinction rates "would produce Big-Five-magnitude mass extinctions in the same amount of geological time that we think most Big Five extinctions spanned" (p. 55). Projected into the future, ongoing rates of extinction will reach the 75% species loss threshold characterizing the other 'Big Five' extinction event in "as little as three centuries" (ibid.). However, the 'Anthropocene extinction event' has only very limited paleontological and biostratigraphic records because of its very recent nature (i.e., fewer fossils occur in younger strata). This means that, technically, the ongoing extinction event "does not yet qualify as a mass extinction in the paleontological sense" (p. 56) because its biostratigraphic and paleontological legacy is yet to fully unfold. For the same reason, characteristic Anthropocene biozones can mostly be defined on their lower limit.

AWG member Anthony Barnosky (2014) has assessed which types of biozone would best represent biostratigraphic signatures of the Anthropocene – and which would not. Range zones are unlikely to be used under the current formulation of the Anthropocene Hypothesis because "no new species are known to have originated during the past few hundred years" (p. 152).[195] If a species were to be selected, *Homo sapiens* would arguably be the most emblematic, both because of the epoch's naming choice and the species' remarkable stratigraphic footprint on the Earth. However, selecting the first appearance of *Homo sapiens* as the lower biohorizon of a range zone would require (1) extending the Anthropocene to ~300 ka – where earliest fossils of *Homo sapiens* are documented (Hublin et al., 2017) – and (2) locating an upper biohorizon that, since our species is not yet extinct, is impossible to locate. Given that neither condition is optimal nor satisfiable, a taxon-range zone cannot be used to define the biostratigraphic signature of the Anthropocene. Concurrent-range zones could be defined based on the concomitant appearance of a taxon of domesticated animals and plants (e.g., pig, cow, horse, sheep, dog, maize, etc.). However, locating the lower biohorizon at ~8 ka (i.e., the Neolithic Revolution) has not been considered an ideal biozone, given the primary chemostratigraphic signature of the Anthropocene Hypothesis at ~1950 (following section).

The issues in characterizing Anthropocene range zones also apply in characterizing Anthropocene interval zones – that is, no documented species (of stratigraphic value) have originated in the last few centuries. Hence, no lowest-occurrence zones can be defined. Barnosky (2014) considers highest-occurrence zones a possible, yet unlikely, option due to the difficulties in relating documented species extinctions in the past 500 years to single-taxon global synchronous biostratigraphic signatures (not to be confused with the global synchronicity of *different* species extinctions). None of the documented extinct species has so far provided a worldwide synchronous proxy as sound as other biostratigraphic marks in the past epochs.

Lineage zones are not delimited by "the origin and/or extinction of species," but rather "by rapid, morphologically significant changes within an evolutionary lineage (typically within species)" (p. 153), and might thus represent valuable biostratigraphic signatures of the Anthropocene. Changes in species have been extensively documented in plant species related to human agriculture. Corn (*Zea mays* subspecies *mays*, the only domesticated of the four documented *Zea mays* subspecies) has been considered as a possible proxy for delineating a biostratigraphic lineage zone of the Anthropocene because of its pollen and phytolith fossil record (Pohl et al., 2007, quoted in Zalasiewicz & al., 2019b, para 3.3.2.1) and because of its present global distribution (found on every continent except for Antarctica). However, Zalasiewicz et al. (2015a; 2019b) have observed that the diachronous timeline of corn spread documented in its sedimentary record does not meet the criteria for characterizing a biostratigraphic signature for an Anthropocene Series.

Interesting and suggestive evidence of anthropogenically induced morphological changes in animals is the bone-size evolution of domesticated chickens (*Gallus gallus domesticus*), the world's most populous bird species. A study from Bennet et al. (2018) compared the red jungle fowl (*Gallus gallus*,

[195] If considered a morphospecies, the broiler chicken could in fact be used as a range zone marker for the 'Anthropocene.' This point is further discussed below.

ancestor of the *domesticus*) and two broiler datasets with chicken bones collected from archaeological sites dating from the Roman era to the 20th century. It is generally after a surge in chicken production from the 1950s onwards that the greatest morphological changes are observed, with a remarkable threefold width increase and twofold length increase of lower limb bones of domesticated chickens compared to red jungle fowls of the same age. In terms of body weight, "[b]roilers from a 1957 breed are between one-fourth and one-fifth of the body weight of broilers from a twenty-first century breed" (p. 6). Genetically Modified Organisms (GMOs) may be considered additional biostratigraphic signatures (Zalasiewicz et al., 2019b, para. 3.1) defined by lineage-type zone. Yet, the utility of lineage zones in characterizing an Anthropocene Series "remains to be proven" (Barnosky, 2014, p. 153).

Barnosky finds assemblage and abundance zones to be the most useful biozones in delineating the biostratigraphic profile of the Anthropocene. Assemblage zones could potentially be discernible in the co-occurrence of neobiota scattered directly (e.g., through domestication) or indirectly by humans worldwide, especially over the past two centuries. Essentially, Anthropocene assemblage zones would identify the presence of certain related groups of fossilizable species "that are unique associates with respect to the fossils of previous epochs" (p. 155). Ichnofossils (especially abundant at 1950 CE) may also provide paleontological records to define Anthropocene assemblage zones (Barnosky, 2014). Whilst assemblage zones are region-specific, invasive neobiota have been considered "very good Anthropocene markers" (Zalasiewicz et al., 2019b, p. 119) because they provide a global biostratigraphic signal of 'alien' species overlying native species in possible future stratigraphic records through biozonation (i.e., the formation of biozones). In other words, region-specific assemblage zones can be correlated globally based on the similar human-mediated introduction of 'alien' species – fulfilling the synchronicity requirement needed to formally locate an Anthropocene GSSP. Many neobiotic species have been documented in aquatic as well as terrestrial environments worldwide – for instance, *Trochammina hadai* (a foraminifera living in marine and brackish environments), translocated in the early/mid-20th century from coastal areas of the Pacific Ocean to the Western US coast, where it rapidly dominated the local environment at the expense of native foraminiferal fauna; or rats (*Rattus rattus*, *Rattus exulans*, *Rattus norvegicus*), translocated to all continents but Antarctica. The San Francisco Bay and Delta – one of the most invaded estuaries in the world (Cohen & Carlton, 1998) – and the Kaua'i island of Hawaii have been used to show biostratigraphic correlation among successions of geographically distant regions (Zalasiewicz et al., 2019b, para. 3.3.3.1, 3.3.3.2). Assemblage zones for both successions can be drawn based on the introduction of invasive species (mostly by ship transit), the majority occurring during the 20th century. These represent distinctive biostratigraphic markers that, despite being limited in terms of time span, can be compared to earlier biostratigraphic signals of the Quaternary.

Lastly, Barnosky (2014) considers abundance zones to be another useful biozone type for defining the Anthropocene. Whereas assemblage zones identify the quantity of different taxa in a rock succession, abundance zones identify the statistical quantity of individuals of one or more taxa in a rock succession. Again, human-introduced neobiota provide evidential support for defining Anthropocene abundance zones because invasive species can spread and multiply rapidly once introduced. For instance, the zebra mussel (*Dreissena polymorpha*), native to Eastern Europe, now spreads across parts of Western Europe, Britain, and North America, and can reach densities of 11,000 individuals per square meter (Aldridge et al., 2004, also quoted in Zalasiewicz & al., 2019b, para. 3.3.1; Himson et al., 2020) – displacing native species in the process. Cohen and Carlton (1998, also quoted in Barnosky, 2014) recognize that invasive species in the San Francisco Bay and Delta area "typically account for 40 to 100% of the common species, up to 97% of the total number of organisms, and up to 99% of the biomass" (p. 556). In addition to human-introduced neobiota, Barnosky (2014) has suggested that abundance zones could be characterized by "the number of specimens that represent human remains preserved in cemeteries or elsewhere, remains of domestic megafauna (cows, horses, pigs, sheep, goats, etc.) preserved in sediments, and remains of wild megafauna (animals such as deer, bighorn sheep, antelope, large carnivores, elephants, etc.)" (p. 158).

Ecostratigraphy based on coral reef research has also been proposed as possible biostratigraphic marker of the Anthropocene, as reef ecosystems have been sensitive to global changes in marine settings throughout their evolutionary history (Zalasiewicz et al., 2019b, para. 3.4). Humans have extensively impacted the world's coral reefs through water pollution, overfishing, human-induced global warming, or alteration of the pH levels of specific water regions (para. 3.4.2) – leaving a mark on coral reefs in the process. Severe bleaching events have occurred in recent times, the most prominent occurring in 2016 across the Great Barrier Reef, around Papua New Guinea and Queensland, Australia. Considering that reefs provide stratigraphic proxies for sea surface temperature (SST) during the Cenozoic, human disruption of coral reefs can provide an additional bio/ecostratigraphic marker of certain gravity – depending on future reef management scenarios.

3.1.2.5 Chemostratigraphic Evidence

Chemostratigraphy concerns "the characterization and correlation of strata based on geochemical composition of the sediments, rocks, and rock components of interest" (Saraswati, 2015, p. 93). It is located at the crossroads of stratigraphy and geochemistry – the latter being an interdisciplinary discipline implementing principles in chemistry to explain large-scale geological systems (Albarède, 2009).

As of 2021, neither the NACSN (2005; see also Figure 3.1) nor the *Guide* treats chemostratigraphic units as an independent stratigraphic classification method. Different reasons can be conjectured for this. Firstly, the discipline itself is very young – the term 'chemostratigraphy' only appearing during the 1980s in publications on online scientific databases (Ramkumar, 2015). Secondly, chemostratigraphy, while applied by all stratigraphers large, is mostly used in the petroleum exploration industry (Ramkumar, personal communication, September 30, 2020). Thirdly, no sound group has been advancing the recognition of chemostratigraphic units by the North American Stratigraphic Code or the ICS.[196] The NACSN mentions

[196] The latter two reasons have been suggested by the geologist and chemostratigraphy specialist Muthuvairavasamy Ramkumar via personal communication. His 2015 edited volume *Chemostratigraphy: Concepts, Techniques, and Applications*

chemical (and physical) properties as characterizing pedostratigraphic (NACSN, 2005, Article 57b) or allostratigraphic (Article 58b) units, but litho- and biostratigraphic units also incorporate elements of (geo)chemistry (Irabien et al., 2015; Ramkumar, 2015). Chemical signatures are also used to informally distinguish lithodemic units (NACSN, 2005, Article 58b), which are bodies of "predominantly intrusive, highly deformed, and (or) highly metamorphosed rock, distinguished and delimited on the basis of rock characteristics" (p. 1570, Article 31).

Despite the lack of official recognition of chemostratigraphic classification, analytical chemistry can provide useful insights in terms of characterizing and defining the Anthropocene as a formal geological unit. Various chemostratigraphic evidence has been advanced in this regard, connected to the various and widespread chemical traces left by anthropogenic activities. These traces are mostly recorded in stalactites, marine and freshwater sediments, ice cores, polar ice, corals, stalactites, and tree rings (Gałuszka et al., 2017). For instance, stable Pb (lead) isotopes ratios and ^{137}Cs (caesium-137) radioactive isotopes have been used by Irabien et al. (2015) as possible litho- and chemostratigraphic markers, signaling respectively the onset of heavy mining activities during the Industrial Revolution, and atmospheric nuclear testing. However, as the researchers note, the diachronous nature of lead concentrations and stable isotope ratios as well as the high transportability of ^{137}Cs make these chemostratigraphic markers difficult to correlate globally (a necessary requirement for formal recognition).

Another recent study from Gałuszka, Migaszewski, and Rose (2020) considers polychlorinated biphenyls (PCBs) as a possible chemostratigraphic marker to define Anthropocene strata. PCBs are a group of 209 congeners (a term used to identify variants of a common chemical structure) sharing a basic chemical structure ($C_{12}H_{10-n}Cl_n$). They are artificial chemical compounds first synthetized in 1876. Because of their properties (e.g., low flammability, high longevity, resistivity), they saw increasing industrial production and commercial distribution after 1929 (Elabbas et al., 2013). PCBs had been manufactured on the industrial scale throughout most of the 20th century before studies began to show potential toxic and hazardous effects for the environment and human health. They were thus banned in the US (one of the major PCBs producers) in 1978, and by the Stockholm Convention on Persistent Organic Pollutants in 2001, and are now classified as persistent organic pollutants (POPs).

PCBs are mostly detectable in sediments and animal tissues, and are present in lower but geographically spread concentrations in air and water. Their chemostratigraphic importance lies in their global distribution through atmospheric transport, their synchronous appearance and high persistence, and their interaction with microplastics. While PCBs clearly represent a novel sedimentary record, Gałuszka, Migaszewski, and Rose (2020) also note some drawbacks in using PCBs as potential stratigraphic markers – namely, (1) the uneven geographical distribution of lower- and higher-chlorinated PCBs in, respectively, low temperature (e.g., Arctic) and high temperature zones (e.g., the Equator); (2) the lack of sufficient data to assess sedimentary PCB longevity on a geological scale; and (3) the fact that environmental PCB archives

also constitutes a plea to formalize chemostratigraphy as an independent and distinctly recognized method of stratigraphic classification.

may be disturbed by factors such as "potential mobility, post-depositional processes and biodegradation" (p. 151), resulting in much less clear and detectable markers in the geological future. Nevertheless, marine and lacustrine environments reflecting increased PCB concentrations during the mid-20th century may provide a valuable marker for an Anthropocene Epoch/Series as of the present.

The AWG has undertaken extensive research on possible chemostratigraphic signatures of the Anthropocene – also "continuing the classic work of Charles Keeling" (Zalasiewicz et al., 2019b, p. 161) on carbon dioxide emissions. Carbon-based compounds such as CO_2 (carbon dioxide) and CH_4 (methane) are major *topoi* of the global environmental discourse, in that they are associated with anthropogenic fossil and natural gas combustion, and consequently with the recently documented anthropogenic global warming and climate change. In Anthropocene Studies, they have been used as proxies for the 'Anthropocene' since Crutzen's (2000) seminal article, and have also been used as evidence for the early anthropocene hypothesis.

Measurements of atmospheric CO_2 have been conducted since 1958 from the Mauna Loa Observatory in Hawaii, and may be linked with ice core records which provide a record for the past 800,000 years (Lüthi et al., 2008). These latter measurements are based on air bubbles trapped within ice layers (mostly in Antarctica) and document the alternate glacial–interglacial phases characterizing the Quaternary Period (Lüthi et al., 2008). Since the Late Pleistocene (< 0.126 Ma), CO_2 concentrations swung between ~180 ppmv (parts per million volume) and ~260 ppmv. During the Holocene interglacial period (< 11.7 ka), records from Taylor Dome (Antarctica) ice cores show limited variability – from 268 ppmv at 10.5 ka to 260 ppmv at 8.2 ka (Indermuhle et al., 1999). For about 7,000 years, the upper Holocene variability of CO_2 stabilized at around 285 ppmv. Since 1850 CE, in conjunction with the latter part of the Industrial Revolution, CO_2 concentrations have increased steadily, reaching 296 ppmv by 1900 and 338 ppmv by 1978 (Etheridge et al., 1998). As of September 20, 2021, daily observations of atmospheric CO_2 concentration from the Mauna Loa Observatory have been documented at around 413 ppmv[197] – a value decisively above the Holocene variability.[198]

Increase in CO_2 concentration is an important proxy of chemostratigraphic value because of its consequences, for instance, on the carbon cycle or on ocean acidification. In addition to an increase in carbon dioxide concentrations, changes to nitrogen, sulfur, and metal flows have been considered as characteristic of the Anthropocene chemosphere. The invention of the Haber-Bosch process for the production of NH_3 (ammonia) by reaction of N_2 (nitrogen) and H_2 (hydrogen), and its subsequent application on an industrial scale (mostly for producing fertilizers), has had a significant impact on the global nitrogen cycle, contributing "double the natural rate of terrestrial nitrogen fixation, and […] around 45% of the total fixed nitrogen produced annually on Earth" (Canfield et al., 2010, p. 195). This may

[197] Daily measures of CO_2 concentrations by the Mauna Loa Observatory are available at https://www.esrl.noaa.gov/gmd/ccgg/trends/monthly.html (accessed on April 23, 2021).

[198] The reported excess in atmospheric CO_2 concentration ppm outside the Holocene variability is an example of normative-functional statement (see section 1.3.1), in that documented measures locates the current concentrations outside the expected (or 'normal') Holocene atmospheric carbon dioxide concentration. If these records are used as evidence (either auxiliary or primary) for the Anthropocene Hypothesis, then it is inferred that the hypothesis entails normative-functional statements – as anticipated in the first chapter.

constitute the greatest perturbance to the nitrogen cycle since its origin around 2.5 billion years ago, and is largely reflected in stable isotope ratios. Some consequences, such as the creation of vast hypoxic zones (i.e., dead zones) in marine environments, have biostratigraphic rather than chemostratigraphic value because species composition responds to these changes (Zalasiewicz et al., 2019b, para. 5.4.1). Sulfate and atmospheric S (sulfur) from coal combustion (associated with commercial applications) has also been considered as a possible marker for the Anthropocene, given its dramatic increase during the 20th century (para. 5.5.2).

Additional chemostratigraphic signals of the Anthropocene have been associated with metals and their production. Metals (para 5.6) have a long documented history in environmental pollution, with the first signs dating as far back as 30 to 40 ka. The global-scale enrichment of Pb (lead), Cu (copper), and Zn (zinc) among the Earth's environments is considered "one of the most important stratigraphic markers of the Anthropocene" (p. 178). Their increased distribution since the mid-20th century has been considered as a suitable chemostratigraphic marker of the Anthropocene (para. 5.6.3). Researchers have coined the term 'anthrobiogeochemical cycle' to include anthropogenic activity as a structural feature in the functioning of metal biogeochemical cycles (Rauch, 2012).

Most of these signals, from PCBs to greenhouse gasses and metals, represent mostly *auxiliary* evidence in support of the Anthropocene Hypothesis. The most important chemostratigraphic marker seemingly matching several requirements for formal stratigraphic recognition is the sudden and widespread distribution in the mid-20th century of artificial radionuclides associated with nuclear bomb testing fallout (Sanchez-Cabeza et al., 2021; Zalasiewicz et al., 2019b, para. 5.8). Such a signal is traceable in sedimentary material, and has often been mentioned as a global and isochronous signal of *primary* stratigraphic (and chronostratigraphic) value. This marker represents a "unique pattern of radioactive isotopes captured in the layers of the planet's marine and lake sediments, rock, and glacial ice that can serve as a clear, easily detected bookmark for the start of a new chapter in our planet's history" (Waters et al., 2015, p. 47). From July 16, 1945 – when the first atomic bomb (the Trinity) was tested in the Jornada del Muerto Desert, New Mexico, USA – to 1998, when India and Pakistan last tested nuclear weapons,[199] a total of 2,419 nuclear tests were conducted, 543 of which were in the atmosphere (UNSCEAR, 2000, Table 22). Especially the largest nuclear devices, based on thermonuclear fusion (e.g., the Tsar Bomba), left a widespread radionuclide fallout signal – generally in ^{90}Sr (strontium-90), ^{137}Cs (caesium-137), ^{3}H (tritium), ^{14}C (radiocarbon or carbon-14), and ^{239}Pu (plutonium-239) – peaking during 1961–1962 (Waters et al., 2015), after which a decline in nuclear tests followed from international ban treaties.

Not all radioisotopes generated from nuclear fallout are geologically relevant. This is because of their short half-lives – 28.81 years for ^{90}Sr; 30.17 years for ^{137}Cs; 12.43 years for ^{3}H; 14.33 years for ^{241}Pu – meaning that they will not be detectable by extant dating techniques in a geologically distant future. With a

[199] The latest nuclear tests have been conducted by the Democratic People's Republic of Korea on six different occasions. See the Wikipedia page "Nuclear weapons testing" for further information (accessed on April 20, 2021. Last revision: April 16, 2021, 14:47 CET by SporkBot).

half-life of 5,730 years,[200] radiocarbon is one of the most "abundant radionuclides dispersed in fallout" (Zalasiewicz et al., 2019b, p. 198), but its high degree of transportability, its diachronous onset in the Southern Hemisphere, and its assimilation in the biotic carbon cycle makes it too weak to be a primary marker for the Anthropocene (Hancock et al., 2014). ^{239}Pu has been considered a suitable marker because of its significantly long half-life (24,110 years). Its overall stability in sedimentary records will provide reliable (i.e., unaltered) archives for future geological records detectable as far as 100,000 years into the future (Hancock et al., 2014; Waters et al., 2015; Zalasiewicz et al., 2019b, para. 5.8.2), after which it will decay into ^{235}U (uranium-235), with a half-life of 703.8 Ma.

Several types of chemical signatures are traceable for the Anthropocene – from POPs, metals, and mineral-like compounds to radioactive isotopes and anthropogenic greenhouse gasses. While detecting the anthropogenic causes of these chemical traces worldwide is not an issue *per se*, difficulties arise in recognizing them for a formal time unit – especially considering the lack of formal recognition of chemostratigraphy by the *Guide* and NACSN's Code. Another major difficulty is the lack of knowledge of the full extent of anthropogenic alteration of the chemosphere and the Earth System, both in terms of composition and future consequences (Chiaia-Hernandez et al., 2017).

3.1.2.6 Chronostratigraphic Evidence

Chronostratigraphy is "[t]he element of stratigraphy that deals with the relative time relations and ages of rock bodies" (Salvador, 1994, p. 77). The purpose of chronostratigraphic classification is "to organize systematically the rocks forming the Earth's crust into named units (chronostratigraphic units) corresponding to intervals of geologic time (geochronologic units) to serve as a basis for time-correlation and a reference system for recording events of geologic history" (p. 85). In simpler terms, chronostratigraphy concerns "the taxonomy and classification of geological time" (Lucas, 2018, p. 2) through meaningful and useful time units.

The basic conceptual units of chronostratigraphic classification are *chronostratigraphic units*. These are the only time-dependent material categories among stratigraphic units (Figure 3.1) because they are based exclusively on the time (either relative or absolute) of formation of rocks, regardless of other properties that the rocks exhibit (e.g., lithology, fossil content, remanent magnetism, etc.). A chronostratigraphic unit is *material* in the sense that it represents a "body of rocks that includes all rocks forming during a specific interval of geologic time and only those rocks formed during *that time span* [emphasis added]" (Salvador, 1994, p. 78). The 'time span' corresponds to specific *geochronological units* – that is, "units of time during which chronostratigraphic units were formed" (p. 77). Unlike chronostratigraphic

[200] Measurements in carbon dating often assume radiocarbon's half-life to be 5,568 years, which is the value originally set by chemist Willard Libby when he developed radiocarbon dating during the 1940s. Although more recent studies have reported a value of 5,730 years (the so-called Cambridge half-life), the Libby value is still used to avoid comparison errors with studies that used this value. For more information, see https://www.radiocarbon.com/tree-ring-calibration.htm (accessed on July 5, 2021).

units, geochronological units are abstract, non-material categories reflecting periods of time (i.e., an observer can see and touch a Jurassic System, but cannot see and touch the Jurassic Period, the latter only representing a time interval), and are therefore not stratigraphic units. Figure 3.4 summarizes the main chronostratigraphic units and their respective geochronological units.

CHRONOSTRATIGRAPHIC UNITS	GEOCHRONOLOGICAL UNITS
Eonothem	Eon
Erathem	Era
System	Period
Series	Epoch
Stage	Age

Figure 3.4. Chronostratigraphic units and their respective geochronological units.

Chronostratigraphic units form the basis of international chronostratigraphic chart (see Appendix), whereas their correspondent geochronological units define the geological time scale. The apparent redundancy of the existence of parallel timescales, as well as the counterintuitive relationship between geochronology and chronostratigraphy, have been object of debate in the past decades (Walsh, 2004; Walsh, 2001). Some authors (including Zalasiewicz himself) have questioned the utility of maintaining this dualism (Zalasiewicz, 2004; Zalasiewicz et al., 2004), or proposed a realignment of the 'dual' hierarchy (Zalasiewicz et al., 2013). Nevertheless, it seems that the majority of geologists seem to endorse the dualism by considering it necessary and obvious (Finney & Edwards, 2016).

The stage is the basic rank-unit of chronostratigraphy "because it is suited in scope and rank to the practical needs and purposes of intraregional chronostratigraphic classification" (Salvador, 1994, p. 77). The lower boundary of a stage is defined through its boundary-stratotype or GSSP (later in this section), which can also be used to define the lower boundary of chronostratigraphic units of higher rank (e.g., the boundary-stratotype/lower boundary of the Gelasian Stage at Monte San Nicola at Gela, Sicily, Italy, also defines the boundary-stratotype/lower boundary of the Quaternary System). Chronostratigraphic units are correlated to other types of stratigraphic units (especially biostratigraphic units) to reflect changes and events in the Earth's history, and the higher the rank of a chronostratigraphic/geochronological units, the greater the magnitude of those changes.

Chronostratigraphic units have been chosen as international point of reference among stratigraphers because they are defined on a universal property: time. The ultimate goal of chronostratigraphy is to provide a classification of all rocks in relation to time and, in doing so, to provide a comprehensive international scale serving as a reference system for time-correlation (i.e., the International Chronostratigraphic Chart). As stated by the *Guide*, chronostratigraphic units "offer the best promise of being recognized, accepted, and used worldwide and of being, therefore, the basis for international communication and understanding" (ibid. p. 90). By correlating with other stratigraphic units, chronostratigraphic classification "stands out as the basis to reach the ultimate goal of stratigraphy and to improve the knowledge and understanding of the Earth's rock bodies and their history" (p. 103).

A central concept and method for chronostratigraphic classification is the Global Boundary Stratotype Section and Point (GSSP), informally known as the 'golden spike.' A GSSP is "the designated type of stratigraphic boundary identified in published form and marked in the section as a specific point in a specific sequence of rock strata and constituting the standard for the definition and recognition of the stratigraphic boundary between two named global standard stratigraphic (chronostratigraphic) units" (Cowie et al., 1986, p. 5). In practical terms, it is a bronze, spike-like mark (hence 'golden-spike') inserted in rock strata in a determined location defining the base of a stratigraphic unit and serving as an international standard of reference. For instance, the visible golden spike inserted in a Monte San Nicola section (stratotype section) in Sicily, Italy, is used to define the lower base (boundary) of the Gelasian Age/Stage as well as the Pleistocene Epoch/Series, and the Quaternary Period/System, and serves as a standard for global correlation for other Gelasian, Pleistocene, and Quaternary rocks.

1. A GSSP has to define the lower boundary of a geologic Stage.
2. The lower boundary has to be defined using a primary marker (usually first appearance datum of a fossil species).
    a. There should also be secondary markers (other fossils, chemical, geomagnetic reversal).
    b. The horizon in which the marker appears should have minerals that can be radiometrically dated.
    c. The marker has to have regional and global correlation in outcrops of the same age.
    d. The marker should be independent of facies.
3. The outcrop has to have an adequate thickness.
4. Sedimentation has to be continuous without any changes in facies.
5. The outcrop should be unaffected by tectonic and sedimentary movements, and metamorphism.
6. The outcrop has to be accessible to research and free to access.
    a. This includes that the outcrop has to be located where it can be visited quickly (International airport and good roads), has to be kept in good condition (Ideally a national reserve), in accessible terrain, extensive enough to allow repeated sampling and open to researchers of all nationalities.

i. The boundary-stratotypes must be selected in sections representing essentially continuous deposition. The worst possible choice for a boundary-stratotype of a chronostratigraphic unit is at an unconformity.

ii. The boundary-stratotypes of Standard Global Chronostratigraphic Units should be in marine, fossiliferous sections without major vertical lithofacies or biofacies changes. Boundary stratotypes of chronostratigraphic units of local application may need to be in a nonmarine section.

iii. The fossil content should be abundant, distinctive, well preserved, and represent a fauna and/or flora as cosmopolitan and as diverse as possible.

iv. The section should be well exposed and in an area of minimal structural deformation or surficial disturbance, metamorphism and diagenetic alteration, and with ample thickness of strata below, above and laterally from the selected boundary-stratotype.

v. Boundary stratotypes of the units of the Standard Global Chronostratigraphic Scale should be selected in easily accessible sections that offer reasonable assurance of free study, collection, and long-range preservation. Permanent field markers are desirable.

vi. The selected section should be well studied and collected and the results of the investigations published, and the fossils collected from the section securely stored and easily accessible for study in a permanent facility.

vii. The selection of the boundary stratotype, where possible, should take account of historical priority and usage and should approximate traditional boundaries.

viii. To insure its acceptance and use in the Earth sciences, a boundary stratotype should be selected to contain as many specific marker horizons or other attributes favorable for long-distance time correlation as possible.

Figure 3.5. On the top: list of extant criteria established by the ICS for a GSSP to identify a geologic section. On the bottom: additional criteria from the abridged *Guide*. Another list of similar or equivalent criteria has also been compiled by Remane et al. (1996). (Top source: ICS, https://stratigraphy.org/gssps/, accessed on July 5, 2021; bottom source: Murphy & Salvador, 2000)

The GSSP method has been promising for identifying internationally agreed-upon boundary-stratotypes in chronostratigraphy since the 1960s (Lucas, 2018). Currently, the great majority of Phanerozoic chronostratigraphic units are defined through this method.[201] After a vote held online in May 2019, the

[201] As of July 2021, 77 GSSPS have been ratified. For a list of all GSSPs, see https://en.wikipedia.org/wiki/List_of_Global_Boundary_Stratotype_Sections_and_Points (accessed on July 5, 2021. Last revision: June 30, 2021, 20:22 CET by Benniboi01).

AWG chose the GSSP method to characterize the Anthropocene as a chronostratigraphic unit. A list of requirements necessary to propose a geologic section as a possible GSSP have been outlined by the ICS and the abridge version (Murphy & Salvador, 2000) of the *Guide* (Figure 3.5), which has been encouraging the standardization of this methodology in chronostratigraphic/geochronological research.[202]

Requirement (1) establishes the *rank-level* at which GSSPs are placed, and the *position* of a material stratigraphic section (i.e., a layered rock exposure) where the golden spike is placed. As previously mentioned, the selected rank-level for the boundary-stratotype of a chronostratigraphic unit is stage (and age, its geochronological equivalent). This choice reflects epistemic gains of a practical and methodological nature (see Salvador, 1994, section 9.C.2). The selected position in a material stratigraphic section for locating a GSSP is its lower boundary (i.e., the lowermost end of a vertical chronostratigraphic section), which represents the boundary-stratotype of chronostratigraphic units. Indeed, chronostratigraphic units are not defined by their material content (or unit stratotype), but rather by their beginning (i.e., boundary stratotype), which is delimited upward by the lower boundary of the next chronostratigraphic unit (e.g., the upper boundary of the Pleistocene (2.58 Ma) is defined by the lower boundary of the Holocene at 11.7 ka). This choice followed from methodological issues in defining chronostratigraphic units based on their content (Remane, 2003; Walsh et al., 2004).

Requirement (2) requires a GSSP to be defined by a *primary marker* – that is, the signal that is most distinctive of the geological section being considered. For most Phanerozoic units, the primary marker has been defined by the first (but also last) appearance datum of a species. This means that primary markers are usually of a biostratigraphic nature. Secondary markers of a different stratigraphic nature are also necessary to define a GSSP (requirement 2a), and both the primary and secondary markers need to be *global* and *synchronous* (requirement 2c). The synchronicity requirement is an important aspect of the Anthropocene Hypothesis, and has raised criticism among its detractors.[203] Additionally, the selected rock exposure must present different characteristics, from having an adequate thickness (requirement 3), being unaltered (requirement 5), and being easily accessible (requirement 6). The ICS oversees the choice, evaluation, and placement of a GSSP (Lucas, 2018) by appointing working groups within their respective subcommissions. The AWG represents the group tasked with assessing whether an Anthropocene type boundary or GSSP can be characterized and defined.

The nature of the GSSP methodology has been a debated theme in geological literature (Remane et al., 1996; Walsh et al., 2004). Philosopher of science Alisa Bokulich (2020c) has observed that a GSSP is not immediately "defined in terms of a numerical 'absolute' time age, but rather is defined stratigraphically as a precise moment in 'relative' time" (p. 53). A GSSP is *not* chosen based on a given date. Only if "there is suitable material at the boundary to be radiometrically dated, then an absolute age may be associated with

[202] Another comprehensive overview of the requirements for a GSSP in the context of Quaternary stratigraphy has been compiled by Head and Gibbard (2015, see Table 1). The authors also note that "[n]ot every global stratotype section will meet all requirements. Common sense and experience usually determine what compromises can be made in order to avoid eternalizing the search for the perfect section" (p. 3, Note 1). Indeed, rather than binding requirements, these criteria should be understood as more or less flexible research guidelines.

[203] Criticism against the Anthropocene Hypothesis is discussed in section 5.2.

the boundary, but it is not taken to define the moment in time" (ibid.). This is an important and clarifying point for Anthropocene Studies. A GSSP is a conventionally stipulated point that identifies a clearly visible and easily accessible (requirement 6a, Figure 3.5) start of a chronostratigraphic unit. It does not immediately entail a numerical date, which can be assigned radiometrically *ex post*, but is rather assigned stratigraphically. A numerical date is not constitutive of a GSSP. What is constitutive is the recognizable and globally detectable presence of a distinct sedimentary layer, usually (but not exclusively) defined by the first appearance datum of a fossil species (requirement 2, Figure 3.5). Therefore, if a numerical date is only secondary to the identification of a recognizable sedimentary layer, the question concerning the political and historical convenience of locating a GSSP in the history of humanity – whether in the Neolithic Revolution, the colonization of the Americas, the Industrial Revolution, the Great Acceleration, or the Atomic Age – becomes only secondary to the identification of a distinguished Anthropocene Series.

Another interesting aspect requiring further investigation here are the apparent epistemic challenges posed by the 'Anthropocene' to geochronology as well as to the GSSP methodology. In criticizing Lewis and Maslin's (2015a) proposal to locate the beginning of the Anthropocene in either 1610 or 1964, Clive Hamilton advances that the seemingly lack of a first appearance datum (FAD) as primary marker "ought to signal that identification of the new geological epoch can be like no previous one and the conventions will have to change (something the AWG is wrestling with)" (Hamilton, 2015, p. 105). This statement is a double-edged sword. On the one hand, it argues that the lack of a biostratigraphic marker represents a unique instance to validate the Anthropocene on different stratigraphic (and perhaps extra-stratigraphic, e.g., Earth System) grounds – granted that substantial evidence is provided to legitimize this exception. On the other hand, it explicitly states that an Anthropocene unit lacks a crucial characteristic of stratigraphic and chronostratigraphic units – that is, a valid biostratigraphic marker (such as FAD).[204]

Furthermore, by locating a possible GSSP in the radionuclide fallout of atomic bomb testing during the 1950s (as currently proposed by the AWG), the 'Anthropocene' seems to bypass many of the traditional issues faced by geochronology, such as Cleland's (2011) search for a smoking gun, the issue of precision and accuracy in radiometric dating (Schoene et al., 2013), and the uncertainty in retroductive reasoning and historical hypothesis (Kitts, 1978; Turner, 2007, 2013) – all these being common in geochronological dating.[205] Perhaps the degree of consilience (i.e., the convergence of multiple independent explanatory lines toward a common explanation) of the evidence or traces shown in support of an Anthropocene unit may be one driver to promote changes in the perception of what constitutes geological evidence in the first place. On a purely speculative level, preservation of this evidence in the deep future will serve short- and long-term future geologists as a valid pool of knowledge to reconstruct the Earth's late geohistory. Indeed, such a scenario has been a central discursive stratagem to either validate or invalidate the hypothesis – as later discussed in Chapter 5.

[204] Despite biostratigraphic markers play a central role in defining the base of chronostratigraphic units, it is not strictly mandatory for any proposed time unit to use biostratigraphic markers as primary makers. Indeed, neither the GSSP for the Quaternary nor for any of its subdivisions coincides with a primary marker of a biostratigraphic nature.
[205] These aspects of primarily a philosophical-epistemological nature are further discussed in section 4.2.

Lucas (2018, 2019, 2020) identifies several problems with GSSP-based chronostratigraphy.[206] One of these is related to the inconsistencies in naming and defining chronostratigraphic units, which Lucas (2018) attributes to the diversified methods and practices of each of the twelve ICS Phanerozoic Subcommissions (one for every system/period in the Phanerozoic). Terminological inconsistency is an aspect also reflected in the different vocabularies implemented among geological cultures. The use of *geosol* versus *paleosol* in pedostratigraphy by the NACSN and the ICS, respectively, is an example of the lack of a unified vocabulary. With respect to chronostratigraphy, naming time units has been one of the first geological practices, and some of the names persist today either formally (e.g., Quaternary) or informally (e.g., Tertiary, Precambrian). When proposing new chronostratigraphic units, subcommissions may introduce new terms rather than using old ones for proposed units (as the Cambrian Subcommission did with the 'Tommotian Stage,' now ratified as Cambrian Stage 2), or simply used existing ones. Naming may also differ across geological cultures and institutions. For instance, in North America, the Mississippian and Pennsylvanian constitute two subsystems of the Carboniferous (358.9–298.9 Ma), while in Europe they are simply identified as Lower and Upper Carboniferous, respectively.[207] Both units (Mississippian and Pennsylvanian) appear on the geological time scale and international chronostratigraphic chart.

Defining time units has also been inconsistent since "other kinds of signals have been used as the primary signal of many GSSPs that are non-biotic and that are inherently not able to be uniquely identified without other (usually biotic) criteria" (Lucas, 2018, p. 10). This is not directly in contrast with the *Guide*'s second requirement (Figure 3.5), which states that lower boundaries require primary markers *usually* of a biostratigraphic nature. The problem stressed by Lucas is the *weight* given to a primary signal when determined only in relation to other signals. This weighting has not been consistent across chronostratigraphic units. Additionally, Lucas (2020) also argues that "we need something better than GSSPs with primary signals based on single taxon LOs, which are highly diachronous and subject to restricted distributions due to facies changes, taphonomic biases and/or provinciality" (p. 10).[208]

Another interesting and problematic aspect of GSSP chronostratigraphy is the question of the arbitrary placement of GSSPs. This is an important epistemological aspect of the GSSP because it concerns its meaning, application, and its ultimate usefulness. Thus, it is also important for the general 'Anthropocene' debate, where the GSSP has been in the spotlight in multidisciplinary research. As Ager (1973) puts it, the issue lies on "whether or not you think that the history of the earth is divisible into units by means of natural events (or revolutions) detectable by man. The alternative is a record without natural breaks, only divisible by arbitrary manmade decisions. It is, if you like, dogmatism versus pragmatism" (p.

[206] Lucas considers inconsistency, arbitrary decisions, reductionism, instability, locality, imprecision, and politics as inherent epistemic issues in defining GSSPs. Here, only inconsistency and arbitrary decisions are treated for their role within the Anthropocene debate. For additional literature on the history, philosophy, and criticism of the GSSP method, see Remane (1996), Walsh (2001), Walsh et al. (2004), Smith et al. (2015), and Bokulich (2018, 2020b).
[207] Interestingly, both the Mississippian and the Pennsylvanian are currently recognized in the 2021 geological time scale and international chronostratigraphic chart, where they stand out as the only subsystems/subperiods visible on both charts (see Appendix). The *Guide* does allow for the use of sub- and superunits at unspecified taxonomical level, but recommends this practice only when deemed necessary.
[208] Taphonomy is the study of decay and fossilization processes of organisms.

61). The pragmatic approach considers the selection of a GSSP only functional to correlation – that is, a GSSP does not have to reflect any particular event because it only needs to be correlatable.[209] The Earth's history can be arbitrarily divided as long as correlation of strata around the globe is possible and meaningful. Ager subscribed to the 'pragmatic' approach by arguing that "[i]t does not matter whether the golden spike is hammered in somewhere in England or in France or in China, so long as we can make an arbitrary decision" (p. 72). On the opposing side of the pragmatic approach, he identifies event-based chronostratigraphy – that is, GSSPs are reflections of events that are attributed significance for reconstructing the Earth's history. Lucas (2018) has subscribed to this stance, arguing that the Earth's history should be divided based on recognizable events, and he expands the definition of event by also recommending that non-biostratigraphic criteria be used more often in defining GSSPs (Lucas, 2019). Objecting to the 'pragmatic' approach, he claims that "[a]rbitrary decisions are random, based on personal choice or whim and thus are not based on any system or line of reasoning. Therefore, arbitrary decisions are not scientific decisions" (Lucas, 2018, p. 10).

While Lucas (personal communication, September 10, 2020) agrees with Finney and Edwards (2016) that that the Anthropocene constitutes a social and/or political statement above and beyond its value as a scientific hypothesis, his observations on the nature of GSSPs are useful for understanding its philosophy and application. This is particularly valuable for Anthropocene Studies, where setting a beginning through GSSP has seen a substantial political turn. For instance, Lewis and Maslin (2015a, 2015b, 2018a) have proposed 1610 as a possible GSSP candidate for the Anthropocene. Alongside the stratigraphic evidence they provide, the authors advocate that this date "highlights social concerns, particularly the unequal power relationships between different groups of people, economic growth, the impacts of globalized trade, and our current reliance on fossil fuels" (Lewis & Maslin, 2015a, p. 177). The authors make explicit that the broader social and political importance of selecting a beginning comes "only *after*" (Lewis & Maslin, 2015b, p. 142) the geological evidence they provide. However, in an article published on *The Conversation*, Maslin and Lewis (2020) state:

> In addition to the critical task of highlighting and tackling the racism within science, perhaps geologists and geographers can also make a small contribution to the Black Lives Matter movement by unflinchingly compiling the evidence showing that when humans started to exert a huge influence on the Earth's environment was also the start of the brutal European colonisation of the world […] Defining the start of the human planet as the period of colonisation, the spread of deadly diseases and transatlantic slavery, means we can face the past and ensure we deal with its toxic legacy. (no page numbers)

Maslin and Lewis's (2020) statement is vividly normative – and legitimately so. However, it generates several epistemic issues as a statement concerning *why* and *when* to locate the beginning of the Anthropocene through a GSSP. Either from an event-based or arbitrary-choice–based GSSP, it is stratigraphic evidence that requires correlation rather than historical significance. This evidence may (or may not) leave certain

[209] This view seems to be shared by present geologists such as Gale and Hoare (2012), who note that "[p]erhaps the most important requirement of a GSSP is that it should be suitable for global correlation" (p. 1492).

marked signals in rocks and strata, and these only determine whether an outcrop can be used as a location to place a golden spike. The broader social and political implications of selecting one location and a specific time are only considered after a section is thoroughly examined – as is the case with the proposed Anthropocene unit. Considerations of a societal nature are not epistemic parameters in the process of validating and selecting a golden spike (although politics *sensu lato* does play a role).

Postcolonial literature (e.g. Davis & Todd, 2017; Keerer, 2020) has repeatedly stressed the importance of using the colonization of the Americas as a possible beginning of the Anthropocene (and rejection of the Anthropocene Hypothesis). Yet, aside from Lewis and Maslin's proposal, most of this literature has had little or no interaction with the basic science behind the stratigraphy of the Anthropocene. Thus, the empirical content of these proposals is difficult, if not impossible, to assess on purely stratigraphic grounds. Feasibly, the selection of one or more starting dates based on normative grounds may have generated a semantic overlap between overlap between the 'Anthropocene' and the Anthropocene Hypothesis. As a consequence, geologists may have grown suspicious of the Anthropocene Hypothesis as a political, rather than scientific, idea (Finney & Edwards, 2016).

An alternative technique only briefly considered by the AWG (Zalasiewicz et al., 2015b) is the use of a Global Standard Stratigraphic Age (GSSA). The GSSA method was introduced in 1989 as an alternative boundary-type definition for Precambrian units, where fossil records are scarce and correlation more difficult. A GSSA defines boundaries in terms of absolute age, providing a conventional numerical date that separates time units, for instance, the Archean (4–1.5 Ga) from the Proterozoic (2.5–0.541 Ga). The 'conventional' nature implies that "the numerical value of the boundary age is a theoretical postulate, independent of the method applied to obtain numerical ages" (Remane et al., 1996, p. 78). Currently, most of the pre-Edicaran (Proterozoic and Archean) time units are divided through GSSAs because of the lack of substantial fossil records and clear correlation – both fundamental requirements for locating GSSPs. It is a generally less preferred method than the GSSP, which is grounded on physical evidence reflecting changes or events that can be correlated. An active effort to replace GSSA-defined boundaries with GSSPs has been ongoing since the GSSP became an established methodology – for instance, with the base of the Cryogenian at c. 720 Ma (Shields-Zhou et al., 2016).

Figure 3.6. Sites for possible location of a GSSP for the Anthropocene as of September 2021. The squared brackets identify the specific type of environmental archive where core samples where extracted (NB: the Searsville Reservoir in California, USA, is juxtaposed to the San Francisco Bay location because they are geographically very close. For a similar map, see AWG, 2020, p. 5). (Source: Google Maps).

The AWG (2020) has considered twelve possible locations for defining the stratigraphic profile of an Anthropocene unit, and locating a GSSP. Figure 3.6 summarize them. Core samples have been extracted from each location and analyzed.[210] Preliminary findings indicate that geochemical markers such as radionuclides associated to nuclear bomb testing are detectable virtually in all samples, corroborating the idea that locating a GSSP around the 1950s is the most suitable option in stratigraphic terms.

A conference/exhibition at the Haus der Kulturen der Welt scheduled for May 2022 will present the research undertaken at each site, accompanied by a special publication to be submitted to *Anthropocene Review* in the same year. This will represent an important and necessary step towards the process of submitting a formal recommendation for recognizing the Anthropocene as a distinct, post-Holocene geochronological and chronostratigraphic time unit.

[210] Some core samples are being analyzed at the time of writing (September 27, 2021).

3.1.3 Remarks on Non-Stratigraphic Evidence

The evidence surveyed in the previous sections does not exhaust the overall scientific and descriptive research on the Anthropocene as a possible geological time unit. That is not solely because research on the Anthropocene Hypothesis is ongoing, but also because dedicated scientific research extends beyond the domain of traditional stratigraphy. As observed at the beginning of the chapter, Earth System science and evolutionary biology and ecology are two examples of major disciplinary grounds providing additional supporting, non-strictly stratigraphic evidence for the Anthropocene Hypothesis. Earth System science has been both historically and conceptually close to the 'geological Anthropocene,' since the term primarily developed within this disciplinary context and later followed its independent research trajectory. The stratigraphic markers located around 1950s largely coincide with Earth System markers. However, as also observed by anthropologist Andrew S. Mathews (2020), the Earth System science 'Anthropocene' is "quite different from the Anthropocene of geologists" (p. 68) because they follow different methodological trajectories – notably, the geologists' quest to locate a GSSP.

Additional disciplinary domains describe the anatomy of the Anthropocene not solely as a reflection of the multidisciplinary nature of this hypothesis, but also of the ontological spectrum of phenomena that may characterize an Anthropocene unit. Archaeology and history are two examples of this.

Archaeology is a discipline historically and methodologically very close to geology (Edgeworth, 2014b). In 18th- and 19th-century geology, when the age of the Earth was believed much shorter, archaeological evidence was often invoked in geological handbooks and research. For instance, in chapter XV of his second volume of *Note ad un corso annuale di geologia* (Stoppani, 1867),[211] Antonio Stoppani described the 'Anthropozoic formations' of the Neozoic Epoch mostly in association with archaeological findings across Europe. In the context of the Anthropocene, the recent deposition of anthropogenic stratigraphic signals makes them object of interest of archaeologists as well.[212] Erlandson & Braje (2013) argue that "archeological records can be utilized by scholars to understand not just *when* humans dominated earth's ecosystems, but the *processes* that led to such domination" (p. 3). In fact, archaeological research has advanced alternative starting dates from the AWG's selected date, suggesting much earlier beginnings to the proposed epoch than the 1950s. Among the topics that emerged withing archaeological discourse, the nature of the 'archaeosphere' (Edgeworth, 2014a) and its relation to stratigraphy has established a strong link between geological and archaeological research – a link that, by the early 20th century (Harris, 1989), originated 'archaeological stratigraphy' as the application of stratigraphic principles to archaeological research.

[211] *Note* represents the first edition of the more popular (and retitled) three-volume *Corso di Geologia*, published between 1871 and 1873.

[212] In 2013, the journal *Anthropocene* published a volume entitled "When Humans Dominated the Earth: Archaeological Perspectives on the Anthropocene," edited by the archaeologists Jon M. Erlandson and Todd J. Braje. The volume includes eleven research articles from archaeology dedicated to the onset and definition of the 'Anthropocene.'

A meeting point between geologists and archaeologists in describing the archeosphere has been the recognition of the existence of artificial ground. These are formed “by the excavation, transport and deposition of natural geological materials and the accumulation of novel materials […] related to urban development, mineral exploitation, waste dumping and land reclamation” (Zalasiewicz et al., 2019b, p. 60). According to Edgeworth & al. (2015), the physical traces of artificial ground may provide evidence for a diachronous onset in defining the Anthropocene by marking “the division between humanly modified ground and natural geological deposits” (p. 1). However, as noted by the AWG (Zalasiewicz et al., 2019b), this is a different research trajectory from considering the Anthropocene as a chronostratigraphic unit because “[a]rtificial ground is not in itself a marker for the Anthropocene […] but one that reflects the classification of physical deposits” (pp. 61-62). Yet artificial ground may provide a useful characterization of the anthropogenic deposits for a diachronous Anthropocene – for instance, by classifying technogenic grounds in relation to the properties and time.[213]

As discussed in section 1.2.3, history has also provided evidence in support of the Anthropocene Hypothesis by shedding light over the social and historical mechanisms behind the starting dates proposed by the AWG throughout the year. The historical (viz. causal) mechanisms behind global and seemingly synchronous anthropogenic signals are not intrinsically part the hypothesis, whose aim is fundamentally stratigraphic. Consequently, the explanatory expectations differ profoundly between historians and stratigraphers. History can bridge this explanatory gap by providing historical and social insights otherwise not accounted by the stratigraphic community – unequipped to deal with such short and human-characteristic times. Such cooperation is especially beneficial for stratigraphers, in that a historical framework is provided for what would otherwise only represent descriptions of certain anthropogenic signals of mainly stratigraphic rather than historical interest.

It is difficult to translate the whole array of anthropogenic influences and signals left on the Earth into the domain of stratigraphy – mostly because evidence of anthropogenic forcings is largely abundant and ongoing. Discerning what does represent stratigraphic evidence among this vast spectrum of signals is a fairly new circumstance for traditional stratigraphic research. Not all anthropogenic signals represent material of *stratigraphic* interest, and they will be even less so from a distant future – that is, from a ‘future geologist observer’ viewpoint. Most surface traces will deteriorate to complete dissipation. This is why the AWG has been looking for long-lived elements such as lead or uranium radionuclides with longer half-lives, and thus higher preservation potential.

The focus so far given has been to the stratigraphic evidence at the core of the Anthropocene Hypothesis. The next section discusses another major and highly debated aspect of the Anthropocene Hypothesis, which is closely connected to the stratigraphy (and particularly chronostratigraphy) of the Anthropocene – that is, its beginning.

[213] One proposal on the classification of artificial ground is advanced by Peloggia & al. (2014). The proposal also provides an overview on past and present approaches in classifying artificial grounds in geological terms.

3.2 The Beginning of the Anthropocene

For any state of affair or phenomenon, multiple scientific hypothesis can be formulated to explain it. As a broader Earth System, geological, and evolutionary phenomenon, the 'Anthropocene' idea has engendered a pool of diversified hypotheses concerned with its beginning – a key ingredient in defining the 'Anthropocene.'[214] These hypotheses compete with, challenge, complement, or expand upon the Anthropocene Hypothesis. Understanding the context and interplay between the Anthropocene Hypothesis and its alternatives or 'competitors' is not just crucial in framing the broader arena of debate – it also represents an intrinsic epistemological aspect of the evolution of the Anthropocene Hypothesis. Therefore, this section scrutinizes this context by analyzing and discussing alternative 'Anthropocene' hypotheses based on their suggested beginning of the proposed time unit. The discussion builds on existing research cataloguing and discussing proposed starting dates of the 'Anthropocene.'[215]

The Anthropocene Hypothesis has been defined specifically as the hypothesis formulated by the AWG. Its stratigraphic basis has been summarized in section 3.1. As observed, a necessary requirement for proposing a formal time unit on the geological time scale is defining its lower stratigraphic boundary or GSSP (at a stage level), which also anchors the beginning of the corresponding geochronological time unit. Selecting a starting date is a task conducted only *after* substantial stratigraphic evidence has been submitted for recognition of a discrete stratigraphic unit in the geological records. This having been fulfilled, then a discussion over the chronostratigraphic beginning of the unit can take place.

Following an online vote held in May 2019, the AWG has chosen the GSSP as the primary method to locate such a boundary, and the radionuclide fallout from nuclear and thermonuclear atmospheric tests during the mid-1950s has been considered a primary candidate to define the lower stratigraphic boundary of the Anthropocene. Zalasiewicz et al. (2015b) argue that assessing when to locate the beginning of the Anthropocene "is *separate* from whether the Anthropocene should be formalized or not" (p. 197). However, since formal ratification requires setting a beginning, and because the 'Anthropocene' would be an empty category if no beginning (whether diachronous or synchronous, formal or informal) would be assigned to it, setting a beginning is a particularly important task for both the AWG and the 'Anthropocene' research community.

In fact, defining the beginning of the proposed time unit is perhaps the most crucial and most discussed aspect of the Anthropocene Hypothesis, and of the overall 'Anthropocene' debate. In stratigraphy, this is because geological time units, either formal or informal, necessarily require a lower stratigraphic boundary or starting date determining the specific time they cover. In the broader

[214] Notably, hypotheses over the beginning of the 'Anthropocene' as a political, historical, and social phenomenon have also been formulated by humanists and social scientists. These, however, are not the primary focus of this section.
[215] See for instance Edgeworth et al. (2015), Lewis and Maslin (2015a), Ruddiman (2018), Santana (2019a), Wagreich and Draganits (2018), Zalasiewicz et al. (2019b, Chap 7), and Zalasiewicz et al. (2014c).

'Anthropocene' discourse, this has important historical and social implications for determining when and how humans became such a powerful geological agent. Discussions over the beginning and unfolding of the proposed epoch have been held among the natural, human, and social sciences using a range of different methods and aims that have resulted in several alternative hypotheses. Some of these hypotheses developed outside the strictly stratigraphic and scientific endeavor by either coining terminological alternatives with different starting dates, or by maintaining the term 'Anthropocene' but proposing starting dates based on non-stratigraphical parameters – for instance, by considering the political, social, ethical, or environmental consequences of a selected starting date. Jason Moore's idea of the 'Capitalocene,' or the broader meaning of the colonization of the Americas in 'Anthropocene' postcolonial literature, are examples of these alternatives. They mostly focus on the historical roots rather than stratigraphic base of the 'Anthropocene' and locate its beginning in the 16^{th} century by stressing the broader historical, but also the normative, value of selecting this time period. This type of hypotheses is not discussed in this section.

Other alternative hypotheses seem to directly compete with the Anthropocene Hypothesis by virtue of the methodological and evidential patterns they follow (e.g., stratigraphic signals, GSSP, etc.). But what does it mean that these hypotheses *compete*?

Competing 'Anthropocene' hypotheses are those hypotheses sharing the fundamental idea that anthropogenic activities may be recognized on the geological time scale, but suggest different beginnings from the one currently proposed by the AWG. They share approximately the same type of scientific evidence (pedological, chemical, stratigraphical, etc.) and methods (the GSSP or GSSA), or bring new evidence or methods relevant within the stratigraphic discourse. They do not implement terminological alternatives to the 'Anthropocene.' They are *competing* because, as is common in science, multiple mutually exclusive descriptions and/or explanation of a phenomenon or state of affairs may coexist before one emerges as the accepted description/explanation of the phenomenon or state of affairs at stake. Given that multiple lower boundaries (i.e., beginnings) cannot be located for geological time units, only one hypothesis can establish itself as the best description of an Anthropocene time unit.

Not all the proposed starting dates surveyed in natural science strictly compete with the Anthropocene Hypothesis. The 'Anthropocene' as developed within the Earth System science community (Syvitski et al., 2020), with its different 'stages' and signatures (Steffen et al., 2007; Steffen et al., 2008), is not inconsistent with the Anthropocene Hypothesis. It represents a different formulation of the 'Anthropocene' sharing much of the evidence, epistemic actors, and research platforms with the Anthropocene Hypothesis. In archaeological research, a diachronous onset of the 'Anthropocene' has been advanced that stretches for thousands of years before the present. Some proponents of a diachronous 'Anthropocene' reject a chronostratigraphy-based definition of the proposed unit. Other proposals advocate for using the Anthropocene as an informal designation.

Another way that alternative hypotheses compete relates to the very meaning and scope of the Anthropocene Hypothesis. Thus, competition occurs on three different grounds: (1) recognition of the Anthropocene as a formal geochronological/chronostratigraphic unit; (2) selection of the appropriate lower boundary reflecting the onset of the unit; and (3) determination of what methodology and/or pool of evidence (and thus discipline) best encapsulate the range of phenomena distinctive to the 'Anthropocene' (a task still occupying a central role in Anthropocene research literature). Discerning these levels of competition is important to grasp the extent to which the Anthropocene Hypothesis is being contested.

What are, then, the alternative hypotheses to the Anthropocene Hypotheses? Because "[t]he start of the Anthropocene depends on the eye of the beholder and the sub-discipline of science being considered" (Syvitski & Kettner, 2011, p. 958), it is not easy to classify proposed starting dates in a perfectly consistent and exhaustive framework. Perhaps the best way to visualize this landscape of hypotheses is chronologically – that is, from the oldest to the most recent proposed starting date. This represents the first parameter of selection of a proposed hypothesis as well as the first criterion for organizing the corpus of alternative candidates. Because the sum of the hypotheses gathered in the following section covers different time periods of human history and prehistory (including one prior to the first appearance of *Homo sapiens* in the fossil record), the most practical and relevant classification divides them within a temporal frame. As a result, four clusters of hypotheses have been identified, namely *paleoanthropocene hypotheses* (1.8 Ma to 11.7 ka), *early Anthropocene hypotheses* (11.7–2 ka), *modern Anthropocene hypotheses* (1500–1945 CE), and *contemporary Anthropocene hypotheses* (1945–1964 CE).[216] Figure 3.6 lists all hypotheses for each of these clusters.

[216] This quadripartite classification adds 'paleoanthropocene hypotheses' as an extra cluster to a common tripartition of proposed starting dates in Anthropocene Studies literature (e.g. Wagreich & Draganits, 2018; Zalasiewicz et al., 2014c).

Cluster	Hypothesis	Proposed Beginning	Primary Markers	Method(s)	GSSP	Source
PALEOANTHROPOCENE HYPOTHESES	**Mastery of Fire**	~1.8 Ma	use of fire, evolutionary traits	archaeology, palaeoanthropology, paleoclimatology	No	Glikson, A. Y. (2013)
	Pleistocene Megafauna Extinctions	~13.8 ka	pollen record, mammoth extinctions	paleoclimatology, paleoecology	No	Doughty, C. E., Wolf, A., & Field, C. B. (2010)
EARLY ANTHROPOCENE HYPOTHESES	**Human Niche Construction**	~11 ka–9 ka	ecosystem engineering, domestication	evolutionary ecobiology, stratigraphy	Yes*	Smith, B. D., & Zeder, M. A. (2013)
	***Homo sapiens* Diaspora**	~10 ka	*Homo sapiens* migrations, domestication, shell middens, anthrosols	archaeology, stratigraphy	No	Erlandson, J. M., & Braje, T. J. (2013)
	Ruddiman Hypothesis	~7 ka / ~ 5 ka	atmospheric CO_2 and CH_4 peaks	archaeology, paleoclimatology	No	Ruddiman, W. F., He, F., Vavrus, S. J., & Kutzbach, J. E. (2020)
	Late Bronze Age	~3 ka / 2 ka	atmospheric Pb peaks	archaeology, chemostratigraphy, stratigraphy	Yes	Wagreich, M., & Draganits, E. (2018)
	Anthropogenic Soils	~2 ka	anthrosols	pedology, pedostratigraphy	Yes	Certini, G., & Scalenghe, R. (2011)
MODERN ANTHROPOCENE HYPOTHESES	**Social Metabolism Hypothesis**	1500 CE	population growth, increased metabolic rates, increased fossil fuels consumption	history, IPAT, socioeconomic metabolism	No	Fischer-Kowalski, M., Krausmann, F., & Pallua, I. (2014)
	Orbis Hypothesis	1610 CE	atmospheric CO_2 dip	chemostratigraphy, history, paleoclimatology	Yes	Lewis, S. L., & Maslin, M. A. (2015a; 2015b; 2018)
	Industrial Revolution**	1780–1864 CE	atmospheric CO_2 increase	earth system science, history, paleoclimatology	No	Crutzen, P. J., & Stoermer, E. (2000); Foley, S. F., et al. (2013); Steffen, W., et al. (2004a)
	Tambora Volcanic Eruption	1815 CE	tephra	paleoclimatology	Yes	Smith, V. C. (2014)
	AD 1900	1900 CE	magnetic pollution particulates	magnetostratigraphy, paleomagnetism	No	Snowball, I., Hounslow, M. W., & Nilsson, A. (2014)
CONTEMPORARY ANTHROPOCENE HYPOTHESES	**Trinity Test Hypothesis*****	1945 CE	Trinity bomb detonation	chronostratigraphy (GSSA)	No	Zalasiewicz, J., Waters, C., Williams, M., et al. (2015)
	Nuclear & Thermonuclear Bomb Testing****	1950 – 1963 CE	atmospheric CO_2 increase, per capita energy consumption increase, radioisotopes	chemostratigraphy, chronostratigraphy (GSSA), earth system science	Yes/No	Syvitski, J., et al. (2020); Waters, C., et al. (2015); Zalasiewicz, J., Williams, M., & Waters, C. N. (2014)
	Bomb Spike Hypothesis	1964 CE	^{14}C peak	chemostratigraphy, dendrochronology	Yes	Lewis, S. L., & Maslin, M. A. (2015a; 2015b; 2018)

Figure 3.6. List of alternative and/or competing Anthropocene hypotheses. Dashes identify time ranges, whereas slashes identify two distinct beginnings. (*The promoted GSSP is coeval with the Holocene GSSP in line with the authors' proposal of a Holocene/Anthropocene unit; **The hypothesis includes different possible starting dates within a range; ***The hypothesis has been superseded; ****The hypothesis includes different possible starting dates within a range.)

How have these hypotheses been selected? Finding a consistent method for including and/or excluding proposed starting dates is once again a difficult task. However, two main parameters have been used to approach extant literature on the beginning of the Anthropocene. The first parameter, as previously mentioned, is locating proposals that assign a precise date or time range. All the hypotheses discussed in the following section propose (with methods and arguments) a determined beginning to the Anthropocene coinciding with some particular important anthropogenic event – either evolutionary, environmental, or Earth System. Thus, eventual proposals that do not specifically address or consider a starting date are excluded (with the exception of proposed diachronous onsets of the Anthropocene that still specifically frame the epoch into discrete stages or phases).

A second parameter distinguishes between descriptive hypotheses and normative hypotheses. As mentioned above, preferred starting dates or periods can be assessed based on normative claims of social, ethical, and political value. These are mostly based on the meaning and implications of selecting one date or another to define the beginning of the 'Anthropocene.' Their scope is primarily creating a socially-oriented narrative of the 'Anthropocene' within existing discourses on environmental history, power relations, capitalism, and postcolonialism. However, this is a different task that unfolds on a different theoretical ground (i.e., the 'Anthropocene') than assessing the scientific nature of the Anthropocene as a stratigraphic unit (i.e., the Anthropocene Hypothesis). Thus, only hypotheses with discernible descriptive, and primarily stratigraphic content, are taken into consideration. While stratigraphic-oriented research is emphasized, this parameter does not exclude non-stratigraphic research *tout court*. Some scientific proposals outside the boundaries of 'pure' stratigraphy are also considered by virtue of their appeal to additional empirical evidence of a scientific nature.

Lastly, two observations are due. The first concerns the nature of the very discussion concerning the GSSP. As anticipated at the beginning of this section, discussions over the lower boundary of an Anthropocene geochronological/chronostratigraphic unit via GSSP is a step that comes *after* a stratigraphic profile for the unit has been delineated. As noted by Stanley C. Finney and Lucy E. Edwards (2016), both geologists and critics of the Anthropocene Hypothesis, "focusing on the definition of the beginning of the Anthropocene can result in the lack of consideration of its stratigraphic content and its concept. It conveys the opinion that units of the geologic time scale are defined solely by their beginnings, rather than their content" (p. 7). Setting a beginning requires that a distinct stratigraphic profile of any unit is first recognized and acknowledged by the stratigraphic community. Selecting a lower boundary for a proposed chronostratigraphic unit only ensues after such a stratigraphic profile (characterized by the range of evidence discussed in section 3.1.2) is clearly identified.

The second observation concerns the future outcome of the Anthropocene as a geological time unit. It is possible that none of the proposed alternative or competing hypotheses may see a successful outcome in the geological community, meaning that an Anthropocene time unit (or any other equivalent terminological variant) may not see formal ratification.

This would imply three things. First, that an anthropogenic signature cannot or should not (yet) be recognized as relevant in a stratigraphic and geological context (in addition to other political and sociological aspects involved in the ratification process). This could be either because scientific evidence is considered insufficient or unconvincing, or because of the stratigraphic community at large does not consider an Anthropocene unit useful for the purpose of stratigraphic research – among other reasons. Second, that no 'epistemic void' (i.e., an unexplained/undescribed but observed phenomenon or state of affairs) would result by rejecting all of the competing hypotheses because, borrowing Kuhnian terms, the 'Anthropocene' would neither constitute a recognized scientific problem nor a puzzle.[217] Third, that the 'Anthropocene' would be best represented as an epistemic category or general term in a non-stratigraphic context. Indeed, while rejection of formal ratification would imply rejection of the Anthropocene Hypothesis, the widespread use of the term 'Anthropocene' in the scientific, but also broader academic and environmental discourse, will likely maintain the concept.

3.2.1 Paleoanthropocene Hypotheses

The term 'paleoanthropocene' was introduced by Foley et al. (2013) "to mark the time interval before the industrial revolution during which anthropogenic effects on *landscape and environment* [emphasis added] can be recognized but before the burning of fossil fuels produced a *huge crescendo* in anthropogenic effects" (p. 84). The authors define its timespan from the appearance of the genus *Homo* around 2.8 Ma (Villmoare et al., 2015) to the onset of the Industrial Revolution, which they set as 1780 CE. Their paleoanthropocene is considered a "transitional period" that is not intended "to compete for recognition as a geological epoch" (ibid.). Thus, it is not defined by a precise beginning (other than the appearance of *Homo*) and should not be related to any geological time unit. Additionally, the authors implement the term in a way that defines an interdisciplinary research area – that is, Paleoanthropocene Studies – that is not bounded to global change (as with the 'Anthropocene'), but that focuses on regional scales emphasizing the spatially bound and time-restricted relationship of *Homo* species and *Homo sapiens* with their surrounding environments.

The meaning hereby attributed to paleoanthropocene is similar to that given by Foley et al. (2013). The paleoanthropocene hypotheses surveyed in this section are mostly reflections of early anthropogenic *landscape* and *environmental* change. Nevertheless, they still provide certain evidence of possible stratigraphic interest. If so, then they might also exhibit a degree of indirect competition with the Anthropocene Hypothesis by locating a different and much older beginning of the contested epoch. Such competition would not occur in stratigraphic terms, but rather in the very meaning of the 'Anthropocene.'

Therefore, the term 'paleoanthropocene' is considered the most appropriate term to classify all pre-Holocene proposed starting dates, and to distinguish these from early Anthropocene hypotheses.

[217] Naturally, this does not exclude the possibility that anthropogenic signals may be stratigraphically and geochronologically relevant for future geologists (as many are presently arguing), and thus that an 'epistemic void' may manifest in the future.

Distinguishing between paleoanthropocene and early Anthropocene hypotheses is important because locating an Anthropocene beginning that is precedent, equal, or antecedent to the Holocene has different implications for the geochronological reconstruction of the Earth's recent geological history.

Only two pre-Holocene or paleoanthropocene hypotheses have been identified in extant literature. Feasibly, this is because both discourses on the 'Anthropocene' and the Anthropocene Hypothesis began by implicitly focusing on the most recent impacts of humans on the planet. Indeed, recent historical periods such as the Industrial Revolution, the Great Acceleration, and the Atomic Age have been at the center stage of such discourses. Seemingly fueled by the broader environmental narratives of the 21st century, these historical time periods gained considerable attention from the geological and scientific community.

One of the hypotheses locates the beginning of the Anthropocene with the early mastery of fire, whereas the second places its commencement with the Late Pleistocene megafauna extinctions.

3.2.1.1 Mastery of Fire (1.8 Ma)

Paleoclimatologist Andrew Glikson (2013) has suggested that the roots of the Anthropocene may be located in the first use of fire by early humans around 1.8 Ma, which also facilitated the evolutionary transition to *Homo erectus*.[218] His argument builds on archaeological, anthropological, and paleoclimatological evidence of discoloration of mammalian bones, charcoal, and ash remains. Glikson defines the Anthropocene as consisting of three stages, namely Stage A (Early Anthropocene),[219] representing the early manipulation of fire by *H. ergaster* (an extinct species or subspecies of early humans of a debated nature) about 2 Ma; Stage B (Middle Anthropocene), representing the Neolithic Revolution; and Stage C (Late Anthropocene), coinciding with the beginning of fossil fuel combustion in the Industrial Revolution. Stage A is a "geologically fundamental step" (p. 91) because it represents the condition of possibility for the other stages to occur; because of its possible consequences in altering the glacial–interglacial Quaternary cycles; and because human-controlled fire has since then been increasing "planetary entropy to levels approaching those of global volcanic events and asteroid impact events" (ibid.).

Additionally, Glikson stresses the evolutionary importance of the mastery of fire for the *Homo* genus, constituting "an essential anthropological development, with consequences related to bipedalism, brain size and the utilization of stone tools" (2013, p. 90). Control of fire is considered one of the most important skills acquired by humans, and it had cascading evolutionary as well as cultural consequences. Attwell et al. (2015) suggest a spectrum of the consequences of fire uses. The effects of firelight on the hormonal production of melatonin may have contributed to the development of sleep patterns (i.e.,

[218] Literature has often described *H. erectus* as an evolutionary descendant of *H. habilis* through anagenesis (i.e., the evolution from one species to another implying the disappearance of the parent species). The relationship between the two taxa has been subject to debate, with authors (Spoor et al., 2007) suggesting that the two taxa evolved through cladogenesis (i.e., the evolutionary splitting of a parent species into two distinct species).
[219] Glikson's use of 'early Anthropocene' coincides with 'paleoanthropocene' in the classification proposed in this section.

photoperiodicity). The warmth and sheltering services of campfires allowed for larger and cognitively challenging social structures, which stimulated gathering together and having communicative interactions, hence increasing sociality. Northward migrations into cooler regions may have required populations to manipulate fire in order to survive colder temperatures during glacial phases, hence geographical spread could have been boosted by fire use. Cooking raw meat and plants had fundamental dietary consequences often associated with evolutionary responses, such as a decrease in jaw and tooth size, a less energy-consumptive digestive apparatus, and an increase in brain size. Overall, fire manipulation ignited "the unique trajectory of hominin evolution toward modern human morphology, behavior and culture" (p. 13).

Stratigraphically, signals associated with the early use of fire are only restricted to a few sites, and are often diachronous, since different stages of fire control (i.e., ignition, maintenance, etc.) were only achieved gradually (Attwell et al., 2015). Hence, they cannot be used as primary marker for a chronostratigraphy-based Anthropocene unit. Additionally, earliest instances of fire manipulation are difficult to distinguish from naturally occurring fires. While differentiating between anthropogenic and natural fires may be possible by calculating the fire temperature at the time it was burning, "there is little that can be done to identify naturally occurring fires that may have been utilized by hominins as and when they occurred prior to their ability to control it even for a short period of time" (p. 3).

Glikson's Paleoanthropocene Hypothesis provides a genealogical explanation of the Anthropocene by tracing its causal roots to one of the most fundamental steps in the evolutionary history of the *Homo* genus. The suggestion of predating the beginning of the Anthropocene to the discovery of fire is also supported by the political theorist and anthropologist James C. Scott (2017).[220] In his book *Against the Grain*, the author suggests that the beginning of the 'thin' Anthropocene (versus the 'thick' Anthropocene, the more recent proposals considering human population numbers) could be dated "with the use of fire, the first great hominid tool for landscaping – or, rather, niche construction" (p. 3). Nevertheless, the AWG (Zalasiewicz et al., 2019b, para. 7.3.2) has not considered its stratigraphic basis sufficient for any formal recognition on the geological time scale. Even more problematic is the rank level that such a beginning would imply for the division of the Quaternary in respect to other established time units. Therefore, while framed as a competing hypothesis, Glikson's hypothesis is perhaps best understood as a broader study on the earliest signs of environmental modification by *Homo*.

3.2.1.2 Pleistocene Megafauna Extinctions (~13.8 ka)

In a less deep proposal timewise, Doughty et al. (2010) associate a rapid increase in the plant genus *Betula* across Siberia, Alaska, and the Yukon, documented in pollen data at ~14–15 ka, with the Late Pleistocene megafauna extinction, particularly that of mammoths. They hypothesize that climatic reasons alone cannot

[220] In his presentation "Anthropogenic Fire as the Hinge between Earth System and Strata," held in occasion of the MPIWG Workshop "Anthropogenic Makers" (Berlin, September 23, 2021), social scientist and environmental scholar Nigel Clark has also advocated for an early beginning of the 'Anthropocene' coincident with the use of fire.

explain this increase in *Betula*, and that mammoth extinction was driven by the arrival of humans in those regions. Based on their model, which correlates *Betula* increase with changes in global climate, the authors conclude that "the human influence on climate began even earlier than previously believed […] and that the onset of the Anthropocene should be extended back many thousand years" (p. 4), namely ~13.8 ka.[221]

The Late Pleistocene extinction or Late Quaternary Extinction (LQE) was an extinction event documented between 50 ka and 10 ka (Burney & Flannery, 2005; Koch & Barnosky, 2006), with earliest extinctions dated around 130 ka (Sandom et al., 2014; van der Kaars et al., 2017). The event killed off about half of the Earth's terrestrial mammal megafauna (i.e., mammals weighing > 44 kg). All continents except Antarctica were affected (DeSantis et al., 2019; van der Kaars et al., 2017; Villavicencio et al., 2016), with Africa showing the lowest rates of extinction.[222] Extinct species included the giant beaver, saber-tooth cat, and giant ground sloth in North America; the glyptodont and the tree-toed liptoderm in South America; woolly mammoths and rhinoceros in Eurasia; and the largest marsupial ever documented, the *Diprotodon*, in Australia (Koch & Barnosky, 2006). The extinction was the most profound in South America, where 52 genera and at least 66 species went extinct (Villavicencio et al., 2016, quoting Brook & Barnosky, 2012). LQE is not considered a mass extinction, yet it represents a unique occurrence because it unfolded "almost instantly on an evolutionary timescale and had a disproportionate bias for megafauna" (Haynes, 2018, p. 219).

Multiple hypotheses have attempted to explain the causes of the sudden and widespread disappearance of large mammals. Overall, these hypotheses either attribute the extinction to climate change, or to the widespread appearance of humans among regions where extinctions are documented (Burney & Flannery, 2005). More recently, combined models have been proposed, suggesting that "humans precipitated the extinction in many parts of the globe through combined direct (hunting) and perhaps indirect (competition, habitat alteration and fragmentation) impacts, but that late Quaternary environmental change influenced the timing, geography, and perhaps magnitude of extinction" (Koch & Barnosky, 2006, p. 240). Braje and Erlandson (2013) also suggest that the LQE and ongoing rates of extinction are part of a continuum that has unfolded over a multi-millennial time scale, and that defining a date "is less important than understanding that the mass extinction we are currently experiencing has unfolded over many millennia" (Braje & Erlandson, 2013, p. 20).

The AWG (Zalasiewicz et al., 2019b) has not directly addressed the hypothesis advanced by Doughty et al. (2010). However, the AWG states that the LQE "suffers from being time transgressive over

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[221] The authors do not explicitly state that this numerical starting date (~13.8 ka) should be considered the starting date for the Anthropocene. In fact, the quoted statement includes a bibliographic reference to Ruddiman (2003), which dates the beginning of the Anthropocene to 7 ka or 5 ka (section 3.2.2.3). Furthermore, the authors are not directly engaging with the Anthropocene debate (aside from a brief mention in the concluding section of the research article), but are rather assessing possible early anthropogenic signals of global geographic and temporal relevance. Nevertheless, their analysis can be interpreted as an alternative, non-stratigraphic hypothesis in locating the onset of the proposed epoch.

[222] Compared to other continents, Africa represents an anomaly in documenting the LQE. Koch and Barnosky (2006) offer three possible explanations for this anomaly. First, small game hunting and food gathering was abundant, hence more remunerative than hunting larger prey. Second, African human population density was lower compared to human populations on other continents. Third, African ecosystems provided more refuge from human predation.

some 50,000 years, and even setting a boundary at the youngest pulse of extinction mean that the Anthropocene largely overlaps the Holocene" (Zalasiewicz et al., 2019b, p. 116). Therefore, the proposed starting date at ~14–15 ka, being regionally restricted and part of a broader diachronous trend, cannot be used as a chronostratigraphic marker.

3.2.2 Early Anthropocene Hypotheses

Existing literature has often used the label 'early Anthropocene hypothesis' in two ways: broadly, to identify any suggested date predating the beginning of the Anthropocene of millennial scales (including paleoanthropocene hypotheses); or specifically, to refer to William Ruddiman's hypothesis, which suggests the onset of the agricultural revolution as beginning of the Anthropocene. In this section, early Anthropocene hypotheses are defined as those hypotheses whose proposed starting dates are situated between the Holocene (11.7 ka) and the beginning of Modern history (as a category used in European historiography) at approximately the end of the 15th century. This cluster of proposed starting dates differs from paleoanthropocene hypotheses in recommending dates within the Holocene range, and from modern Anthropocene hypotheses in extending the proposed beginnings to thousands of years (rather than hundreds) in the past.

Five proposed starting dates have been recognized in extant literature. One considers human niche construction as reference framework to assign a starting date. A second hypothesis provides archaeological and historical evidence supporting a starting date at 10 ka. A third one, the Ruddiman Hypothesis, focuses on the onset of the Neolithic Revolution, and has been a major competitor of the Anthropocene Hypothesis. A fourth hypothesis considers lead contamination during the Late Bronze Age, and the fifth hypothesis considers anthropogenic soils as a possible golden spike for the Anthropocene.

3.2.2.1 Human Niche Construction (~11–9 ka)

In an article entitled "The onset of the Anthropocene," archaeologists Bruce Smith and Melinda Zeder (2013) argue that significant human niche construction or ecosystem engineering associated with domestication provide a clear and unequivocal signal in both the archaeological and stratigraphical record to date the beginning of the Anthropocene at ~11–9 ka. The authors recognize that the proposed boundary almost completely overlaps with the Holocene (11.7 ka), hence they believe it "more accurate, and more useful, to consider the two epochs to be one and the same or coeval […] and that the various boundary points that have been proposed over the past decade as marking the Holocene–Anthropocene boundary are more fruitfully recognized as defining successive phases within the Holocene/Anthropocene epoch" (p. 9). This proposed starting date aims at stressing the causes, rather than the effects, of human behavior by emphasizing the broader utility of an Anthropocene time unit for understanding "the long term and richly complex role played by human societies in altering the earth's biosphere" (p. 12). Lastly, the authors suggest that a Holocene/Anthropocene time unit may be recognized by the ICS and IUGS to accommodate both the scientific context, where 'Holocene' would be employed, and the broader discourse, where 'Anthropocene' has most seen interest.

The authors' reference framework is that of human niche construction (HCN) – an application of niche construction theory (NCT) to human evolution. NCT is a proposed extended version of standard evolutionary theory that seeks to explain the evolutionary role of organisms' niche-constructing activities (Baedke et al., 2020; Matthews et al., 2014; Odling-Smee et al., 2003). Essentially, the theory states that every organism, by altering its and other species' environments through niche-constructing activities, may actively modify natural selection pressures, so that "evolution by niche construction is a possible outcome" (Laland et al., 2016, p. 192). This implies that niche construction should be considered an evolutionary force in addition to natural selection, acting through both ecological and genetic inheritance (Odling-Smee & Laland, 2012) – a view not represented by the current evolutionary framework (where species passively adapt to the environmental pressures they are subject to).

A HCN framework highlights the role of humans as land-forming organisms with highly complex cultural traits to understand the evolutionary and ecological consequences of their niche-constructing activities (Pena Rodrigues & Lira, 2019). Plant and animal domestication has been considered an important case study of evolutionary consequences of HNC (see Zeder, 2016, p. 327, Table 1). Laland et al. (2001) suggest that "[t]he persistent domestication of cattle and the associated dairying activities may have altered the selective environments of some human populations for sufficient generations to select for genes which today confer greater adult lactose tolerance" (p. 24). Zeder (2016) considers domestication an opportunity to reconsider the pace of evolutionary change as well as "an ideal system for exploring the role of acquired behaviors and cultural transmission in the profound evolutionary changes that transformed both plant and animal domesticates and human domesticators" (p. 341). Similarly, B. D. Smith (2011, 2016) recognizes the major evolutionary role that early anthropogenic domestication of plants and animals had on the Earth's history.

The AWG (Zalasiewicz et al., 2019b, para. 7.3.3) has primarily contested the diachronous nature of human niche construction associated with early domestication, the signals of which are mostly terrestrial.[223] Both evolutionary eco-biology and stratigraphy share the basic idea that humans have become the ultimate niche constructor or ecosystem engineer (Smith, 2007). However, not all archaeological, biological, and ecological data associated with domestication can immediately be translated into a stratigraphic marker for the Anthropocene – which requires global correlation and synchronous evidence. Additionally, and consistently with their nature, the determination of geological units "hinges much more on *effect* than on *cause*, not least because of the importance of strata, which are the physical archives of

[223] Marine signals are better preserved because they are not subject to surface sources of erosion. This is also the *Guide* stresses the importance of marine settings for locating a GSSP.

elapsed Earth processes, in their definition" (Zalasiewicz et al., 2019b, p. 15). This goes against Smith and Zeder's argument for stressing the causes of the Anthropocene, which is beyond the task of stratigraphy.

3.2.2.2 Homo sapiens *Diaspora (∼10 ka)*

Similarly to the time-range proposed by Smith and Zeder (2013), archaeologists Jon Erlandson and Todd Braje (2013) selected ∼10 ka as beginning of the Anthropocene. The date represents the moment "after anatomically modern humans spread beyond Africa and Eurasia to Australia and the Americas, then domesticated a variety of plant and animal species" (p. 1). The authors consider the time selected to be a possible historical landmark characterized by a widespread and diversified domestication of animals and plants associated with the diaspora of *Homo sapiens* across all continents except Antarctica. Domestication and agriculture were particularly important moments for the history of human civilizations, leading "to a fundamental realignment in the relationship of humans to their local environments" (p. 5). In addition to the archaeological evidence and historical relevance of the selected date, the authors provide a stratigraphic proxy for the year 10 ka: "the appearance of shell middens and other anthrosols in coastal, riverine, and lacustrine settings worldwide" (pp. 5–6).

Because the proposed starting date suggested by Erlandson and Braje (2013) largely overlaps with the current time span covered by the Holocene Epoch, Braje (2016) has considered the best option "to merge the Holocene and Anthropocene into a single geological unit" (p. 509). He argues that, given that the Holocene already entails anthropogenic activities (e.g., the Pleistocene Megafauna extinction, deforestation), it would be more useful to officialize a Holocene/Anthropocene Epoch to include long-term human impacts. This solution is also endorsed by Smith and Zeder (2013), discussed in the preceding section.

3.2.2.3 The Ruddiman Hypothesis (∼7/5 ka)

The Ruddiman Hypothesis (also known as the 'Early Anthropocene Hypothesis' or 'Early Anthropogenic Hypothesis') is a hypothesis originally proposed by paleoclimatologist William F. Ruddiman in 2003 (Ruddiman, 2003; for a latest update, see Ruddiman et al., 2020). It is one of the most viable competitors of the Anthropocene Hypothesis, and has found substantial support from archaeological research in recent literature (Edgeworth et al., 2019; Edgeworth et al., 2015; Erlandson & Braje, 2013; Ruddiman, 2017). The hypothesis locates the beginning of the Anthropocene (or informal 'anthropocene,' as later explained) within the Neolithic Revolution, when agricultural practices supposedly began to substantially impact land and climate. Specifically, Ruddiman associates the beginning of the proposed epoch with an anomaly in

CO_2 (carbon dioxide) and CH_4 (methane) at 7 and 5 ka respectively.[224] The steady buildup of these pre-industrial greenhouse gasses caused warming of ~0.8 °C by 1800 CE, sufficient enough to delay the next ice age. If this is the case, then human actions became a significant global event thousands of years before the present.

The hypothesis builds on three arguments. The first argument considers the anomaly inconsistent with the cyclic variations of the past 350,000 years driven by Earth-orbital changes as recorded in the Vostok ice core (Petit et al., 1999).[225] CH_4 and CO_2 were expected to follow their natural downward trends. In the case of CH_4, a match between methane and orbital insolation (i.e., the incident solar energy in a given time over a specific object or location) reveals a 23,000-year cycle mostly reflected in tropical monsoon changes (ibid.). According to this orbital-monsoon model, CH_4 levels from 5 ka onwards should have continued following the downward trend. Instead, increasing CH_4 ppb concentrations have been documented in ice records in Greenland (Blunier et al., 1995) and Antarctica (Indermühle et al., 1999; Monnin et al., 2001). Likewise, Ruddiman (2003) argues that an increase in CO_2 documented at 8 ka (Indermühle et al., 1999) is also anomalous. Establishing 'natural' orbital-scale variations for carbon dioxide is more complex than methane because it follows multiple longer orbital insulation cycles whose origins are not fully understood. Hence, Ruddiman has suggested that it is essential to either compare the Holocene to previous interglacial periods, or "to examine the CO_2 trends at each of the three major orbital cycles, define their natural phasing with respect to changes in the corresponding orbital parameters, and then project this average long-term phasing forward into the Holocene" (Ruddiman, 2003, p. 267). In both instances, the CO_2 rise represents an anomaly.

The second argument considers paleoclimatic evidence to reject explanations of the anomaly based on natural forcing. Several hypotheses have been advanced to explain the apparent CH_4 and CO_2 anomaly (Ruddiman, 2017). Most have considered its cause a combination of natural factors. For instance, Indermühle et al. (1999) consider the anomaly "a combination of growth and decay of terrestrial biomass, and an increase in global mean SST, possibly with a contribution from the marine calcite cycle" (p. 125). Broecker et al. (1999) also associate the increase in CO_2 beginning at 8 ka with natural causes related to cessation of forest expansion. Ridgwell et al. (2003) provide an explanation of the CO_2 anomaly by focusing on shallow water carbonate buildup from coral reefs and other sources. Schmidt et al. (2004) suggest that CH_4 emissions from boreal wetlands and river deltas may have increased over the last 5,000 years, adding up to tropical hydrological changes as expected by Ruddiman (2003), thus considering anthropogenic forcing inconclusive. Ruddiman (2003, 2017) considers none of the suggested explanations above to be suitable for explaining the CH_4 and CO_2 anomaly. By "process of elimination" (Ruddiman, 2003, p. 272), and by associating inefficient early rice farming with CH_4 emissions by 5 ka (Ruddiman et al., 2008;

[224] Originally, Ruddiman (2003) proposed 8 ka as the date for the CO_2 increase. However, later publications (Ruddiman & Ellis, 2009; Ruddiman et al., 2020) pointed to 7 ka as a more suitable marker. The former is date is based on Vostok, whereas the latter date is retrieved from Dome C – both drilling sites in Antarctica.

[225] Latest revisions of the European Project for Ice Coring in Antarctica (EPICA) Dome C records were able to reconstruct the history of atmospheric CO_2 concentrations for the past 800,000 years (Bereiter et al., 2015), extending the analysis by Petit et al. (1999) on Vostok ice cores as originally used by Ruddiman.

Ruddiman & Thomson, 2001) and forest clearance with CO_2 by 7 ka (Ruddiman, 2003; Ruddiman & Ellis, 2009; Ruddiman et al., 2020), Ruddiman considers anthropogenic forcing the most plausible explanation for the anomaly.

This brings us to the third and final argument. Ruddiman (2003, 2005, 2017) draws on archaeological, cultural, historical, geographical, and geologic evidence to argue that anthropogenic signals associated with agricultural practice are the most suitable explanation for the CH_4 and CO_2 anomaly. This view is also opposed to locating the beginning of the Anthropocene (as a term defining the earliest *global* impact of *anthropogenic* activities) either at the Industrial Revolution or around the 1950s. The arguments rely on two points, the first of which is based on a 'hare versus tortoise' analogy.

The analogy goes as follow. On the one hand, the average yearly GtC (gigaton carbon) emissions since the Industrial Revolution are an estimated 0.8 GtC/year, totaling 160 GtC over 200 years. On the other hand, pre-industrial average rates are estimated at 0.04 GtC/year, totaling 320 GtC over 7,800 years. Although slower, the pre-industrial 'tortoise' (the agriculture) started much earlier than the industrial 'hare,' and hence is ahead of the race (i.e., it has a larger cumulative GtC impact).

The second point is based on the role of forest clearance associated with agriculture across Eurasia in contributing to the CO_2 rise between 8 ka and 1800 CE. This point, Ruddiman argues, needs three forms of validation: "(1) clearance must begin near 8 ka (when the CO_2 rise began) on a small, yet 'non-negligible' scale; (2) clearance must grow large enough by ~2 ka to explain ~80% of the pre-industrial CO_2 anomaly; and (3) the negative CO_2 oscillations of 4 to 10 ppm after 2 ka also need an explanation" (Ruddiman, 2003, p. 273). Ruddiman gathers evidence supporting all three tests, arguing that land clearance occurred alongside agriculture, that it constituted the major anthropogenic source of carbon, and that negative CO_2 oscillations can be explained through plagues and consequent disease-driven reforestation.

The Ruddiman Hypothesis is not intrinsically a stratigraphic hypothesis in the way the Anthropocene Hypothesis is formulated. This is confirmed by the author's preference of an informal 'anthropocene' (non-capitalized), which he considers more useful than a chronostratigraphy-based Anthropocene (Ruddiman, 2018). In fact, Ruddiman has argued "against *any* formal definition of the Anthropocene" (ibid., p. 457) *because* of the time-transgressive nature of anthropogenic alteration of the planet, which cannot be reduced to an isochronous marker such as the GSSP. [226] The original aim of the hypothesis is to explain an anomalous CH_4 and CO_2 increase at 7 ka and 5 ka respectively in paleoclimatic records – with special emphasis on carbon dioxide, which has seen a "much more vigorous" (Ruddiman et al., 2020, p. 2) debate over the years. The explanation suggested is that anthropogenic forest clearance associated with agriculture caused climatic anomalies, and thus pre-industrial anthropogenic activities should be accounted for in considering planetary alterations. Yet, because the hypothesis attributes anthropogenic causes to the anomalies, and stresses the higher order of magnitude of the cumulative anthropogenic CH_4 and CO_2 emissions in pre-industrial times compared to industrial cumulative emissions,

[226] Interestingly, Ruddiman (2018) addresses the AWG as *Anthropogenic* Working Group, further stressing his rejection of the use of 'Anthropocene' as a formal geological time unit.

it also emphasizes the geological, stratigraphic, and climatic significance of early human societies in altering the Earth's climatic trajectory. For this reason, its claims of anthropogenic planetary changes partially overlap with those of the Anthropocene Hypothesis in attributing geological and stratigraphical significance to a certain period of human history. Consequently, the hypothesis has been part of the 'Anthropocene' conversation almost since the term appeared among academic circles.

Ruddiman's rejection of a formal Anthropocene time unit implies that the Ruddiman Hypothesis does not, technically speaking, compete in locating a formal (i.e., GSSP-based) beginning of the Anthropocene, and generally in granting formal status to the proposed unit on the geological time scale. This is because the time-transgressive nature of the Anthropocene does not find in the GSSP a suitable methodology of study (Ruddiman, 2018, see also section 5.2.2). What other members of the AWG (Zalasiewicz et al., 2019a; Zalasiewicz et al., 2019b, para. 7.3.4) consider an epistemic weakness of the hypothesis (i.e., being diachronous) is, for Ruddiman, an argument *against* formal ratification of the Anthropocene as a chronostratigraphic unit. By his considerations, his suggestion of treating the 'anthropocene' as an informal designation allows a more inclusive account of earlier anthropogenic activities. In turn, this enables scientists to use the term more flexibly to define different phases of the 'anthropocene,' such as "the 'early agricultural anthropocene', the 'pre-industrial anthropocene', the 'industrial-era anthropocene', the 'post-nuclear (late 1900s) anthropocene', and others" (Ruddiman, 2018, p. 457).

3.2.2.4 Late Bronze Age Hypothesis (3/2 ka)

Geologists Michael Wagreich and Erich Draganits (2018) consider two peaks in Pb (lead) contamination from early mining and ore smelting at 3 and 2 ka as a possible lower boundary for a GSSP-based Anthropocene unit. The peaks coincide with or follow the Late Bronze Age and Early Iron Age (~3.6–3 ka). This represents a historical period seeing the development and spread of mining and smelting techniques for bronze and iron production across human societies. The authors use chemostratigraphic signals (specifically, changes in lead isotope ratios) recorded in ice cores in the Northern Hemisphere as a primary marker for defining a possible lower base of the Anthropocene.

At present, lead is the most distributed toxic metal in the world because of its range of applications in human industry (Cheng & Hu, 2010). The possibility of using atmospheric lead contamination from ore smelting as a possible signal of an early Anthropocene had already been considered by Krachler et al. (2009), whose study is also used by Wagreich and Draganits (2018) in support of their hypothesis. Krachler et al. (2009) attempted a historical reconstruction of As (arsenic) and Bi (bismuth) based on ice cores from Devon Island, Canada, between 15,876 ka and 1870 CE. Because both As and Bi (in minor quantities) are often present in metals such as copper and lead, smelters produce both elements as particulates that can deposit in water bodies or rocks and can thus be used as a proxy for human activities. The authors determined background rates of As and Bi normalized to Sc (scandium)[227] and compared them with Holocene rates, finding much greater values for the latter especially around 3 ka and 2 ka. The suggested explanation is correlated with historical and archaeological findings of mining and smelting of lead ores, which released a substantial amount of Pb but also As and Bi in the atmosphere. The authors advanced that "the environmental impacts of metallurgical activities undertaken by past societies and civilizations have been more extensive and had more profound impacts and greater implications than previously believed" (pp. 4-5), and that this evidence should be included in the discussion over the beginning of the Anthropocene.

Consistently with a study by Krachler et al. (2009), Wagreich and Draganits (2018) use a lowering of the $^{206}Pb/^{207}Pb$ ratio[228] at 3 ka and 2 ka connected to increased lead concentrations from mining and ore smelting as chemical primary marker for a possible GSSP. This marker "can be found in several types of terrestrial and marine geological archives, such as ice cores, peat bogs, speleothems, fluvial, lake and marine records" (p. 180), although these archives are largely restricted to the Northern Hemisphere. Additionally, they implement evidence from tephrochronology (a geochronological method based on the chronological reconstruction of the layering of volcanic ash from eruption) as well as paleoclimatology, magnetostratigraphy, and sedimentology as secondary markers for the Anthropocene. The authors argue that their proposal entails several advantages, such as allowing a larger pool of stratigraphic and archaeological evidence as well as conformance to the standard GSSP methodology.

The AWG (Zalasiewicz et al., 2019b, para. 7.3.5) has considered the proposal as a valid practical candidate, in that it would include significant and time-comprehensive evidence for a Holocene–Anthropocene boundary. However, they also consider the proposal problematic in respect to the Holocene subdivision, which has already been subdivided into the Greenlandian (11.7 ka), Northgrippian (8.15 ka), and Meghalayan (4.2 ka). Additionally, they consider early ore mining and smelting not representative of substantial *Earth System* changes. This is an interesting remark, stressing once again the close partnership between Earth System science and stratigraphic research.

3.2.2.5 Anthropogenic Soils (~2 ka)

Soil scientists Giacomo Certini and Riccardo Scalenghe (2011) consider the anthropogenic alteration of the pedosphere as a possible marker for the Anthropocene, and locate a possible GSSP at around 2 ka (i.e., year 0 CE), "when the natural state of much of the terrestrial surface of the planet was altered appreciably by organized civilizations" (p. 1273). The authors contest the original proposal of locating the beginning of

[227] Normalization of chemical data is an important procedure in archaeological studies. Essentially, it compares concentrations of an element against a second proxy or surrogate element to verify, among other things, "whether the variation of elements in sediments is indeed the result of anthropogenic and/or natural activities"(Dias & Prudêncio, 2008, p. 136). Scandium has been chosen as proxy element by Krachler et al. because it behaves "conservatively during chemical weathering and has no preference for specific mineral phases" (Krachler et al., 2009, p. 2), meaning it is relatively constant over time.

[228] The lead isotope ratio provides a method to identify the source of lead contamination known as 'fingerprinting.' For a technical explanation of the method, see Cheng and Hu (2010).

the Anthropocene with the Industrial Revolution by using atmospheric composition as a primary marker.[229] Instead, they suggest that soils can be used as 'golden spikes' in a similar fashion as they are used in geological research because of the "clear memories of past, substantial, widespread, anthropic interventions" (p. 1271).

The pedosphere encompasses the totality of ice-free soils on the outermost layer of the Earth. Many types of natural processes and soil formation processes contribute to the formation of numerous types of natural soils. The UN Food and Agriculture Organization (FAO) has provided a World Reference Base of Soil Resources (WRB) serving as an international reference point for the classification and naming of soils (FAO, 2015). Among the recognized types of soils, the WRB describes 'Anthrosols' as soils "that have been modified profoundly through human activities (p. 147), and 'Technosols' as soils "whose properties and pedogenesis are dominated by their technical origin" and contain "a significant amount of *artefacts*" (p. 177). Certini and Scalenghe (2011) implement this framework to consider 'anthrosolization' as an integral part of soil formation processes, which they argue has considerable geological significance.

The AWG (Zalasiewicz et al., 2019b, para. 7.3.6) has provided four arguments against a soil-based Anthropocene, namely (1) the diachronous unfolding of anthropogenic soils, predating the proposed starting date by 8,000 years, which does not match the GSSP requirements; (2) the regional dependency of stratigraphic archives associated with soils; (3) the lack of a high-resolution stratigraphy of soils as required for a potential Anthropocene GSSP because of the substrate alterations entailed in the formation of soils; (4) and the chaotic and thus unreliable nature of ploughed soils. Criticism against a soil-based GSSP has also been raised by Gale and Hoare (2012), who also note how Certini and Scalenghe's (2011) proposal does not match many of the criteria needed to define the base of a new stratigraphic unit.

3.2.3 Modern Anthropocene Hypotheses

A third cluster of Anthropocene hypotheses locate the beginning of the proposed unit within modern history. As a European historiographic category, the category of 'modern' history comprises human history from the fall of the Eastern Roman Empire (1453 CE) or the arrival of Columbus in the Americas (1492 CE) to the present day (i.e., the late modern age), where it overlaps with contemporary history (1945 CE).

The meaning of 'modern' has been much contested in the humanities, particularly within historical scholarship. In the context of Anthropocene Studies, to use a primarily Eurocentric historiographic framework to address a *global* event/geological boundary such as the Anthropocene seems to read it as an intrinsically European phenomenon. In fact, this is the same type of criticism that has been levied against a pool of starting dates locating the beginning of the epoch with the Industrial Revolution. Nevertheless, this framework maintains the term 'modern' for three main reasons – all of which answer to pragmatic

[229] When the article was published in 2011, the Industrial Revolution was still considered by the recently formed AWG to be a valuable candidate for marking the beginning of the Anthropocene.

needs. First, the term simply represents a practical solution, consistent with the historiographical tradition, for representing the 'Anthropocene' in a time scale. It avoids clustering substantially different hypotheses within the Holocene range by using human history as a reference framework. Second, and as a direct consequence, it helps differentiate from other clusters of hypotheses, particularly the early Anthropocene hypotheses, which are situated within the Holocene but pre-date modern hypotheses on a scale of thousands of years. In purely chronological terms, modern hypotheses only differ on scales of hundreds of years, if not decades. Third, the term 'modern' has a descriptive rather than normative meaning. It is simply implemented as a category to differentiate among hypotheses based on the property of time. It does not imply any value statement or considerations beyond the organization of proposed hypotheses based on time.

Therefore, this section surveys five proposed starting dates for the Anthropocene: namely, the year 1500 CE, the colonization of the Americas, the Industrial Revolution – a time frame encompassing a pool of proposed starting dates mostly superseded in stratigraphic research – the Tambora volcanic eruption, and geomagnetic evidence by the dawn of the 20th century.

3.2.3.1 Social Metabolism Hypothesis (1500 CE)

Fischer-Kowalski et al. (2014) consider the year 1500 CE as a watershed between agrarian and fossil fuel–based metabolic regimes, and thus as a starting point for the 'Anthropocene,' based on a socio-economic analysis using the concept of 'social metabolism' of human societies across time. The concept of 'socioeconomic metabolism' (SEM) represents a pool of diversified methods implemented mostly in ecologically oriented social and economic sciences to understand the biophysical basis and functioning of human societies. In a recent publication, sustainability scholars Stefan Pauliuk and Edgar Hertwich (2015) define SEM as "the self-reproduction and evolution of the biophysical structures of human society" comprising "those biophysical transformation processes, distribution processes, and flows, which are controlled by humans for their purposes" (p. 85). Together, the biophysical characteristics of human society societies and the socioeconomic metabolism "form the biophysical basis of society" (ibid.). Early research on the biophysical basis of human societies and its metabolism dates to the late 1990s.[230]

Fischer-Kowalski et al. (2014) use this framework to "focus on the socioeconomic aspects of defining the Anthropocene and investigate the interaction of the major drivers behind the observed environmental impacts, in particular population, its resource use patterns (or social metabolism) and technology" (p. 9). Their study draws on Paul Ehrlich's popular IPAT formula (*I* for environmental impact, *P* for human population, *A* for affluence or wealth, and *T* for technology) to provide a "quantifiable description of how and when humans acquire the ability to dominate major features of the Earth System" (ibid.). Ehrlich's original formula is readjusted to account for socio-metabolic regimes rather than a

[230] See Pauliuk and Hertwich (2015, para. 1.4, 2.1) for bibliographic references on seminal research on SEM.

homogeneous population (P), whereas affluence (A) is considered the average per capita energy input into the respective socio-metabolic regime. Technology (T) is interpreted as "the coefficient by which one unit of affluence measured as material or energy use translates into a specific environmental pressure" (p. 10). This way, the formula is rewritten as

$$I = P_{1t} * A_{1t} * T_{1t} + P_{2t} * A_{2t} * T_{2t} + \cdots,$$

where the subscript *t* represents a specific time and the numerical index ($_1$, $_2$, etc.) a determined socio-metabolic regime. The equation is then used by the authors to quantitatively assess the environmental impact, or pressure upon the environment (*I*), of the fossil fuel–based socio-metabolic regime (or industrial mode of subsistence), whose beginning is set at 1500 CE. This regime saw an increase in metabolic rates compared to the previous hunter–gatherer and agricultural socio-metabolic regimes, also associated with an overall increase in urban populations. Based on their model, the authors conclude that the year 1500 constitutes a major historical divide as well as a starting point for a new socio-metabolic regime of global-scale impact.

Visibly, this alternative hypothesis does not address the stratigraphic signature of the Anthropocene as a geological unit. Instead, Fischer-Kowalski et al. (2014) aim at providing a quantifiable description of when and how humans acquired a dominant role in the functioning of the Earth System. In doing so, they locate an abrupt shift in social metabolism occurred at 1500 CE. While the hypothesis does not compete with the Anthropocene Hypothesis, it still considers a different beginning to the 'Anthropocene' as a global phenomenon.

3.2.3.2 Orbis Hypothesis (1610 CE)

A widely discussed hypothesis has been advanced by Lewis and Maslin (2015a) in an article published by *Nature* in 2015, later revised and expanded in a chapter of their 2018 book *The Human Planet* (Lewis & Maslin, 2018a). The scientists consider two possible starting dates for the Anthropocene: one in 1610 and one in 1964 (the latter discussed in section 3.2.4.3).

The year 1610 coincides with a 7–10 ppmv dip in atmospheric CO_2 concentrations recorded in ice cores from Law Dome in Antarctica (Rubino et al., 2013) and from the West Antarctic Ice Sheet (WAIS) Divide (Ahn et al., 2012), both documented around 1600 CE and used by Lewis and Maslin (2015a) as ground evidence for their hypothesis. From a historical viewpoint, the year follows more than a century since the European arrival in the Americas, which "led to the largest human population replacement in the past 13,000 years, the first global trade networks linking Europe, China, Africa and the Americas, and the resultant mixing of previously separate biotas, known as the Colombian Exchange" (Lewis & Maslin, 2015a). The authors label this 1610 dip as the 'Orbis spike,' and suggest their proposal be addressed as the 'Orbis hypothesis' (ibid.).

The studies on the Antarctic ice core records do not specify the causes of the sudden atmospheric CO_2 dip. Rubino et al. (2013) advocate for further research to explain the sudden carbon uptake, whereas Ahn et al. (2012) consider it "unclear if the variation is really a signal of atmospheric CO_2 change or experimental uncertainty and/or local variation of ice core quality" (p. 4). An earlier study from MacFarling et al. (2006, also quoted in Lewis & Maslin, 2015a) notes as well that "it is unclear whether the initial CO_2 decrease was driven by the terrestrial biosphere, and some changes to oceanic carbon exchange are possible" (p. 3). Lewis and Maslin (2015a) provide an explanation for the 1610 (± 15 years) dip in CO_2 associated with the hundred-year consequences of the European colonization of the Americas. The precise year is selected based on the lowest CO_2 ppmv concentrations recorded in Law Dome records for the declining trend (MacFarling Meure et al., 2006, see Supporting Information, Table S1).

The argument advanced by the two scientists from the University College London suggests that the European colonization of the Americas led to a significant decline in human populations, especially among peoples of the New World. They estimate the number of inhabitants of the continents ranged between 56 to 61 million by 1492, reduced to a minimum of 6 million by 1650 due to diseases, enslavement, famine, and war as a result of the European colonial enterprise. This dramatic reduction in local populations resulted in reduced agricultural practices and fire management, consequently allowing natural revegetation of around 50 million hectares of biomes and ecosystems. In turn, revegetation increased the terrestrial carbon uptake, which is reflected in the atmospheric CO_2 decline recorded in the Antarctic ice core records. This primary marker for a possible GSSP finds additional secondary stratigraphic evidence in the global translocation of species (represented by the global extension of *Zea mays* fossil records), volcanic tephra, pollen, charcoal reduction, methane decrease, and additional climatic evidence.

Lewis and Maslin (2015a, 2015b) argue that systemic changes in the Earth System represented in stratigraphic deposits and environmental changes are not suitably defined by early Anthropocene hypotheses, such as the Pleistocene megafauna extinction or the Ruddiman Hypothesis, nor by proposals locating the beginning of the epoch with the Industrial Revolution. An additional argument provided is that these events are not reflected in a global and synchronous fashion – a requirement for any GSSP proposal, and an argument often invoked by the AWG when reviewing competing hypotheses. On the contrary, the irreversible exchange of species that followed the colonization of the Americas is global and geologically synchronous, and its consequences "will be one of the few clearly visible changes to Earth over the typical timescale of an epoch of millions of years that can be recorded today" (Lewis & Maslin, 2015b, p. 139). Furthermore, the authors argue that the year 1610 is not just geologically significant, but has important historical and social meaning because it highlights the colonial roots of the Anthropocene as well as the impact of global trade, economic growth, and coal.

As with the Ruddiman Hypothesis, the Orbis hypothesis has also been largely discussed, especially by AWG members. Zalasiewicz et al. (2015a) provide a list of critical points against the Orbis hypothesis, arguing that the 1610 dip (1) does not stand out as an anomaly, (2) falls within natural variation of the Holocene, (3) is not entirely consistent with human population decrease in the Americas, (4) does not account for global trends in human population decrease in respect to carbon uptake, (5) may be consistent with natural variations within the Little Ice Age,[231] and (6) still requires further biostratigraphic research. Concerning the broader social and political value of selecting the Orbis spike as a GSSP, Zalasiewicz et al. (2015a) suggest that "that the positioning of a stratigraphic boundary should simply be pragmatically and dispassionately chosen" (p. 123). The *pragmatic* nature of stratigraphic and geological research is an important epistemological as well as historical ingredient for explanations in geology – as tackled again in section 4.2.

3.2.3.3 Industrial Revolution (1780–1850 CE)

The onset of the Industrial Revolution in England by the end of the 18th century – and its gradual spread across Europe, the United States, the rest of the Northern Hemisphere, and the rest of the world – was the first time period proposed to mark the beginning of the 'Anthropocene,' whether as a geological time unit or as an Earth System singularity. Because of the revolutionary transformations hatched from this period in terms of energy consumption, modes of production, population growth, and especially environmental transformation, the Industrial Revolution has been generally accepted as the birthplace of the 'Anthropocene' by most early research literature. Most of the present 'Anthropocene' research in Earth System science and stratigraphy has now redirected its attention toward the 20th century, shifting the focus onto the Great Acceleration and/or the Atomic Age. However, the Industrial Revolution is still an important historical phase for Anthropocene Studies. Thus, is it relevant to the present analysis to highlight the major hypotheses related to the Industrial Revolution because of the way they have informed and shaped the 'Anthropocene' debates as well as the Anthropocene Hypothesis.

Rather than a single hypothesis, a pool of starting dates with diverse authorship have addressed the Industrial Revolution as the reasonable cradle of the Anthropocene. These proposals either pinpoint a precise year or a time period, or consider stages or phases of a longer and diachronous unfolding of the Anthropocene. This subsection briefly reviews a few of these proposals in light of the Anthropocene Hypothesis.

As recollected in Chapter 2, Paul Crutzen and Eugene Stoermer's 2000 IGBP article represents the notorious cradle of the 'Anthropocene.' They first proposed locating the beginning of the Anthropocene at the end of the 18th century – conscious that alternative proposals could be made. In their view, this period reflected the time when "human activities [had] become clearly noticeable" (Crutzen & Stoermer, 2000, p. 17), particularly in terms of emissions of greenhouse gasses such as CO_2 and CH_4. The authors suggest a date, namely 1784, coinciding with James Watt's invention of the steam engine – implicitly stressing its importance for the dawn of the Anthropocene. The date was reproposed by successive publications by

[231] The Little Ice Age was a cooling period defined in terms of *climate* (1570–1900 CE) and *glacierization* (1300–1950) that followed a warmer trend (Matthews & Briffa, 2005). Scholars debate on the actual temporal extent of this colder period (see Kleeman, 2020). The Orbis spike locates within this cooler trend.

Crutzen (2002a, 2002d; Crutzen & Steffen, 2003), but it was never given any formal stratigraphic attention prior to the establishment of the AWG (despite Crutzen's recommendation of using the term 'anthropocene' to address the current *geological* epoch).[232]

A later appeal to locate the beginning of the geological Anthropocene at the end of the 18th century has been proposed by Foley et al. (2013), who also coined the term 'paleoanthropocene' for early and minimal anthropogenic environmental changes. They propose maintaining the Industrial Revolution as starting date for the Anthropocene, specifically around 1780 – a year marking "the beginning of immense rises in human population and carbon emissions as well as atmospheric CO_2 levels" (p. 83). Interestingly, the authors consider the year 1780 as the onset of the Great Acceleration, despite this designation being used today to address the post-WWII surge in socioeconomic and Earth System trends.

The Earth System science community, and especially the IGBP, widely adopted the Industrial Revolution as the starting date for the Anthropocene. The IGBP seminal report *Global Change and the Earth System: A Planet Under Pressure* (Steffen et al., 2004b, 2004c), discussed in section 2.1.3.3, considers the Industrial Revolution as a watershed between the pre-industrial localized and negligible anthropogenic influence on the Earth System, and the post-industrial "societal capacity to extract, consume, and produce" (Steffen et al., 2004b, p. 81) on a scale capable of affecting Earth System functioning. Hence, Steffen et al. (2007) consider the time frame 1800/1850 as the beginning of the Anthropocene's 'Stage 1,' namely, the first of three stages followed by the Great Acceleration (Stage 2, 1945–present) and by future trajectories of the Earth System determined by human responses to this state of affairs (Stage 3, present–?). To assign a more precise date, Steffen et al. (2011a) argue that the year 1800 "could reasonably be chosen as the beginning of the Anthropocene" because "in 1750, the Industrial Revolution had barely begun but by 1850 it had almost completely transformed England and had spread to many other countries in Europe and across the Atlantic to North America" (p. 849). Standing in between, the year 1800 provided a practical signpost to date the beginning of the new epoch.[233]

Lastly, Williams et al. (2019) consider the development of underground metro systems to "provide an important signal of sedimentary deposits that may be associated with a potential Anthropocene Epoch of geological time" (p. 451). The first metro system opened in London on January 10, 1863, developing thereafter on each continent (except Antarctica) over the next 150 years. The authors associate geological, stratigraphical, and biological significance with metro systems as 'trace fossils,' namely records of biological activity. No date is explicitly considered as starting point for the Anthropocene. However, by considering the material flow and sedimentary records (including technofossils) associated with the construction, use,

[232] As pointed out at the beginning of section 3.1 and in section 2.2.1, the 'geological' claim in Crutzen and Stoermer (2000) is best understood within an Earth System science framework rather than a geological proposal.

[233] In a recent publication, Syvitski et al. (2020) suggest that "[h]umans became a *geological force* over the last 300 y, particularly after the start of the *global industrial revolution* in 1850 CE when excess energy (fossil fuel) became widely available" (p. 8, emphases added). The authors do not explicitly consider the date as the beginning of the Anthropocene (in fact, they argue for a starting date to be placed at 1950 CE), but rather a point marking the geological scale of human actions – which, as addressed in section 3.1, is a different claim from the stratigraphic one. Additionally, the authors stress the importance of the Industrial Revolution as a global phenomenon, rather than focusing on the later Anglocentric 18th- and 19th-century industrialization.

and ontology of metro systems as a distinctive mark of the Anthropocene, the authors are locating its beginning within the late Industrial Revolution.

The Industrial Revolution is still rightfully represented in Anthropocene literature as part of the historical roots of the epoch, laying out the conditions of possibility for the societal, technological, and economic developments for later stages of human history. Nevertheless, the AWG (Zalasiewicz et al., 2019b, para. 7.4.3) has considered the beginning of discernible human impact to hold greater significance than the beginning of the underlying process. Considering that the "Industrial Revolution's impact on the global cycle remained negligible for several decades after the deployment of steam engines" (p. 253), then its diachronous and regional nature has been rejected by most of the AWG as a valid stratigraphic marker for the Anthropocene Hypothesis.

3.2.3.4 Tambora Volcanic Eruption (1815 CE)

A study by archaeologist Victoria C. Smith (2014) suggests that the 1815 eruption of the Tambora stratovolcano on Sumbawa Island, Indonesia, may be used as a starting date for the Anthropocene. The same event had already been briefly considered as a possible stratigraphic marker by Zalasiewicz et al. (2008b) one year prior to the formation of the AWG and the birth of the Anthropocene Hypothesis. This proposal is situated within the Industrial Revolution, but it stands out from other related starting dates by considering a natural event as a possible base for the Anthropocene.

The Tambora eruption is one of the largest volcanic eruptions recorded in the past two thousand years. The relative explosiveness of a volcanic eruption is measured through the Volcanic Explosivity Index (VEI). The scale was created in 1982 by volcanologists Christopher G. Newhall and Stephen Self, who recognized the lack of a quantitative scale for measuring historical volcanic eruptions (Newhall & Self, 1982). It represents a composite semiquantitative scale assigning a value from 0 (lowest explosivity) to 8 (highest explosivity) based on different factors, such as type of eruption (e.g., strombolian or plinian), duration, dense rock equivalent (DRE, an estimate of erupted volume), or eruption column height (i.e., troposphere or stratosphere injection). Most of the documented eruptions have a VEI value of < 3, meaning that higher VEI eruptions are rarer.

The 1815 Tambora eruption has been assigned a VEI of 7, and it is often considered the cause of the sudden decrease in global mean temperature and climate anomalies of 1816 – the 'year without a summer.' The eruption released approximately 53–58 Tg of SO_2 (sulfur dioxide) which generated 93–118 Tg of sulfate aerosols (Smith, 2014, quoting Self & al., 2004), and its ashes were reported as far as 1800 km away from the eruption site. Electrical conductivity measurements (ECM, a reflection of ice acidity) and sulfate peaks record the event in ice cores both in Antarctica and Greenland (as well as other sites in Bolivia and the U.S.), making the event virtually synchronous and global in stratigraphic terms. Considering that tephra layers offer both a relative and absolute chronology, and that accompanying archives of various scientific as well as historical natures provide additional stratigraphic evidence, Smith concludes that "[t]he

1815 Tambora eruption is an ideal marker for defining the onset of the Anthropocene as it occurs just before major anthropogenic changes observed in key climate records" (p. 294).

The Tambora eruption provides a seemingly isochronous and global signal with a possible GSSP marker for locating the beginning of the Anthropocene. Indeed, Lowe and Bostock (2015) have argued that "the Tambora eruption deserves serious consideration as the GSSP for the start of the Anthropocene because it generated a demonstrably globally synchronous signal that ties in with associated evidence of increasing human impact, namely the atmospheric greenhouse gas rise from the early 1800s" (p. 117). Whilst selecting a *natural* signal over an anthropogenic signals seems to undermine the basic idea behind the 'Anthropocene,' the AWG (Zalasiewicz et al., 2019b, para. 1.3) has noted that "an effective Anthropocene boundary […] need not be based on a human-made signal" (p. 16). Nevertheless, the 1815 Tambora event is recognized as too small (though not negligible) an event to be used for a GSSP, and difficult to correlate globally in stratigraphic record.

3.2.3.5 AD 1900 event

A paleomagnetic study from Snowball, Hounslow, and Nilsson (2014) considers anthropogenic traces in mineral magnetic records from fossil fuel burning and deforestation as a possible late base for the Anthropocene. They select the date of 1900 CE, reflecting "major fossil fuel burning in Europe and eastern North America, probably related to coal burning" (p. 132) and shifts in soil properties associated with deforestation.

By the time the article was written and published, the Industrial Revolution was still considered the best candidate for locating the beginning of the Anthropocene. The evidence they provide has been assimilated by the AWG as paleomagnetic and magnetostratigraphic evidence for the Anthropocene, but it has only been considered as an auxiliary marker for determining the stratigraphic signature of the Anthropocene. Despite the Industrial Revolution having ultimately been rejected by the AWG as a possible time period to locate the beginning of the Anthropocene, the AD 1900 event hypothesis stands out as an autonomous, magnetic-based argument for locating the beginning of the Anthropocene. This makes it worth mentioning, although briefly, along the spectrum of scientific alternatives to the Anthropocene Hypothesis.

3.2.4 Contemporary Anthropocene Hypotheses

Modern Anthropocene hypotheses have been defined as those hypotheses situated within the historiographic category of 'modern history.' Another cluster of hypotheses sharing even closer proximity to the present is situated after 1945 CE. This year is another important historiographic signpost. It marks the end of WWII as well as the beginning of the Atomic Age and the Great Acceleration. The development of nuclear technology, and the testing of nuclear and thermonuclear devices amidst the international tensions defining the Cold War, hold particular importance in Anthropocene Hypotheses debates. This is not solely because the Anthropocene Hypothesis itself locates the optimal beginning of the proposed epoch within this time period. Abundant scientific literature has documented the scale and magnitude of human forcings on the planet during the second half of the 20th century. This footprint brings unprecedented evidence to the stratigraphic discussions over the Anthropocene as a geological unit, and over its broader significance.

As mentioned, the post-WWII era has been assigned different labels, from the Great Acceleration and the Atomic Age to the late modern age and contemporary history. Selecting one label over another mostly depends on the specific features of time period being discussed – from historical events through political tensions to energy transitions. Consistent with the historiographical choice adopted for modern Anthropocene hypotheses, the following hypotheses are addressed as 'contemporary Anthropocene hypotheses.' This decision follows the same three principles of practicality, differentiation, and time-range similarity that justified the grouping of modern hypotheses.

The Anthropocene Hypothesis locates the beginning of the proposed stratigraphic and chronostratigraphic unit at ~1950. As such, it falls within this cluster of Anthropocene hypotheses. All of the hypotheses surveyed in this section share with the Anthropocene Hypothesis the basic belief that atomic bomb testing left a substantial stratigraphic (particularly chemostratigraphic) marker in sedimentary records that could be interpreted as a global and synchronous marker for the unit. However, this pool of hypotheses varies in terms of identifying the precise year that would serve as a geochronological threshold. Such a discussion may look trivial: what difference would it make, geologically speaking, whether the Anthropocene were to begin in the year 1945, during the 1950s, or in 1964? The meaningful differences among these proposals do not lie in the time frame or date selected, but rather in the methodologies chosen to select these dates. Therefore, to select one date or the other means establishing a preferred methodology to define the Anthropocene, and ensuring the selected methodology is given stratigraphic recognition.

3.2.4.1 Trinity Test Hypothesis (1945 CE)

Among the possible starting dates initially considered, the AWG (Zalasiewicz et al., 2015b) had proposed to date the beginning of the Anthropocene with the use of the world's first nuclear device. The Gadget was detonated at 05:29:21 a.m. (±2 seconds) Mountain War Time (-6 hours GMT) on July 16, 1945, at the White Sands Proving Ground (now White Sands Missile Range) in the Jornada Del Muerto Desert, New Mexico. The date represents the beginning of the Atomic Age, which in stratigraphic terms is defined by a seemingly global and synchronous radiogenic signal associated with the scattering of anthropogenic radionuclides by nuclear fallout, especially ^{137}Cs (caesium-137), which is formed by nuclear fission of ^{235}U (uranium-235). While radiogenic signals are more prominent in the two subsequent decades, the authors considered the date to represent a "clear, objective moment in time" (p. 200).

Originally, the authors believed that a GSSP would not offer a "significant practical advantage over a GSSA" (p. 200) in defining a boundary. In fact, they considered a Global Standard Stratigraphic Age or GSSA "to be simpler and more direct than one based on a GSSP" (p. 201) because the historical observational record and stratigraphic evidence can be associated with a numerical (i.e., calendar) age with higher precision than a GSSP. As explained in section 3.1.2.6, a GSSA is a conventional numerical date used when stratigraphic evidence, and in particular the fossil record, is either absent, too scarce, or too difficult to correlate globally. This situation applies to most of the Precambrian (> 541 Ma), and thus virtually to most of the Earth's history, when life was scarce and less complex. However, according to the AWG (Waters et al., 2014a; Zalasiewicz et al., 2011a), the Holocene was defined by a numerical age stipulated at 10 ka (although not officially recognized as a GSSA) before it was assigned a GSSP in May 2008 based on ice cores from the North Greenland Ice Core Project (NGRIP) reflecting signals in climatic warming (Walker et al., 2009).

Already in 2011, Zalasiewicz et al. (2011a) had used the case of the formerly GSSA-defined Pleistocene–Holocene boundary to advance the possibility of defining a Holocene–Anthropocene boundary with a numerical age. Then, the authors had assigned its beginning at 1800 CE. This possibility was further considered by Waters et al. (2014b) in the Geological Society of London's special publication *A Stratigraphical Basis for the Anthropocene* (Waters et al., 2014a). The authors argued that "[w]ith the definition of the base of the Anthropocene possibly at a time of tens to hundreds of years before present, the resolution of dating techniques is at least decadal if not annual, and definition of a GSSA at a specific year is feasible and arguably preferable to using a proxy indicator" (p. 7). Rather than assigning a numerical date at 1800 CE, Waters et al. (2014b) began considering different types of evidence exhibiting substantial stratigraphic signatures post-dating 1945, hence "leading to the suggestion that this date may be a suitable age for the commencement of the Anthropocene should it prove useful and necessary to define it" (p. 17).

The proposal to define the Anthropocene based on its numerical beginning (at 1945 CE) rather than its stratigraphic base was contested by Stanley Finney, then Chair of the ICS, and Lucy E. Edwards, NACSN commissioner (Finney & Edwards, 2016). The authors, who advocate against the formalization of the Anthropocene, argue that "focusing on the definition of the beginning of the Anthropocene can result in the lack of consideration of its stratigraphic content and its concept" because "[i]t conveys the opinion that units of the geologic time scale are defined solely by their beginnings, rather than their content" (p. 7). That means that physical evidence of global and synchronous correlatability should determine a Holocene–Anthropocene boundary, rather than a numerical date. Additionally, Finney and Edwards (2016) reported that a GSSA at 10 ka was never formalized by the ICS nor the IUGS for the Pleistocene–Holocene boundary, and hence cannot be used as an example of using a GSSA in recent times. According to Walker et al. (2015, also quoted in Finney & Edwards, 2016), the date was selected during the Holocene Commission meeting at the eighth International Union for Quaternary Research Congress held in Paris in 1969, with participants agreeing that the Pleistocene–Holocene boundary should be placed chronometrically at 10 ka. But no GSSA was formalized at that time, nor afterward.

The original proposal by Zalasiewicz et al. (2015b) to use the GSSA method to date the beginning of the Anthropocene at July 16, 1945 CE has been superseded by the current AWG research direction, whose members voted in favor of using a GSSP methodology to locate a possible lower boundary around the mid-20th century.[234] The Anthropocene researchers realized that "[t]he 1945 detonation of the Trinity device would make a well-defined, historically important reference point, but a single detonation lacks a clear signature in the global geological record" (Waters et al., 2015, p. 49), which is necessary to consider the Anthropocene as a geological time unit. Nevertheless, the Trinity Test Hypothesis played an important role in the broader conceptual development of the Anthropocene Hypothesis because it transitioned the stratigraphic focus from the Industrial Revolution to the Atomic Age, which is currently the main area of focus for the AWG.

3.2.4.2 Nuclear/Thermonuclear Bomb Testing (1950–1963 CE)

Radionuclide signals associated with atomic bomb testing are currently the most promising marker for the Anthropocene and are advocated by the majority of AWG members. This time period, covering the 1950s and 1960s, also coincides with the onset of the Great Acceleration, thus providing a meeting point between stratigraphy and Earth System science. Several individual starting dates within this time frame have been advanced in research literature. These proposals do not necessarily compete with one another in the way other proposals do (e.g., Ruddiman Hypothesis, Orbis Spike Hypothesis), because they constitute possible 'options' within the Anthropocene Hypothesis as currently formulated by the AWG (they also differ from the Trinity Test Hypothesis, in that the latter implemented a different methodological framework superseded by extant research). However, if a single date is required in the process of formalizing the Anthropocene, then only one can ultimately be chosen as an ideal starting date based on convincing stratigraphic evidence. A few of these proposals are reviewed in this section.

The year 1950 has been a common date in Earth System science and geological literature (Waters et al., 2016) because it determines the onset of the Great Acceleration. While stating that defining a beginning is relative to the discipline undertaking the effort, geologist Jaia Syvitski and hydrologist Albert Kettner (2011) associate the beginning of the proposed epoch at 1950 with surface-temperature records based on evidence presented in the IPCC *Climate Change 2007* synthesis report (IPCC, 2007).[235] However, their study does not directly engage with the issue of determining the beginning of the Anthropocene.

A more recent study by Syvitski et al. (2020) also proposed 1950 as the beginning of the Anthropocene. The study analyzes the geological impact of human energy consumption across Holocene

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[234] Results available on the group's page, http://quaternary.stratigraphy.org/working-groups/anthropocene/ (accessed on October 3, 2021).

[235] It should be mentioned that neither the synthesis nor the full report nor the summary for policymakers mentions the 'Anthropocene.' However, the report emphasizes the consequences of anthropogenic climate change (e.g., sea level rise, average temperatures, etc.) especially during the second half of the 20th century, hence logically creating a 'threshold year' at 1950 CE.

human history, showing that a number of factors characterize the post-1950 interval as a substantially different geological and historical epoch: the burning of fossil fuels in the past 70 years led to a 0.9°C increase in atmospheric temperature; the increase of atmospheric CO_2 to above 400 ppmv in 2015 – a level unprecedented in the past 3 million years (Lindsey, 2020) – and the consequential cryosphere loss, sea-level rise, and ocean acidification; rapid growth of the human population, with an average growth rate of 1.63%/y (compared to 0.8%/y during the 1850–1950 CE interval) and 71 million new individuals per year; per capita energy consumption reaching ~61 GJ/y (range 40 to 75 GJ/y), against industrial levels of ~27.2 GJ/y (range 22 to 40 GJ/y) and pre-industrial (1670–1850 CE) average of 18.4 GJ/y (range 13.5 to 22 GJ/y). Furthermore, the authors provide a list of sixteen additional examples[236] in support of the "Anthropocene Epoch thesis" (Syvitski et al., 2020, p. 5), discussing some of the trends of the Great Acceleration and highlighting further aspects not represented in the canonical twenty-four graphs. Lastly, they suggest that the evidence they provide "strongly underpin the trajectory of the Earth System away from a Holocene state of the system, substantially and globally, around the mid-20th century, circa 1950 CE" (p. 9).

In a stratigraphic context, Zalasiewicz et al. (2014c) consider 1950 as a practical starting date for the Anthropocene, regardless of the means used to define it (GSSP or GSSA). The authors consider the Anthropocene not to "represent the detectable incoming of human influence […] but major change to the Earth system that happens to be currently driven by human forcing, and which may geologically soon be more significantly controlled by a number of secondary positive feedbacks, such as methane release from permafrost and ice-albedo changes" (p. 40). As a turning point in Earth System functioning, the year 1950 is selected in combination with worldwide signals, from radionuclide fallout to sedimentation and changes to biota, that "are traceable by scientists living today, and not just by hypothetical 'far-future' geologists" (ibid.). Radiogenic signatures and radionuclides from nuclear and thermonuclear weapon testing fallout is considered by Waters et al. (2016) as "[p]otentially the most widespread and globally synchronous anthropogenic signal" (p. aad2622-5), and is in fact central evidence supporting the Anthropocene Hypothesis. Waters et al. (2016) consider the mid-20th century as the most consistent time frame for the evidence provided in their analysis, essentially representing the AWG's current position on the beginning of the Anthropocene.

The year 1952 has been considered by Waters et al. (2015) as a possible candidate to locate the beginning of the Anthropocene. The date has been used by Davies (2018) in his monograph, *The Birth of the Anthropocene*, suggesting also that a GSSA could perhaps be used to date the beginning of the Anthropocene with the detonation of Ivy Mike, the first thermonuclear device, on November 1, 1952, 07:14:59.4 (±0.2s) a.m. local time. Waters et al. (2015) associate the date with extensive thermonuclear testing that had begun by 1952, which "deposited large amounts of radionuclides in the environment and left a well-defined radiogenic signature" (p. 49). Whilst this signal is most evident in later years, it is a

[236] The examples provided are artificial nitrogen fixation, damming, road systems development, industrial mining, industrial agriculture, release of POPs, coastal engineering, plastic production, creation of human mineral-like compounds, concrete production, water evaporation from warming, overfishing, total livestock biomass, anthropogenic sulphur emissions, alien species invasion, and radionuclide fallout.

common practice in stratigraphy to place stratigraphic boundaries at the beginning of a determined excursion (e.g., chemical, but also fossil appearance) rather than its peak (Zalasiewicz et al., 2015a). Waters et al. (2015) do not explicitly mention a GSSP or a GSSA as a preferred methodology, although the emphasis on physical evidence (hence a GSSP-based boundary) over a chronologically established date is implicit.

While only marginally considered, Zalasiewicz, Waters, Williams, et al. (2015b) also presented 1954 as a possible Anthropocene GSSA, a year marking "the first *widespread* appearance of artificial radioisotopes in the geological record" (p. 201). The radioisotopes are particularly clear in caesium-137 in the Northern Hemisphere, appearing prominently in 1954 and peaking in 1963 – the latter year also corresponding to the Partial Test Ban Treaty, an international agreement setting strong limits to nuclear testing.

3.2.4.3 Bomb Spike Hypothesis (1964 CE)

Chronologically, the most recent starting date proposed for an Anthropocene time unit has been advanced by Lewis and Maslin (2015a, 2015b, 2018a) – also promoters of the Orbis Spike Hypothesis. The authors consider the year 1964 another possible beginning of the Anthropocene. The year corresponds to a peak in radionuclide fallout, specifically ^{14}C (radiocarbon), recorded in tree rings.

Tree ring (or growth ring) dating, or dendrochronology, is a useful dating technique with a wide spectrum of applications, enabling disciplines such as stratigraphy, paleoclimatology, forestry, chemistry, archaeology, and climate science to explain and/or correlate types of findings (e.g., age of a sample, traces of a chemical element, climatic conditions at a given time, age of wooden artifacts, etc.). Essentially, trees receive and react to environmental changes in their surroundings, and because trees are stationary organisms, they provide a reliable source of information for reconstructing the climatic or environmental history of a determined geographical area. Trees respond almost immediately to environmental changes, which are recorded in tree rings forming mostly on a yearly cycle (i.e., one ring per year).

Lewis and Maslin (2015a) suggest that a GSSP could be placed at Niepołomice, a small village 25 km east of Krakow, Poland, within tree rings of a pine tree (*Pinus sylvestris*) recording the radiocarbon peak at 1964 CE. This GSSP is based on a study on radiocarbon dating of CO_2 emissions for environmental monitoring by Rakowski et al. (2013) that attempts to calculate CO_2 emissions from combustion of fossil fuels. The authors use pine tree rings from Niepołomice as evidence for their study, showing a peak of 894.3 $\Delta^{14}C$ ‰ (radiocarbon per-mille) at 1964 CE attributed to nuclear weapon testing (see Rakowski et al., 2013, Table 1). Among the pool of possible secondary markers, Lewis and Maslin (2015a, 2015b) consider plutonium isotope ratios ($^{240}Pu/^{239}Pu$), caesium-137, and iodine isotopes (^{129}I) found among sediments, marine sediments, and soils as possible auxiliary markers for the proposed beginning. The authors believe that the year 1964 serves as an optimal starting date and GSSP because it allows "global correlation, can be dated to an unambiguously annual resolution, and provides the best correlation potential with other radionuclide species" (Lewis & Maslin, 2015b, p. 140).

In addition to meeting the criteria for a possible GSSP, the authors also consider the broader meaning of selecting this specific date, considering that "[c]hoosing the bomb spike tells a story of an elite-driven technological development that threatens planet-wide destruction" (Lewis & Maslin, 2015a, p. 177).

In the Correspondence section of *Nature*, Zalasiewicz (2015) briefly commented on the Bomb Spike Hypothesis, suggesting that the selected date is located beyond the commencement of the Great Acceleration. This implies that including this time frame in defining the Anthropocene should be paramount. In fact, such a statement is consistent with the close proximity established between stratigraphic and Earth System research – the former attempting to include the latter in a stratigraphic definition of the Anthropocene. Indeed, Zalasiewicz argues "that year 1964 is later than the near-synchronous upward inflections of many physical and socio-economic trends and their respective stratigraphic signals, which date to around 1950" (p. 436). The synchronicity requirement finds an additional issue in geographical terms. Waters et al. (2016) observe that "the peak is diachronous between hemispheres" (p. aad2622-5), suggesting that it cannot be used to locate the beginning of the proposed unit.

Following internal voting opinions held on the occasion of the 35th International Geological Congress in Cape Town, South Africa, on August 29, 2016, 1.3 votes were issued in favor of selecting the year ~1964 CE as a starting date, against 28.3 votes in favor of a ~1950 boundary (Zalasiewicz et al., 2017a). This resulted in the AWG's present research direction of locating the beginning of the Anthropocene by the 1950s.

This chapter surveyed the empirical and methodological basis informing the Anthropocene Hypothesis as well as the landscape of alternative hypotheses conceptualizing, complementing, or contesting the stratigraphic variant of the 'Anthropocene' formulated by the AWG. These aspects are paramount in delineating an epistemology of the Anthropocene Hypothesis.

A further aspect of epistemic significance is locating the hypothesis in the context of scientific knowledge at large. This aspect is explored in the following chapter, where a complementary analysis of a more 'theoretical' nature is conducted.

CHAPTER 4

EPISTEMOLOGY OF THE ANTHROPOCENE HYPOTHESIS

The first and essential acid test for any theory
is whether it provides acceptable answers to interesting questions:
whether, in other words*, it provides satisfactory solutions to important problems.*

—Larry Laudan, *Progress and Its Problems*

Scientific hypotheses say something about the world. The way scientists formulate and test hypotheses makes them different from mere conjectures, lucky guesses, personal beliefs, or popular opinions, in achieving (or failing to achieve) a kind of expected cognitive success (Steup & Neta, 2020). Different areas dedicated to the study of science and scientific knowledge confirm this – from studies on the social, historical, organizational, and financial dimensions of science, to philosophically oriented analyses of the epistemological, linguistic, or cognitive aspects of scientific ideas. The nature of scientific hypotheses differs (socially, epistemically, etc.) between sciences as well – meaning that hypotheses formulated, for instance, in geology differ from hypotheses formulated in other disciplines in the way that expected cognitive success is achieved (or failed to be achieved). If the Anthropocene Hypothesis is to be considered a *scientific* hypothesis, then, in addition to its historical and social context (Chapter 2) and empirical basis (Chapter 3), another key aspect to consider is its distinctive *epistemological structure*[237] – that is, what particular epistemic properties and knowledge-statements make the hypothesis scientific in terms of how it is expressed and articulated. This is the central theme explored in this chapter, which develops on two main trajectories.

[237] In this chapter, 'epistemology' is intended in its strict sense as the philosophical analysis of knowledge-statements.

The first trajectory explores the research status of the Anthropocene Hypothesis in extant scholarship in philosophy. To do so, section 4.1 first assesses how the 'Anthropocene' and its stratigraphic variants have been assimilated in philosophical discourses. Then, the research status of the Anthropocene Hypothesis is considered within extant scholarship in philosophy of science. It is recognized that the discipline has had almost no interaction with the Anthropocene Hypothesis, with only a few contributions exploring the significance of the hypothesis. Reasons for this state of affairs are discussed together with extant contributions from the philosophy of science.

The second trajectory directly engages with the Anthropocene Hypothesis by applying theories and models in philosophy of science related to the *types* of scientific hypotheses, *scientific explanation*, and *scientific understanding*. These represent major themes developed within the philosophical tradition, and have been crucial in distinguishing *philosophical* analyses of science from other approaches to science and scientific knowledge. While theories on the topics differ virtually from philosopher to philosopher, it is generally considered a *desideratum*, if not a fundamental epistemic requirement, that a scientific hypothesis should be able to *explain* something about the world, and to provide *understanding* of the thing it seeks to explain in a way that is considered useful. Therefore, section 4.2 considers what type of scientific hypothesis the Anthropocene Hypothesis represents, and what this implies in epistemological terms. It furthermore assesses whether the Anthropocene Hypothesis is (in principle) invested with any type of explanatory power and intelligibility, and if so, how.

4.1 The 'Anthropocene' in Philosophy

As illustrated in Chapter 2, humanistic engagement with the 'Anthropocene' began sporadically by the end of the 2000s. Between 2000 and 2009, only a dozen texts in the literature exhibited engagement of a philosophical nature, primarily raising questions of a normative nature. In the decade that followed, philosophy (like other humanistic disciplines) witnessed a surge in interest in the 'Anthropocene.' This interest has, to date, reflected the original trend, primarily focusing on normative aspects of the 'Anthropocene,' but it has also touched upon other domains of philosophical inquiry.

What knowledge areas pertaining to philosophy have become particularly interested in the 'Anthropocene' as a philosophical category? Answering this question requires a preliminary understanding of the organization of philosophy as an academic discipline and space of inquiry.

Perhaps unsurprisingly, philosophy is a discipline difficult to organize into rigidly defined thematic clusters. The task of delimiting and organizing the space of inquiry of philosophy (and human knowledge) has been a philosophical quest of its own at least since Ancient Greece. Today, at least four organizational schemes can be identified to separate philosophy into meaningful branches. The first fourfold scheme divides philosophy into metaphysics or ontology (the study of the ultimate principles of things), epistemology (the study of the nature, structure, and value of knowledge), axiology (the study of the nature, meaning, and purpose of 'value'), and logic (the study of inferential reasoning and truth). A second twofold scheme distinguishes between theoretical philosophy (e.g., epistemology, metaphysics, logic, etc.) and practical philosophy (e.g., aesthetics, political philosophy, social philosophy, etc.). The third scheme distinguishes among seven main branches of philosophy – namely, aesthetics, epistemology, ethics, logic, metaphysics, philosophy of mind, and philosophy of science.[238] Lastly, the fourth scheme is based on philosophical traditions rather than themes or knowledge areas, and distinguishes between analytical philosophy, continental philosophy, and pragmatism. These traditions differ in terms of the meaning and methods of philosophical inquiry, and have a strong geographical basis.[239] Feasibly, the division of philosophy into knowledge domains often follows pragmatic and educational necessities and requirements posed by individual university departments.[240]

Following the sevenfold scheme above, the 'Anthropocene' has become a category of philosophical interest particularly for two branches of philosophy – namely, ethics and aesthetics. Each of the two is discussed in the following sections.

The concept has not resonated as an object of interest for epistemology, logic, metaphysics,[241] philosophy of mind, or philosophy of science. This is rather intuitive for some of these branches, such as logic, metaphysics, and philosophy of mind. It is unlikely that the concept (or any of its variants) provides any added value to the study of reasoning and truth. The same applies for the study of the ultimate principles of fundamental entities such as being, truth, time, mind, matter, necessity, and so forth. Issues concerning the mind–body problem, consciousness, or mental properties seem also not to grant the 'Anthropocene' any functional space within philosophy of mind.

However, it seems that the concept – specifically, its stratigraphic variant, the Anthropocene Hypothesis – *does* have space within epistemology, and philosophy of science.

Epistemology is the study of knowledge and its nature. It overlaps in many ways with philosophy of science as the study of *scientific* knowledge. While the Anthropocene Hypothesis has no utility in discussions on traditional epistemological problems (e.g., the Münchhausen trilemma, skeptical arguments,

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[238] The latter systematization is also the one used for the Wikipedia page 'Outline of philosophy' (https://en.wikipedia.org/wiki/Outline_of_philosophy, accessed on August 12. Last revision: May 24, 2021, 13:51 CET by Thi).

[239] Analytical philosophy developed within the Austrian-born tradition of logical empiricism, spreading especially in UK and USA as a consequence of events surrounding the rise of the German National Socialism. Continental philosophy (a category most used by analytical philosophers rather than 'continental' philosophers to distinguish their approaches) stems from mainland Europe (particularly Germany through German Idealism, and France through post-structuralism and existentialism). Pragmatism is virtually the only American-born philosophical tradition, generated by the end of the 19th century through Pierce, James, and later Dewey.

[240] Each of the organizational schemes highlighted above can be found through a simple Google search within a substantial pool of different sources.

[241] If considered part of metaphysics, religion studies have also been a contributor in discussions on the 'Anthropocene.' For related literature, see Bedford-Strohm (2017) and the Multidisciplinary Digital Publishing Institute (a publisher of open access scientific journals) special issue "Faith after the Anthropocene" (https://www.mdpi.com/journal/religions/special_issues/Faith_Anthropocene, accessed on August 17, 2021). See also PAS workshops discussed in section 2.1.3.3.

etc.), the fact that the hypothesis challenges traditional disciplinary boundaries (Inkpen & DesRoches, 2019; Luciano, 2019) has repercussions for the way that knowledge is (or should be) formulated. In turn, this has implications for *how* knowledge about the Anthropocene as a geological time unit is produced, and *what* knowledge describes it. This fact alone is sufficient to explain why the hypothesis is *epistemologically* interesting.

Philosophy of science concerns questions dealing with the nature of scientific knowledge. As such, it seems intuitive that the Anthropocene Hypothesis as a *scientific* hypothesis should represent an object of interest for philosophers of science. However, this has not been the case. Philosophy of science scholarship has been largely silent over the scientific debates revolving around the Anthropocene Hypothesis. Section 4.1.3 explores a major historical and intellectual reason behind this circumstance, and discusses a few isolated contributions from philosophers of science engaging with the Anthropocene Hypothesis.

4.1.1 Ethics

Ethics is the branch of philosophy concerned with "systematizing, defending, and recommending concepts of right and wrong behavior" (Fieser, 2021). Philosophers traditionally divide ethics into *normative ethics* (the study of the principles of right and wrong conduct), *applied ethics* (the study of the application of ethical norms to specific issues of ethical and moral concern), and *metaethics* (the study of the origin, nature, and meaning of ethical standards). With the exception of metaethics, ethics is primarily a *normative* effort because it seeks to discern what is good and bad, and therefore what ought to be done or not done.

Ethics has emerged as one of the branches of philosophy that has most inquired about the 'Anthropocene.' Scholars have discussed the 'Anthropocene' as an object of ethical concern, and as a vehicle for reframing questions of a philosophical nature concerning the relationship between humans and the Earth in the context of deep time, mass extinctions, geological agency, or climate change – among others. As such, the 'Anthropocene' is situated at the intersection of normative ethics and applied ethics.

The normative-ethical connotations associated with the 'Anthropocene' have been developing within preexisting discourses at the crossroads of the ethics of nature, environmental philosophy, and ecophilosophy (e.g., Leopold, 1981; Naess, 1989; Sessions, 1995; White, 1967). The emergence of these subdomains of ethics represented a reaction to increasing social and scientific awareness of the major environmental challenges of the present time, from anthropogenic climate change and global warming to increasing species extinctions and extreme weather events. This reaction has developed the discrete philosophical field of inquiry of environmental ethics. This constitutes an "interdisciplinary-oriented practical philosophy which reconstructs the essential types of argumentation that can be made for protecting natural entities and the sustainable use of natural resources" (Ott, 2020, p. 1). At the core of environmental ethics is the normative task of ascribing a specific set of ethical values to non-human natural entities. Environmental philosophers have raised questions on *how* to ascribe any ethical value (e.g., intrinsic values vs. extrinsic values); *why* such values should be ascribed in the first place (e.g., deontology vs.

consequentialism); *which* ethical values should precisely be formulated (e.g., protection, sustainability, care, etc.); and *to whom* these values should be conferred (e.g., living entities, non-living entities, bacteria, complex life, etc.). Answering these interrogatives is crucial in overcoming anthropocentrism – considered by "many environmental philosophers the ethical attitude the field [of environmental ethics] was created to overcome" (Minteer, 2008, p. 58, quoted in Dzwonkowska, 2018, p. 724).

By the late 2000s, the 'Anthropocene' began appearing sporadically in environmental ethics texts (Dalby, 2007b; Hall, 2009; Rolston III, 2007), or in topics related to sustainability (Lapka & Cudlinova, 2009), the concept of 'nature' (Drenthen et al., 2009), biotechnology (Crook, 2008), or the ethics of technology and infrastructures (Allenby, 2006a, 2006b, 2008, 2009). The term remained, however, an informal designation and background notion rather than an epistemically significant term, encompassing and encapsulating in a single semantic unity the spectrum of challenges posed by anthropogenic pressures on the Earth. Things changed after the 'humanistic turn' around 2009. The concept moved from mere background notion and informal neologism to a hub for philosophically dense discussions over the place and responsibility of humans in engendering a (proposed) new epoch of geological time. In particular, the term was assumed (and also contested) for its value in centralizing the role of humans in (re)shaping nature, and consequently in (re)shaping the system of values framing the interaction between humans and the rest of nature.

Interdisciplinary ecologist Benjamin S. Lowe (2019) has reviewed sample literature (books and edited volumes on the ethics of nature) emblematic of the ethical commitment to the 'Anthropocene' developed in the past decade. He notes that "[t]he Anthropocene in general and climate change in particular are not just scientific or technical issues. They are also moral problems, requiring moral solutions" (p. 480). Ethical systems based on intergenerational justice and sustainability, on virtue ethics, on hope, on science communication, and on pragmatism offer specific solutions to these moral problems, emphasizing specific ethical and moral virtues important for facing and reacting to the 'Anthropocene' predicament. Lowe notes that, across the literature surveyed, particular attention is given to future generations as well as the role of virtue ethics.

'Future generations' was notoriously a terminological choice selected by the United Nations 1987 Brundtland Report (also known by its title, *Our Common Future*) in the definition of 'sustainable development' as the "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987, p. 43). The concepts of 'Anthropocene' and 'sustainability' formed a close partnership during the former's first years of existence.[242]

'Virtue ethics' represents one of three major approaches in normative ethics – the others being consequentialism and deontology (Hursthouse & Pettigrove, 2018). Virtue ethics emphasizes the centrality of moral virtues as a fundamental normative category leading a moral agent to take a moral action, and it has been one of the ethical frameworks considered relevant for facing the 'Anthropocene' (e.g.,

[242] See section 2.1.3.

Dzwonkowska, 2018) because "it focuses on making us better people, regardless of the outcomes. As a result, it can serve as an intrinsic source of ethical motivation and action even when the future appears bleak, complex, and overwhelming" (Lowe, 2019, pp. 484–485). In turn, this "may help increase our resilience and enable our communities to sustain higher levels of stability and functioning as socio-ecological stresses increase" (p. 485).

Sustainability and virtue ethics are only a few of the topics explored by philosophers and scholars engaging with ethical and moral questions around the 'Anthropocene.' Writer and scholar Joanna Zylinska (2014) articulates the 'Anthropocene' as an "ethical pointer rather than as a scientific descriptor" (p. 19) – implicitly subscribing to a difference between a normative-ethical and descriptive-scientific 'Anthropocene.' As an ethical category, the 'Anthropocene' serves "as a designation of the human obligation towards the geo- and biosphere, but also towards thinking about the geo- and biosphere as *concepts*" (ibid.). These concepts would enable "a call for a return to critical thinking" (p. 20). Her proposal for a 'minimal ethics' for the 'Anthropocene' represents an updated version of environmental ethics starting from the premise that humans play a pivotal role in the rearrangement of the natural world. It aims at describing an ethics of life working at various scales – interactions among humans as well as human and non-human interactions. In this framework, the 'Anthropocene' designates an ethical form of thinking that is "strongly post-anthropocentric […] in the sense that it does not consider the human to be the dominant or the most important species, nor does it see the world as arranged solely for human use and benefit" (p. 20), but simply appeals to the capacity of humans to shape the world and, in doing so, rearrange ethical interactions with nature.

In his book (or 'travelogue,' as the author defines it) *Philosophy of the Anthropocene*, philosopher Sverre Raffnsøe (2016) frames the 'Anthropocene' as a time "characterized by the overarching importance of the human species in a number of respects. Closely related to this new role is a new heightened sense of human responsibility, but also the recognition of human dependence and precariousness" (p. xii). The philosopher locates an ongoing 'human turn' – that is, "a new, altered relationship between humankind and its surroundings" (p. xiv). This human turn is heralded by the dawn of the 'Anthropocene,' representing a state that "fundamentally changes the character of the world that we humans inhabit, and also our relationship with this world, be it on a local or a global scale" (p. xv). This fundamental change implies a change in the ethical norms governing human interaction with the world as well as humankind's perception of itself. Philosophy (viz., ethics) can help in understanding this fundamental change and human turn, and provide answers to the ethical challenges these conditions pose.

An interesting observation about Raffnsøe (2016) concerns the very title of his book – not 'Ethics' *of the Anthropocene*,' but rather 'Philosophy' *of the Anthropocene*. This is emblematic of the implicit assumption that philosophy (which comprehends fields as diverse as logic, epistemology, metaphysics, and philosophy of science) is invested with a normative-ethical responsibility when tackling the concept of 'Anthropocene.' This assumption is a double-edged sword. On the one hand, it considers it necessary for philosophy to engage with discussions about the 'Anthropocene' as a boundary object of ethical and moral interest. On the other hand, it seems to implicitly delimit the space of philosophical inquiry *exclusively* to the ethical, and broader normative aspects, of the 'Anthropocene.' This implicit assumption leaves little space for extra-ethical considerations of the 'Anthropocene,' and more precisely, of the Anthropocene Hypothesis. The absence of substantial literature from the philosophy of science seems to further corroborate the idea that philosophy has perceived the 'Anthropocene' primarily as a theoretical object confined within the domain of environmental ethics (or aesthetics).

The ethics-oriented purpose of philosophy in 'Anthropocene' discourses is made explicit by philosopher Richard Polt and political scientist Jon Wittrock (2018) in their edited volume *The Task of Philosophy in the Anthropocene* – a collection of contributions "sensitive to concerns that are typical of the so-called continental philosophy" (p. xiii). The authors observe that "[a]rt, literature, history, and the humanities at large are challenged to respond in their own ways to the Anthropocene by drawing on the accumulated reserve of human meanings and experiences to make sense of our new relationship with the planet" (p. x). To this end, philosophers are invested with "a special responsibility to participate in the discussion" (ibid.). Besides "understanding the Anthropocene and its roots," the authors suggest, "philosophers may have a responsibility to ask whether there is anything that they, as philosophers, can do. Can we affect the future *for the better* [emphasis added]?" (ibid.). The task of philosophy, thus, is a normative effort striving toward an amelioration of the present and the future in the face of the 'Anthropocene.' Like other works in ethics engaging with the 'Anthropocene,' Polt and Wittrock also construe a notion of philosophy that starts from the observation of a fundamental, radical shift in the relationship between humans and the planet. The task of philosophy is, therefore, a task of a primarily ethical drive – that is, redefining the ethical norms for developing a sustainable and responsible relationship with the Earth.

Another contribution from Schmidt et al. (2016) articulates a "research agenda regarding how ethics both remain relevant to the Anthropocene and at the same time necessitate thinking through transitions implied by the increasing human impacts on the Earth System" (p. 3). Here, ethics is once again evoked as an area theoretically and practically affected by the dawn of the 'Anthropocene,' a time "where previous ethical norms require reassessment and novel problems arise in what are often metaphysical blind spots" (p. 9). The authors advance a series of points that extant ethical discourses must face, from reconsidering present ethical norms to discussing new and unprecedented concerns.

This sample literature provides a snapshot of the philosophical engagement with the 'Anthropocene' within ethics (see also Callicott, 2018; Hamilton, 2017; Lowe, 2019; Merchant, 2021; Williston, 2015). What emerges is a picture of a concept that encompasses a range of phenomena generating questions of profound ethical value. These questions converge toward two seemingly central problems in contemporary ethics *in* and *of* the 'Anthropocene' – namely, whether a revision of traditional ethical systems is called for; and which ethical system (novel or old) is the most suitable solution for reframing humans' relationship with the world. As an ethical category, the 'Anthropocene' functions as a catalyst for joining these discourses into a unified framework – although criticism addressing it ethical utility have been raised, as later addressed in section 5.1.4.

4.1.2 Aesthetics

Aesthetics is a branch of philosophy encompassing a wide range of philosophical questions over the nature of sensorial perception and statements, particularly in relation to beauty and taste. The term assumes various designations, such as "a kind of object, a kind of judgment, a kind of attitude, a kind of experience, and a kind of value" (Shelley, 2020). Aesthetics is closely tied with philosophy of art, where aesthetic evaluation of artworks plays a central role. It also overlaps with and transcends the academically defined boundaries of philosophy, merging with academic and non-academic domains such as visual culture, music, art exhibitions, and museum expositions.

Scholar Robert Emmett (2018) has stressed that the 'Anthropocene' concept "necessarily involves aesthetics" because it "travels not only as a scientific and political [and ethical] object of knowledge, but also as a call to artists, writers, and makers of many kinds to reflect on human un-making of living worlds" (p. 159). Over the past decade, the 'Anthropocene' has become an aesthetic phenomenon of vast interest for the artistic and visual community. Museum and gallery exhibitions, documentaries, and music performance and culture are among the ways in which the 'artistic Anthropocene' has manifested itself in a contemporary aesthetic sensibility. This constellation of contributions has engendered the 'Anthropocene' as an aesthetic category – one that narrates by visual, sensorial, and broader artistic means the meaning and implications of considering humans a novel geophysical agent. This heterogenous body of research has developed to answer fundamental aesthetic questions – namely, how can the 'Anthropocene' be visualized? What sensory experiences are most emblematic of the 'Anthropocene'? What does it mean, aesthetically, to live in the 'Anthropocene' and, for humans, to be a geological agent? How does one 'experience' the 'Anthropocene'?

The Anthropocene Slam is an example of aesthetic engagement with the 'Anthropocene.' This event was organized by the Nelson Institute's Center for Culture, History, and Environment (CHE) at the University of Wisconsin–Madison, in cooperation with the Rachel Carson Center in Munich, and the Environmental Humanities Laboratory at KTH Royal Institute of Technology in Stockholm. It took place at CHE in November 2014, where scholars, artists, and scientists of international provenance were brought together to select a pool of objects best representing the cabinet of curiosities or *Wunderkammer* of the 'Anthropocene.' Some of these objects were displayed months later as part of the collection of the Deutsches Museum exhibition *Welcome to the Anthropocene*, held between 2014 and 2016. The collection (Möllers et al., 2015) exposed objects as aesthetic mediums that could "summon all at once the past, present, and future, blending the global and local – and thus they can disrupt linear narratives, including those about the Anthropocene" (Mitman et al., 2018, p. xi). Some of these objects, from a trestle steam engine and a manual gasoline pump to a 1984 Apple Macintosh personal computer and a hairdryer, tell of "important technological milestones along our path into the Anthropocene" (Trischler, 2015, p. 130). This "Wall of Anthropocenic Objects" (ibid.) provided visitors of any occupation, background, and age with an aesthetic representation of the 'Anthropocene,' and what it means to live in it.

The idea that some objects could grant an aesthetic 'body' to the concept of 'Anthropocene' drew from designer and sound artist Yesenia Thibault-Picazo, who developed an Anthropogenic Specimens Cabinet in collaboration with Jan Zalasiewicz. The Cabinet is part of the *Craft in the Anthropocene* project, "a speculative design project which raises questions and stirs a debate around the novel theory of the Anthropocene."[243] The project (launched in 2013) began with Thibault-Picazo creating three household objects – a pestle made of Cumbrian Bone Marble (an imagined future rock resulting from the 2001 outbreak of foot-and-mouth disease in the UK), a mortar made out of PPC (Pacific Plastic Crust), and an aluminum vessel – reflecting future geological material of anthropogenic origin. Each object symbolizes the impact of humans not simply on the environment, but on the geology of the planet, foretelling of a stratigraphic footprint that humans will leave behind. As such, the project represents a speculative aesthetic visualization of the future rocks and soils on the 'Anthropocene' Earth, provoking reflection "around our conception of nature and ultimately to invite [us] to reimagine how we inhabit the world" (Yalcinkaya, 2018).

Art has been a pivotal aesthetic vehicle for communicating the 'Anthropocene.' Introducing their edited volume *Art in the Anthropocene*, humanist Heather Davis and philosopher Etienne Turpin (Davis & Turpin, 2015b) ask, "[W]hat does it mean for art to encounter the Anthropocene? […] [H]ow can aesthetic practices address the social and political spheres that are being set in stone?" (p. 3). In this aesthetics-based interpretation, art does not solely arouse individual sensory experiences in perceiving and visualizing the dawn of a new epoch. Art becomes a vehicle for social and political communication about the heavy burden posed by humans on the planet. Indeed, "art, as the vehicle of *aesthesis*, is central to thinking with and feeling through the Anthropocene" (ibid.). That is because, first, the 'Anthropocene' represents a sensorial experience – "the experience of living in an increasingly diminished and toxic world" (ibid.). Second, because aesthetic experiences complement and transgress satellite imagery, data visualization, and other modelling and visual techniques representing the Earth as a whole. Third, because art may also provide a "non-moral form of address that offers a range of discursive, visual, and sensual strategies that are not confined by the regimes of scientific objectivity, political moralism, or psychological depression" (p. 4).

Visual culture theorist Nicholas Mirzoeff (2014) writes that "to visualize the Anthropocene is to invoke the aesthetic" (p. 213). Visualization has been a central theme in aesthetics, as it is the pivotal concept at the core of visual cultures. It constitutes a process of representing complex phenomena or entities by means of a wide array of visual techniques. Visualization has been a central aspect in science, where phenomena unobservable with the naked eye (e.g., subatomic interactions, black holes) are often represented through digital models and photographs; in art, through practices such as painting, sculpture, and architecture; and in society at large, where visual images play a crucial role in the mechanisms behind the functioning of modern societies – from simple commercials to ideological propaganda and military strategy. Mirzoeff observes that the goal of visualization "is to maintain the authority of the visualizer, above and beyond the visualizer's material power" (p. 216). Just like "the Empire of nineteenth-century

[243] See https://yeseniatp.com/THE-ANTHROPOGENIC-SPECIMENS-CABINET (accessed on August 11, 2021).

imaginations, then the West of the Cold War, and now the Market" (ibid.), the 'Anthropocene' entails a visuality whose authority "can be felt across the world" (p. 217) by means of human actions. This authority is left unchallenged, so that

> Anthropocene visuality allows us to move on, to see nothing and keep circulating commodities, despite the destruction of the biosphere. We do so less out of venal convenience, as some might suggest, than out of a modernist conviction that "the authorities" will restore everything to order in the end. […] Anthropocene visuality keeps us believing that somehow the war against nature that Western society has been waging for centuries is not only right; it is beautiful and it can be won. If this is certainly a Western imperial project, the shame and the crisis is that it has affected every living thing whatsoever. But, as we shall see, it does not do so evenly and equitably. (ibid.)

Such aesthetics of the 'Anthropocene' has "emerged as an unintended supplement to imperial aesthetics" (p. 220). It legitimizes a visuality that does not simply hinder the search for solutions to the very problem it poses, but it also legitimizes a colonial relationship between the world's superpowers (and top contributors to climate change) and the poorer countries. Escaping this visual framework requires a 'countervisuality' that grounds on three claims: "a claim to move out of the 'place' allocated to one by birth, a claim to democracy on behalf of the part that has no part, and a means of sustaining these claims beyond the spontaneous moment of uprising" (p. 226).

That the aesthetics (viz., visualization practices) of the 'Anthropocene' entails some aspects requiring problematization has been also advanced by T. J. Demos (2017). In his book *Against the Anthropocene*, the visual culture theorist asks, "How does the Anthropocene enter into visuality, and what are its politics of representation?" (p. 12). As a geological time period, the 'Anthropocene' stretches temporally and spatially, therefore presenting "major challenges to representation systems" (p. 13). Demos notes that

> Anthropocene visualizations, which seldom focus on environmental emergencies and attritional scenes of slow violence, introduce an added complexity in that they often do not employ photography as their visual medium of choice, but rather opt for high-resolution satellite imagery that provides photographic-like pictures, such as those employed by Globaïa[244]. […] Yet in most cases regarding lay usage, these images have not only been carefully edited in order to show generally positive examples of modern development, but they have also already been interpreted for viewers (or rather consumers), insofar as they have been packaged as pictures, but without typically offering access to location data, ownership, legibility, or source information. In other words, the images seem hyper-legible, but in fact they are far from transparent or direct.

These visualization practices engendering the 'Anthropocene' complement the seemingly universalizing rhetoric of the concept – where *all* humans are equally responsible for the dawn of this new epoch.[245] Such practices developed within a "specific political and economic framework, comprising a visual system

[244] Demos is particularly referring to Globaïa's website, https://globaia.org/ (accessed on August 12, 2021).
[245] On criticism of the implicit universalization of the *anthropos* in the 'Anthropocene,' see section 5.1.1. This has been a shared argument against the 'Anthropocene' concept and discourses among critics.

delivered and constituted by the post-Cold War and largely Western-based military-state-corporate apparatus" (p. 18). Deconstructing this visual representation of the 'Anthropocene' is paramount in order to engage with political effort for social change. This is a task akin to Mirzoeff's idea of 'countervisuality,' except that, instead of providing an *alternative* imagery to the 'Anthropocene' concept, Demos renders this concept almost null, as it "can be roundly criticized for its assorted failings – terminological, philosophical, ecological, political" (p. 85). The only space left for the 'Anthropocene' is in "register[ing] the geological impact of colonial and industrial activities on Earth's natural systems" (ibid.). This connotation (and the visual representations around it) may prove useful in confronting climate change denial, and the fossil fuel industry behind it.

One last and well-known contribution to aesthetic representations of the 'Anthropocene' comes from Edward Burtyinsky. In 2018, the artist and photographer launched *The Anthropocene Project* – a "multidisciplinary body of work combining fine art photography, film, virtual reality, [and] augmented reality" (Burtynski, n.d.). The project included visualizations of the 'Anthropocene' through photographs of anthropogenically altered landscapes, a travelling museum exhibition (first opening on September 28, 2018, at the Art Gallery of Ontario and National Gallery of Canada), and a documentary film. This work provides a comprehensive visual body for the 'Anthropocene,' while simultaneously stressing the magnitude of human impacts as a geophysical agent.

As an aesthetic object, the concept of the 'Anthropocene' encompasses a broad range of artistic expressions (and critiques) at the intersection of visual culture, political commitment, science communication, and social call. Representing a spatially and temporally extended geological time unit is an aesthetic challenge, especially when defined in terms of deep time, but also in terms of social perception of this novel time period. The body of work surveyed in this section embodies an attempt in this direction, a discussion on the visual means, implications, and significance of the 'Anthropocene' as an aesthetic category.

4.1.3 Philosophy of Science

Philosophy of science "includes all philosophical questions asked about or within the sciences" (Ladyman, 2019, p. 189). It largely overlaps with epistemology in raising fundamental questions about *scientific* knowledge in terms of its nature, justification, and purpose. From Bacon, Descartes, Leibniz, Hume, and Kant through Comte, Peirce, Mach, and Boltzmann to logical empiricism, Kuhn, and Quine, philosophy of science has historically been a structural component of 'Western' philosophical reflections on the methods, foundations, and purpose of science. As such, it represents an indispensable contributor to understanding the epistemology of the Anthropocene Hypothesis as a *scientific* hypothesis.

The 'Anthropocene' was not as successful in the philosophy of science as it has been in ethics (as an ethical category) or aesthetics (as an aesthetic category).[246] Engagement with this hypothesis from philosophy of science has been scarce, and only a very limited number of philosophers of science have tackled the 'Anthropocene' as a scientific idea in recent years (Foster, 2018; Inkpen & DesRoches, 2019; Santana, 2019a). The lack of a substantial commitment from the philosophy of science represents a major research gap and, necessarily, a problem for discussing the Anthropocene Hypothesis.

Why, then, is it the case that philosophers of science have had very little voice in debates surrounding the hypothesis? Section 1.3.3 anticipated some plausible reasons behind this fact, including recent developments in the philosophy of science in light of newly emerging approaches to the study of science; the fact that the term did not echoed among philosophers of science; or the seemingly 'political' nature of the 'Anthropocene' debate overshadowing the 'analytical' nature of the Anthropocene Hypothesis. Another possible reason is the institutional absence of a philosophy of geology (intended as 'epistemology of geology') as a subdiscipline of philosophy of science.

Throughout the 20th century, increased knowledge specialization engendered a transition from the philosophy of *science* to philosophies of *sciences* – such as philosophy of physics, biology, artificial intelligence, neurosciences, cognitive sciences, medicine, and so forth. As noted by philosopher Derek Turner (2013), "[r]ather than starting with a general picture of how science works (or is supposed to work) and then asking how well particular fields fit that picture – a top-down approach – many philosophers these days prefer to start at the bottom with a careful characterization of some limited domain of scientific practice" (2013, p. 12). However, this transition did not fully materialize for the domain of geology, resulting in the institutional absence of a philosophy of geology as a discrete and autonomous field of inquiry. A resulting consequence of this academic vacuum is that the epistemology of an entire disciplinary domain has not been adequately framed, neither within traditional *topoi* in philosophy of science (e.g., scientific discovery, scientific progress, scientific explanation, etc.) nor within the specific epistemic aspects distinguishing geology as a discipline.

In the following section, it is advanced that the circumstances leading to an institutional absence of the philosophy of geology are fundamentally related to the role that physics played as an exemplar science in the 20th-century philosophy of science. This aspect is worth probing more deeply as it represents a major hindrance insofar as discussing the epistemology of a *geological* hypothesis needs to be located within a philosophy of *geology* framework. After this brief detour, extant scholarship in the philosophy of science discussing the Anthropocene Hypothesis is examined.

[246] It seems that science-oriented philosophical analyses of continental imprint have had more success than traditional 'analytical' philosophy of science in discussing the 'Anthropocene' and the Anthropocene Hypothesis. Recently, several articles engaging with the 'Anthropocene' have appeared in the journal *Foundations of Science* (e.g., De Preester, 2021; Lemmens & Van Den Eede, 2021; Pandilovski, 2021; Zwart, 2021). These articles draw on hermeneutics, Hegelian dialectics, and Heidegger to approach the 'Anthropocene,' science, and technology. Because of their methodological diversity, they are not discussed in the present context.

4.1.3.1 Physics as Paradigm

As observed by geologist Victor Baker (2013), physics has been regarded (more or less explicitly) as the "exemplar for all science" (p. vi) in philosophy of science for most of the 20th century up to the present day. Philosophical theories and models *of* and *about* science have largely drawn on physics (particularly theoretical physics) as the discipline that most embodies the epistemic virtues of science. Similarly, traditional philosophical textbooks of seminal importance – from Popper's *The Logic of Scientific Discovery* (1959) to Kuhn's *The Structure of Scientific Revolution* (1962) – systematically draw on historical and philosophical examples from physics, in particular theoretical physics and astronomy. There are several reasons behind this.

As part of *philosophia naturalis*, physics, and most notably astronomy, had already established itself as the main protagonist of the so-called Scientific Revolution. In fact, the very picture of the scientific method that emerged was largely sculpted around the epistemology and methodology of physics. Its popularity as 'mother of all sciences' was well-established not merely by the success of Newtonian mechanics (whose philosophical influence is exemplified by Kant's conceptions of space and time), but also by the positions invested in society and research institutions by many father figures in natural philosophy, such as Isaac Newton,[247] René Descartes, Tycho Brahe, and Galileo Galilei, to name a few. Furthermore, many physicists of the late 19th and early 20th century were also philosophers, and vice versa – from Ernst Mach, Henri Poincaré, and Ludwig Boltzmann, to Paul Feyerabend and Thomas Kuhn. Questions of physics were *also* questions of philosophy – to the point that philosophy of science in the 20th century "has come to be identical with philosophy of analytical physics" (Baker, 1996b, p. 197). During the 1950s, naturalistic philosophies began to approach philosophical problems by looking at answers from science, especially psychology (as famously advocated by Quine) or physics – somewhat inverting the 'traditional' relationship between philosophy and science. Philosophy of physics was certainly under the spotlight during the 20th century (Ladyman, 2019), only paralleled by philosophy of biology during the 1970s and 1980s.

A second reason is connected to the nature of philosophical questions. Virtually since the inception of philosophy with the Ionian school in Ancient Greece (6th century BCE), philosophers began exploring the nature of things by posing fundamental questions that, with the development of modern science and specialized knowledge, were reformulated in terms of fundamental physics (Schrödinger, 1956). With the development of special and general relativity as well as quantum mechanics, philosophical and scientific questions became one entangled pursuit. For instance, logical empiricism contested Kant's *a priori* conception of space-time based on the discovery of non-Euclidean geometries, notably the Minkowski spacetime implied by Einstein's special relativity. Questions about the nature of reality seemed to shift from a matter of metaphysics or traditional epistemology to one of theoretical physics and astronomy – both

[247] Interestingly, during the last years of his life, Newton made a calculation of the age of the Earth based (as was common at that time) on biblical scriptures suggesting that the Earth was 6,000 years old (Leddra, 2010). Newton was in fact considered an exemplar scientist among the emerging natural sciences throughout the 18th and 19th century, including Earth sciences (Gould, 1987; Leddra, 2010, quoting Cadbury, 2000, p. 155).

inquiring into the nature of the universe from the smallest to the largest scale by providing naturalistic explanations of reality. To an extreme, the enthusiasm and confidence in physics is embodied in caricature by Ernest Rutherford's oft-cited claim that all science is either physics or stamp collecting (Birks, 1962).

Related to this is the fact that physics has been attributed a 'special' epistemological status due to the nomological, abstract, immanent, deductive, and predictive structure of its knowledge domain (Moharir, 1993), mostly due to its close and successful partnership with mathematics (a discipline highly regarded at least since Ancient Greece). These features – which are often "taken to be laudatory, but need not necessarily be so" (p. 285) – granted physics the status of the "most methodologically precise and theoretically convergent of the natural sciences" (Baker, 1999, p. 634). In opposition, historical sciences such as geology were considered rather concrete, historical, inductive, and descriptive – all epistemic attributes regarded as lesser than those of physics.

A fourth reason is related to the success of physics during the 20th century – besides Einstein's contributions and the development of quantum mechanics. Particle physics unveiled a whole new subatomic reality, whose array of properties and particles could no longer be encapsulated by the concept of 'atom.' Superconductivity, a property of certain materials of crucial importance for contemporary advancements in technology, was discovered in 1911 by Heike Kamerlingh Onnes. The cosmological model known as the Big Bang emerged, corroborated by the observations of galactic redshift by Edwin Hubble in 1929, and by the (accidental) discovery of a cosmic microwave background in 1965 by Arno Penzias and Robert Wilson. Antiparticles, antimatter, and dark matter were discovered as additional components of the universe. The famous physicist Richard Feynman developed a revolutionary approach in representing subatomic interactions known as Feynman Diagrams. Lastly, a unified framework explaining three (out of four) of the fundamental forces of the universe was developed. These key developments, which informed and stimulated philosophical research as well as popular culture, do not exhaust the overall discoveries and restructuring of knowledge that physics brought about during the 20th century.

A fifth reason explaining the role of physics in society and in philosophy during the 20th century concerns the broader social and political role that it played after the discovery of nuclear fission in 1938. Physicists were at the core of the Manhattan Project, which led to the creation, testing, and use in warfare of the first atomic devices. In the aftermath of World War II, physics stood at the forefront of the increasing political tensions between the so-called 'Western' and the 'Eastern' Blocs. The 'Space Race' and the arms race that characterized the Cold War positioned scientists at the center of the debate,[248] and physicists at

[248] The importance of physics in the Cold War Science context does not diminish the importance of other disciplines involved in the scenario. As shown by historian and geologist Naomi Oreskes (1999), geology (viz., applied geology) itself played an eminent role in the Cold War period, in that geologists participated in intense mining practices that fueled the high military as well as social and economic demands. Historian Jürgen Renn (2020) also notes that the "development of the earth sciences in the second half of the twentieth century was driven by strong economic and military interests – in particular, by the search for natural resources and geostrategic advantages in the Cold War" (p. 240). The environmental historian Andrea Westermann (2015) highlights the contribution of geology in generating a "systematic and international supply of mineral resources" (p. 152) by the late 19th and early 20th century. This scholarship is important for ensuring that geology's societal role and impact prior to, during, and after the Cold War period are not diminished.

the very frontline. Physics was at the center stage of Cold War Science – namely, the politically, socially, and economically driven development of science under the pressure of tense international relationships between NATO and the Warsaw Treaty Organization. This was reflected by the massive economic and educational maneuvers that the United States implemented after the end of World War II. In fact, "[b]y 1953, the level of spending for 'fundamental' physics research within the United States was 20 to 25 times greater than it had been in 1938" (Kaiser, 2000, p. 132). Spending was accompanied by a growth in graduate student enrollment to meet an increasing demand for "physicists-manpower" (p. 133).

The annual number of doctoral degrees in physics granted by institutions in the United States saw an unprecedented and steady growth – to the extent that inconveniences such as "lack of office space, overcrowded laboratory conditions, proliferation of new bureaucratic procedures, a widespread feelings of 'facelessness,' and a perilous loss of 'intimacy'" (p. 136) were common among physics departments. Between 1945 and 1951 alone, the growth rate of PhDs granted in physics was 200% of the average growth rate across all fields (p. 136). This was unparalleled in any other field.

The growth of physics in academic infrastructure affected other disciplines as well. After the almost sudden conversion of the international geological community to continental drift and plate tectonics during the 1950s and 1960s, physics began to play a major role in geology curricula, and "[g]eology departments began to hire physicists and to insist that their graduate students acquire much greater competence in physics than had previously been the case" (Laudan, 1982, p. 10). Accordingly, philosophy of physics became a central theme in philosophy of science (Ladyman, 2019). The necessity of discussing the knowledge provided by research in physics, but also its role in society, further forged the identity of philosophy of science as based upon physics.

One last reason relates to the seminal role that logical empiricism played in the early 20th century in initiating a physics-oriented tradition in the philosophy of science. The movement gravitated especially around two circles – the Vienna Circle (including Moritz Schlick, Otto Neurath, Rudolf Carnap, Hans Hahn, and Kurt Gödel) and the Berlin Circle (Hans Reichenbach, Carl Gustav Hempel, and David Hilbert) – but it also included intellectuals from the UK, the US, Poland, and even as far as China (Creath, 2020). Figures associated with, but not directly part of, the movement included Albert Einstein, Ludwig Wittgenstein, Bertrand Russel, and Karl Popper. Although the movement diversified in terms of philosophical views, the members shared a common enthusiasm for natural sciences, logic, mathematics, and language, and an explicitly strong anti-metaphysical commitment – exemplified by the Wittgenstein-inspired doctrine of 'Verificationism,' which considered most (if not all) the questions of traditional (viz., continental) philosophy as meaningless in virtue of not being (in principle) verifiable. Many members affiliated with the movement shared a training in physics, logic, or mathematics. These disciplines largely shaped the movement's 'scientific world conception,' as outlined by their manifesto:

> especially since 1900, […] there was in Vienna a sizeable number of people who frequently and assiduously discussed more general problems in close connection with empirical sciences. *Above all these were epistemological and methodological problems of physics* [emphasis added], for instance Poincare's

> conventionalism, Duhem's conception of the aim and structure of physical theories (his translator was the Viennese Friedrich Adler, a follower of Mach, at that time privatdozent in Zurich); also questions about the foundations of mathematics, problems of axiomatics, logisticand the like. (Neurath, 1973, p. 303)

Further reasons could be found for the 'special' role that physics has played in the 20th century, and that it still plays in contemporary debates on scientific knowledge. Assimilation in popular culture phenomena is also an example of this. Intriguing and fascinating *Gedankenexperimente*, such as Schrödinger's cat (to illustrate quantum indeterminacy) or the twin paradox (to illustrate special relativity), have been major drivers for popular perception of science in recent decades – although this constitutes a product, more than a cause, of the popularity of physics. Perhaps the most emblematic example of popular assimilation of physics in very recent times is *The Big Bang Theory*, the famous twelve-season American sitcom with genius-but-awkward physicists as the main characters of the show. Curiously, Season 7, Episode 20 ("The Relationship Diremption") sees Sheldon Cooper, a theoretical physicist from Caltech and one of the protagonists, denigrating geology (something he is fond of doing) by labelling it as the "Kardashian of science." While this is only fictional, a 'derivative view' (at times besmirching) of geology has been a shared belief among philosophers as well as geologists themselves even before the 20th century.[249]

The reasons highlighted above quickly surveyed the general place and role of physics in 20th-century philosophy of science. An indirect consequence of the privileged epistemic and social position that physics enjoyed within philosophical discourses on science was the difficulty in developing a discrete tradition in the philosophy of geology.

Geology has not been utterly unknown to philosophers of science, although it is hardly recognized compared to physics, biology, or chemistry. To illustrate this, comparing 'philosophy of geology' with 'philosophy of physics' and 'philosophy of biology' by using the Google Book Ngrams Viewer shows that the former trigram has remained largely unused throughout the century (Figure 4.1). Notably, the graphic is consistent with the historical and political role of physics during the early and middle phase of the Cold War, and with the growing interest in biology in the 1970s that stemmed from Niles Eldredge and Stephen J. Gould's theory of punctuated equilibrium (Eldredge & Gould, 1972).

[249] The idea of geology as a derivative science was not uncommon among theoretical discussions on the fundamentals of geology during the 20th century. The geologist David B. Kitts (1978) noted that "[t]he view that geological principles are comprehended by physical laws dates from the very beginning of geology in the 18th century" (p. 215). Writing in 1989, the geologist and historian William Brice (1989) subscribed to this view, claiming that "concepts in geology can never be developed to the point where they would be independent of other sciences" (p. 85). This view seems to be endorsed (more or less explicitly) in the present by some philosophers of science. For instance, Nicholas Maxwell (2017) discusses the major problems of philosophy of science in the context of theoretical physics. He argues, "I do this because it is above all in this context that these problems arise in their most pristine form. All these problems arise for all branches of natural science, and for natural science as a whole, but when it comes to sciences other than physics, there is always some more fundamental science whose results are more or less taken for granted. This means that in chemistry, biology, astronomy, or geology, theories are never accepted on the basis of evidence alone: there are always the results of some more fundamental science which influence what is accepted. Only in fundamental theoretical physics, it seems, is it the case that there is no more fundamental science whose results may be taken for granted" (p. 7).

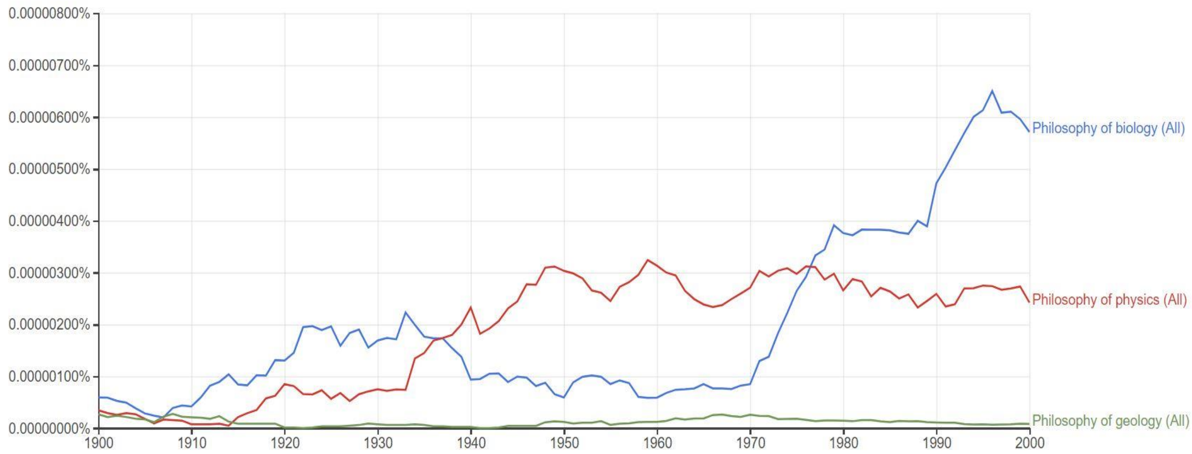

Figure 4.1. The graphs represent the appearance (in terms of relative frequency, Y-axis) of the selected n-grams in the English corpus (2012) between 1900 and 2000. Results are case-insensitive and smoothed to a value of 3. (Source: Google Book Ngram Viewer, accessed on July 8, 2020)

Even by looking at the number of results for each of the three fields on Google Scholar, philosophy of physics ranks first with 2.97 million results, followed by philosophy of biology with 2.73 million results. Only 384,000 results are associated with philosophy of geology.[250]

These figures show quantitative evidence that philosophy of geology "has largely been underappreciated as 20th century philosophy of science pursued its successive fads of logical positivism, critical rationalism, relativism, and deconstructivism – for all of which 'science' is synonymous with 'physics'" (Baker, 1996b, p. 197; see also Baxter, 2003). This equivalence of 'science' and 'physics' is elegantly summarized by Stephen J. Gould in his popular 1987 book *Time's Arrow*, where he states:

> Geology resides in the middle of this false continuum, and has often tried to win prestige by aping the procedures of sciences with higher status, and ignoring its own distinctive data of history. This problem, born of low self-esteem, continues to our day. Hutton pursued a chimerical view of rigor by deference to Newton, and hoped to assimilate time to Newton's models for space. Today, this deference may be expressed in a fetish for quantification that leads psychologists to conceive intelligence as a single, measurable thing in the head, or biologists to classify organisms by computer without judging the different historical value of characters (the marsupial pouch as more informative than body length). Charles Lyell recognized the link between Hutton and Newton, but he also noted an unhappy comparison – the triumph of cosmology versus the limited success of Hutton's world machine. […] Hutton's rigidity is both a boon and a trap. It gave us deep time, but we lost history in the process. Any adequate account of the earth requires both. (Gould, 1987, p. 97)

The consequences are that philosophy of geology has remained largely unexplored and underdeveloped, when compared to other subfields within philosophy of science. Even in history of science, where geology has seen more attention, the discovery of deep time and the true age of the Earth is the least frequently

[250] Results retrieved on September 28, 2021.

mentioned among scientific revolutions (Dodick & Orion, 2003). Post-WWII historiography of geology largely addresses the history of geology from the 17th to the 19th century (Oldroyd, 2002), and only until recently has 20th-century geology seen substantial historical research (Frankel, 2012; Oreskes, 1999). Yet its importance could be considered, to use Sigmund Freud's famous words, another "great outrage" upon humans' "naïve self-love" (Freud, 2014, p. 250): in addition to the heliocentric (Copernican Revolution) and the anthropocentric (Darwinian Revolution), there is the 'chronocentric'[251] wound inflicted by the discovery of the Earth's true age (Rudwick, 2005).

The lack of a sound philosophical commitment to geology has repercussions in understanding the epistemological setting of the discipline. This represents a particularly important issue in framing the Anthropocene Hypothesis as a *stratigraphic* hypothesis. Intuitively, if much of the discourse and concepts developed by philosophers of science to study science are stamped upon the image of physics, then it is plausible that these discourses and concepts (e.g., explanatory power, intelligibility, utility) may be unsuitable for conducting an epistemological analysis of the Anthropocene Hypothesis. While philosophical literature interested in geological research has been disjointedly emerging over the last few decades,[252] developing a discrete traditional and institutionally sound philosophy of geology remains an open issue still to be tackled by the international philosophy of science community.

4.1.3.2 The Anthropocene Hypothesis in the Philosophy of Science

Three contributions from the philosophy of science have given particular attention to the Anthropocene Hypothesis. None of these contributions explicitly articulates the 'Anthropocene'/Anthropocene Hypothesis distinction in the way exposed and articulated throughout this research. Therefore, the two entities are at times interchanged and overlapped semantically. Nevertheless, a set of considerations over the *stratigraphic* nature of the 'Anthropocene' is distinctly identifiable. This makes it justifiable to recognize these considerations as implicitly addressing the Anthropocene Hypothesis.

The first contribution is Carlos Santana's (2019a) "Waiting for the Anthropocene," published by *The British Journal for the Philosophy of Science* in December 2019. The article was awarded the 2019 Karl Popper Prize, conferred annually to the best papers appearing in the journal.

Santana explores the epistemic legitimacy of the Anthropocene Hypothesis by adopting a 'future geologist perspective' and a 'synchronic perspective.' The future geologist perspective projects the present stratigraphic footprint of humans far into the future to determine its geological significance. Invoking a future geologist perspective has been a recurrent *topos* in Anthropocene Studies research, and has been

[251] The term 'chronocentrism' was coined by media theorist Jib Fowles in 1974 to describe "the belief that one's times are paramount, that other periods pale in comparison. It is a faith in the historical importance of the present" (Fowles, 1974, p. 65). Whereas Fowles stresses the ethnographic matrix of this belief, the term is implemented in the present research metaphorically to characterize human's history in the context of deep time.
[252] In particular, see the work of Claude Albritton (1952, 1963a, 1963b, 1975, 1988), David Kitts (1963a, 1963b, 1977, 1978, 1982), and Rachel Laudan (1977; 1978, 1982, 1983, 1987, 1992). For more recent literature, see Carol Cleland (2001, 2002, 2009, 2011), Derek Turner (2005; 2007, 2013), and Alisa Bokulich (2013, 2018, 2020a, 2020c).

implemented by both sides of the debate in rejecting or advocating for the stratigraphic significance of an Anthropocene Epoch/Series. The synchronic perspective assesses the *present* legitimacy and utility of formalizing the Anthropocene unit. This present-based perspective is grounded in a political standpoint: it asks whether ratifying the unit would be beneficial for the public in a way that "will convince the public and policy-makers that humans are having [a] significant effect on the environment" (p. 1088).

The philosopher denies both that the Anthropocene Hypothesis holds sufficient arguments and stratigraphic evidence for formalizing an Anthropocene Epoch/Series; and that a 'political' recognition of the Anthropocene as a geological unit would result in increased public understanding and sympathy toward the environmental crisis. Concerning the former point, Santana holds that "extant geological changes don't reach the thresholds necessary to define a new epoch, and predictions about the future are impossible given human capability to slow and reverse anthropogenic effects" (p. 1077). This argument draws on the future geologist perspective, which is separately analyzed in section 5.2.1.1. Concerning the latter point, Santana argues that "adopting the Anthropocene as a political tactic is unlikely to change perspectives on the environmental crisis, and may even make things worse" (p. 1090). This is particularly the case for climate deniers – an important social, cultural, and political obstacle in the resolution of environmental threats.[253] Santana's thesis follows from three observations, namely, (1) recognition of the Anthropocene without a sufficient stratigraphic basis may fuel climate deniers' "paranoia that the science they disagree with is driven by a liberal political agenda" (p. 1089); (2) extant work of climate denialism "casts serious doubts on the claim that we would change their minds by ratifying the Anthropocene" (ibid.); and (3) acknowledging publicly that humans have entered the 'Anthropocene' (as a concept or geological unit) "conveys no detailed, mechanistic facts about how humans affect the planet" (p. 1090).

Santana's contribution makes three valuable observations for delineating an epistemology of the Anthropocene Hypothesis.

The first observation concerns the distinction between a Geological Claim and a Stratigraphic Claim. This distinction was advanced in section 3.1.1 to differentiate between humans as a *geological force*, and the *stratigraphic footprint* of humans. It was advanced that the latter was the claim underpinning the Anthropocene Hypothesis, whilst the former is an implicit assumption requiring a different theoretical ground for discussion. Santana (2019a) also recognizes this distinction, observing that "whether the Anthropocene should be designated a new epoch is not the same as asking whether humans are significant geological agents" (p. 1075). Intuitively, advocating for a geological time unit based on the actions of *Homo sapiens* requires the species to invest some degree of significance in its interaction with the natural world, upon which the species has been leaving its stratigraphic mark. Nevertheless, humans' geological agency, whatever its degree, does not immediately translate into a claim for official recognition on the geological time scale.

[253] Santana addresses climate deniers as 'climate skeptics.' Here, the former designation is considered more suitable, as criticism raised by deniers does not exhibit skeptical means of inquiry as understood in traditional epistemology.

The second observation is also related to the epistemic identity of the hypothesis. Santana notes that "[t]he Anthropocene question runs deeper, involving both the *kind of impact* humans are having on the geological record, and the *degree of that impact*" (p. 1075, emphases added). Besides the author's disagreement with claims advanced by the Anthropocene Hypothesis, he highlights two important aspects of epistemic significance in framing the hypothesis – namely, the *kind* and *degree* of impact that humans are having. The critical observations advanced by the author acknowledge the *stratigraphic kind* of the hypothesis. This is equivalent to Claim 1 – that is, '*Homo sapiens* has left a discernible *stratigraphic* signature of significant magnitude in recent geological history.' Emphasizing the stratigraphic nature of the Anthropocene Hypothesis (regardless of one's personal stance on its claims) in light of the kind of impact humans are leaving is a basic epistemic characteristic of the hypothesis. It serves to distinguish it from other variants of the 'Anthropocene,' but also to delimit the epistemological domain wherein the hypothesis is situated (i.e., stratigraphic classification). The *degree* of impact relates to the appropriate translation into a stratigraphic vocabulary of the human stratigraphic footprint. The Anthropocene Hypothesis holds that that this degree of impact could be translated into a unit of geological time (Claim 2), and more precisely as a geochronological/chronostratigraphic epoch/series (Claim 3). Determining the stratigraphic kind and degree of human impact are fundamental heuristics engendering the epistemology of the Anthropocene Hypothesis.

The third observation concerns the epistemological nature of the Anthropocene Hypothesis as a *historical* hypothesis. Santana holds that "[i]deally, stratigraphers would apply [a] similar [stratigraphic] methodology to identifying a possible Anthropocene, but since we're contemporaneous with the proposed epoch, we can't" (p. 1076). This assumption leads the philosopher to infer that the stratigraphic legitimacy of the Anthropocene can be assessed, on stratigraphic grounds, only from a viewpoint of a future geologist.[254] He argues that "[a]sking such a question is a radical shift for a historical science like geology, because it requires the historical science to become a science of prediction; to tell us not about what happened thousands or millions of years ago, but to tell us what the Earth will look like thousands or millions of years from now" (ibid.). In Santana's account, the Anthropocene Hypothesis would represent a *predictive* rather than *historical* hypothesis. However, Anthropocene researchers have noted that sufficient stratigraphic evidence *already* exists, and can be documented widely in geological archives (Waters et al., 2016; Zalasiewicz et al., 2019a; Zalasiewicz et al., 2019b; Zalasiewicz et al., 2017b). If this is the case, the Anthropocene Hypothesis can still be treated as a *historical* hypothesis. This has implications for determining the epistemology of the hypothesis because historical hypotheses differ from predictive or experimental hypotheses in a number of ways, as later discussed in section 4.2.1.

[254] He also quotes geologist Eric Wolff (2014) in his contribution to the special publication of the Geological Society of London's *A Stratigraphical Basis for the Anthropocene* (Waters et al., 2014a). The geologist wrote that the idea of formalizing an Anthropocene Epoch/Series "has to be considered from the viewpoint of a geologist viewing sequences thousands or millions of years in the future" (Wolff, 2014, p. 255, quoted in Santana, 2019a, p. 1076). However, the argument that being contemporaneous to the proposed epoch does not allow to use traditional stratigraphic methodologies does not seem to hold. Indeed, the AWG has been making extensive use of stratigraphic principles and methods (see section 3.1) to define and characterize the Anthropocene as a stratigraphic unit from a *present* perspective.

The second contribution is Jay Foster's (2018) "Let's Not Talk About the Anthropocene," published in a volume of *Analecta Hermeneutica* dedicated to the 'Anthropocene.' Whilst hermeneutics (the focus of the journal) is not traditionally understood as a branch of (nor a discipline close to) philosophy of science, Foster draws on literature from that field and advances arguments that could easily be considered to fall within the spectrum of philosophy of science. Thus, his contribution can be used as an example of engagement from the philosophy of science with the 'Anthropocene' and the Anthropocene Hypothesis.

Foster draws on preexisting work from Chakrabarty (2009) and Bruno Latour (2015) on the meaning and nature of the 'Anthropocene' in terms of human exceptionality. He argues that "[a]ssumptions and claims about human exceptionality are at work even in formal discussions of the Anthropocene carried out largely in the scientific community. […] [T]hese assumptions are often implicit in the discussions and debates that are focused on evaluating the Anthropocene as a formal geological unit" (Foster, 2018, p. 4). This process of evaluation, the philosopher observes, is deeply nominalistic. It is based on a voting procedure among AWG members deliberating over whether the Anthropocene (as a geological time unit) is stratigraphically real, if it should be formalized, what hierarchical level it should be assigned, when its beginning should be placed, what method should be used to place its beginning (i.e., GSSP or GSSA), and what best represents its primary marker.[255] These votes are "quite literally voting for, or better *nominating*, an essence for a category" (p. 12).

The idea of nominating an essence for a category draws explicitly on the work of 17th-century philosopher John Locke, who distinguished between real essence (what makes something what it is) and nominal essence (the conventional and abstract idea of shared similarities among objects). Foster implements this distinction (also through the work of philosopher and nominalist Nelson Goodman) by arguing that "members of the Anthropocene group are engaged in a process of evaluating the ways in which the Anthropocene is a 'relevant kind' *not* whether it is a natural kind" (p. 15). A 'relevant kind' is the conventional organization of knowledge according to that particular knowledge system, whereas a 'natural kind' is a "grouping that reflects the structure of the natural world rather than the interests and actions of human beings" (Bird & Tobin, 2018). To ensure that the Anthropocene represents a relevant kind, the AWG must "strike a balance between showing that the Anthropocene fits within established practices of geochronology and making a case for 'evolving tradition' to accommodate the new era" (Foster, 2018, p. 15). This requires debating the practices of stratigraphy and geochronology.

Among the variety of criteria used to establish geological time units, Foster locates three epistemic requirements the Anthropocene time unit must meet – namely, it must be *manifest*, *persistent*, and *salient*. The author considers being manifest the "easiest and least controversial of the three conditions" (p. 17). This is because of the wide spectrum of well-documented anthropogenic alterations of the Earth. A more difficult task is assessing which among this large pool of manifested anthropogenic signals will be persistent after a geologically relevant period of time. This is a similar line of inquiry as the one advanced by Santana (2019a)

255 The specific questions and their voting results are exposed in Zalasiewicz et al. (2017a), which is based on a presentation held on occasion of the 35th International Geological Congress in Cape Town, South Africa, on August 29, 2016.

concerning the epistemic shift from historical to predictive science that the Anthropocene Hypothesis seemingly entails. Foster (2018) notes that "evaluating the persistence of a rock signal clearly involves much more guesswork than establishing that a signal is manifest" (p. 18). This is because it is largely uncertain what signals will survive in a geologically distant future, leaving the question of the persistence of the Anthropocene unit open. Lastly, being salient faces the issue of "explaining why geological changes made by the human species are to be marked in geochronology while enormous changes produced by other species are not" (p. 20). This is especially the case, for instance, in light of the enormous impact that cyanobacteria had in creating an oxygen-rich atmosphere, but also in the evolution of plants and complex life (a line of critique also advanced by Finney & Edwards, 2016). If such large-scale and geologically significant events were not used to demarcate the beginning of a "Cyanobacteriocene" or "Seedlessvascularplantocene" (Foster, 2018, pp. 22–23), then it seems that an Anthropocene does not satisfy salience as a necessary epistemic requirement.

Additionally, Foster argues that the naming choice of 'Anthropocene' breaks with the spirit of geochronological nomenclature by naming the *causes* (i.e., *anthropos*) rather than the *effects*. This nominalistic observation "is indicative of a more general propensity in the Anthropocene literature" (p. 25) in emphasizing human exceptionality at the expense of a variety of non-human species that "ongoingly change the Earth system – indeed, very plausibly maintain homeostatic states of the Earth system – at various scales and levels" (p. 27). Human exceptionality in the 'Anthropocene' concept is further reinforced by claims of the self-awareness and self-consciousness of human beings – the only species aware of their own impact on the Earth System. For Foster, this is a Cartesian approach that places humans in an unprecedented state of exceptionality, reversing Freud's reading of the history of science (i.e., the self-inflicted wounds to narcissism) by once again separating the 'exceptional human' from the rest of nature.

Based on seemingly epistemic deficiencies and implicit claims of human exceptionality, Foster concludes that is best to "not talk about the Anthropocene" (p. 37). From a philosophy of science viewpoint, this is a peculiar conclusion, as the discipline has barely talked about the 'Anthropocene' (and less the Anthropocene Hypothesis) in the first place.

The author's critical analysis provides interesting insight into the perception of the Anthropocene Hypothesis in philosophy. Similar to Santana (2019a), he identifies several issues with formally recognizing an Anthropocene unit. Some of these issues pertain to the epistemology of stratigraphy – such as the requirement of geological units to be manifest, persistent, and salient. Others pertain to the nominalistic nature of the term 'Anthropocene,' and the implicit anthropocentric remarks that the term entails, while also breaking with the traditional nomenclature praxis. Further issues relate to the broader portrayal that 'Anthropocene' literature has given of the proposed epoch, reminiscent of Cartesian dualism and a Hegelian type of history. Besides the author's personal take on the 'Anthropocene' debates, what emerges is a picture of a scientific hypothesis (i.e., the Anthropocene Hypothesis) requiring further consideration concerning the epistemological requirement it needs to meet in order to advocate for formal recognition of an Anthropocene time unit. If, however, further considerations are required – for instance, by envisioning the utility of an Anthropocene Epoch among the geoscientific community – then it is recommended, if not necessary, *to talk about the Anthropocene Hypothesis* from a philosophical viewpoint. It is paramount for developing a discrete analysis of the hypothesis, and for dissecting the epistemic contexts, virtues, and requirements engendering it. This is only possible, *au contraire*, by talking about the 'Anthropocene.'

The third and last contribution hereby discussed is a short paper entitled "Revamping the Image of Science for the Anthropocene," authored by philosophers Andrew Inkpen and Tyler DesRoches (2019) and published in *Philosophy Theory and Practice in Biology*. The authors do not probe into the epistemology of the Anthropocene Hypothesis. Rather, they reconsider the image of science *given* the 'Anthropocene.'

The philosophers recognize that the "Anthropocene has become a uniquely powerful destabilizing force, and thus offers novel opportunities for rethinking science's image" (p. 2). This image of science "is usually described in disciplinary terms" (ibid.) similarly associated with the Kuhnian picture of 'normal' science. Kuhn (2012) famously understood scientific change in terms of paradigm shifts. Any mature science evolves[256] through phases of normal science and revolutionary or extraordinary science. During periods of normal science, an existing 'paradigm' dictates the methods and practices of science, providing puzzle-solution power to existing scientific questions. However, an existing paradigm may not provide solutions to one or more encountered problems or 'anomalies,' and thus those anomalies become untreatable by the existing paradigm. When this happens, scientific consensus over the paradigm is shattered, and a period of crisis follows. During this phase of revolutionary science, fundamentals (either conceptual or methodological) are questioned, alternatives research strategies are pursued, and multiple coexisting paradigms emerge. Among these competing paradigms, one (and only one) emerges as the most suited to provide solutions to the anomalies the science is facing. The paradigm shift that follows reestablishes a new phase of normal science, where the epistemological boundaries (i.e., methods and objects of research) of a discipline are (re)affirmed.

Inkpen and DesRoches (2019) suggest that a discipline-based image of science is no longer tenable in the 'Anthropocene,' and that three issues underpin any characterization of the new 'normal' science in the 'Anthropocene.' The first issue is the fact that a new ontology requires a new epistemology. The 'Anthropocene' does not solely "proclaim an abrupt and irreversible departure from the Holocene, it [also] posits an intermingling of the human and the non-human in systems at every scale" (p. 2). Despite this, the epistemological consequences of the new ontology brought about by the 'Anthropocene' are not yet fully appreciated in extant debates on science. The authors observe that "current debates over Anthropocene science leave unanalyzed the relation between the ubiquity of human-natural systems and current methodological standards – between what the world is like and how it should be studied" (p. 3).

[256] The term 'evolved' is not chosen by chance. Kuhn himself argued that "[t]he analogy that relates the evolution of organisms to the evolution of scientific ideas can easily be pushed too far. But with respect to the issues of this closing section [XIII, Progress through Revolution] it is very neatly perfect" (Kuhn, 2012, p. 171). By his account, competing paradigms are selected based on the fitness of their puzzle-solution power (for a Darwinian reading of Kuhn, see Paksi, 2007).

The second issue concerns the boundary between descriptive and normative in science. The authors state that "[s]cience in the Anthropocene will increasingly involve discussions that inextricably link the normative and the scientific, where questions of how and what we should study imply questions of value" (ibid.). Indeed, this has been the case with discussions on the broader societal implications of formalizing an Anthropocene time unit, and the meaning of selecting a starting date (e.g., the Neolithic Revolution, the Columbian Exchange, the Industrial Revolution, etc.). In this framework, "Anthropocene science is not and cannot be divorced from social values" (p. 4), and will require scientists to cooperate with humanists and social scientists in dealing with a concept fraught with normative as well as descriptive value.

The third issue pertains to the promotion of mechanisms of interdisciplinarity. This is a particularly relevant issue at the core of Anthropocene Studies (Toivanen et al., 2017). It is also a general academic burden, as interdisciplinary research has seen consistently lower funding success than disciplinary-based research (Bromham et al., 2016). Inkpen and DesRoches (2019) identify some of the issues hindering interdisciplinary research, such as the fact that "the norms governing its success are less codified than intradisciplinary work; tensions arising from the distinct goals of researchers from different disciplines hinders collaboration; ingrained cultural hierarchies privilege some sciences over others; and institutional features of funding structures" (p. 4).

In Inkpen and DesRoches (2019), the 'Anthropocene' works as a cardinal concept in promoting a new image of science – one that overcomes traditional disciplinary boundaries as conceived both by philosophers of science and by institutions. Their analysis hints at the epistemic potential inherent in the term, without probing into the particular epistemic challenges and requirements the stratigraphic formulation of the 'Anthropocene' is facing. This epistemic potential is reflected in important aspects of Anthropocene Studies – for instance, in the spectrum of disciplines that have engaged with the 'Anthropocene,' or in the multidisciplinary composition of the AWG. As such, the contribution also gives rise to possible research trajectories; it anticipates a new model, meaning, and purpose of 'science' and, consequently, reframes much of the traditional discourse within the philosophy of science.

The three contributions analyzed here provide a springboard for possible research trajectories in philosophy of science concerning the Anthropocene Hypothesis. They do not exemplify extant scholarship within this domain – primarily because not enough scholarship exists for them to exemplify anything. Nevertheless, some themes of interest emerge from these rare approaches toward the 'Anthropocene' and the Anthropocene Hypothesis.

First, both Santana (2019a) and Foster (2018) are critical of the hypothesis. They both find the epistemic requirements necessary to validate the Anthropocene as a unit of geological time to be insufficient. This criticism is paralleled to an interpretation of the principles of stratigraphic classification. This may feasibly be understood as work in the philosophy of geology, and more precisely the philosophy of stratigraphy. Second, both authors identify a crucial temporal tension between geological past and geological future underpinning the arguments advanced by the Anthropocene Hypothesis. In Santana

(2019a), this is evident in the future geologist perspective, which he considers a necessary perspective to adopt when assessing the stratigraphic validity of the Anthropocene as a time unit. In Foster (2018), the persistence of extant anthropogenic signals in future geological records is regarded as a key epistemic factor for the Anthropocene Hypothesis. Third, the 'Anthropocene' as a broader metaphor for global change raises issues concerning scientific knowledge, and the meaning of science itself. While Santana (2019a) and Foster (2018) consider anomalies in naming, in the potential persistence of anthropogenic records, in adherence to stratigraphic classification, and in salience as an epistemic deficiency, a certain reading of Inkpen and DesRoches (2019) may help interpret these as early signs of an image and praxis of science that is changing. These aspects still remain to be thoroughly examined in philosophical discourses on science, and therefore remain open questions.

4.2 The Anthropocene Hypothesis as a Scientific Hypothesis

A central goal of this research is discussing the implications of considering the Anthropocene Hypothesis a *scientific* hypothesis, and more precisely a *stratigraphic* hypothesis. Defining the Anthropocene Hypothesis as such is not solely useful in separating it conceptually from the 'Anthropocene,' but it also suggests that it can be approached as an object of philosophical, and specifically epistemological, interest.

But what is a scientific hypothesis? And what *kind* of scientific hypothesis does the Anthropocene Hypothesis represent?

Broadly understood, a scientific hypothesis is a proposed *scientific explanation* of one or more phenomena in the natural world that attempts to successfully deliver a form of cognitive success via *scientific understanding*. Scientific hypotheses are not isolated and atemporal theoretical entities. They are shared by small or large groups of individuals in a historically situated system of intellectual and cultural knowledge (Renn, 2020), providing (or attempting to provide) "satisfactory solutions to important problems" (L. Laudan, 1977, p. 13) within specific disciplinary domains. Scientific hypotheses differ *within* sciences based on varying epistemic goals and methods behind their aim and formulation (e.g., statistical hypotheses, logical hypotheses, experimental hypotheses, historical hypotheses, etc.), meaning that multiple *types* of scientific hypotheses exist.

This extremely condensed and ready-made definition highlights three structural aspects of scientific hypotheses – namely, *explanation*, *understanding*, and *type* of scientific hypothesis. Each of these epistemic aspects is defined as *scientific* (at the cost of being repetitive). This is necessary to delimit the scope of a scientific hypothesis, and of the analysis hereby conducted on the Anthropocene Hypothesis. Extant epistemological scholarship agrees virtually unanimously that not every knowledge type that explains and delivers understanding is scientific. This is equivalent to saying that epistemic virtues such as explanatory power, usefulness, or intelligibility are not characteristics *exclusive* of science. However, philosophers of science generally agree that these aspects are epistemic virtues characterizing scientific knowledge, or that scientific knowledge ought to pursue. They are basic *desiderata*,[257] and as such, require some consideration if the Anthropocene Hypothesis is to be recognized as a *scientific* hypothesis.

Therefore, section 4.2.1 articulates what type of scientific hypothesis the Anthropocene Hypothesis represents. The research has multiple times stressed the *stratigraphic* nature of the hypothesis. Beyond delimiting the disciplinary and epistemic domain, this designation is also useful to frame the hypothesis in epistemological terms. Indeed, the nature and formulation of the hypothesis makes it a *historical* hypothesis, meaning that a certain set of epistemic properties and challenges commonly attributed to historical research should reflect the form and content of the Anthropocene Hypothesis. Subsequently, section 4.2.2 determines how (if at all) the hypothesis entails any explanatory power. This is done by surveying three main models of scientific explanation developed in philosophy of science literature. Then, section 4.2.3 discusses the intelligibility of the hypothesis in light of recent models emphasizing the value of scientific understanding for scientific knowledge (de Regt, 2017, 2020; de Regt & Dieks, 2005; de Regt et al., 2009). Lastly, section 4.2.4 advances some remarks over a broader social and historical importance considered useful in framing further analyses of the Anthropocene Hypothesis.

4.2.1 Historical Hypotheses

Hypotheses differ in the way they are formulated within science. In particular, some disciplines formulate hypotheses about past events and phenomena. Philosopher Carol Cleland (2001) addresses these disciplines as *historical sciences*, characterized by "hypotheses that postulate particular past causes for currently observable phenomena" (2001, p. 987). Historical sciences differ from experimental and predictive sciences (such as physics) because the "main emphasis is on analyzing and sharpening *traces* [emphasis added] so that they can be identified and properly interpreted" (p. 989). Stratigraphy is an example of historical science: it seeks to reconstruct a meaningful timeline of the history of the Earth based on available 'traces' in rocks and strata. It does not seek to predict the geological future of the Earth, and it does not *reproduce* past events (e.g., the extinction of most dinosaurs at 66 Ma) in a laboratory setting, but it *reconstructs* them.[258] Historical hypotheses are tested against available traces, rather than against future results. Ultimately, since effects

[257] It is intuitive to understand why some of these virtues are *desiderata* in science. It is unlikely that any hypothesis that does not *explain* has any scientific value. Any hypothesis that fails in delivering scientific understanding of some phenomena seems to undermine one of the very purposes of science – that is, *understanding* things *scientifically*.

[258] This epistemological aspect has raised criticism among the ranks of more 'rigorous' scientists who claim that "[n]o science can ever be historical" (Gee, 1999, p. 8, quoted in Cleland, 2001, p. 987) – a statement echoing Rutherford's notorious claim on science as physics. Experimental sciences have been perceived as 'superior' to historical sciences because of their (predictive) ability to test and verify/falsify hypotheses – as testified by the perception of physics as exemplar science. Additionally, the claim of 'superiority' seemed to find philosophical justification in both verificationism (Baconian inductivism and logical empiricism) and falsificationism (Popper), where hypotheses need to be empirically verifiable or falsifiable in principle to be considered scientific. This point also raised concerns as to whether Popper's falsificationism would rule out historical sciences from science (Moharir, 1993).

often overdetermine their causes,[259] the major challenge of the historical sciences is finding a 'smoking gun,' namely, "a trace(s) that unambiguously discriminates one hypothesis from among a set of currently available hypotheses as providing "the best explanation" of the traces thus far observed" (Cleland, 2002, p. 481).[260]

The Anthropocene Hypothesis seems to exhibit epistemic traits common to historical hypotheses by (1) focusing on past events,[261] (2) emphasizing 'traces' (Cleland, 2001) as anthropogenic signals, and (3) requiring a 'smoking gun' (Cleland, 2002) as the global and synchronous signals for a GSSP. Indeed, the hypothesis seeks to explain anthropogenic signatures left in the stratigraphic record in a way that is useful for geological research.

Furthermore, historical hypotheses seek to "*explain* puzzling associations among traces discovered through fieldwork" (Cleland, 2011, p. 552), and are accepted or rejected based on their explanatory power (in addition to other epistemic and social variables). They differ from *experimental hypotheses* because their explanatory power does not coincide with their predictive power. The equation between predictive and explanatory power has been central in much philosophical literature on science influenced by physics during the 20th century. This resulted in experimental sciences, and thus predictive sciences, being "held up as the paradigm of successful (a.k.a. good) science" (Cleland, 2002, p. 474). Historical hypotheses do not aim at predicting certain phenomena; rather, they seek to explain past phenomena. In philosophical terms, they provide *historical explanation*, and thus deliver *historical understanding* of certain past phenomena. Since the Anthropocene Hypothesis constitutes a historical hypothesis, it thus provides a type of explanation and understanding that is *historical*.

As such, the Anthropocene Hypothesis is an example of *historical research*[262]: it attempts to reconstruct a meaningful chronology of past successions of events. Examples of historical forms of research commonly occur in disciplines such as archaeology, paleontology, historical geology, and history, where

[259] According to philosopher David Lewis (1979), a 'fact' in a deterministic world is *determined* by some causes when "a minimal set of conditions [is] jointly sufficient, given the laws of nature, for [explaining] the fact in question. (Members of such a set may be causes of the fact, or traces of it, or neither)" (p. 474). Whenever two or more different *determinants* are available for a fact, each sufficient by itself to explain it, then the fact is said to be *overdetermined*. Conversely, when the available determinants are not by themselves sufficient for explaining a fact, then the fact is said to be *underdetermined*. Cleland borrows Lewis's notion of 'asymmetry of overdetermination' to expand on the differences between historical and experimental hypotheses, upon which she believes they are founded (differently from Lewis, in probabilistic rather than deterministic terms). The 'asymmetry of overdetermination' is the condition where "most *localized* events overdetermine their past causes (because the latter typically leave extensive and diverse effects) and underdetermine their future effects (because they rarely constitute the total cause of an effect)" (Cleland, 2011, p. 570).

[260] A 'smoking gun' can be understood as the historical counterpart of the 'crucial experiment' of experimental sciences. The 'smoking gun' thesis has been criticized by Forber and Griffith (2011), whilst Cleland's (2011) use of Lewis's asymmetry of overdetermination to justify the underlying epistemological equality between historical and experimental sciences is also criticized by Turner (2005; 2007). The latter also considers local underdetermination a bigger issue in historical sciences than experimental science, hence rejecting Cleland's thesis that the two science clusters hold equal epistemic value. It is neither true, Turner argues, that "earlier causes are usually, or even very often epistemically overdetermined by their effects" (Turner, 2007, p. 45).

[261] Despite being extremely recent from a geological viewpoint, the anthropogenic markers considered to characterize and define an Anthropocene unit are still located in the past.

[262] Cleland (2001, 2002, 2011) distinguishes between historical *sciences* and experimental *sciences* rather than *research*. However, because sciences such as geology or astronomy entail both historical and experimental aspects or hypotheses, differentiation at the research level is considered more suitable for framing the present discussion.

hypotheses explaining *past* events are formulated based on available evidence. The Big Bang theory, the evolutionary lineage of *Homo sapiens*, and the Alvarez Hypothesis are examples of historical theories/hypotheses. Historical research seems generally different in method and object of research from *experimental research*, mostly conducted in disciplines such as physics, biology, and chemistry, where hypotheses are tested through experiments (often in high-control laboratory conditions) and predictions about *future* outcomes are made (although historical aspects are not utterly absent from these research fields). General relativity, Boyle's gas law, and conditioning experiments in psychology are examples of experimental theories or laws that can be tested and reproduced in laboratory settings by conducting experiments or by making predictions regarding some future phenomena based on certain premises.

But what does it mean for the Anthropocene Hypothesis to be a *historical* hypothesis? Before tackling this question, a terminological elucidation is due.

The term 'historical' is invested with particular significance in Anthropocene Studies. This is because, first, as observed in section 1.2, the ambiguity of the phrase 'history of the Anthropocene' opens up into different research trajectories on the 'Anthropocene' as an Earth System singularity, geological time unit, historical period, and term/idea. Second, the starting date currently located by the AWG around the 1950s makes the beginning of the Anthropocene an object of interest both to history (in its historiographic sense) and geohistory. Third, the lack of a sound historical dimension entailed in the term 'Anthropocene' has been a major source of criticism toward the term and the hypothesis. These facts may generate confusion over the meaning and status of the designation *historical* hereby ascribed to the Anthropocene Hypothesis.

The Anthropocene Hypothesis is *not* a historical hypothesis in terms of 'human history.' Being 'historical' is an epistemological attribute: its knowledge claims concern past events whose traces (viz., anthropogenic signatures) are explained based on available evidence. Such epistemology is highly complex, and faces multiple types of uncertainties. As Kitts (1978) noted, "[s]tatements about the geologic past are generated within an immensely complicated inferential context" (p. 218) – reflected by the complexity of reconstructing, either empirically or theoretically, events or states that extend from hundreds of thousands to billions of years in the past.

Forber and Griffith (2011) go deeper into some of the challenges posed by historical reconstruction – the most prominent being the 'the problem of access.' This issue concerns the uniqueness of historical events, which does not allow for certain past phenomena or events to be observed or reproduced in laboratory settings. In turn, this generates underdetermination problems[263] that are particularly challenging for historical sciences. Although underdetermination is a common issue across all sciences, historical disciplines are bound to further problems that exacerbate underdetermination, such as the disturbance of available traces from heterogenous causes, the limited patterns of regularity observable (or supposed) in available data, or the action of "information-destroying processes" (2011, p. 2) – namely, processes that

[263] Broadly, the impossibility of discerning, through evidence, the best among competing and mutually exclusive hypotheses.

erase traces of particular importance for historical reconstructions. The authors reject Cleland's (2001, 2002, 2011) notion of 'smoking gun' as a solution for discriminating among competing historical hypotheses, which they consider to primarily depend on historical and sociological contexts. Rather, they argue that "the main source of epistemic support in historical investigations comes from the *consilience* [emphasis added] of multiple independent lines of evidence on the chronology or key quantitative properties integral to causal history" (Forber & Griffith, 2011, p. 3). Consilience, they argue (by using the Cretaceous–Paleogene (K-Pg) mass extinction boundary as a case study), is better equipped to test a hypothesis against issues of underdetermination as well as holism (i.e., the Duhem-Quine Thesis).[264]

But what is exactly 'consilience'? Broadly defined, a theory or hypothesis is said to be consilient if it is able to explain (i.e., if it is supported by) multiple independent lines of evidence. While the term is evocative of Edward O. Wilson's ideal of unity of science, its use in philosophy of science is often dated to William Whewell (1794–1866), a polymath figure of importance in the history and philosophy of science (he is often attributed the coinage of the term 'scientist'). In his first volume of *The Philosophy of the Inductive Sciences*, Whewell (1840a) argued that "*The Consilience of Inductions* take place when an Induction obtained from one class of facts, coincides with an Induction, obtained from another different class. This consilience is a test of the truth of the Theory in which it occurs" (1840a, pp. xxxix, XIV, also quoted in L. Laudan, 1971, and Bokulich, 2020). A second definition with examples is given in his second volume:

> Accordingly the cases in which inductions from classes of facts altogether different have thus *jumped together*, belong only to the best established theories which the history of science contains. And as I shall have occasion to refer to this peculiar feature in their evidence, I will take the liberty of describing it by a particular phrase; and will term it *Consilience of Inductions* […] The theory of universal gravitation, and of the undulatory theory of light, are, indeed, full of examples of this Consilience of Inductions. (Whewell, 1840b, pp. 230, 232)

Apparently, consilience was a "commonly held" (Ruse, 1978, p. 249) topic of discussion about sciences during the 1970s, when discussions about different reasoning patterns among the sciences began to emerge (for instance, Laudan, 1971). As more recently highlighted by Bokulich (2020a), what is epistemically interesting about consilience is that it is not just a product of agreement about any evidence. Underdetermination, testing holism, and observational biases would still represent substantial problems when assembling different evidence in support of a hypothesis. Rather, it is the *independency* of separate evidential lines and their *unlikely* convergence that provide support for a consilient hypothesis: "The greater the degree of independence (in respects that are relevant) of these evidential lines, the more unlikely it is that they would converge apart from H [H being any given hypothesis] being true, of independence (in respects that are relevant) of these evidential lines" (p. 435). Consilient hypotheses are particularly relevant

[264] The Duhem-Quine Thesis, named after French physicist Pierre Duhem (1861–1916) and American philosopher William van Orman Quine (1908–2000), is one of the major problems in the scientific theory of knowledge. As formulated by Quine (2003), "[s]ometimes also an experience implied by a theory fails to come off; and then, ideally, we declare the theory false. But the failure falsifies only a block of theory as a whole, a conjunction of many statements. The failure shows that one or more of those statements is false, but it does not show which" (p. 335).

in the discussion of past events, and are commonly held in disciplines such as geochronology, archaeology, and evolutionary biology. In the context of the Anthropocene Hypothesis, different stratigraphic evidence (e.g., lithostratigraphic, biostratigraphic, etc.) can be interpreted as independent lines of evidence. This is further corroborated by extra-stratigraphic lines of evidence independent from one another – from Earth System science and environmental history to oceanography and environmental studies. While their convergence may not seem unlikely (i.e., being caused by humans), consilience occurs in the widely documented array of anthropogenic impacts, some of which may be translatable into stratigraphic terms.

To consider the Anthropocene Hypothesis a historical hypothesis means ascribing to it a set of epistemic qualities common in historical explanations of past phenomena. Cleland (2002) delineates a prototypical epistemology of the evidential reasoning applied in historical research (which she contraposes to experimental research):

> In the prototypical scenario, an investigator observes puzzling traces (effects) of long-past events. Hypotheses are formulated to explain them. The hypotheses explain the traces by postulating a common cause for them. Thus the hypotheses of prototypical historical science differ from those of classical experimental science insofar as they are concerned with event-tokens instead of regularities among event-types. […] [I]t is hardly surprising that historical explanations often have the character of stories that, lacking reference to specific generalizations, seem inherently untestable. Nonetheless, it would be a mistake to conclude that hypotheses about the remote past can't be 'tested.' (p. 480)

Two considerations are drawn from this prototypical scenario.

A first consideration concerns the meaning of 'long-past events.' Being long-past seems to represent a structural feature about historical conjectures in Cleland's (2011) account. The 'Anthropocene' does not represent a long-past event, especially when compared to the temporal length of other geological time units. In fact, it represents a very recent[265] event whose ontology is yet to completely unfold. This is a major epistemic peculiarity (and source of criticism) of the Anthropocene Hypothesis, in that the hypothesis seems to rather easily overcome traditional epistemic challenges of historical reconstruction – such as the search for a 'smoking gun.' Indeed, both the cause (*Homo sapiens*) and the effects (stratigraphic records) of the proposed epoch and its beginning are extensively documented, although precision and accuracy – two central epistemic factors in geochronology (Schoene et al., 2013) – are still not easy epistemic parameters to obtain in terms of defining the stratigraphic properties of the Anthropocene via core samples (Waters et al., 2018).

Being a very recent time unit does not immediately rule out the Anthropocene Hypothesis as a historical hypothesis.[266] Firstly, because time-depth is a function of traces and event-tokens rather than a

[265] Being 'very recent' is a relative epistemic property (just like an event being 'long-past') determined through comparison to other evidence used in geochronological and chronostratigraphic research. In fact, this is a major point of discussion within the scientific debate over the Anthropocene Hypothesis (see section 5.2.1).

[266] This statement diverges from Santana's (2019a). The philosopher holds that, because we are contemporaneous to the proposed Anthropocene unit, we must consider the stratigraphic legitimacy of the Anthropocene from a future

discriminatory epistemic quality *per se* (i.e., the older the event, the lower the traces and event-tokens). What makes an explanation historical is not time-depth, but rather the presence of traces with which the explanation of past causes is attempted. Secondly, time-depth is related to Cleland's (2002) conception of a 'smoking gun' – namely, "a trace(s) that unambiguously discriminates one hypothesis from among a set of currently available hypotheses as providing 'the best explanation' of the traces thus far observed" (p. 481). Retrieving a smoking gun is considered the goal of historical research, and "successful historical hypotheses explain traces by *unifying* them under a consistent *causal* story" (p. 482). The iridium-rich layer at the K-T boundary is an example of a smoking gun in support of the Alvarez Hypothesis. However, in the case of the Anthropocene Hypothesis, the search for a smoking gun is not a primary concern, in that the causal story behind the set of (anthropogenic) traces is already known from a stratigraphic viewpoint (i.e., *Homo sapiens*).[267] Once again, this is due to the recent nature of the proposed Anthropocene lower boundary. Thus, the Anthropocene Hypothesis is a historical hypothesis despite not dealing with long-past events.

A second consideration concerns the nature of the traces of the Anthropocene Hypothesis as a historical hypothesis, and how these traces relate to 'testing' the hypothesis in a historical sense. It is a textbook assumption in scientific literature, as well as literature about science, that scientific hypotheses need to be testable (or falsifiable) in principle to be considered scientific (in addition to other epistemic requirements, such as sufficient empirical adequacy and logical consistency). Thus, to claim the Anthropocene Hypothesis represents a scientific hypothesis means somehow that it can be tested. This requires that at least one of its core claims should be testable.

Anthropogenic signals in the stratigraphic record define the empirical body in support of the Anthropocene Hypothesis. In terms set by Cleland (2002), this stratigraphic record contains the traces that the Anthropocene Hypothesis seeks to explain and understand. The hypothesis identifies a common cause for these traces – that is, *Homo sapiens*. For Cleland, "[t]races provide evidence for past events just as successful predictions provide evidence for the generalizations examined in the lab" (p. 480). This implies that anthropogenic signals in stratigraphic records provide evidence for the Anthropocene Hypothesis in a way that the hypothesis is *tested* (in a historical sense) against this evidence. But how is the Anthropocene Hypothesis tested, and what about it is being tested? From an epistemological standpoint, Claim 1 ('*Homo sapiens* has left a discernible stratigraphic signature of significant magnitude in recent geological history') is the claim implicitly being directly tested. Indeed, Claim 1 is true if (1) substantial evidence of a *recognized* stratigraphic nature is retrieved from within the epistemic framework of stratigraphic evidence, and (2) if

geologist perspective. This leads him to infer that the Anthropocene Hypothesis is a prediction rather than a historical reconstruction ("Would that future geologist see justification for driving a golden spike into a rock layer that was formed around the twentieth century? Asking such a question is a radical shift for a historical science like geology, because it requires the historical science to become a science of prediction," p. 1076). However, since a lower boundary has been located in the past rather than the future, the Anthropocene Hypothesis can still be considered a historical hypothesis, despite its extremely short geological span. If the Anthropocene Hypothesis raised the question "Will there be a marked pool of stratigraphically significant anthropogenic signals in the future?", then the hypothesis could be considered a predictive (rather than historical) hypothesis.

[267] A different discussion is required if the smoking gun is considered the earliest globally synchronous signal(s) of anthropogenic alteration of the Earth System. This discussion has been advanced in section 3.2 when surveying alternative and competing Anthropocene hypotheses.

Homo sapiens (rather than any other species or natural event) is the cause of this stratigraphic signature. The fact that the evidence has to be *recognized* explicitly acknowledges the social dimension of stratigraphic evidence.

Claim 1 does not merely seek social recognition: it advocates for the very existence of such traces, regardless of further claims of formal recognition on the geological time scale. Additionally, it does not aim to assess whether anthropogenic signals support further claims of formal ratification on the geological time scale. Claim 2 ('The stratigraphic signature left by *Homo sapiens* could be translated into a geochronological and chronostratigraphic unit of time') and Claim 3 ('The proper unit level reflecting the magnitude of the stratigraphic signature of *Homo sapiens* on the geological time scale and international chronostratigraphic chart is that of epoch/series') aim to do so, and thus they do not require any similar testing because they relate to the theoretical organization of knowledge about the Earth which, while grounded on empirical evidence, is mostly pragmatic and socially dependent. Rather, Claim 1 aims to (1) consider these traces as *stratigraphic evidence*, and (2) consider *Homo sapiens* as the causal agent behind the existence of these traces. Both these claims can be empirically verified (or falsified), so that only Claim 1 is testable – meaning that the Anthropocene Hypothesis overall is testable.

Therefore, to test the Anthropocene Hypothesis (in its entirety) means first to assess whether there is any such thing as stratigraphic evidence of anthropogenic signals. If this happens to be the case (meaning that the empirical aspect of the hypothesis is verified), then Claim 1 is true. If this is not the case, then the hypothesis is falsified.[268] If Claim 1 is verified, it must be discussed within the pertinent epistemic community whether these stratigraphic signals could see formal ratification with a chosen hierarchical level (stage/age, series/epoch, or system/period). These are aspects advocated by Claim 2 and Claim 3, which promote the formalization of this body of seemingly stratigraphic evidence into a unit of geological time on the geological time scale or international chronostratigraphic chart. If all three claims are accepted by the pertinent geological authorities (SQS, ICS, and IUGS), the hypothesis is accepted, and a new formal time unit defined by anthropogenic signals at its lower boundary is recognized on the geological time scale. Notably, Claim 2 and Claim 3 neither logically nor empirically follow from Claim 1. Recognition of the stratigraphic importance of anthropogenic signals does not immediately translate into the proposal of formal ratification. This also implies that an eventual rejection of the hypothesis will need to be considered in respect to what specific claim has been rejected (either Claim 1, or Claims 2 and 3).

As a historical hypothesis, the Anthropocene Hypothesis is characterized by certain epistemic predispositions (as well as challenges).[269] These predispositions are reflected in other epistemic aspects of major importance for science and philosophy of science, such as explanatory power and intelligibility.

[268] Notably, if Claim 1 is verified, only *this* claim is verified – not the hypothesis overall. On the contrary, if Claim 1 is falsified, then the overall hypothesis is falsified. This is not blunt falsificationism: it is a reasonable consequence of rejecting that there is any such thing as anthropogenic *stratigraphic* evidence, or that humans are a relevant geological agent.

[269] Turner (2005; 2007, 2013) highlights some of these challenges, such as local underdetermination (which he considers more widespread in historical sciences than experimental sciences, making the latter, *contra* Cleland [2001, 2002], epistemically inferior in this respect) and information-destroying processes.

Scientific explanation and scientific understanding have been important epistemic features (and for some, central epistemic aims) of science considered by 20th-century philosophy of science. However, as observed by Cleland (2001, 2002, 2011), much of the discussion about explanation and understanding in science has developed with experimental science (and thus physics) at the center. In the following sections, these themes are briefly explored and related to the Anthropocene Hypothesis as a historical hypothesis.

4.2.2 Scientific Explanation

A distinctive ingredient of scientific hypotheses is that they deliver cognitive success by *explaining*, in a logically consistent and empirically adequate way, the phenomena they seek to explain. Intuitively, a hypothesis that does not have any explanatory power has little to offer in terms of achieving cognitive success. The type of explanation expected in scientific hypotheses is *scientific* explanation. If the Anthropocene Hypothesis represents a scientific hypothesis, then it should, in principle, entail some degree of explanatory power.

But what is a *scientific explanation*? What makes any explanation *scientific*?

Answering these questions has been a defining task of philosophy of science, and at the core of much historical and sociological research at least since the second half of the 20th century. Generally speaking, a scientific explanation has been conceived in philosophical literature as an explanation of *why* certain phenomena happen (Weber et al., 2013; Woodward, 2019). Philosopher Bas van Fraasen holds that "[a] theory [or hypothesis] is said to have explanatory power if it allows us to explain; and this is a virtue" (van Fraasen, 1980, p. 97). Einstein's general relativity provides a scientific explanation of the perihelion precession of Mercury (among other phenomena). Darwin's theory of evolution by natural selection explains how species evolved and diversified through time. The Alvarez Hypothesis (i.e., meteor impact at 66 Ma) explains the iridium anomaly at the Cretaceous–Paleogene boundary, and also explains the main driver behind the K-Pg extinction event. These are examples of scientific explanations of natural phenomena: they provide convincing arguments, supporting evidence, and/or verifiable claims to answer an *explanation-seeking 'why' question* (i.e., Why is the Mercury perihelion advance anomalous?[270] Why are there so many species, each seemingly adapted to its environment? Why is there an iridium anomaly at the K-Pg boundary/Why non-avian dinosaurs became extinct?). The nature of scientific explanation has been a central theme in philosophical discourses about science,[271] especially during the second half of the 20th century. Philosophers have developed different models of scientific explanations, each emphasizing distinct – and at times contrasting – aspects of scientific explanation.

[270] The 'anomaly' is only such within a Newtonian framework. There is nothing intrinsically 'anomalous' about Mercury's perihelion precession.

[271] It should be noted that scientific explanation is a vast theme not exclusively of a philosophical nature, stretching to the cognitive sciences, linguistics, science communication studies, and more.

STATEMENT	Scientific	Non-Scientific
Explanatory	(a) Scientific Explanation 'Non-avian dinosaurs became extinct as a result of a large asteroid collision on the Earth'	(b) Non-Scientific Explanation 'Life exists as a product of a divine intellect'
Non-Explanatory	(c) Scientific Description 'Oxygen is a chemical element with atomic number 8'	(d) Non-Scientific Statement 'I like techno music'

Figure 4.2. Types of scientific and non-scientific statements in respect to explanation. (NB: this division is only pragmatical, and does not entail any value judgment concerning non-scientific statements. Additionally, much of what is considered (or not) 'scientific' heavily depends on linguistic, social, historical, and epistemic factors, and escapes a rigidly defined characterization of language-statements. The table only represents an oversimplification of the propositional consequences of assuming the existence of any such a thing as 'scientific explanation')

The idea that there is any such thing as a 'scientific explanation' has at least two theoretical implications (Woodward, 2019). First, that there is any such thing as *non-scientific explanation* (Figure 4.2, b) – namely, that some things can be explained without recourse to science (in its broad sense). In his *Tractatus*, Wittgenstein (2019) affirmed that "[t]he totality of true propositions is the whole of natural science (or the whole corpus of the natural sciences)" (4.11). Inspired by this philosophy, logical empiricism argued that all meaningful sentences are *only* those from science. Within this philosophical framework, only scientific explanations are true and meaningful explanations. This view has been largely rejected, allowing a more inclusive view of explanation as something broader and unrestricted to the domain of science (and philosophy of science). Intuitively, one does not seem required to provide a scientific explanation for loving someone, for enjoying playing chess, or for one's musical taste to justify their own passion for someone or something. In these circumstances, a non-scientific explanation may be satisfying enough to answer an explanation-seeking 'why' question. Religious explanations, e.g., concerning reality, goodness and evil, or the meaning of life also fall under this category.

The second implication is that there is something which is *not* an explanation – either scientific or otherwise. In propositional terms, this further implies the existence of *non-explanatory scientific statements* (Figure 4.2, c), and *non-explanatory, non-scientific statements* (Figure 4.2, d).

Philosopher James Woodward (2019) defines (c) *non-explanatory scientific statements* as 'merely description' – namely, those statements that are "true, accurate, supported by evidence, and so on and yet unexplanatory" (Scientific Explanation, para. 1). He also argues that "[a] presupposition of most recent discussion has been that science sometimes provides explanations (rather than something that falls short of explanation – e.g., 'mere description') and that the task of a 'theory' or 'model' of scientific explanation is to characterize the structure of such explanations" (ibid.). In fact, philosophy of science has attributed explanation (viz., prediction) a higher epistemic value than the description of phenomena – as discussed in the previous section. However, primarily historical and descriptive sciences such as stratigraphy do provide descriptive analyses that are nevertheless epistemically useful and rich. Historical sciences are particularly keen on providing descriptions of past events that are also explanatory in relation to their respective epistemic expectations. They are simply grounded in different epistemological settings because they face different epistemic challenges and implement different forms of reasoning (e.g., retrodiction), and therefore deliver different cognitive success. If so, then historical hypotheses traditionally interpreted as 'merely descriptive' can also be invested with explanatory power – contrary to the idea that explanation only occurs in predictive statements.

Is there any such thing as a (d) *non-explanatory, non-scientific statement*? This question could be rephrased as follows: is there any form of knowledge-seeking statement that does not seek to explain, nor to endorse the epistemic virtues commonly attributed to scientific knowledge? Subjective statements of a purely descriptive nature, such as 'I am hungry' or 'I like to play chess,' seem to fall under this category, in that such sentences simply state a specific state of affairs without recourse to further explanatory reasoning, and without necessarily drawing on epistemic virtues commonly associated with scientific knowledge (e.g., precision, accuracy, etc.).

To prove that the Anthropocene Hypothesis represents a scientific hypothesis with explanatory power means (1) rejecting that its core statements are statements of type (b) and (d), and (2) showing that descriptive statements of the type (c) may still hold explanatory power (e.g., description of core samples may be informative in an explanatory way). This task is equivalent to determining that the Anthropocene Hypothesis entails some degree of explanation.

Extant literature considering the explanatory status of the 'Anthropocene' provides a starting point for this analysis. For instance, in an article published in *The Anthropocene Review*, Rosol et al. (2017) write:

> for all its provocative force, the Anthropocene is first of all a descriptive concept, taking stock of the many indicators that speak for or against such a transition. It tells us where we are: sitting in a mobile home with few windows, rapidly curveballing down an unknown path at the end of which stands a new state of the Earth (and a finally definitive entry on the chronostratigraphic chart). But it does not tell us how we got on board this wildly moving vehicle, nor what powers and propels it. *As a geological terminus technicus, the Anthropocene lacks explanatory power; it does not tell us what the driving forces behind the current, 'real-time' exodus from the Holocene are nor how these forces operate and function* [emphasis added]. (p. 2)

This point is further endorsed by one of the authors of the article, the historian of science and director of the Max Planck Institute for the History of Science Jürgen Renn (2020), who holds in his book *The Evolution of Knowledge* that

> it is important to remember, however, that the Anthropocene, with all of its provocative impact, is first of all a descriptive concept, a controversial geological terminus technicus. The question of when exactly the Anthropocene began as a stage in earth history is a specifically geological question, related to the characteristic tools, criteria, and standards used by this discipline to establish its temporal classification scheme. *The concept therefore lacks explanatory power and does not tell us what the*

> *driving forces behind the current exodus from the Holocene are, nor how these forces operate and function* [emphasis added]. How humanity became a geological force is a question that cannot be answered by the earth sciences alone. (p. 358)

Both excerpts emphasize the claim that the 'Anthropocene' concept, or the Anthropocene as a 'terminus technicus,' lacks explanatory power. In both instances, the argument provided is that the 'Anthropocene' does not explain the driving forces (viz., causal-historical forces) behind the anthropogenic stratigraphic layer that has been depositing over approximately the past seventy years. This view seems to also be endorsed by members of the AWG (Zalasiewicz et al., 2019b, para. 1.3), who assert that the definition and characterization of geological units "hinges much more on *effect* than on *cause*" (p. 15) – meaning that geological units aim at *describing* rather than *explaining* their content matter.

This understanding of the term is in fact consistent with the nature of geological time units (formal or informal) intended as labels to classify and organize geological time in a meaningful and consistent way. Geological designations such as 'Holocene,' 'Cretaceous,' 'Phanerozoic,' or 'Precambrian' do not technically explain anything *per se*. They are merely signposts useful for geologists and stratigraphers to mark specific times on a stratigraphic basis. For instance, to say that a rock formation is a Holocene Series merely means to assign the formation some descriptive properties entailed in the definition of Holocene – that is, being formed in the past 11,700 years. However, to simply ascribe a rock formation the status of Holocene Series does not explain *how* that formation happened to be *Holocene* Series (rather than a Pleistocene Series, for instance). Similarly, the Anthropocene as a geological time unit aims at describing the stratigraphy that makes the epoch/series functionally and stratigraphically different from the Holocene (Waters et al., 2016), rather than explaining why and how this happens to be the case.

While the 'Anthropocene' as a terminus technicus is a descriptive term with no inherent explanatory power, the explanatory virtues of the Anthropocene Hypothesis are more problematic to determine.

First, this is because the lack of explanatory power of the 'Anthropocene' as a time label does not immediately translate into lack of explanatory power for the Anthropocene Hypothesis overall. Intuitively, these two entities are related, in that the 'Anthropocene' is the name given to the geochronological/chronostratigraphic entity described by the Anthropocene Hypothesis. Yet they represent different theoretical entities requiring separate considerations. Indeed, a consequence of this semantic overlap is that the lack of explanatory power in the term 'Anthropocene' has been sometimes perceived as an epistemic deficiency of the Anthropocene Hypothesis.

Second, epistemic virtues traditionally praised in philosophical research, such as explanatory power and intelligibility, have not yet been thoroughly discussed in light of this recent hypothesis. This is a direct consequence of the lack of commitment from extant philosophy of science and geology research to the study of the Anthropocene Hypothesis, as previously discussed.

Third, the multidisciplinary nature of the Anthropocene Hypothesis, both detectable in its content and in the epistemic actors implementing this hypothesis, makes it difficult to frame within traditional epistemic categories. This difficulty is exacerbated by the seemingly contradictory fact that the Anthropocene Hypothesis represents a *stratigraphic* hypothesis of a nevertheless *multidisciplinary* nature – an aspect considered later in this chapter.

Fourth, the Anthropocene Hypothesis has been accused of being a political statement (Finney & Edwards, 2016). This kind of criticism can be paraphrased as claiming the Anthropocene Hypothesis to be a non-scientific statement. If adjoined with the thesis that the Anthropocene Hypothesis lacks explanatory power (meaning that it is a non-explanatory statement), then it seems inferable that the Anthropocene Hypothesis is a non-explanatory, non-scientific statement. This type of criticism is addressed in the following chapter.

These aspects inform much of the semantic tension between the 'Anthropocene' as a terminus technicus and the Anthropocene Hypothesis. This tension needs to be untangled by looking at the core statements of the hypothesis by means of philosophical analysis. One way to go about it is discussing three models of scientific explanation of wide importance in philosophy of science; these are addressed in the following sections. First, there is Carl Hempel's Deductive-Nomological (DN) model: this model pioneered the discussion on the nature of scientific explanation during the 20th century, and it also provided a reference framework for geologists to discuss the epistemological structure of their own discipline. Second is Wesley Salmon's Causal-Mechanical (CM) model: this theory of scientific explanation rejected Hempel's model and provided a philosophy of causality that is relevant in framing the causal forces of the Anthropocene – a discussion of major importance in the history of the Anthropocene as well. Third is Ban van Fraasen's pragmatism: this account offers an example of pragmatic approaches to scientific explanation, and provides interesting insight into the contextual nature of scientific explanation to assess whether the Anthropocene Hypothesis entails explanatory power.

4.2.2.1 The Deductive-Nomological Model

For most of the second half of the 20th century, philosophical literature on scientific explanation was largely influenced by Carl Hempel's Deductive-Nomological (DN) model of scientific explanation, often referred to as the 'received view' (Galavotti, 2018, para. 5.1).[272] As a partial representative of logical empiricism, Hempel's model (or covering-law model) of scientific explanation has been conceived once again around the rigorous standards of physics, and by emphasizing the logical or 'formal' properties of explanation in science.

According to Hempel, for an explanation to be sound, (1) the *explanandum* (i.e., the thing to be explained) must follow deductively from the *explanans* (i.e., that which provides the explanation), (2) the *explanans* must contain at least one statement in the form of general law, (3) the *explanans* must be testable,

[272] Wesley Salmon (1998, discussed in the next section) notes that Hempel and Oppenheim's original 1948 paper "was almost totally ignored for a full decade," and that "[m]ost of the work on explanation during that period focused either on explanation in history or on teleological/functional explanation" (p. 68).

at least in principle, and (4) the *explanans* must be true (Hempel & Oppenheim, 1948). An *explanans* that has not yet been empirically verified is a prediction. Otherwise, if the *explanans* has been empirically verified, the argument provides an explanation of some observed phenomena. This is called the prediction/explanation symmetry thesis (McGrew et al., 2009), for which to explain and to predict are structurally identical (hence not being able to predict means not being able to explain).

The DN model was widely popular during the second half of the 20th century; it saw supporters such as Popper, who considered deductive reasoning to best represent theory building, both in normative and descriptive terms. This model has by now been rejected by most scholars in the philosophy of science, as its requirements appear too stringent and exclusive of other forms of scientific explanation from emerging natural sciences. The model also incurred seemingly unescapable forms of explanatory asymmetries and irrelevancies. Yet it is important to discuss it as the model that informed many 20th-century discussions within philosophy of geology concerning the role of explanation in geology.

In his contribution to *The Fabric of Geology* (Albritton, 1963a), Claude Albritton's landmark book in philosophy of geology, Wilmot Hyde Bradley (1899–1979), a prominent figure in the American geological community, considers scientific laws to be rare in geology. Based on mathematician Karl Pearson, he defines scientific laws as statements concisely expressing "a group of more or less complex interrelationships that have repeatedly been observed to be consistent," or "convenient packages of knowledge" that "simplify our efforts to explain the phenomena we study" (Bradley, 1963, p. 13). According to Bradley, most of the field's generalizations are extrapolated from knowledge of physics, biology, and chemistry, upon which geology is based (i.e., the derivative view on geology). To further stress this point, Bradley provides a graphical representation illustrating geology's dependence on these disciplines in developing law-statements.

Bradley realized that among the root causes of this lack of law-statements might be the different reasoning geology undertakes, and thus the goals (i.e., degree of generalization) that geology, as opposed to chemistry or physics, wishes to achieve. The different reasoning strategies, and therefore the goals, of geology are partially conditioned by his 'derivative' nature – a view shared by geologists, but also by some philosophers of geology. However, Bradley locates a 'hardcore' or 'spine' in geology that is independent of other disciplines; its defining feature is the geochronological reconstruction of the Earth's history and the relational study of its components, from rocks constitution to orogenesis. The methodological difficulties (e.g., testing procedures, observation of past phenomena, spurious data, inaccessibility of most of the Earth's surface) that arise from pursuing this goal necessarily lead geologists "to reason analogically, inductively, and with imagination" (p. 15). These inferential patterns – 'imagination' representing the capacity of mentally visualizing past processes based on available and incomplete data – are not exclusive to geological research, but are considered by Bradley to be defining traits of geological reasoning (although Bradley's conception of 'induction' is actually more similar to the definition of abduction, which has been particularly emphasized by geologists and philosophers of science for its role in historical reconstructions).

To the American geologist, imagination – a virtue marginally stressed in traditional philosophy of science[273] – is an especially important property of geological reasoning: "A geologist who has no imagination is as ineffective as a duck without webs between his toes" (p. 16).

Given the epistemic nature of geological reasoning, Bradley concludes that very few geologists seek to formulate general laws capable of providing deductive-nomological types of explanations. However, Bradley's view does not imply that general laws are epistemically impossible in geology. Steno's four law (Superimposition, Original Horizontality, Lateral Continuity, Cross-Cutting Relationships) could be considered as four foundational laws in geology. The processes of weathering and erosion might be conceptually formulated as universal laws if restricted to the Earth (although they could be explained in terms of entropy, and thus part of thermodynamics rather than geology). Bradley himself claims that 19th-century geology was much more prone to identifying general laws than the geology of his time, and that advancements in geophysics and geochemistry may lead to a revision of the laws in geology. Besides trends in geological research, Bradley's main argument is that geological explanation does not necessarily need to fit law-based models of scientific explanation (such as Hempel's deductive-nomological mode), nor any other model built upon physics or chemistry as a model. This seems to be the case since "[h]istorical sciences also differ from experimental science in that they are studying *unique occurrences* whereas the latter may observe the same (or essentially the same) phenomena repeatedly" (Vann & Stewart, 2011, p. 23).

Bradley's view was also championed (among others) by the American paleontologist George Gaylord Simpson (1902–1984). Simpson was another contributor to Albritton's *Fabric*. He argued that no laws can *ever* be drawn in historical sciences, and he rejected the cover-law model of science applied to geological sciences. However, the idea that geology does not aim at providing general laws, and thus that geological explanations do not adhere to the covering-law model of scientific explanation, was contested by Richard Allan Watson (1931–2019), an American philosopher and speleologist. Watson posed several questions, some of which are of importance for the present discussion – namely, (1) whether there are any *irreducible* geological facts, (2) whether geological laws are possible, (3) what kind of laws exist in geology, and (4) what kind of science geology is.

The first question is given two meanings, namely, an ontological meaning (i.e., the existence in the world of geological facts which are irreducible to other entities or properties) and an epistemological meaning (i.e., the existence of descriptive linguistic and conceptual categories that cannot be further reduced without loss of meaning). Given that, ontologically speaking, the class of geological facts can always be broken down to more fundamental properties (e.g., minerals to atoms), only in the epistemological sense can geological facts be considered irreducible. A geologist engaging with the study of mountain ranges will

[273] This is especially the case given the underlying distinction between a context of discovery (i.e., the processes of generation of new hypotheses) and a context of justification (i.e., the formal verification and validation of the truth of the hypotheses) in 20th-century philosophy of science. Indeed, the implications of this distinction can "hardly be overestimated" (Schickore, 2018, para. 5). It informed the very identity of modern philosophy of science, whose domain was delimited by the study of the context of justification, and thus by the purely formal analysis of science in themes such as scientific discovery or scientific explanation. Presumably, imagination was conceived as a cognitive and psychological feature of the context of discovery, and thus beyond the scope of philosophical inquiry on science.

not see these merely as a collection of atoms. Thus, the first question is answered positively because the "need of a 'distinguisher' is what is irreducible" (Watson, 1969, p. 489).

The second question – whether geological laws are possible – is again given an ontological and epistemological meaning. If geological facts are ontologically reducible to fundamental properties or entities, then the seemingly geological regularities are functions of more basic regularities in the physical or chemical world. Thus, no geological laws *exist*, properly speaking. However, since there are regularities among geological facts of an epistemological nature, then there exist geological laws of a descriptive nature whose reduction to more fundamental entities or properties would result in a loss of meaning. Thus, Watson infers from an epistemological viewpoint that geological laws exist.

But what kind of geological laws exist? Answering this third question, Watson identifies three possible kind of laws describing geological regularities, namely, cross-sectional laws (i.e., laws describing the "relationships among a number of factors at a given time," ibid.), functional laws (laws describing the values for all factors at any given time), and historical laws (laws describing prevailing trends, possibly in a teleological fashion). Of these, only the first two are empirical and ultimately constitutive of geology – laws about orogenesis or petrogenesis being examples of these.

To answer his fourth question concerning the nature of geology, Watson argues that "the description of particular things or sequences of events can be explanatory only if it relates them to the general way things and events of these given types regularly behave" (p. 491), because that is fundamentally the method of science – to extrapolate generalizations (laws) from particular circumstances. This stance, aligned with Hempel's deductive-nomological model, rejects the view that historical sciences do not appeal to (nor are able to generate) laws because they merely describe the particular history of an outcrop, a location, or a geological time in the past. On the contrary, descriptions of past events or phenomena can be explanatory insofar as they are related to general laws that govern the existence of such events or phenomena. Translated into the present context, Watson's view would argue that statements describing the Anthropocene (as for any other geological time unit) are explanatory if, and only if, they refer to law-like geological generalizations about the world.

This brief excerpt from the philosophy of geology reveals once again the influence that physics had in shaping the 20th-century philosophy of science, which in turn affected discussions among geologists about the nature of geology and geological explanation (Turner, 2013). However, it also reveals the interest among geologists in understanding the epistemological nature of their own discipline, especially with regard to the kind of scientific explanation geology delivers differently from other natural sciences such as physics or biology. Besides the fact that Hempel's model of scientific explanation has now largely declined, it seems a practical oddity to attempt to frame geological explanations, especially concerning the Earth's taxonomical division, by researching more or less implicitly law-like statements.

This is especially true in light of the seemingly pragmatic-oriented (Baker, 1996a, 1996b) and hermeneutical (Frodeman, 1995) style of geological reasoning. Indeed, philosopher Robert Frodeman (1995) argues that "[i]n geology, the goal is not primarily to identify general laws, but rather to chronicle the particular events that occurred at a given location" (p. 964), and even that "geologists practiced a type of earthbound phenomenology rather than an activity best described by the covering laws of the philosophy of science" (Frodeman, 2003, p. 14). Philosophers James Woodward and Christopher Hitchcock (2003) hold that "[f]ields of scientific inquiry that deal with complex systems – the life sciences and social sciences, as well as branches of the physical sciences such as meteorology and geology – seem to provide generalizations that are not truly exceptionless and which lack many of the other features standardly assigned to laws" (pp. 1–2). Lastly, philosopher Michael Friedman (1974) also argues that "[e]xplanations of particular events are comparatively rare – found only perhaps in geology and astronomy" (p. 5), hence suggesting the difficulty of generating law-like statements in geological (and especially historical geological) research. These seem more suitable views in representing the epistemological setting of the Anthropocene Hypothesis as a stratigraphic hypothesis, and thus in answering whether the hypothesis entails any form of scientific explanation.

4.2.2.2 The Causal Mechanical Model

An argument against the explanatory power of the 'Anthropocene' as a terminus technicus is that it lacks knowledge of the "*the driving forces* [emphasis added] behind the current, 'real-time' exodus from the Holocene [and] how these forces operate and function" (Rosol et al., 2017, p. 2). A similar line of critique could be raised against the Anthropocene Hypothesis – that is, asking whether the hypothesis is oblivious to the *causal* forces (e.g., social, natural, cultural, etc.) behind the dawn of an anthropogenic geological time unit. This critique stresses the role of *causality* as a central aspect of scientific explanation, so that a lack of adequate explanation of the causal mechanisms engendering the Anthropocene as a geological time unit results in a lack of explanatory power for the hypothesis *tout court*.

Causality is the central concept in the Causal Mechanical (CM) model of scientific explanation. This model emphasizes the role of causality in delivering adequate scientific explanation, and it provides a suitable starting point for considering the relationship between those 'driving forces' of the Anthropocene and the explanatory content of the Anthropocene Hypothesis. Causality has been a central theme in the history of Western philosophical thought at least since Aristotle's doctrine of four causes, and it gained prominence in David Hume's deconstruction of causality. Its importance and meaning are hereby only discussed in its relation to scientific explanation, and in light of what possible explanatory form the Anthropocene Hypothesis conveys (if any at all).

The CM model was developed in the 1980s by philosopher Wesley Salmon (1925–2001), a central figure in the 20th-century philosophy of science and empiricist tradition. Influenced by his mentor Hans Reichenbach (founder of the Berlin Circle and adherent to logical empiricism), Salmon originally developed a Statistical Relevance (SR) model that placed probability and statistics at the foreground of notions of truth, inductive reasoning, and scientific explanation (Galavotti, 2018). In his later work, he began developing an alternative model to Hempel's covering-law model of scientific explanation, abandoning "the attempt to characterize explanation or causal relationships in purely statistical terms" (Woodward, 2019, para. 4.1), but without abandoning "the hope, perhaps vain, that reductive analyses within the framework of the logical empiricist (*not* logical positivist) program can be given" (Salmon, 1997, p. 477). Salmon's main work on the subject, *Scientific Explanation and the Causal Structure of the World*, was published in 1984 and revised through a series of publications in order to respond to and include criticism during the 90s (Salmon, 1994, 1997).

At the core of Salmon's causal mechanical model is the notion of 'causal process,' which he believes to provide "an acceptable answer to the fundamental problem Hume raised about causality[274]" (Salmon, 1997, p. 469). Salmon defines causal processes as those "capable of transmitting energy, information, and causal influence from one part of spacetime to another" (Salmon, 1998, p. 71). Causal processes are ontological categories rather than epistemological categories, meaning that Salmon affirms a realist theory of causality. They differ from 'pseudo-processes' (e.g., a shadow of an object) because the latter does not involve any kind of 'conserved quantity.' Salmon (1994) borrowed the idea of conserved quantity from philosopher Phil Dowe (who had raised criticism of Salmon's early attempt to develop a 'mark theory' of causal transmission) in order to build his notion of 'causal interactions' – namely, an intersection of two processes where both "are modified in the intersection in ways that persist beyond the point of intersection, even in the absence of further intersections" (Salmon, 1998, p. 71). Two balls colliding is an example of such causal intersection, where certain conserved quantities (e.g., momentum, kinetic energy) are exchanged. Hence, a process is causal if it is based on a causal interaction, namely, if it transmits or involves an exchange of conserved quantity. According to Salmon (1997), "[a] *process transmits a conserved quantity* between A and B *(A≠B) if* and only if *it possesses* [a fixed amount of] *this quantity at A and at B and at every stage of the process between A and B without any interactions in the open interval* (A,B) *that involve an exchange of that particular conserved quantity*" (p. 462).

Thus, to explain anything (scientifically) means, according to the CM model, stating the causal mechanisms behind a determined causal process in a way that satisfies the question of *why* a determined causal process happened. While this may seem trivial, Salmon (1979) notes that the question of 'why' has not always been thought of as characteristic of science, which authors like Karl Pearson (who Salmon quotes) consider a descriptive and mostly predictive endeavor. Contrary to this view of science as merely descriptive, Salmon believes scientific explanation to offer "knowledge of the mechanisms of *production* and *propagation* of structure in the world. That goes some distance beyond mere recognition of regularities, and of the possibility of subsuming particular phenomena thereunder" (p. 422). To provide a scientific explanation in causal terms is the ultimate *desideratum* of science.

Can this account of scientific explanation help locate the explanatory status of the Anthropocene Hypothesis? The CM model seems to have been less noticed among philosophers of geology or geologists than Hempel's DN model of scientific explanation. Salmon's model subscribes to a research tradition dedicated to the study of scientific explanation that reflects the practices of language analysis and

274 On Hume's problem of causality, see Morris and Brown (2021, para. 5.1).

epistemological research shared among many 20th-century philosophers of science – a tradition also sharing much enthusiasm for physics as exemplar science. This latter point is confirmed by the fact that Salmon systematically draws on examples from particle and theoretical physics to provide a fundamentally sound theory of *physical* causation, which underwrites his account of scientific explanation. In fact, Woodward (1988) considers Salmon's *Scientific Explanation and the Causal Structure of the World* "a lucid and perhaps definitive statement of a distinctive conception of scientific explanation, *a conception which clearly seems to capture important aspects of causation in many classical physical contexts* [emphasis added]" (p. 323). However, this is not to say that for Salmon *all* explanations must be *physical* explanations of phenomena. For instance, Salmon (1998) considers functional explanations as legitimate explanations with a less fine-grained causal character than causal explanations due to the nature of the causal processes and interactions considered (e.g., biology). Nevertheless, it seems for Salmon that even complex mechanisms require fundamental causal processes that underwrite the explanation of those phenomena at the most fundamental (i.e., particle) level.

A causality-based model may be suitable for explanations concerning the most fundamental components of reality, such as bosons and fermions (as Salmons hints at by providing multiple examples of these cases).[275] However, this framework is impractical for assessing whether or not the Anthropocene Hypothesis provides scientific (causal) explanation. The subatomic or physical mechanisms behind the formation of anthropogenic strata play an important role in defining and characterizing a possible Anthropocene boundary-stratotype, especially in terms of its geochemical markers (e.g., radioactive isotopes). Nevertheless, the Anthropocene represents a phenomenon whose complexity requires further levels of causation and explanation beyond subatomic interaction. In fact, complexity of physical systems has been one kind of criticism developed against Salmon's conception of causal process and scientific explanation (Woodward, para. 4.3). Scientific explanation requires criteria beyond simple causal mechanisms and interaction, as also observed by philosopher James Woodward (1988) in reviewing Salmon's landmark publication:

> Consider also explanations in cognitive psychology of human inferential errors which make reference to patterns of information processing or the standard explanation in microeconomics of why a monopoly will raise prices and restrict output. It is unclear in what sense, if any, such explanations successfully trace continuous causal processes and even less clear how the causal/ mechanical model provides useful criteria for assessing such explanations. (p. 324)

Furthermore, criticism against the explanatory status of the 'Anthropocene' and the Anthropocene Hypothesis is not so much about the lack of explanatory power connected to the *physical causes* of the Anthropocene, but rather to the *historical causes* that enabled humans to become the geophysical agent behind the Anthropocene. This implies, first, that different types of non-physical causation exist depending on the

[275] Philosopher Hank W. de Regt (2017) considers Salmon's CM model to be highly problematic *especially* at the deepest level of subatomic interactions. According to de Regt, Salmon's notion of causal chains (i.e., space-time continuums where conserved quantities are transmitted from one entity to the other) does not exist "according to the standard interpretation of quantum theory" (p. 61).

particular epistemic framework one adopts. Causation of a particular kind may be epistemically acceptable in one framework, but not another. Second, the supposed lack of explanatory power of the Anthropocene Hypothesis must be addressed both in respect to its underlying *physical* causality and *historical* causality. That is because the 'Anthropocene' both is a *physical* entity and has *historical* roots (as historians have been pointing out), and a lack of either would result in the lack of explanatory power for the hypothesis.

In physical terms, the body of evidence overviewed in Chapter 3 extensively documents the physical outcome (effects) of human activities (causes), and how they are relevant to stratigraphic research. Nuclear and thermonuclear bomb testing is known to be the *cause* of the radionuclide markers detected in ice cores, lake sediments, estuaries, and other paleoenvironmental archives (Waters et al., 2015; Zalasiewicz et al., 2019b). Human activities associated with hunting or land appropriation are considered the *cause* of a sixth major extinction event (and its biostratigraphic signature). Extraordinary human energy consumption (Syvitski et al., 2020) is considered the *cause* of the departure of the Earth System from its Holocene state. These examples show that the mechanisms of causation behind the descriptive ontology of the Anthropocene are actually known – although perhaps not to their full temporal and spatial extent. In fact, they are what make the Anthropocene Hypothesis a particularly unique, and also contested, stratigraphic hypothesis: the causes and effects behind the proposed boundary are clearer than any other geological boundary in the history of the Earth.

In historical terms, causation has also been an important category for historical research, and historians and philosophers of history have long discussed the role and meaning of causation in history (Brien, 2013; Oldroyd, 1999). Philosopher Morris Raphael Cohen (1880–1947) considers causation "as equivalent to the sum of necessary and sufficient conditions," noting that "[t]he application of this concept to the events which constitute human history is both a necessary ideal and yet inherently difficult of attainment" (Cohen, 1942, pp. 28-29).[276] E. J. Tapp (1952) holds that "[a]mong the many problems that touch most nearly the field of history one of the most important is that of causation" (p. 67), to the point that "[w]ithout it there could be no history" (p. 68, also quoted in Brien, 2013). In his 1961 book *What Is History?*, historian Edward Hallett Carr (1892–1982) writes that "[t]he study of history is a study of causes" (Carr, 1990, p. 87), and the work of a historian is to continuously ask the question 'Why?' – the same defining question of scientific explanation in much philosophical research. He also recognizes multiple kinds of causes, from physical and biological to psychological and historical, and distinguishes historical methodology in terms of (1) determining several causes of single events, (2) establishing an order and hierarchy of causes, and (3) simplicity of explanation. As in philosophical research, causation has played a crucial role in historical research on explanation.

[276] Interestingly, Cohen (1942) considers the work of historians similar to that of geologists, in that both describe past events and causal links without appealing to general laws (this was considered by logical positivism a desideratum for science). He writes: "Though history must implicitly or explicitly involve laws if we are to pass from present data to past facts, the search for the latter as they actually occurred distinguishes truthful history from works of fiction. And it is a demonstrable error to suppose that anything in regard to specific existence can be deduced from purely logical considerations. In this respect history is like geology or any branch of applied rather than theoretic physics" (p. 25).

Research on the (environmental) history of the Anthropocene has focused on the historical/causal roots of the Anthropocene, mostly *explaining* the proposed epoch in terms of the rise of Western capitalism and its worldwide institutionalization, the dawn of fossil fuel economies, the advent of a world market, and so forth. This kind of explanation is precisely what is lacking within the Anthropocene as terminus technicus, according to Rosol et al. (2017) and Renn (2020). As anticipated, this is true for the Anthropocene as a geological time unit, given the conventional and descriptive nature of geological terms used for naming time units. However, the most pressing question is whether the Anthropocene Hypothesis lacks explanatory power because it lacks knowledge of the causal (viz., historical) mechanisms behind the dawn of the proposed epoch. If the historical research is understood as complementary to the stratigraphic nature of the Anthropocene Hypothesis, then it seems reasonable to consider the hypothesis to entail a certain degree of causal-historical explanation. A case is made for this claim, argued later in section 4.2.2.4 after considering another model of scientific explanation.

4.2.2.3 Pragmatism and Scientific Explanation

Both the DN and the CM models share the idea that to explain something means to provide the *correct* explanation of phenomena, where 'correctness' lies more within the formal structure of the explanation rather than its specific context.[277] For Hempel, to explain something essentially means to derive it deductively from law-like statements. For Salmon, to explain means to illustrate the causal mechanisms behind a given phenomenon. While pragmatic elements are traceable in both accounts, they "assume that there is a *non-pragmatic* [emphasis added] core to the notion of explanation which it is the central task of a theory of explanation to capture" (Woodward, 2019, para. 6.1). Philosopher Peter Achinstein (1984) highlighted this point by distinguishing between pragmatic-type sentences (such as 'Account A explains fact X to person P') and non-pragmatic-type sentences (such as 'Account A explains X'). The former account for an explainer and an audience, whereas the latter only concerns the epistemic (and other linguistic and logical) properties of the explanation given.

Theories that attempt to include 'pragmatic' aspects in models of scientific explanation as *constitutive* features are *pragmatic theories of explanation*. Pragmatism is an American-born tradition that originated in the 1870s with the work of Charles Sanders Peirce (1839–1914), a trained chemist and geodesy practitioner, and William James (1842–1910), a founding figure of American psychology. A third figure of great importance for American pragmatism was John Dewey (1859–1952), who advocated decisively for the social, political, and educational aims of philosophy.

Virtually the only fully American philosophical tradition, pragmatism played a central role in American scholarship and society during the 20th century. Early pragmatism emphasized clarity of concepts and hypotheses by looking at their meaning *in practice*, providing what developed as a philosophical

[277] This is a form of reiterating the distinction between context of justification and context of discovery previously mentioned.

alternative to the language- and logic-based approaches (later embodied by logical empiricism and analytical philosophy) and to the continental tradition (or between 'tough-minded' empiricism and 'tender-minded' rationalism, as formulated by James, 1922). Briefly summarized, the tradition emphasizes utility, simplicity, and empirical research as epistemic virtues to pursue in philosophical analysis, while also stressing the importance of juxtaposing philosophical research with scientific inquiry. Pragmatic views extend beyond the domain of philosophy, also reaching politics, education, and religion (Legg & Hookway, 2020).

According to Baker (1996b), there is a continuity between this American philosophical tradition and the geology of the late 19th century. He considers writing from geologists and geographers in the early 20th century (specifically, Grove Karl Gilbert, Thomas Chrowder Chamberlin, and William Morris Davis) as inspired by pragmatism, and as representative of the praxis-oriented methods of geology. This action-oriented, empirical, fallibilistic, and antifoundationalist philosophical setting reflected geology's "reverence for fieldwork, a humility before the 'facts' of nature" (Baker, 1996b, p. 197). Whilst "positivists were obsessed with theories and their logical verification or falsification in an ideal world of perfect objectivity, pragmatists were concerned with the process of inquiry in the real world of human beings and the natural environment that they sought to understand" (p. 208).

It could be argued that, with the exception of the "mathematically oriented physical geologists" (Oreskes, 1999, p. 19) supporting a progressionist or catastrophist[278] view of the Earth, pragmatism aligned with the overall tone of international geology of the late 19th century, a time where fieldwork in historical and applied geology (more than physical geology) was gradually established as the *conditio sine qua non* of geological research.[279] In fact, past and present historiography of the geosciences define 'armchair' geology both as a watershed between the old, religion-based geology and the slow emergence of empirical and naturalistic approaches, and occasionally use this term as a derogatory label for scientists not engaging in concrete fieldwork. This pragmatic orientation defined different methodologies within geological research itself. As noted by geologist Michael Leddra (2010), "field geology looked (and still looks) at the physical evidence in the rocks and fossils and is therefore observational, qualitative, and inductive [or abductive], whereas physics, mathematics, chemistry, and geophysics are primarily quantitative" (p. 244).

American pragmatism substantially influenced the development of 20th-century philosophical discussions on the discipline.[280] If it is true that there is an underlying consistency between the pragmatic

278 Progressionism is "the idea that the history of the earth was directional and controlled primarily by progressive cooling from an initially molten state" (Oreskes, 1999, p. 203). This idea was opposed to uniformitarianism (i.e., 'the present is the key to the past') and was instead close to catastrophism, which argued that the Earth's history has been punctuated by abrupt and radical events.

279 Interestingly, the perception of fieldwork was inverted in the 18th century – a time when "Hutton was scoffed at by his critics for 'running about the hill-sides with a hammer to find out how the world was made'" (Lewis, 2000, p. 16).

280 The generalization that pragmatism mirrored the practice of geological research *internationally* should be made carefully. Whereas pragmatic components can be observed in the late 19th-century international geological community *sensu lato*, differences in theories, methods, and practices – and therefore in research cultures – existed between American, European, and British geologists (see also Fairchild, 1932). Some of these differences are made clear by historian and geologist Naomi Oreskes (1999) in her book *The Rejection of Continental Drift*. For instance, American geologists had different views on the origin and evolution of the Earth (championed by James Dwight Dana) than Europeans, mostly as a function of the kind of data they emphasized, and by Americans' precautionary attitude toward

philosophical tradition and the science of geology, then it seems appropriate to briefly consider pragmatic theories of scientific explanation to consider the explanatory status of the Anthropocene Hypothesis.

Woodward (2019) distinguishes between two meanings of the term 'pragmatic.' One meaning derives from the use of the word in association with values of utility and practicality. A second meaning – which is the meaning relevant in the context of theories of scientific explanation – concerns contextual, and especially psychological, factors as central features in the process of delivering and receiving scientific explanation. The former meaning is implicit in any theory of scientific explanation. It is hard to envision a scientific explanation that does not relate on any level to utility and practicality. The latter meaning seems to "resist incorporation into the sort of general theory" (para 6.1) sought after by traditional models of scientific explanation such as DN and CM, and is a distinctive mark of pragmatic theories of scientific explanation. It is in contrast to the idea of any 'formal' theory of scientific explanation, emphasizing its contextual factors as essential features of any characterization of explanation in science.

An example of the pragmatic approach to scientific explanation is given by the Dutch philosopher Bas van Fraasen. His remarks on scientific explanation reach conclusions that are hereby regarded as useful in dissecting the epistemology of the Anthropocene Hypothesis. In his Chapter Five of *The Scientific Image* (van Fraasen, 1980) he considers scientific explanation in the context of his theory of constructive empiricism – a general anti-realist theory of science which is developed through his landmark publication. Constructive empiricism holds that "[*s*]*cience aims to give us theories which are empirically adequate; and acceptance of a theory involves as belief only that it is empirically adequate*" (p. 12). Empirical adequacy, rather than truth, is the ultimate aim of science, of which scientific explanation "is a pragmatic virtue" (p. 97) – not the defining characteristic of science. This stance is in opposition to Salmon's conception of science (the latter arguing his view to be also shared by the majority of philosophers of science), who claimed "science can and does explain a wide variety of natural phenomena, and that to do so is one of the most basic goals of science" (Salmon, 1998, p. 79). To van Fraasen (1980), "explanation is something quite pragmatic, related to the concerns of the user of the theory and not something new about the correspondence between theory and fact" (p. 100). His discussion begins with an example very similar to the criticism raised over the explanatory power of the Anthropocene Hypothesis, and it is thus worth considering:

> Why are there no longer any Tasmanian natives? Why are the Plains Indians now living on reservations? Of course it is possible to cite relevant statistics: in many areas of the world, during many periods of history, upon the invasion by a technologically advanced people, the natives were displaced and weakened culturally, physically, and economically. But such a response will not satisfy: what we want is the story behind the event.
>
> In Tasmania, attempts to round up and contain the natives were unsuccessful, so the white settlers simply started shooting them, man, woman, and child, until eventually there were none left. On the American Plains, the whites systematically destroyed the great buffalo herds on which the Indians relied for food and clothing, thus dooming them to starvation or surrender. There you see

Europeans' supposedly "unhealthy scientific authoritarianism and autocracy" (p. 136). American geologists advocated for a 'static' view of the Earth's evolution, where "[c]ontinents were always continents, oceans were always oceans" (p. 19). European geologists advocated for a 'dynamic' view, where "[o]cean basins could be elevated into continents, continents could collapse to form ocean basins, and change occurred across the globe" (ibid.).

> the story, it moves by its own internal necessity, and it explains why. […] [I]t may be held that, *to be an explanation, a scientific account must still tell a story of how things did happen and how the events hang together, so to say* [emphasis added]. (pp. 112–113)

If a scientific explanation requires a story (and not merely a chronology) of how things happened in causal terms, and if the Anthropocene Hypothesis does not entail a causal/historical account associated with its descriptive claims, then it seems that the Anthropocene Hypothesis does not just lack explanatory power, but it also lacks a requirement for being considered a scientific account *tout court*. Before reaching too hastily this striking conclusion (further tackled in the following section), it is useful to analyze Fraasen's account of the relationship between causality and why-questions (two central concepts in philosophical theories on explanation), and their context – the latter constituting a central notion in his theory of explanation.

Van Fraasen articulates his definition of 'context' in terms of use of natural language. He argues that "which proposition a given sentence expresses will vary with the context and occasion of use," where the context of use "is an actual occasion which happened at a definite time and place, and in which are identified the speaker (referent of 'I'), addressee (referent of 'you'), person discussed (referent of 'he' [[281]]), and so on" (p. 135). While mostly focusing on language use, van Fraasen is not excluding extra-linguistic features defining the context of scientific explanations. A certain degree of background theory and factual information constitute additional defining feature of contexts, and these determine whether or not a specific why-question arises or is rejected "in one context and not in another" (p. 145).

Contexts affect epistemic actors in selecting *salient* features within a complex net of causal relations underpinning natural phenomena that inform a determined scientific theory. The "salient feature picked out as 'the cause' in that complex process, is salient to a given person because of his orientation, his interests, and various other peculiarities in the way he approaches or comes to know the problem" (p. 125). All these represent contextual factors in characterizing scientific theories and explanations that require causality. Additionally, he argues that since counterfactual arguments (e.g., propositions such as 'If X had *not* occurred, then Y would *not* have occurred') play a central role in defining causality (and thus scientific explanation), we should conclude that "explanation harbours a significant degree of context-dependence" (p. 118). It is precisely the context that determines what causal processes are selected in a scientific explanation.

Context-dependence also applies to explanation-seeking why-questions. Van Fraasen formulates these as "Why (is it the case that) P *in contrast to* (other members of) X?" (p. 127), where P represents a specific phenomenon, and X a set of possible alternatives that he names *contrast-class*. For instance, in asking 'Why is it the case that humans have become a geological agent?', contrast-classes can be represented by other species that could have become geological agents (e.g., why is it the case that *humans* have become a geological agent *rather than any other species*?), or other types of natural agency that humans as a species could have embodied (e.g., why is it the case that humans have become a *geological* agent *rather than any other type of*

[281] The author is using the male gender pronoun, but should be interpreted as gender neutral. The same applies for the statements quoted later in the section.

agent?). To provide an answer to these types of why-questions is, according to van Fraasen, to provide an explanation, and thus "a theory of explanation must be a theory of why-questions" (p. 134).

The emphasis placed on context within van Fraasen's general theory of science leads the philosopher to conclude that "scientific explanation is not (pure) science but an application of science" (p. 156). Explanation does not entail any *sui generis* virtue above and beyond description, but is rather a different application of science. In fact, van Fraasen argues that there is little difference between explanation and description: "if you ask a scientist to explain something to you, the information he gives you is not different in kind (and does not sound or look different) from the information he gives you when you ask for a description" (p. 155). Theories and hypotheses vary from context to context because they represent answers to interrogatives that themselves vary between contexts, so that "explanation is essentially relative" (ibid.). Thus, is there is no such thing as *sui generis* explanation, and there can neither be "no question at all of explanatory power as such" (p. 156) – meaning for the present discussion that to answer whether the Anthropocene Hypothesis entails explanatory power depends on the context informing the question asked, and the answer given.

Van Fraasen's theory of scientific explanation is in contrast with the traditional account of explanation in 20th-century philosophy of science. However, despite his emphasis on the context of science and rejection of general tenets of science, his discussion of scientific explanation is still delimited and articulated within the traditional physics-oriented method of analysis of philosophy of science. This is also confirmed by his reiteration of scientific examples from physics – as observed, a shared practice among 20th-century philosophers of science.

4.2.2.4 Does the Anthropocene Hypothesis Lack Explanatory Power?

Salmon (1998) wrote that "perhaps it is futile to try to explicate the concept of scientific explanation in a comprehensive manner. It might be better to list various explanatory virtues that scientific theories might possess, and to evaluate scientific theories in terms of them" (1998, p. 78). This is perhaps the best way to express the approach adopted in evaluating the epistemology of the Anthropocene Hypothesis – namely, not in relation to pre-existing models of science often confined within a rigid logico-linguistic picture of science, but rather in terms of the specific epistemic virtues they possess. While this seems to undermine the very aim of philosophy of science, in fact it allows the epistemic categories developed within this research tradition to be applied in specific instances of scientific thought. This effort does not beg the question as long as the epistemology of science is understood within its broader social, historical, and cultural context.

In the case of scientific explanation, it has been argued in the previous sections that neither the DN model nor the CM model provides a satisfying enough theoretical framework to answer the question of whether the Anthropocene Hypothesis entails any explanatory power. The emphasis given by the DN model on deductive mechanisms underpinning scientific explanation seems to poorly suit the epistemological status of the Anthropocene as a proposed geological time unit. Additionally, because the Anthropocene Hypothesis entails little (if any) predictive power, the underlying explanation/prediction symmetry thesis seems to rule out any explanatory potential retraceable in the hypothesis. While some 20th-century geologists found in the received view a possible philosophical architecture with which to build their epistemological identity, this model is no longer held in extant philosophical discourse, and it is thus of little use in investigating the epistemology of the Anthropocene Hypothesis.

One of its main alternatives, the CM model, provides a physics-based picture of causality that is of little use in understanding the driving forces (viz., causal mechanisms) behind the dawn of the Anthropocene (although its emphasis on *processes* as ontological categories may be useful in framing the ontological unfolding of the proposed epoch). These forces represent causal mechanisms of larger complexity than mere exchanges of certain physical quantities at a subatomic level. However, the analysis of this model led to considerations of the philosophy of causality that, in turn, unveiled the importance of distinguishing between physical and historical causes of the Anthropocene. The claim that the Anthropocene lacks explanatory power derives from the term's technical blindness toward the historical causes of the proposed epoch, in that the physical causes have been largely documented across the planet.

Nevertheless, it is argued that this is not the case for the Anthropocene Hypothesis. The thesis hereby promoted is that the Anthropocene Hypothesis does in fact entail forms of historical explanation. This means that the hypothesis entails explanations about the historical causes of determined stratigraphic evidence besides *also* describing the stratigraphy of the Anthropocene as a geological time unit. However, because the hypothesis is not strictly historical, but rather stratigraphical, the historical evidence is not the primary evidence required by the hypothesis in order to be validated or rejected.

The thesis that the Anthropocene Hypothesis entails both *historical* and *physical* explanations of the *raison d'être* of the Anthropocene is based on three arguments.

The first argument draws on the way that stratigraphic evidence (i.e., physical evidence) is presented, especially (though not exclusively) by the AWG. Historical considerations have been a structural component of the 'Anthropocene' narrative virtually since Crutzen and Stoermer's (Crutzen & Stoermer, 2000) seminal publication (see also Robin & Steffen, 2007). AWG members and Anthropocene researchers have often presented stratigraphic evidence supported by historical accounts (e.g., Steffen et al., 2011b; Waters et al., 2015; Zalasiewicz et al., 2019b; Zalasiewicz et al., 2011a). Most notably, the current radionuclide signal adopted by the majority of the AWG to date the beginning of the Anthropocene is enmeshed in historical significance. Fallout from nuclear and thermonuclear bomb testing is the known *physical* as well as *historical* cause of the seemingly isochronous and global signal of radioactive isotopes. Another example is the morphological change of the broiler chicken, another candidate for a biostratigraphic marker for the Anthropocene. The history of *Gallus gallus domesticus* has been well documented, both in terms of physical and historical causes behind its increase in size during the second half of the 20th century (Bennett et al., 2018). An additional example is the history of anthropogenic minerals. The histories of some human-mediated mineral-like compounds (i.e., the lithostratigraphic signature of the Anthropocene) have been (and are being) documented in terms of their spread on the Earth's surface, but also in terms of their historical and social utility among human societies (Hazen et al., 2017). If the Anthropocene Hypothesis was merely descriptive, it would simply detect and describe the radionuclide peak without further inquiring into its causes. On the contrary, the hypothesis does explain why these signals exist within the limits of stratigraphic pertinence. For instance, a study published by Waters et al. (2016) states that "[t]he *driving human forces* [emphasis added] responsible for many of the anthropogenic signatures are a product of the three linked force multipliers: accelerated technological development, rapid growth of the human population, and increased consumption of resources" (p. aad2622-2). This shows awareness of the general (extra-stratigraphic) social and historical mechanisms behind the Anthropocene.

The network of research generated by the Anthropocene Hypothesis presents its stratigraphic evidence in a way that is not disconnected from its historical counterpart – a view consistent with the idea that scientific hypotheses are rarely isolated entities, but part of a knowledge network.[282] The hypothesis, if not directly involved, is at least indirectly inclusive of a historical account of its stratigraphic basis. This is also consistent with the complementary view of historical and geological research advocated in section 1.2.3. The AWG (Zalasiewicz et al., 2021) itself, which includes historians, has stressed the complementary nature of non-geological research on the Anthropocene Hypothesis, arguing that, "given that the AWG considers human phenomena and time scales as well as geological processes, it includes representatives beyond, *but for the purposes of the AWG work complementary to* [emphasis added], the geological sciences" (p. 2). Observed as the focal point of a research network rather than in isolation, the Anthropocene Hypothesis extends beyond the domain of stratigraphy, while still maintaining its stratigraphic identity. If this is the case, then the Anthropocene Hypothesis entails explanatory power in historical as well as physical terms.[283]

The second argument draws on the multidisciplinary nature of the Anthropocene Hypothesis and the AWG. As anticipated, there seems to be a contradiction in claiming that the Anthropocene Hypothesis specifically represents a *stratigraphic* hypothesis of a *multidisciplinary* nature. Likewise, it seems contradictory to frame the AWG as a stratigraphic group of a multidisciplinary nature. The contradiction (i.e., being disciplinary and multidisciplinary at the same time) dissolves once the context of the hypothesis and the AWG is considered. The context can be analyzed by distinguishing between the *aim* and the *methods* of the hypothesis and research group.

The aim of the Anthropocene Hypothesis is specifically *stratigraphic*. It provides a range of evidence in support of a formal ratification of the Anthropocene as a discrete geological time unit on the geological time scale. However, while maintaining traditional and necessary aspects of stratigraphic research (e.g., GSSP, stratigraphic evidence, formal requirements, core samples, etc.), its methods are multidisciplinary

[282] This approach is similar, yet not identical, to Quine's conception of holism, which can be articulated in different ways but essentially claims that scientific hypotheses are never tested (and hence do not exist) in isolation, but are always part of a broad system of beliefs.
[283] It could be argued that the degree of historical explanation entailed in the Anthropocene Hypothesis is not in-depth enough to make it historically sound. However, this is a different argument than claiming that the Anthropocene Hypothesis does not entail explanatory power *tout court* because it lacks any historical explanation.

because several disciplinary domains are called upon to investigate the *stratigraphic* nature of the Anthropocene in a complementary way – from archaeology and environmental history to Earth System sciences and oceanography. For instance, historical studies have served to better frame the causes behind the presence of specific stratigraphic markers, in particular radionuclides associated to nuclear testing or disasters (e.g., Chernobyl), but also biotic markers (e.g., the San Francisco Bay). Similarly, Earth System science has laid the conceptual ground of the Anthropocene Hypothesis by framing it within the context of the Great Acceleration. The convergence of multiple disciplinary viewpoints in analyzing the same phenomenon reflects the multidisciplinary nature of the Anthropocene Hypothesis, and of the methods informing its conceptualization.

In the same fashion, the AWG is specifically one among many research groups recognized by the IUGS dedicated to the study of geological time units. Its aim is to assess whether sufficient *stratigraphic* evidence exist to warrant ratification of the Anthropocene on the geological time scale. However, the multidisciplinary composition of the group (including lawyers, philosophers, sociologists, and historians among the more traditional geologists and stratigraphers) reflects the plurality of viewpoints adopted by the group to investigate the stratigraphic nature of the Anthropocene. More importantly, such a multidisciplinary nature extends the semantic reach of the hypothesis by including forms of historical explanation for the existence of salient anthropogenic markers.

Thus, if the historical 'Anthropocene' research is understood as *complementary* (rather than conflicting), then the Anthropocene Hypothesis does entail historical forms of explanation. If it does, then the Anthropocene Hypothesis entails explanatory power in *historical* as well as physical terms.

A third argument draws on a comparative analysis between the Anthropocene Hypothesis and another geological hypothesis, the Alvarez Hypothesis.[284] The Alvarez Hypothesis was first proposed in 1980 by a team of scientists conducting geological research in the Umbrian Apennines in Italy (Alvarez et al., 1980). It posits that a large collision of an asteroid with the Earth in Mexico's Yucatán Peninsula (Chicxulub crater site) explains the high concentrations of iridium (Ir) present in clay at the Cretaceous–Paleogene (K-Pg) boundary as well as the concomitant Cretaceous–Paleogene mass extinction event (Alvarez et al., 1980). Iridium is a very rare element on Earth, mostly depleted in the crust and upper mantle during early stages of the Earth's formation. Because asteroids and debris from space were known to contain iridium concentrations, an asteroid impact was considered the most suitable explanation for the iridium-rich layer – later confirmed by refined paleontological studies and the discovery in 1991 of the impact crater in the Yucatán Peninsula (Wohl, 2007). As noted by Cleland (2002), the hypothesis provides "the greatest causal unity to the diverse and puzzling body of traces (fossil record of the dinosaurs, fossil record of the ammonites, etc., and iridium anomaly, shocked quartz, Chicxulub Crater, etc.)" (p. 483). This means that the hypothesis *explains* a vast range of traces by locating the causal mechanisms that brought them about – most notably, the iridium anomaly and the K-Pg mass extinction event (and the Alvarez

[284] The hypothesis is named after Luis and Walter Alvarez, the father-and-son scientists who, together with Lawrence Berkeley Laboratory chemists Frank Asaro and Helen Michel, first proposed the hypothesis (sometimes also termed the Asteroid Impact Theory).

Hypothesis does so in a better way than competing hypotheses, such as the Supernova Hypothesis; see Alvarez & al., 1980, pp. 1102–1104). Likewise, the Anthropocene Hypothesis *explains* a vast range of anomalies in ongoing extinction rates, atmospheric greenhouse gasses, radionuclides in sedimentary layers, human-mediated mineral-like compounds, and so forth, by positing human activities as the unifying cause. As such, the explanation it provides is also of a historical kind.

Lastly, van Fraasen's pragmatic model of scientific explanation argues that there is no such thing as explanatory power of scientific hypotheses and theories without contexts defining them. This is a crucial point because it enables us to better frame the explanatory status of the Anthropocene Hypothesis. So far, the discussion has been advanced as if the hypothesis considered would have explanatory power *only if* it entailed *historical* (in the sense of human historical) explanation. In fact, this is the observation made by Rosol et al. (2017) and Renn (2020) on the Anthropocene as terminus technicus: it lacks explanatory power because it lacks historical depth. This consideration is consistent with the nature of geological units, as already stated multiple times. However, this line of criticism does not equally hold against the Anthropocene Hypothesis. The arguments promoted above should already grant the Anthropocene Hypothesis with *historical* explanatory power.

Nevertheless, if one assumes that the Anthropocene Hypothesis still lacks a sound historical explanation (i.e., lacking the human historical causes of the dawn of the Anthropocene as a geological time unit), then its context of formulation should determine its explanatory power. The context is determined by the geological, and specifically the stratigraphical, community, which is the community wherein the Anthropocene Hypothesis (and *not* the 'Anthropocene') was conceived and wherein its scientific fate is decided. Such a community of epistemic actors would assess the epistemic validity and explanatory power of the hypothesis based on its usefulness, relevance, robustness of evidence, and so forth. This implies that the depth of the historical explanation as a function of the hypothesis' epistemic utility largely depends on the cognitive expectations of a particular group of epistemic actors or disciplinary domain. Within these epistemic grounds, what may appear as a deficiency in explanatory power from one community (e.g., historians) may not be such for another community (e.g., geologists and stratigraphers). This means that ultimately it is the epistemic context that determines what (and which theories and hypotheses) entail explanatory power. Since the Anthropocene Hypothesis is a hypothesis-in-the-making, the question of its context-dependent explanatory power is yet to be answered.

4.2.3 Scientific Understanding

A scientific hypothesis with explanatory power provides *scientific understanding* of natural phenomena. Undoubtedly, a hypothesis achieving scientific understanding is also *scientifically useful*: it helps scientists solve certain problems and achieve some understanding of the world. Achieving understanding of the world is often considered one of the central aims of the sciences. It is reasonable to consider as a desideratum the fact that scientific hypotheses deliver some type of scientific understanding: any scientific hypothesis *H* explaining a certain phenomenon *P* is preferable over any hypothesis H_n explaining *P* if *H* delivers some sort of scientific understanding and H_n does not – *ceteris paribus*. If the Anthropocene Hypothesis is invested with a certain kind of explanatory power, then it should also be able to deliver some sort of scientific understanding (and, consequently, useful). This section attempts to answer this question – that is, whether the Anthropocene Hypothesis entails any form of scientific understanding.

A preliminary remark first. In English usage, the term 'understanding' (as with the term 'explanation') encompasses a wide spectrum of cognitive capabilities (not restricted to humans). Multiple disciplines are involved in the study of the processes of understanding, from neurosciences, psychology, and linguistics to pedagogy and anthropology. The specific type of understanding hereby discussed is the kind of scientific understanding discussed within philosophical research on science. It is not claimed that scientific understanding is the *only* valid kind of understanding, nor that scientific understanding is a *better* form of understanding than any other kind. The Anthropocene Hypothesis constitutes a *scientific* hypothesis, thus *scientific* understanding is necessarily the type of understanding that needs to be taken into consideration. Since scientific understanding is an important topic in the philosophy of science, it is reasonable to consider this disciplinary domain in answering the question posed in this section.

The discussion regarding the nature and importance of scientific understanding is a byproduct of debates over scientific explanation. The value of understanding varies across theories and models of scientific explanation developed by philosophers during the second half of the 20th century.[285] Intuitively, while explanation and understanding seem connected (is an explanation that no one understands truly an explanation?), much of the philosophical work influenced by logical empiricism considered understanding as part of the psychological, historical, and social dimension of science (i.e., the 'context of discovery'). For early logical positivists, these features were outside the boundaries of philosophical inquiry, which was delimited by the objective study of the logical and conceptual nature of science (i.e., the context of justification), and by the uncovering of the objective link between theory and evidence. This resulted in philosophers of science largely ignoring the theme of scientific understanding as an important aspect in philosophical debates on science and scientific explanation (de Regt, 2017, para. 2.1).

For instance, Hempel considers understanding as expecting a phenomenon to occur under particular circumstances and under certain laws in question (Woodward, 2019). Essentially, to understand implies to grasp the laws under which phenomena are explained. However, he also believes that "such expressions as 'realm of understanding' and 'comprehensible' do not belong to the vocabulary of logic, for they refer to the psychological or pragmatic aspects of explanation" (Hempel, 1966). Understanding is excluded from his logically structured analysis of scientific explanation as a psychological rather than philosophical object of analysis. For Salmon, understanding means to comprehend the causal interactions and causal processes of phenomena. Causality is considered the standard for the intelligibility of theories, and causal explanations are the most desirable forms of explanations in science. In his essay "The

[285] A pioneering study in the role of understanding in philosophy of science is Michael Friedman's (1974) "Explanation and Scientific Understanding." Friedman rejects Hempel's views on understanding as outside the boundaries of philosophy of science, acknowledging understanding as a pragmatic value of paramount epistemic importance.

Importance of Scientific Understanding" (Salmon, 1998), he distinguishes between multiple types of human understanding – of which the scientific kind constitutes only but one, belonging to the understanding of natural phenomena. Salmon specifies that "[w]e come to understand a meaning when we can say *what* something means; we come to understand a phenomenon when we can explain *why* it occurred" (p. 83). In this view, to understand why a phenomenon occurred means to understand its causal mechanisms.

The reference framework hereby adopted to assess whether the Anthropocene Hypothesis delivers any form of scientific understanding about the world draws on the recent work of philosopher Henk W. de Regt (2006, 2017, 2020; de Regt & Dieks, 2005; de Regt et al., 2009). His account emphasizes the nature of scientific understanding as "an essential ingredient of the epistemic aims of science" (de Regt & Dieks, 2005, p. 141). It stresses the pragmatic and context-dependent nature of scientific understanding without being restricted to one or more epistemic virtues such as deducibility from general laws or understanding of causal mechanisms. Within this view, deduction of phenomena from laws and an understanding of their causal mechanisms constitutes *some* of the epistemic virtues of scientific understanding. They are applied in specific scientific contexts, but they reflect neither a universal structure of scientific explanation nor the nature of scientific understanding. More importantly, this stance does not solely recognize scientific understanding as a pragmatic virtue of science (as many logical empiricists also argued), but considers it one of the *fundamental aims* of science.[286] It holds that "the pragmatic nature of understanding is not inconsistent with it being epistemically relevant" (ibid.), and should thus be a necessary element of the philosophical discussion on science (rather than simply a matter of psychology, history, or sociology). Additionally, this view contrasts with van Fraasen's approach on scientific understanding, in that de Regt considers explanation (and similarly understanding) to be a pragmatic characteristic that is nevertheless epistemically irrelevant in terms of developing a theory of science and scientific explanation.

De Regt's (2017) theory of scientific understanding resonates with the underlying pragmatic philosophy informing geological research unveiled throughout this chapter. Thus, it is considered to help develop favorable grounds for a discrete epistemological analysis of the Anthropocene Hypothesis, and doing so by providing the operating definition of scientific understanding herby adopted.[287]

At the core of his definition is the notion of 'intelligibility,' which he defines as "the value that scientists attribute to the cluster of qualities of a theory (in one or more of its representations) that facilitate the use of the theory" (p. 40).[288] De Regt argues that "[s]cientists prefer theories with properties that

[286] Theories of science and scientific explanation such as Hempel's DN model also recognize understanding as a pragmatic virtue, but do not consider it an essential characteristic of science because it concerns the psychology of single individuals. Thus, the literature highlighted above does not stress the role of understanding as a *pragmatic* virtue, but as a *defining* virtue of science.

[287] One model that de Regt addresses multiple times in his work is the Unificationist Model of scientific explanation. The model considers scientific explanation "a matter of providing a unified account of a range of different phenomena" (Woodward, 2019, para. 5.1). Unificationist attempts have been promoted by philosophers such as Michael Friedman and Philip Kitcher. This model is not addressed in the present chapter as it is not considered relevant in assessing the explanatory and intelligible status of the Anthropocene Hypothesis.

[288] Concerning the different possible representations of a theory, de Regt (2017) specifies that "[i]t often happens that a theory can be represented in different ways (think of the various formulations of classical mechanics), and each of

facilitate the construction of models for explaining phenomena, and that is the case if their skills are attuned to these properties. If such an appropriate combination of a scientist's skills and theoretical properties occurs, the scientist has pragmatic understanding of the theory" (pp. 39–40). Pragmatic understanding is equivalent to intelligibility, so that "[i]f scientists understand a theory, the theory is intelligible to them" (p. 40). This means that intelligibility is central to scientific understanding: a scientific theory or hypothesis delivers scientific understanding if it is intelligible (a theory that no scientists understand is unintelligible, and provides no scientific understanding). Intelligibility is considered a pragmatic virtue, and the standards for intelligibility (e.g., simplicity, aesthetic factors, causality, etc.) are always context dependent: they change across scientific communities and historical periods. Additionally, intelligibility "is not an intrinsic property of a theory but an extrinsic, relational property because it depends not only on the qualities of the theory but also on the skills of the scientists who work with it" (ibid.). A theory or hypothesis may (or may not) be intelligible for a particular group of scientists who endorse the epistemic qualities that the theory or hypothesis represents, meaning that intelligibility may vary from context to context "through time, across disciplines, or even within a particular discipline" (ibid.).

De Regt distinguishes between three ways understanding relates to scientific explanation: the phenomenology of understanding (the feeling connected to understanding an explanation, e.g., *Aha!* Experience), understanding a phenomenon (having a satisfactory explanation of a phenomenon), and understanding a theory (being able to use it). The last constitutes the pragmatic aspect of a theory, which de Regt argues to be necessary to understand a phenomenon. Intelligibility concerns understanding a theory (rather than a phenomenon or the feeling of understanding), so that a theory or hypothesis is intelligible if it is able to be used (and understood). This implies that "understanding involves abilities, and that it is thereby pragmatic and context-dependent" (p. 26) – that is, it relies on skills and judgements from scientists, making it untenable to separate epistemic and pragmatic aspects of science. Epistemic virtues such as simplicity[289] or visualizability allow scientists to select one or the other theory or hypothesis, and it is the context of these theoretical virtues that scientists value, and that determine the skills that scientists possess.

In de Regt's account, the notion of intelligibility entails the fact that a theory, other than being understood, should be able to be used ("skills cannot be acquired from textbooks but only in practice because they cannot be exhaustively translated into explicit rules," p. 28). *How* a theory is used largely draws on how physicists, in particular, generate and use their theories. De Regt himself states that his work "focuses mainly on physics" (p. 31, note 17), meaning that using a theory mostly implies being able to make some predictions with it – which is a central aspect of physics.[290] As observed in section 4.2.1, prediction

these representations may have its own specific qualities, which may be relevant to the intelligibility of the theory" (p. 40, footnote 25).

[289] According to Brice (1989), simplicity was one of the central characteristics that allowed continental drift and plate tectonics to become established as a paradigm in geological research.

[290] It should also be noted that de Regt addresses *theories* rather than *hypotheses* in developing his theory of scientific understanding. In philosophical literature, theories are usually understood as broader theoretical entities than hypotheses – the latter being delimited to either single phenomena or a restricted range of phenomena. Nevertheless, because hypotheses are also capable of conveying scientific understanding (because they provide scientific explanation), de Regt's theory on scientific understanding is assumed to be equally functional for scientific hypotheses.

is not considered an epistemic virtue of the Anthropocene Hypothesis. This is because it is a historical hypothesis, concerned with reconstructing past and present events rather than predicting new ones.[291] In the Anthropocene Hypothesis, predictions can relate to the possible geological length of the anthropogenic stratigraphic signature. However, the hypothesis represents a historical and descriptive[292] hypothesis because it focuses on the *past* and *present* anthropogenic signatures. The intelligibility or kind of scientific understanding of the hypothesis under scrutiny should not be assessed based on its predictive power – as this represents one among many epistemic virtues of scientific theories and hypotheses. The Anthropocene Hypothesis is not *used* in the canonical sense of using a theory (e.g., plate tectonics, general relativity) to explain some phenomena within a bigger framework (despite the term playing such a role in the broader environmental discourse). Rather, the hypothesis promotes the use of a temporal label (i.e., the 'Anthropocene,' or other equivalent terminological alternatives) to designate a specific boundary in geological time determined by anthropogenic signatures of a varying stratigraphic nature. Such usage is consistent with that of other geological time units used to divide geological time in a meaningful way.

If hypotheses need be able to be used in order to be intelligible, and if intelligibility is always context dependent, then the *context* and *use* of the Anthropocene Hypothesis need to be assessed to consider whether the hypothesis is intelligible and, ultimately, capable of delivering some kind of scientific understanding. Presumably, the primary context of the Anthropocene Hypothesis is that of stratigraphic classification, in particular the definition of the 'Anthropocene' as a geochronological and chronostratigraphic unit. This is because of the nature of the hypothesis as a *stratigraphic* hypothesis, aiming to formalize an Anthropocene Epoch/Series on the geological time scale and international chronostratigraphic chart. Thus, the question concerning the intelligibility of the hypothesis is to be resolved within the stratigraphic community.

While a separate theoretical entity, the Anthropocene Hypothesis is not immune to the larger debates over the 'Anthropocene' promoted by the broader academic landscape. This is particularly the case since the theoretical distinction between the 'Anthropocene' and the Anthropocene Hypothesis has not been fully appreciated among Anthropocene scholars and research from various fields of knowledge. The multidisciplinary composition of the AWG corroborates the idea that the stratigraphic variant is enmeshed in a larger debate that, in some ways, has affected the production of stratigraphic knowledge about the 'Anthropocene.' Therefore, the broader 'Anthropocene' may be considered as the 'outer context' of the Anthropocene Hypothesis – a context that plays a role in framing the hypothesis' intelligibility.

A related consideration regarding the context of the hypothesis in question (as with any scientific hypothesis) pertains to its historical embeddedness. The historicity of scientific ideas was not unknown to more 'traditional' philosophers of science. Salmon (1998) argued that "we can say that we have *scientific*

[291] Nevertheless, predictive elements are present, if not central, to the notion of the 'Anthropocene' as a broader conceptual unit.

[292] The fact that the Anthropocene Hypothesis is addressed as descriptive does not contradict the claim that the hypothesis entails explanatory power, as some traditional categories in philosophy of science would frame it. A description can entail explanatory power as well (i.e., all explanations are descriptions, whereas not all descriptions are explanations), as also argued by van Fraasen (see section 4.2.2.3).

understanding of phenomena when we can fit them into the general scheme of things, that is, into the *scientific world-picture*" (p. 87). A scientific world-picture represents a historically determined system of knowledge granting the conditions of possibility for scientific understanding. The idea that scientific understanding relies on a general scientific world-picture is the tenet of historical research on science: "if we look into the history of science also with the aim to find resources for reflection on science in its present state, then we have to avail ourselves of this richer concept of *science in context* as an analytical tool in our historical investigations as well" (Renn, 1996, p. 1). The nature of scientific understanding cannot be extracted from its historical context. On the contrary, it is heavily dependent on the *episteme* or conditions of possibility of knowledge (Foucault, 1970) of that specific historical and cultural context, so that "the question of the nature of scientific understanding is also a historical question" (de Regt, 2017, p. 2). The quest for a universal theory of (unbiased) science (somewhat portrayed by critics of 'science' more than philosophers today) pioneered by the early 20th-century logical positivists failed with the realization that there is no such thing a one universal and static 'science,' but rather *sciences* whose languages and methods change over time. Thomas Kuhn (2012) famously pioneered this historical turn with *The Structure of Scientific Revolutions*. Larry Laudan (1984), another pioneering figure in the historical turn in philosophy of science, observed that "we have seen time and again that the aims of science vary, and quite appropriately so, from one epoch to another, from one scientific field to another, and sometimes among researchers in the same field" (p. 138). As the aims of science (and science itself) change, so do the methods and forms of scientific explanation and scientific understanding of natural phenomena. This makes the historical context of any hypothesis a transient yet important feature for understanding epistemic values such as explanatory power or intelligibility.

Indeed, to underline the historical context of the Anthropocene Hypothesis means to stress the historical nature of epistemic concepts and virtues such as 'explanatory power' or 'intelligibility.' This research methodology is promoted by historians of science who embrace historical epistemology as a method of analysis for epistemic concepts (Feest & Sturm, 2011), such as Lorrain Daston (1994, 2017) and Jürgen Renn (1996, 2020). In this account, epistemic categories such as 'objectivity,' 'belief,' and 'knowledge' are not ahistorical, but rather "emerge within specific practices and contexts, over time become transferred to new domains of application, and sometimes become so general that we think they have no history" so that "[i]t is the task of the historian-philosopher to study the backgrounds and contexts of these concepts" (Feest & Sturm, 2011, p. 289). Likewise, the explanatory power and intelligibility of scientific hypotheses or epistemic concepts rely on the defined historical and cultural meaning attributed to them. As shown in sections 4.1 and 4.2, much of the philosophical (but also historical) discourse on science assumed physics to be the measure for all of the natural sciences. Philosophical discussions on scientific explanation and understanding emerged from these settings, so that scientific explanations were mostly conceived as resembling explanations from physics. The "universalizing tendency in epistemology and philosophy of science" (p. 285) left little space to assess what explanation and understanding meant for a discipline like geology – not to mention the subdisciplines of geochronology and stratigraphy. Thus, to understand the historical context of the Anthropocene Hypothesis (from an epistemological viewpoint) means to consider the epistemic meaning of the categories of 'explanation' and 'intelligibility' within its disciplinary context.

Another determinant of the context of the Anthropocene Hypothesis is related to its *utility*. How is this hypothesis *used* by the scientists endorsing it? That is, how is an Anthropocene Epoch/Series useful for science?

As argued, the hypothesis is considered to entail explanatory power both in *historical* and *physical* terms. This claim is based on the way stratigraphic evidence is presented, the multidisciplinary methodologies adopted, and the range of signals the hypothesis encompasses in explanatory terms. To use the Anthropocene Hypothesis means, thus, to be able to translate the vast array of anthropogenic marks on the Earth into stratigraphic evidence. In turn, this evidence would be used by geologists and scientists to mark a new unit of time of the geological time scale – that is, the Anthropocene (or a stratigraphically equivalent terminological variant). Thus, the application of this hypothesis manifests in a twofold fashion. On the one hand, the hypothesis lays out a new epistemology of anthropogenic signals for stratigraphers and geologists to use. Anthropogenic alternations of the world's environments and ecosystems had been extensively documented long before the hypothesis came to be. However, no other hypothesis, especially among competing and alternative Anthropocene hypotheses (surveyed in the previous chapter) *explained* in such a comprehensive manner the stratigraphic trace of *Homo sapiens* within the present knowledge system of stratigraphy and geochronology.[293] On the other hand, the hypothesis promotes the use of the Anthropocene as a discrete time unit both on the geological time scale and the international chronostratigraphic chart, providing international standards of reference for the various types of stratigraphic evidence gathered so far.

Is, then, the Anthropocene Hypothesis intelligible? Does the Anthropocene Hypothesis deliver any form of scientific understanding? According to de Regt's (2017) model, "[a] phenomenon P is understood scientifically if and only if there is an explanation of P that is based on an intelligible theory T and conforms to the basic epistemic values of empirical adequacy and internal consistency" (p. 92). This constitutes his Criterion for Understanding Phenomena (CUP), which forms the basis of his theory of scientific understanding. Because intelligibility is included in the definition, CUP is also implicitly a pragmatic principle. CUP can be used to reformulate the questions above in the following way: Is there an explanation of P (the Anthropocene) that is based on an intelligible hypothesis H (conforming to the basic epistemic values of empirical adequacy and internal consistency) so that the phenomenon P is understood scientifically? A partial answer to this question is provided by the AWG itself (Zalasiewicz et al., 2019b, para 1.3) when discussing the utility (viz., what the hypothesis explains and what it can be used for) of formalizing an Anthropocene time unit. Its utility is considered in respect to geology (para. 1.4.1), the

[293] The existence of conceptual antecedents discussed in section 1.2.3 may suggest that the hypothesis does not provide any new epistemology that was not already developed or considered in stratigraphic and geochronological research. The argument promoted in that section is that the 'Anthropocene' concept represents a discrete instance of geological reflexivity. This argument can be reiterated for the purpose of stressing the singularity of the Anthropocene Hypothesis within the extant stratigraphic and geochronological knowledge system. Seen thus, the Anthropocene Hypothesis does provide a unique form of explanation within a novel epistemological setting.

natural sciences (para. 1.4.2), and beyond the natural sciences (para. 1.4.3). Because the Anthropocene Hypothesis is a stratigraphic hypothesis, its utility within the geological context is the most important aspect to consider, as such a context represents the epistemological background granting the conditions of possibility for the hypothesis to be intelligible.[294]

The authors argue that the wide array of stratigraphic signatures, some of which have no prior counterparts in older geological time units (e.g., radionuclides, mineral-like compounds, plastic), "reflects a demonstrably distinct phase in Earth history" (p. 32). The Anthropocene is "clearly geologically 'real' both as a unit of time and process and as a distinctive stratal unit across a large range of environments" (p. 33). Based on these premises, the researchers first recognize the general usefulness of labelling the Anthropocene as a distinct phenomenon "to enable and facilitate scientific discussion" (p. 32). This aspect underlines the *social utility* of the Anthropocene Hypothesis – namely, its potential to ignite and fuel scientific discussions that are deemed useful in generating knowledge about the world within a given knowledge system (i.e., geochronology and stratigraphy). Then, the researchers suggest that "mapping distinct Anthropocene deposits" (p. 33) is useful in a local and global way. On a local scale, anthropogenic deposits serve not exclusively as a means of geochronological dating (both in terms of dating anthropogenic material and in establishing a boundary-section between the Holocene and the Anthropocene), but also as distinctive features in engineering geology, where "foundation design will require knowledge of the age of the underlying anthropogenic strata" (p. 34). On a global scale, a possible utility in formalizing the Anthropocene will lie "in producing a world map of Anthropocene deposits" (ibid.) to visualize highly complex processes (e.g., city building) of stratigraphic interest. These aspects underline the *stratigraphic utility* of the Anthropocene Hypothesis – namely, the recognition of Anthropocene strata for the purposes of geochronological dating and engineering geology. In addition, the AWG argues that "the process of investigating the definition of the Anthropocene […] may help geologists better navigate the process of defining GSSPs in deep-time successions" (ibid.). This last aspect underlines the *theoretical utility* of the Anthropocene Hypothesis by stressing the general theoretical implications of adopting the GSSP methodology for setting a lower boundary for an Anthropocene time unit.

Whether the Anthropocene Hypothesis does in fact entail social, stratigraphic, and theoretical utility has been a matter of debate in the past years. A definite answer on the matter would inevitably be anachronistic in respect to future decisions from the AWG and the geological community, insofar as the Anthropocene Hypothesis is a hypothesis-in-the-making. For the present analysis, it is only necessary to dissect the epistemology of the hypothesis to assess whether it entails forms of understanding, and whether it is intelligible in the epistemological framework of geochronology and stratigraphy.

It seems reasonable to consider the Anthropocene Hypothesis intelligible based on three observations. First, intelligibility is a consequence of the link between explanation and understanding. If the Anthropocene Hypothesis entails explanatory power (meaning that it is capable of explaining something

[294] Notable, CUP applies for any other scientific variant of the 'Anthropocene,' such as Earth System science or evolutionary biology.

about the natural world), it must also provide understanding of that thing it explains. An explanation that does not deliver any form of understanding (among the epistemic actors implementing such an explanation) can hardly be considered an explanation at all. Second, it must also be considered whether the Anthropocene Hypothesis explains something *new* – that is, if novelty constitutes one of its epistemic virtues. Novelty is a major epistemic virtue of modern research, whether scientific or humanistic. Novelty is not related *per se* to intelligibility (a hypothesis can claim to bring new knowledge, but fail to be intelligible), but rather to the phenomenon being explained. One of the criticisms raised against the hypothesis is that it restates something already known (Scourse, 2016): it does not introduce any new knowledge and thus is useless. However, Chapter 3 provided an overview of the empirical context of the hypothesis, casting doubt on this kind of criticism. Third, the social, practical, and theoretical utility advocated by the majority of the AWG confirms that, at least on a community level, the Anthropocene Hypothesis is intelligible – although further developments will weigh into this consideration.

If the Anthropocene Hypothesis is intelligible (and if it conforms to basic empirical adequacy and internal consistency), then the hypothesis satisfies CUP and can be regarded as delivering scientific understanding of the phenomena that engender the Anthropocene. Additionally, it is argued that the hypothesis delivers scientific understanding (and is intelligible) regardless of its formal acceptance (i.e., recognition of the Anthropocene as a geological time unit) from the wider geological community. A rejection would necessarily cause geologists not to use (at least formally) the proposed time unit to differentiate specific anthropogenic strata and biota. This would imply a rejection of Claim 2 (and necessarily Claim 3) – that is, that the stratigraphic signature left by *Homo sapiens* could be translated into a unit of time on the geological time scale. However, rejection of formal ratification would not affect Claim 1 ('*Homo sapiens* has left a discernible stratigraphic signature of significant magnitude in the recent geological history') because this represents an *ontological* rather than *epistemological* claim. It does not directly address the way geology divides geological time according to the methods of geochronology and stratigraphy. Rather, the claim states a determined state of affairs that, although caused by us, is now independent of us. If *Homo sapiens* were to disappear instantaneously, its anthropogenic signals would persist in the geological records.

Lastly, while scientific utility is an epistemic and pragmatic virtue closely related to explanatory power and intelligibility, utility is much more reliant on social factors requiring further consideration from sociological analyses of science. Ultimately, the question over the scientific utility of an Anthropocene time unit is answered within the stratigraphic community – the main field of knowledge concerned with the division of geological time in a useful, meaningful, and consistent way. Debates over the utility of an Anthropocene unit are further discussed in section 5.2.4.

4.2.4 Further Remarks

The analysis conducted in this chapter attempted to apply models in philosophy of science by discussing the epistemological nature of the Anthropocene Hypothesis as *scientific* and *historical* hypothesis. It sought to shed light on its explanatory power, its intelligibility, its usefulness, and the type of understanding it seeks to convey. Each of these represents a major theme in the modern philosophy of science that, either unwittingly or deliberately, developed primarily within specific theoretical coordinates – that is, the overlap of 'science' with physics, the context distinction, the epistemic privilege attributed to predictive hypotheses, and so forth.

As a scientific hypothesis, the Anthropocene Hypothesis is part of a social, cultural, and historical context that affect its premises (both methodological and theoretical), formulation, and content. One of the major forms of criticism that partially redirected research methods in philosophy of science in the past decade was the absence of historical depth. This was due to the methodological boundaries (i.e., context of justification and context of discovery) established under logical empiricism. The historical turn pioneered by Kuhn, Lakatos, and Laudan ensured that history became a *conditio sine qua non* of philosophical research on science. Following this trend, a philosophy of geology needs to be historically sound. How can philosophy of geology and epistemology thus meet history?

A recent attempt to merge epistemological analysis and historical research has been named 'historical epistemology.' Historian of science Lorraine Daston (1994) defines historical epistemology as "the history of the categories that structure our thought, pattern our arguments and proofs, and certify our standards for explanation" (p. 282). Renn (1996) provides a further definition of historical epistemology as conducted by the Max Planck Institute for the History of Science, namely as an attempt

> to open up a space for exploring the relationship between all relevant dimensions of the development of scientific knowledge […] [by comprising] the reconstruction of central cognitive structures of scientific thinking, the study of the dependence of these structures on their experiential basis and on their cultural conditions, and the study of the interaction between individual thinking and institutionalized systems of knowledge. (p. 4)

Such an approach "requires an integration of social, cultural, and cognitive studies of science" (ibid.). While cultural tensions between historical epistemology and philosophy of science exist (Brenner, 2016), historical epistemology may provide complementary tools of analysis to avoid reiterating a 'formal' (meaning ahistorical) philosophy of geology. First, this is because historical epistemology is "not interested in long dead concepts or styles, but with those that are active today" (Nasim, 2013, p. 23). Second, "if scientific concepts or styles all contain in them some trace of their origin" (ibid.), then the origin of the Anthropocene Hypothesis must be traceable in the years prior to its formulation by the Anthropocene Working Group. These 'traces' are present in the concept's most recent history as well as in its genealogical background, but also in less explicit forms of thinking about geological time developed within the geosciences – an aspect investigated in this chapter. Third, historical epistemology "wants to emerge from out of some transformation in history, so that one can determine whether or not before the period of transition there was such a concept or style possible" (ibid.).

The 'Anthropocene' idea emerged from a process of reconfiguration of knowledge about the Earth and its history that was articulated through four main moments. First, the recognition of anthropogenic signals expressed in geological (relative) units in 19th-century European and 20th-century Russian geology. Second, the revolution in geochronological sciences consequent to the discovery and application of radiometric dating in the first half of the 20th century, which allowed for the discovery of deep time. Third, the novel approach of Earth System science, which transitioned from environmental sciences to the study of the Earth as a system (Hamilton, 2016). Fourth, the increasing popular, academic, and institutional recognition of the anthropogenic impact on the Earth in the second half of the 20th century. These are important historical and theoretical moments that engender the very possibility of conceptualizing the contemporary 'Anthropocene,' and thus of formulating the Anthropocene Hypothesis.

Sociological aspects are important to consider too when analyzing the 'Anthropocene' concept as well as the Anthropocene Hypothesis – despite the strong antagonism between sociological approaches to science and traditional philosophy of science. In epistemological terms, social epistemology may represent a third complementary approach in dissecting the knowledge claims of the Anthropocene Hypothesis. Challenging the 'individualistic' assumption of traditional epistemology (where notions such as truth, belief, and fact usually depend upon individual subjects), social epistemology configures "an enterprise concerned with how people can best pursue the truth (whichever truth is in question) *with the help of*, or *in the face of*, others" and with "truth acquisition by groups, or collective agents" (Goldman & O'Connor, 2019, para. 1). Social epistemic aspects, such as group acceptance, are structural for Claim 2 and Claim 3 of the Anthropocene Hypothesis. The claims advocate for a reconfiguration of knowledge that is heavily dependent on the epistemic actor (i.e., social groups) involved, namely the AWG itself, the Subcommission on Quaternary Stratigraphy, and the remaining parental geological bodies.

Further research on the historical epistemology and social epistemology aspects of the Anthropocene Hypothesis will be necessary for developing (or rather, initiating) discussions on the 'geological Anthropocene' as a scientific hypothesis.

CHAPTER 5

DEBATING THE ANTHROPOCENE HYPOTHESIS

A discussion between people who share many views is unlikely to be fruitful, even though it may be pleasant, while a discussion between vastly different frameworks can be extremely fruitful, even though it may sometimes be extremely difficult, and perhaps not quite so pleasant (though we may learn to enjoy it).

—Karl Popper, *The Myth of the Framework*

The birth, development, and acceptance or rejection of scientific ideas is not an uncontested process. In fact, constructive skepticism is a distinguished characteristic of (democratic) science – a characteristic allowing concepts, conjectures, hypotheses, and theories to flow and to be critically discussed prior (and subsequent) to their acceptance or rejection among scientific communities. In a sense, the absence of this social dimension of critical inquiry means the absence of science. Karl Popper notoriously champions this view, as evident by the opening quote of this chapter. Advocating against the problem of relativism (i.e., that mutual understanding among different frameworks is impossible), he argues that "*the growth of knowledge depends entirely on the existence of disagreement*" (Popper, 1994, p. 34). Without disagreement, and the critical debates that ensue thereafter, there is no possibility for scientific knowledge. If the Anthropocene Hypothesis truly represents a *scientific* hypothesis, then there *must be* some degree of scientific disagreement and debate concerning its claims and epistemology.

Therefore, this fifth and final chapter surveys the debate gravitating around the Anthropocene Hypothesis. More precisely, it explores two grand types of criticism raised within Anthropocene Studies – namely, against the 'Anthropocene' boundary object, and against the Anthropocene Hypothesis.

Criticism of the 'Anthropocene' is discussed in section 5.1. This criticism stems primarily from the humanities and social sciences. It addresses multiple aspects of the 'Anthropocene' both as a concept and discourse, focusing mostly on the normative (i.e., ethical, social, political) implications that the term seems to entail – either unwittingly or explicitly. Surveying this criticism is crucial because criticism of the 'Anthropocene' often overlaps semantically with criticism of the Anthropocene Hypothesis. This is because much extant literature does not clearly distinguish between these two distinct theoretical entities. Therefore, it is necessary to consider whether arguments against the 'Anthropocene' equally hold against the Anthropocene Hypothesis.

Criticism of the Anthropocene Hypothesis is discussed in section 5.2. This type of criticism – raised both by geologists and natural scientists, but also stemming from human sciences such as archaeology – engenders scientific discussions around the epistemic validity, epistemic legitimacy, methodological consistency, and usefulness of the hypothesis. Surveying this criticism is paramount in identifying the dialectical process that led the hypothesis to its current empirical and methodological formulation. This section aims at detecting the major theoretical challenges faced by the Anthropocene Hypothesis according to the scientific community.

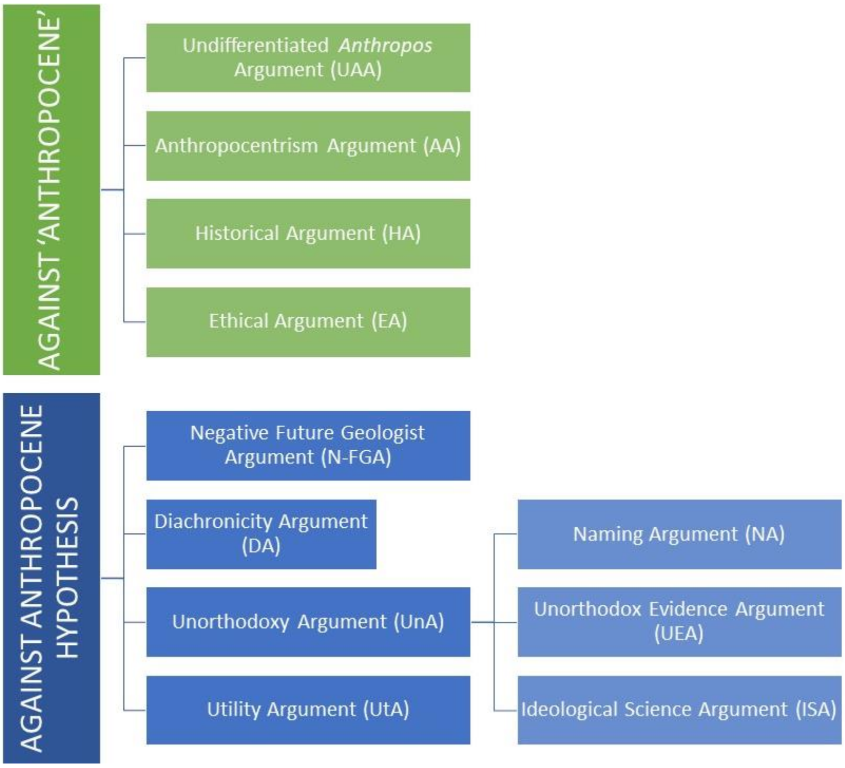

Figure 5.1. Summary of the main arguments against the 'Anthropocene' (green) and against the Anthropocene Hypothesis (blue).

Both types of criticism are discussed by delineating central arguments in critical literature (Figure 5.1). These arguments are expressed in the form of single short statements summarizing the main theoretical points and discursive hubs advanced by critics of the 'Anthropocene' and the Anthropocene Hypothesis. This methodological choice reflects the necessity of (1) distinctively identifying the core criticism recurrently expressed by authors and researchers in Anthropocene Studies, (2) clarifying the central lines of arguments advanced by criticism, and (3) discussing the meaning and implications of criticism as formulated in each argument.

This methodological choice is primarily descriptive in respect to the criticism surveyed. The chapter does not seek to shield the Anthropocene Hypothesis from criticism *ex ante*, nor to lean in favor or against of the hypothesis. The question over the *epistemological status* or validity of the Anthropocene as a scientific hypothesis is a different question from whether or not the hypothesis should see formal approval. The criteria adopted to discuss criticism only aim at connecting extant criticism with the purpose of thoroughly investigating the epistemological nature of the Anthropocene Hypothesis. As illustrated in this chapter, some criticism from the humanities is considered only marginally or not at all pertinent to the scientific core of the Anthropocene Hypothesis. This is not so in virtue of the arguments advanced, but because of the object of criticism (i.e., one of more aspects of the 'Anthropocene'). In a similar way, scientific debates of a technical nature are substantially different from the critique advanced by humanistic approaches to the 'Anthropocene.'

However, some considerations expressed in this chapter take a step further from merely mapping and describing criticism. This is particularly the case for section 5.1, where it is argued that much criticism advanced against the 'Anthropocene' does not equally hold against the Anthropocene Hypothesis. Such a stance does not reflect a 'preference' toward the hypothesis, nor does it argue that such criticism is invalid *per se*. It simply clarifies what arguments directly concern the epistemological nature and status of the Anthropocene as a scientific hypothesis. This can be assessed by considering whether and how criticism addresses the system of knowledge of stratigraphy – the theoretical domain of the Anthropocene Hypothesis – and by considering the logical and semantic implications of the arguments advanced. The nature of the arguments advanced necessarily side with specific viewpoints over the meaning, scope, and aim of the Anthropocene Hypothesis as a scientific formulation. Notably, taking any such side is a consequence of the argumentative legitimacy of the reasons proposed rather than a predefined desire of siding with one or other factions in extant debates.

5.1 Against the 'Anthropocene'

It is difficult to identify in detail the several lines of criticism that the notion of 'Anthropocene' has received since its coinage (and especially during the last decade). The difficulty arises not solely because of the amount and breadth of the criticism raised, but also because of the particular definition of 'Anthropocene' that each critique implicitly or explicitly provides. Such difficulty mostly arises from the issue of definition – one of the major hindrances to establishing a multi- and interdisciplinary functional framework for Anthropocene Studies, as observed in the opening chapter of this research. The multiple interpretations, meanings, and purposes attributed to the notion by recent scholarship make any attempt to thoroughly map criticism – while also doing justice to each individual argument – a daunting task.

This predicament is particularly relevant in terms of framing criticism generating from the humanities and social sciences. Their engagement with the 'Anthropocene' begun around 2007-2009, escalating in the following decade to become the leading research fields in Anthropocene Studies. While maintaining a basic shared identity (as a global, emergent, and human-mediated environmental predicament), the term roamed and shapeshifted across disciplines – at times remerging as one among now many existing terminological variants. Either by criticizing, reformulating, or restating the new term, the 'Anthropocene' has been quite a successful linguistic and theoretical device across humanists and social scientists, whose contributions made the term "the most influential concept in environmental studies" (Moore, 2016a, p. 2) in recent times. Yet the rapid interest in the term (witnessed by the increasing number of publications featuring 'Anthropocene' in the title or subtitle) does not often translate in defining *what about* the 'Anthropocene,' or even *which* 'Anthropocene,' is being considered. As a result, criticism unwittingly addresses conceptual 'layers' of the term, generating confusion over the specific issue at stake.

Nevertheless, an attempt to chart these muddy waters is made. This effort is based on two premises. The first premise is normative-methodological. Charting criticism from the humanities and social sciences *should be done* because such criticism has had an influence in forging the very 'scientific Anthropocene' as concept and discourse. Most notably, this criticism urged the AWG to delineate the boundaries of the 'stratigraphic Anthropocene' to differentiate it from variants of the broader 'Anthropocene' (a separation very close to the preliminary distinction grounding this research). In the group's latest monograph (Zalasiewicz et al., 2019b), it is clarified that the 'stratigraphic Anthropocene' "does not in any way restrict (or seek to restrict) the potential use of the word in other meanings, by other communities, as it has indeed been the case in the last decade" (p. 3). This statement does not merely witness the proliferation of multiple conceptual units of the 'Anthropocene,' it also witnesses the necessity of delineating the AWG's mandate as well as the conceptual and epistemological identity and purpose of the "geological Anthropocene" (ibid.) in light of the term's increasing polysemy. Thus, while maintaining the standpoint of the Anthropocene Hypothesis in order to survey criticism, it is considered paramount to address the broader discussions generated by the interplay of natural sciences, social sciences, and humanities in engaging with the 'Anthropocene.'

The second premise is descriptive. Criticism advanced so far exhibits observable similarities in addressing theoretical flaws seemingly implicit in the term as conceived by the natural sciences as well as the broader normative implications of its rhetoric. These similarities have been noted by 'Anthropocene' scholars who have also attempted to map existing criticism by either endorsing existing lines of criticism or by simply shedding light on extant debates. For instance, literary theorist Daniel Hartley (2016) summarizes five problems that the geological discourse of the Anthropocene – which would be otherwise "relatively harmless" (p. 155) – entails when translated into the political arena. These are (1) a seemingly ahistorical, unifying, and abstract conception of humanity, blind to the historical and cultural differentiations across societies; (2) an Anglocentric and apolitical technological determinism that promotes a model of historical causality "inadequate to actual *social* and *relational* modes of historical causation" (p. 156); (3) the subsumption of historical time to a single, "homogeneous time of linear succession, which increasingly contracts as catastrophe approaches" (p. 157); (4) a Whig view of history based on endless progress and enlightenment; and (5) the promotion of strong technocratic, managerial, and apolitical solutions by "Anthropocene scientists [who] cannot see technology as a political force, [and] so they cannot see politics as a material force" (ibid.).

Another attempt to navigate criticism and discussions of the 'Anthropocene' and its stratigraphic variant comes from Julia A. Thomas (2020). The historian defines three types of narratives or 'stories' of the 'Anthropocene' within Anthropocene Studies – namely, 'Anything Goes,' 'Singular Story,' and 'Democracy of Voices.' The 'Anything Goes' approach[295] sees disciplines engaging freely with the term by telling their own versions of the 'Anthropocene' with "little reference to the science" (Thomas, p. 43); the 'Singular Story' perceives humans' history as "integrated into the biogeophysical one" (p. 57) – that is, it sees human and Earth System history as an integrated continuum; and the 'Democracy of Voices' advocates for a "wider range of inventive possibilities" (p. 62) by exploring local stories and responses to the global 'Anthropocene.'

A third interesting attempt in navigating 'Anthropocene' criticism appears in an article published by the editors of *Scientific American* (2018). The article highlights some problems that the 'Anthropocene' concept and narrative entail. The first problem they identify is hubris, which they connect to the critique of anthropocentrism advanced by sociologist Eileen Crist (2013, but also present in other scholars, e.g., Mitman, 2018; Brannen, 2019). A second problem is the underlying unifying connotation of the 'Anthropocene' concept that dissolves responsibilities in engendering the Anthropocene. A third critique they find among anthropologists and social scientists addresses the implicit role that human nature, rather than human culture, invests in causing the dawn of a new epoch – a critique parallel to that of the term's supposed lack of historical (hence cultural) depth.

One last instance worth mentioning is Christophe Bonneuil's (2015) critique of the naturalist narrative. The historian finds three interrelated themes informing Earth System science and geosciences portraying the 'Anthropocene' within the natural sciences, namely:

> (1) the front-staging of 'the human species' as the undifferentiated causal force changing the Earth; (2) the recency of environmental consciousness thanks to Earth monitoring science, breaking with centuries of a modern dark age of unconscious impacts; and (3) the erasure of civil society and laypeople as producers of environmental knowledge and solutions, associated with a self-celebration of scientists as shepherds of humankind and of Earth and the advocacy of more science and green technologies to save the planet. (pp. 18-19)

[295] The terminology chosen to encapsulate this approach echoes Paul Feyerabend's (1993) famous epistemological anarchism, for which "[s]cience is (and should be) an essentially anarchic enterprise: theoretical anarchism is more humanitarian and more likely to encourage progress than its law-and-order alternatives" (p. 9). Feyerabend's approach suggested altogether abandoning the idea of a fixed scientific method and scientific rationality, and that only one 'rule' adapted to all circumstances in describing and directing science – that anything goes.

Bonneuil considers these aspects crucial in deconstructing the naturalistic narrative, which "tends to reproduce the grand narrative of modernity, that of Man moving from environmental obliviousness to environmental consciousness, of Man equaling Nature's power, of Man repairing Nature" (p. 23).

These excerpts provide a validating point for the premises set in this section – that is, the possibility as well as the necessity of mapping criticism. Notably, the criticism just surveyed seems to converge toward (at least) four specific arguments against the 'Anthropocene,' namely, (1) the unifying *Anthropos* argument, (2) the anthropocentrism argument, (3) the historical argument, and (4) the ethical argument. These are arguments at the forefront of humanistic and social science literature in Anthropocene Studies, engendering most of the discussions about and against the 'Anthropocene.' They share a common normative (viz. ethical, moral, aesthetic, political) matrix, as exemplified by Crist's (2013) critique of the term: "If a new name were called for, then why not have a conversation or a debate about *what it should be* [emphasis added], instead of being foisted (for a very long time, I might add) with the Age of Man as the 'obvious' choice?" (p. 142). Because the Anthropocene Hypothesis does not entail these types of normative statements, these four lines of critique necessarily mean to contest the 'Anthropocene' as a concept fraught with ethical, social, and political significance.

Before moving to an analysis of each of the arguments outlined above, two preliminary remarks are due. Firstly, it should be noted that arguments against the 'Anthropocene' are often semantically entailed. A clear example of this is T. J. Demos's (2017) critique of the 'Anthropocene.' The visual culture theorist states that

> Anthropocene rhetoric – joining images and texts – frequently acts as a *mechanism of universalization* [i.e., UAA], albeit complexly mediated and distributed among various agents, which enables the military-state-corporate apparatus to *disavow responsibility* [i.e., EA] for the differentiated impacts of climate change, effectively *obscuring the accountability* [i.e., HA] behind the mounting eco-catastrophe and inadvertently making us all complicit in its destructive project. (p. 19)

This excerpt shows three different arguments – that is, Undifferentiated *Anthropos* Argument (UAA), Ethical Argument (EA), and Historical Argument (HA) – relating to one another in a single paragraph. What this means is that separating each line of critique does not mean that each exists independently. Commonly, the main arguments against the 'Anthropocene' appear simultaneously in critical literature. Nevertheless, the rationale and purpose behind each argument justifies a basic and purely descriptive separation among different lines of critique.

Secondly, as anticipated at the beginning of the chapter, the lack of a multidisciplinary framework makes it difficult to precisely frame whether criticism is addressing the 'Anthropocene' or the Anthropocene Hypothesis. This distinction has not (yet) been established as an analytical tool in Anthropocene Studies. Criticism against the 'Anthropocene' often overlaps (explicitly or implicitly) with criticism against the Anthropocene Hypothesis. Nevertheless, the normative-descriptive divide assumed in section 1.3.1 provides an analytical tool for navigating different types of criticism based on content, assumptions, rationale, and purpose.

5.1.1 The Undifferentiated *Anthropos* Argument

Perhaps the most common (and intuitive) type of criticism against the 'Anthropocene' is the seemingly undifferentiated notion of *Anthropos* that the term conveys. This criticism rejects the notion of a single humanity acting as a synchronous and equally responsible agent for the dawn of the 'Anthropocene.' Defining the *Anthropos* has been a central question for scholars from the humanities and social sciences contributing to Anthropocene Studies because its definition has implications "for how we collectively imagine the human place on the planet, who gets counted under that umbrella of humanity, and how that vison should dictate the future of our socioecological relations on this planet and beyond" (Hoelle & Kawa, 2021, p. 1).

Criticisms against universalizing notions of 'humanity' long precede 'Anthropocene' debates. The humanities and social sciences (especially in terms of postcolonial literature) have been meticulously deconstructing Eurocentric or Western-centric narratives of *Anthropos* in the past decades. For instance, in introducing their volume *Rethinking Environmental History*, Hornborg et al. (2007) make clear that rather than focusing on "the abstract accretion of landscape changes or technological inventions as a collective human experience over time, it [the volume] seeks to highlight how such changes are distributed in space. *It acknowledges that humanity is not a single 'we' but deeply divided in terms of reaping the benefits versus carrying the burdens of development*" (p. 1, quoted in Robin & Steffen, 2007). Bonneuil and Fressoz (2016) also note that "[f]rom the Marxist concept of class to the anthropology of Claude Lévi-Strauss, feminist and post-colonial studies, these works have attacked the old universalism of 'Man' and emphasized the equal dignity but also diversity of cultures, societies, social classes and sexual identities" (p. 23). This increasing skepticism toward 'grand narratives' or seemingly all-inclusive concepts, particularly addressed towards the natural sciences, has echoed throughout Anthropocene Studies. Environmental historians, sociologists, philosophers, and anthropologists have been particularly attentive to deconstructing the seemingly unifying notion of *Anthropos* in the 'Anthropocene' by unveiling its assumptions, implications, and rhetoric – especially within the normative (political and ethical) arena. Here are some examples.

Sociologist Bronislaw Szerszynski (2012) asks "whose name [we would] be putting on the Anthropocene golden spike if one were ever placed in the great stone book" (p. 172). He argues that, similarly to biological nomenclature, the *Anthropos* in the Anthropocene represents a 'onomatophore' – namely, agreed reference points in biological typification represented by determined specimens whose characteristics embody the group they belong to.[296] If the Anthropocene is to be represented by our species through golden spikes, then what *Anthropos* "would be the onomatophore of the Anthropocene?" (p. 173). Szerszynski surveys different 'types' of *Anthropos* to answer this question – namely, *Homo faber*, the goal-oriented human whose ceaseless work has engulfed the Earth of its products; *Homo consumens*[297] or *Homo*

[296] For an epistemological discussion on the nature of types in scientific nomenclature and typification in science (including geology), see Bokulich (2020b).
[297] A similar term recently used by social scientists is *Homo consumericus*. See related Wikipedia page (accessed on April 28, 2021. Last revision: May 19, 2020, 18:47 CET by Zdravko mk).

colossus, the consumerist human whose indirect actions are increasingly exhausting and degrading the Earth's ecosystems; and *Homo gubernans*, the 'helmsman' whose actions will "inevitably become conditioned by those of the matter he attempts to steer, as he progressively entangles himself in the potentialities of matter" (p. 176).[298] He considers these 'syntypes' rather than 'holotypes' of the 'Anthropocene' – the former representing multiple specimens equally representing onomatophores of their species, the latter representing a single specimen acting as an individual onomatophore for its species. Based on this analogy, Szerszynski concludes that the *Anthropos* "is dispersed into a series of syntypes, multiple subject and object positions," meaning that no single *Anthropos* is representative of the 'Anthropocene,' but the plurality of its existential conditions.

Bonneuil and Fressoz (2016) deconstruct the *Anthropos* in the 'Anthropocene' in the fourth chapter of their book *The Shock of the Anthropocene*. They argue that the 'Anthropocene' thesis "supports the idea of a totalization of the entirety of human actions into a single 'human activity' generating a single 'human footprint' on the Earth," presenting "an abstract humanity uniformly involved – and, it implies, uniformly to blame" (pp. 65–66). This vision of an undifferentiated humanity ignores the multiple timescales of human societies under a generalist and quantitative view of human histories. It ignores specific questions of responsibility by attributing no weight to the uneven contribution to the environmental challenges characterizing the Anthropocene:

> But what is this *anthropos*, the generic human being of the Anthropocene? Is it not eminently diverse, with extremely different responsibilities in the global ecological disturbance? An average American, for example, consumes thirty-two times more resources and energy than an average Kenyan. A new human being born on Earth will have a carbon footprint a thousand times greater if she is born into a rich family in a rich country, than into a poor family in a poor country. Should the Yanomami Indians, who hunt, fish and garden in the Amazonian forest, working three hours a day with no fossil fuel (and whose gardens have a yield in energy terms nine times higher than the French farmers of the highly fertile Beauce) feel responsible for the climate change of the Anthropocene? (p. 70)

The authors suggest that the term 'Oliganthropocene' (originally introduced by the geographer Erik Swyngedouw[299]) may better represent the reality of the 'Anthropocene,' in that it would attribute its dawn

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[298] *Homo faber* is a term popularized by philosopher and political theorist Hannah Arendt to identify the goal-oriented and utility-driven existential condition of modern working humans. *Homo consumens* was coined by sociologist and philosopher Eric Fromm (1965), who defined it as "the man whose main goal is not primarily to *own* things, but to *consume* more and more, and thus to compensate for his inner vacuity, passivity, loneliness, and anxiety" (p. 214). *Homo colossus* was coined by the sociologist William Catton (1982), who used the term in his 1980 monograph *Overshoot*: "When the earth's deposits of fossil fuels and mineral resources were being laid down, Homo sapiens had not yet been prepared by evolution to take advantage of them. As soon as technology made it possible for mankind to do so, people eagerly (and without foreseeing the ultimate consequences) shifted to a high-energy way of life. Man became, in effect, a detritivore, Homo colossus. Our species bloomed, and now we must expect a crash (of some sort) as the natural sequel" (p. 155). Lastly, Szerszynski attributes the designation *Homo gubernans* to the philosopher Michel Serres (1995, quoted in Szerszynski, 2012).

[299] The original source of Swyngedouw's use of the term is a Power Point presentation held at the conference Sustained Unsustainability at the University of Bath on December 6, 2013. The presentation was entitled "Anthropocenic Promises. Interrogating Post-Democratization: Reclaiming the Political Environment." Slide 6 provides a definition of the Oliganthropocene as "an epoch of few men and even fewer women."

to a fraction of humanity (namely, the wealthiest and most energy-intense countries) rather than to all of it. They reject the use of 'human species' (viz. *Homo sapiens*) to identify the *Anthropos* of the 'Anthropocene,' denouncing "its effects on the type of 'solutions' that are proposed for ecological problems, whether they are legitimated or not in the narrative of the anthropocenologists" (p. 77).

The rejection of the species-narrative had already been advanced by Bonneuil (2015) in an edited volume published the year before, together with philosopher Clive Hamilton and political scientist François Gemenne (Hamilton et al., 2015a). Bonneuil considers the *Anthropos* portrayed by natural sciences a "biological category, the 'species' or the 'population', rather than specific social groups bearing situated cultural values and taking particular socio-economic and technical decisions" (p. 19). In his view, *Homo sapiens* is implemented as a causal explanation of human history in a way that obscures the actual (historical and socio-economic) causal mechanisms that engendered the Anthropocene phenomenon.

Criticism against attributing the dawn of the 'Anthropocene' to human nature has also been raised by human ecologists Andreas Malm and Alf Hornborg (2014). Examining the scientific literature on the 'Anthropocene' (at that time still largely focused on the Industrial Revolution as a possible starting date for the Anthropocene), the authors deconstruct the notion of *Homo sapiens* arguing that "[s]team engines were not adopted by some natural-born deputies of the human species: by the nature of the social order of things, they could only be installed by the owners of the means of production," who only represented "an infinitesimal fraction of the population of *Homo sapiens* in the early 19th century" (pp. 63–64). The bio-geological portrayal of *Anthropos* given by the natural sciences is argued to be "oblivious to its [own] anti-social tendencies" (p. 66), and to be ultimately analytically defective (other than ethically inefficient) because "[g]eologists, meteorologists and their colleagues are not necessarily well-equipped to study the sort of things that take place between humans" (ibid.). The Anthropocene is not causally determined by *Anthropos* (viz. *Homo sapiens*), but by specific societies, power relations, and modes of production related to a fossil-based economy.

A contributor to Moore's (2016a) *Capitalocene or Anthropocene?*, Hartley (2016) observes that "[a]t the heart of the Anthropocene lies the *Anthropos*: the human. But what or who is this *Anthropos*? No clear definition is ever given" (p. 155). His argument, based on a Marxist reading of the 'Anthropocene,' denounces the historical blindness of the term, which presupposes an abstract notion of humanity "belying the reality of class struggle, exploitation, and oppression" (p. 156). In line with the criticism expressed by authors throughout Moore's popular volume, it is the lack of historical depth – and the dangers entailed in burying the capitalist roots of the Anthropocene – that most concerns Hartley's reading of the term.

In addition to the historical and bio-geological questions, the issue of what *Anthropos* is represented in the 'Anthropocene' has also raised questions about gender. The archaeologist Alfredo González-Ruibal notes that, while humans need necessarily be acknowledged for their role, "we also have to acknowledge that the new geological era is not the work of generic humans, but of Man. It has been the Man of humanism – white, Western, male […] – that has created the critical conditions of our age. Yet the concept of Anthropocene conflates Man and human. It makes all humankind guilty of something for which many are not – if anything, they are the victims" (p. 4). Similarly, the ecofeminist and environmental scholar Giovanna di Chiro (2017) stresses critically the predominantly male composition of the AWG, and the Global North provenance of most of its members[300] – arguing that, "[m]irroring the race, gender, and class composition of other climate and environmental research and policy arenas, the Anthropocene might more appropriately be coined the *Man*thropocene" (p. 489). This type of discourse has consequences in terms of framing issues of environmental justice in ways that disregard the particular communities and groups historically and presently most afflicted by the 'Anthropocene.'

All these examples converge in criticism of one or multiple implications of the portrayal of an undifferentiated *Anthropos* drawn by the natural sciences engaging with the 'Anthropocene.' To better frame and discuss this criticism in respect to the Anthropocene Hypothesis, it seems reasonable to express it as follows:

> **UAA (Undifferentiated *Anthropos* Argument):** The concept/discourse of 'Anthropocene' postulates an undifferentiated and species-based notion of *Anthropos* that is historically inaccurate, ethically irresponsible, and analytically inefficient.

There are several observations to be made about UAA, the first of which concerns the concept/discourse distinction. The humanities and social sciences have been addressing issues entailing both aspects of the 'Anthropocene.' On the conceptual side, the term seemingly signifies too broad a category to provide any detailed representation of precisely *who* engendered the Anthropocene and *how*. However, there has been little research conducted from the perspectives of linguistics, philosophy of language, or theories of cognition and the mind regarding the status of the 'Anthropocene' as a *concept*. Since "[c]oncepts are the most fundamental constructs in theories of the mind," raising "so many controversies in philosophy and cognitive science" (Margolis & Laurence, 1999, p. 3), further research in this direction in Anthropocene Studies is much needed – especially from critics of the 'Anthropocene' concept. Multiple linguistic labels attributed to the term, from meta-concept to threshold concept and boundary object, make it even more problematic to represent the nature of the 'Anthropocene' as a concept.

On the discursive side, it seemingly provides strong technical and managerial solutions to problems of mostly scientific rather than social, political, or ethical framing. For instance, Crist (2013) defines *discourse* as "the advocacy and elaboration of rationales favoring the term in scientific, environmental, popular writings, and other media. The advocacy and rationales communicate a cohesive though not entirely homogeneous set of ideas, which merits the label 'discourse'" (p. 130). She then considers the 'Anthropocene' discourse as "constituted by a blend of interweaving and recurrent themes, variously developed or emphasized by its different exponents," noting that "the discourse goes well beyond the Anthropocene's (probably uncontroversial) keystone rationale that humanity's stratigraphic imprint would be discernible to future geologists" (ibid.). Her criticism of the 'Anthropocene' discourse as anthropocentric

[300] Di Chiro's observations are based on the AWG composition as of February 4, 2016.

is analyzed in section 5.1.2. Bonneuil (2015) also recognizes four different narratives or discourses within Anthropocene Studies, further proving the existence of the 'Anthropocene' discourse beyond its conceptual outline and perception among disciplines.

The second observation concerns the exclusion of the past and present multiplicity of human modes of existence in defining the 'Anthropocene' concept, and informing its discourse, by postulating an undifferentiated *Anthropos*. This criticism does not simply address the apparent lack of a detailed socio-historical and economic analysis of the Anthropocene phenomenon. It also concerns the past and present ways in which human societies have experienced (and are experiencing) the 'Anthropocene' – both as a concept and state of affairs. This is a particularly important question raised by anthropologists (e.g., Mathews, 2020) – that is, how do different systems of knowledge experience the Anthropocene? While every human society may not necessarily be engaging with the term or concept (which is, after all, a product of a specific knowledge system), the global extent of the phenomena that the 'Anthropocene' represents makes it a shared experience across human societies. Dissolving the past and present multiplicity of experiences under a single *Anthropos* means (according to UAA) privileging a particular viewpoint – that of a fundamentally Western *Anthropos*.

A related, third observation addresses the species-based definition of *Anthropos* informing the 'Anthropocene' concept/discourse. Many of the tensions between scientific and humanistic conceptions of the 'Anthropocene' stem from this specific framing. As criticized by Bonneuil (2015), "the 'species' or the 'population', rather than specific social groups bearing situated cultural values and taking particular socio-economic and technical decisions, is elevated to a causal explanatory category in the understanding of human history" (p. 19). This criticism aims at deconstructing the idea that *Homo sapiens* caused the 'Anthropocene' in a deterministic, naturalized fashion. The historical and ethical implications of this criticism are explored in later sections. Here, it is important to note that UAA considers *Homo sapiens* the key conceptual tool making the 'Anthropocene' a defective concept/discourse.

Does criticism raised by UAA also address the Anthropocene Hypothesis? That is, is the *Anthropos* postulated in the Anthropocene Hypothesis an efficient epistemic category?

The Anthropocene Hypothesis is a stratigraphic hypothesis. As such, it adheres to the practices and methods of traditional stratigraphic classification. However, by posing the commencement of the proposed epoch as the 1950s, and by attributing humans causal and geological agency, the hypothesis necessarily merges with (recent) human affairs. This circumstance is at the core of much of the conceptual overlap between the 'Anthropocene' and the Anthropocene Hypothesis. Indeed, it seems that the hypothesis requires several layers of analysis – from history, anthropology, and sociology to economics, international law, and stratigraphy – that are far beyond the traditional epistemology of stratigraphy. These layers of analysis are also reflected in the broader 'Anthropocene' which, as a concept and discourse unrestricted to the quest of formal geological ratification, requires a broader understanding of the phenomenon beyond pure stratigraphy. Locating these layers of analysis is of primary importance in understanding the stratigraphy of the Anthropocene, and directing its research in a complementary way –

as observed multiple times throughout this research. This is the case for the nuclear and thermonuclear bomb testing – an event associated with a substantial stratigraphic signal of major importance that has been *also* largely documented from a historical viewpoint. The recorded history of this event provides stratigraphy with additional explanatory power in framing phenomena of interest for the Anthropocene Hypothesis.

The multidisciplinary composition and method of the AWG has been one preliminary solution to the challenge of threading several layers of analysis together. This solution allows the generation of a research network around the Anthropocene Hypothesis that has been providing it with a certain degree of multidisciplinary explanatory power (as argued in section 4.2.2, the hypothesis does entail historical explanation as long as it is not taken in isolation, but within the research network that it has generated over the years). This network allows the AWG to explore research fields that would not (and could not) otherwise be part of traditional research interests within stratigraphy. Insofar as the historical research is seen as complementary, the *Anthropos* in the Anthropocene Hypothesis is not historically inaccurate.

Another observation is also due. To argue that the *Anthropos* is historically inaccurate presupposes that the Anthropocene Hypothesis requires a high-grain and historically sound definition of *Anthropos* to achieve an explanation and understanding of certain phenomena. However, *whether* and *to what extent* the *Anthropos* should be historically accurate in order to achieve these epistemic goals is assessed against the epistemological framework of stratigraphy, rather than history. That is because the aim of the Anthropocene Hypothesis is stratigraphic rather than historical. To request a thorough historical analysis *within* the Anthropocene Hypothesis is a knowledge-domain conflict: it is equal to requesting a stratigraphic classification of historical events such as the fall of the Western Roman Empire, the Battle of Lepanto, the First World War, or the election of Donald Trump. Intuitively, none of these requires stratigraphy to be comprehended, because stratigraphy is an unnecessary epistemic framework for delivering an explanation and understanding of these phenomena and events. This is not to say that historical research should not be frameworks to use to comprehend the broader implications of the 'Anthropocene' phenomenon. Rather, it means that the 'historical soundness' of *Anthropos* in the Anthropocene Hypothesis is ultimately judged by the stratigraphic actors supporting (or rejecting) the hypothesis.

Lastly, UAA claims that the notion of *Anthropos* in the 'Anthropocene' is ethically faulty, meaning that it avoids urgent questions of responsibility concerning both specific contributions to a certain undesirable state of affairs (i.e., the 'Anthropocene'). This criticism holds for the 'Anthropocene' in the broader normative (viz. ethical and moral) arena, and has been a central theme in philosophical approaches to it (Dalby, 2007b; Polt & Wittrock, 2018; Raffnsøe, 2016; Zylinska, 2014). However, because the Anthropocene Hypothesis *per se* does not entail normative claims of an ethical fashion, ethical responsibility is not a necessary epistemic parameter for delineating the *Anthropos* in the Anthropocene Hypothesis. Despite its implicit ethical overtone, amplified by popular culture as well as academic literature, the hypothesis does not provide any normative guidelines to follow, nor value-judgements connected to the stratigraphic signature of *Homo sapiens*. The hypothesis seeks to explain this anthropogenic signature, and to see possible ratification on the geological time scale – itself an organized system of knowledge that, disputes of a sociological nature aside, is not grounded on epistemic parameters of an ethical nature (i.e., it does not ask whether geological time units are ethically good or not). This is also one of the reasons behind the use of the broader epistemic category of *Homo sapiens* for delineating the *Anthropos* in the Anthropocene Hypothesis across literature (including the present research). This latter aspect needs further consideration.

5.1.1.1 Homo sapiens *in the Context of Stratigraphic Classification*

Does the species-based definition of *Anthropos* represent an analytical flaw for the Anthropocene Hypothesis? That is, is *Homo sapiens* an insufficient epistemic category, as argued by UAA?

The answer to these questions depends on the type of explanation and understanding expected, which in turn depends on the specific disciplinary framework one is located within when raising such questions. Intuitively, *Homo sapiens* would be too broad a category in historical, sociological, or anthropological research – where the existence of a vast array of human cultures throughout the history of humanity is a defining epistemic premise that cannot be deduced from a broader, species-based category. However, because the Anthropocene Hypothesis seeks to explain the anthropogenic signature in stratigraphic terms, stratigraphy represents the reference framework determining whether or not the category of *Homo sapiens* is analytically flawed. This requires an understanding of the use of '*Homo sapiens*' within stratigraphic classification.

Homo sapiens is the taxonomical label used in virtually all of the natural sciences, from evolutionary biology and genetics to comparative neuroanatomy and paleoanthropology, to separate (and locate in the larger 'tree of life') the anatomical and genetic traits that distinguish our species from other species, from other apes, and from earlier hominins[301] (Carroll, 2003). The term was first used in 1758 by the Swedish botanist Carl Linnaeus (Tattersall, 2020) – renowned for developing the binomial nomenclature in biological taxonomy[302] – in the tenth edition of his *Systema naturae* (Tattersall, 2020). Today, the term provides (not without debates on the matter) biological unity to all members of our species – so that all *Anthropoi* potentially share, in principle, the basic (descriptive) properties of *Homo sapiens*.

Geology has never widely used the term – mostly because it did not need to. For instance, Charles Lyell's (2003a, 2003b, 2003c) three-volume *Principles of Geology* does not seem to use the label '*Homo sapiens*,' instead addressing humans simply as humans, or as the 'human race' or 'human species.' Discussions on the geological agency of humanity in 19th-century geological literature do not seem to engage with this label

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301 The term "'hominins' refers to humans and our evolutionary ancestors back to the separation of the human and ape lineages; 'hominids' to humans and the African apes" (Carroll, 2003, p. 849).

302 Binomial nomenclature is a taxonomical system used to classify living organisms based on *generic name* (e.g., *Homo*) and *specific name* (e.g., *sapiens*). The system underpins the present nomenclature codes for algae, fungi, and plants (*International Code of Nomenclature for algae, fungi, and plants* (ICN)); animals (*International Code of Zoological Nomenclature* (ICZN)); bacteria and archaea (*International Code of Nomenclature of Prokaryotes* (ICNP)); cultivated plants (*International Code of Nomenclature for Cultivated Plants* (ICNCP)); plant associations (*International Code of Phytosociological Nomenclature* (ICPN)); and viruses (*International Code of Virus Classification and Nomenclature* (ICVCN)). See the Wikipedia page 'Nomenclature codes' for an overview (accessed on July 23, 2021. Last revision: July 16, 2021, 01:21 CET by Beland).

either, despite the 'proximity' of geological time and historical time.[303] With the discovery of the Earth's true age, and the paleoanthropological research on humans' lineage, geological and historical time further expanded, making *Homo sapiens* (either as a species or as a geological agent) somewhat 'irrelevant' in the reconstruction of the Earth's history. Only with the onset of the 'Anthropocene' debates has the term *Homo sapiens* garnered substantial interest in the geological jargon.[304] Why, then, select this category, given its seemingly scarce historical and theoretical application in geological research?

One answer reiterates the fact that stratigraphy is not equipped "to study the sort of things that take place between humans" (Malm & Hornborg, 2014, p. 66) – as also recognized by critics of the 'Anthropocene' concept. Because humans have occupied only an infinitesimal fraction of geological time, the study of the Earth's history has mostly evolved (especially in the 20th century) without attributing to *Homo sapiens* any special role (except, perhaps, for biblical readings of geological time). Our species only represents one among countless species that have existed, and will exist, in the depth of the Earth's history. While reconsidering humans' geological agency through *Homo sapiens* perceived negatively by critics as "an attempt to conceptually traverse the gap between the natural and the social – already thoroughly fused in reality – through the construction of a bridge from one side only" (ibid.), it rather represents a condition grounded in the specific epistemology of stratigraphy. This supposed 'deficiency' is countered by establishing a research network that allows scholars to probe the multiple historical and cultural realities of *Homo sapiens* – something that stratigraphy alone does not (and cannot) do.

Another possible answer looks at the historical epistemology of geology. Throughout the late 18th and 19th centuries, biology and geology formed a strong partnership. Both were at the forefront of imperialistic exploration (and colonial) initiatives. Especially during the 19th century, "the foundations of geology could scarcely be separated from biological concerns" (Davis, 2011, p. 79). Both geology and biology underwent major theoretical developments – uniformitarianism in geology, championed by Charles Lyell in his *Principles of Geology*,[305] and biological evolution through natural selection, championed by Charles Darwin in his 1859 landmark publication *The Origins of Species*. Darwin himself was well versed in geology, and its role, contributions, and inspiration from and to the discipline have been recently revived (e.g., Herbert, 1986, 1991, 2005; Nature, 2009). Fossils represented material of scientific, philosophical, and theological interest for geologists, who speculated on the origins and age of fossils; and for biologists, who had begun to systematically classify past and present living organisms and speculate on the origins of life. Geology "provided the time scale and time frame in which evolution has been generated" (Leddra, 2010, p. 151) – a time frame consistent (after some initial resistance) with Darwin's theory of evolution. Conversely, fossils provided geologists with the means to divide geological time, providing additional material to develop a relative time scale. This disciplinary partnership has continued to the present day. Indeed, modern chronostratigraphy uses biostratigraphic markers (usually the first appearance datum of a fossil species, see section 3.2.1.6) as primary markers for defining the base of chronostratigraphic units

[303] This does not mean that humans were not an object of geological discussion, which they were. See Davis (2011).
[304] With the exception of those instances of geological reflexivity briefly discussed in section 1.2.4.
[305] For a detailed history of geology during the 19th century, see Greene (1982).

through GSSPs. Likewise, it is standard practice for evolutionary biologists (and natural scientists dealing with deep time) to use geological time as reference framework. This applies not simply to prehistoric species, but also to our very own *Homo* lineage – as exemplified by literature describing important evolutionary steps of *Homo sapiens* (e.g., a "marked increase in absolute brain size by the *Early Pleistocene* and again in the *Middle Pleistocene*," Carroll, p. 851 [emphases added]).

A third connected answer is that the use of *Homo sapiens* is a matter of frameworks. This point has also been noted by Chakrabarty (2009):

> It is clear that different academic disciplines position their practitioners differently with regard to the question of how to view the human being. All disciplines have to create their objects of study. If medicine or biology reduces the human to a certain specific understanding of him or her, humanist historians often do not realize that the protagonists of their stories—persons—are reductions, too. (p. 215)

The 'reduction' of humans to *Homo sapiens* is only functional to the specific understanding that the Anthropocene Hypothesis aims at conveying. As long as this category is useful in providing "acceptable answers to interesting questions" (L. Laudan, 1977, p. 13), there is no reason for the hypothesis not to use this particular framing of humans.

These short answers hint that selecting *Homo sapiens* as the preferred category underpinning the Anthropocene Hypothesis has been the most practical and natural choice by geologists and stratigraphers. The category resonates with the epistemology of stratigraphy, and with the linguistic developments in this field as a result of its partnership with other natural sciences, particularly biology. Nevertheless, attempts to employ a finer-grain lens of analysis while maintaining the *Homo sapiens* category have been advanced. For instance, ecological research authored by the environmental scientist and AWG member Erle Ellis (2011a, 2015, 2016b; Ellis et al., 2009; Ellis et al., 2013; Ellis & Ramankutty, 2008) attempts to map the present relationship between *Homo sapiens* and ecosystems in terms of anthropogenic biomes or 'anthromes.' A biome is a basic ecological concept historically "identified and mapped based on general differences in vegetation type associated with regional variations in climate" (Ellis & Ramankutty, 2008, p. 439). Anthromes represent biomes shaped and characterized by human actions, and they "offer a framework for incorporating humans directly into global ecosystem models" (p. 446). They provide the stratigraphic category of *Homo sapiens* with ecological foundations (especially because anthropogenic stratigraphic signals are also *ecological* signatures) by implementing time-sensitive indicators such as population density, land use, and land cover. In fact, Ellis (2011a) hypothesizes that "changes in the terrestrial biosphere made directly by human populations and their use of land represent the emergence of a suite of novel geologic processes in the Earth system comparable in scale with those used to justify the major divisions of geologic time" (pp. 1010–1011). These changes include alterations of "patterns of soil erosion, soil and sediment chemistry, sedimentation rates, isotope signatures, charcoal, artificial substances, and plant and animal remains" (p. 1017) – all of which may reflect stratigraphic evidence for the Anthropocene Hypothesis.

As Ellis (2016b) argues, the "capacity of human societies to construct their ecological niche at increasing social and spatial scales" (p. 63) represents the *explanation* of why *Homo sapiens* (rather than other species) has become such a predominant geological agent. This explanation is grounded in the epistemology of stratigraphy (because of the emphasis placed on stratigraphic markers) and eco-evolutionary biology. Particularly, human niche construction (Boivin et al., 2016; Ersten et al., 2016; Kendal et al., 2011a, 2011b; Laland et al., 2001) provides a useful framework to ensure that the category of *Homo sapiens* (as used in the Anthropocene Hypothesis) does ultimately entail epistemic power beyond the mere taxonomical label because it poses central questions about the relationship between humans and their surroundings – which have now extended to planetary scales. While historians have criticized this deduction of human transformative power from humans' outstanding niche-constructing capacities, this analysis neither contradicts nor contrasts with the historical analysis. It simply complements it from a different epistemological framework. This framework does not raise questions of a strictly historical, social, or ethical nature because *Homo sapiens* represents a descriptive category, implemented within a determined system of knowledge (that of the natural sciences). It is not meant to answer broader philosophical questions of an existential, social, or political nature (despite the fact that it might raise them) – lest it commit the naturalistic fallacy.

Hence, if *Homo sapiens* can be further dissected in a way that aligns with the practices and language of stratigraphy (for instance, through evolutionary ecology) while also providing new knowledge, it seems reasonable to infer that *Homo sapiens* is not analytically flawed. If so, then based on the previous analysis of the sub-arguments informing UAA, it can be argued that UAA does not hold for the Anthropocene Hypothesis.

5.1.2 The Anthropocentrism Argument

Another common argument against the 'Anthropocene' accuses the concept/narrative of being anthropocentric. This critique accuses the term of investing humans with an unjustified and alarming form of exceptionality. Authors have considered the 'Anthropocene' idea the "latest incarnation of anthropocentric thinking" (Suckling, 2014), or even "supreme narcissism" (Jensen, 2013). In what ways is the 'Anthropocene' anthropocentric? Should the Anthropocene Hypothesis also be considered anthropocentric? To answer these questions, one has to look at what makes any concept and/or narrative anthropocentric in first place.

While anti-anthropocentrism has become a theoretical and methodological postulate and goal for the great majority of environmental scholars, the meaning of 'anthropocentrism' is in fact more problematic than is often acknowledged. This is mostly because many connotations of the term exist, rendering it difficult, if not vague, to contest 'anthropocentrism' without specifying which kind is being considered.[306]

[306] For a list of possible meanings of 'anthropocentrism' in academic literature, see Mylius (2018).

Therefore, defining anthropocentrism is paramount in assessing criticism against the 'Anthropocene' and determining whether or not such criticism holds for the Anthropocene Hypothesis.

Debating and deconstructing *ethical anthropocentrism* – according to environmental ethics, the philosophical doctrine or "belief that value is human-centered and that all other beings are means to human ends" (Kopnina et al., 2018, p. 109) – has become an overarching goal across disciplines such as ecocriticism, environmental history, ethnography, postcolonial studies, and environmental philosophy. Debunking narratives of traditional humanism is also the purposes of recent intellectual movements such as posthumanism or neo-materialism. Particularly in contemporary environmental ethics, the discussion between anthropocentrism and non-anthropocentrism has been central at least since Lynn White's (1967) radical article "The Historical Roots of Our Ecological Crisis," which famously criticized Christianity (especially in its 'Western' guise) as "the most anthropocentric religion the world has seen" (p. 1205) and modern science and technology as the "Occidental, voluntarist realization of the Christian dogma of man's transcendence of, and rightful mastery over, nature" (p. 1206). The idea that anthropocentric worldviews, and particularly the Judeo-Christian tradition, were responsible for the present global environmental predicament "has been most enthusiastically received by environmentalists and environmental scholars" (Minteer & Manning, 2005, p. 164), who use it to construe alternative, more inclusive ethical systems (e.g., systems ascribing non-human animals ethical status).

Ethical anthropocentrism is not the only type of anthropocentric. The environmental political theorist Tim Hayward (1997) considers anthropocentrism to be a problem that is largely misunderstood. He recognizes different types of anthropocentrism, noting that "there are some ways in which humans cannot help being human-centered" (p. 51). Based on Ferré (1994), he defines this view as *perspectival anthropocentrism*. This is the same type of anthropocentrism recognized by political philosopher Ben Mylius (2018) as a *perceptual anthropocentrism* – namely, an anthropocentrism that "is directly or indirectly informed by data received or gathered by the senses of the human body" (p. 166). It represents a type of anthropocentrism wired to the neurocognitive and evolutionary functions and characteristics distinctive of *Homo sapiens*, and therefore unobjectionable. Perspectival or perceptual anthropocentrism is descriptive – that is, it is a form of anthropocentrism that is neither good nor bad, but simply explains what makes forms of human-centeredness unavoidable; it is "it is 'centered upon' *Homo sapiens* or the concept of 'the human' in one (or many) ways" (ibid.). Hayward (1997) argues that recognition of the inescapability of some forms of human-centeredness makes the equation between human-centeredness and anthropocentrism untenable – if anthropocentrism is considered undesirable. Instead, he suggests using the terms 'speciesism' or 'human chauvinism' – the former representing arbitrary and unjustified discrimination on the basis of species, the latter representing the arbitrary, unjustified, and self-proclaimed superiority of human characteristics, functions, or capabilities (e.g., language, opposable thumbs, abstract thinking) in a way that favors humans themselves – as better representatives of "illegitimate ways of giving preferences to human interests" (p. 53).

Hayward also notes a second type of anthropocentrism (in addition to ethical anthropocentrism) usually criticized by environmental ethicists – that is, *ontological anthropocentrism*. This doctrine "assumes human-centeredness and the privileged position of human beings" and "claims a superior ontological position of human beings and perceives them as the pinnacle of creation" (Dzwonkowska, 2018, p. 724). Biblical geocentric cosmological models,[307] the Intelligent Design argument, or human exceptionality in the universe are examples of ontological anthropocentrism. Ontological anthropocentrism does not necessarily entail ethical anthropocentrism, and vice versa (although they might support each other). To claim that humans are the physical center of the universe and creation does not imply that humans are the highest ethical subject. Conversely, being the highest ethical subject does not require that humans occupy a particular ontological position in the universe or creation. Hayward (1997) considers ontological anthropocentrism an "error" (p. 49) or "mistake" (p. 50). While his concerns mostly address ethical anthropocentrism, he also argues that the ontological "displacement of human beings from the center stage in the greater scheme of things has been made possible, above all, by developments in modern science" (ibid.) – characterized by a principle of objectivity and neutrality (*sensu lato*) that debunked humans' ontological primacy and their place in the universe. Copernicus's heliocentric model or Darwin's theory of evolution by natural selection are common examples of such developments.

A third kind of anthropocentrism concerns *epistemological anthropocentrism*. As defined by the ecologist and philosopher Dominika Dzwonkowska (2018), this type of anthropocentrism "is directly connected with our cognitive capabilities, which are limited to knowing the world from our perspective only" (p. 726), and thus cannot be overcome. This formulation seems to equate epistemological anthropocentrism to perspectival or perceptual anthropocentrism. However, because epistemology, by definition, concerns the nature, structure, and value of knowledge, to reduce knowledge *only* to perceptual or sensorial capabilities (only *one* of the characteristics of knowledge) does not intimately grasp the meaning of epistemology. Thus, epistemological anthropocentrism should not be equated to sensorial perceptual/perspectival anthropocentrism – despite the latter as a precondition for the former. Rather, epistemological anthropocentrism implies that all human *knowledge* (regardless of its specific historical or cultural system) is necessarily anthropocentric: "human beings are such that the limits and form of their knowledge necessarily takes a human reference" (Faria & Paez, 2014, p. 100). It takes a further step from delimiting the *sensorial* limits of humans to defining the *epistemic* limits of humans. Epistemological anthropocentrism shares similarities with Mylius's (2018) *descriptive anthropocentrism* because they both emphasize knowledge claims of a descriptive nature (statements of fact rather than statements of value) – despite the fact that epistemological anthropocentrism may also include value judgements. Descriptive

[307] It should be noted that placing humans at the center of the universe does not immediately translate into ontological anthropocentrism. One has to first account for the historical and social context wherein certain geocentric cosmological models were formulated based on the evidence and observations available at the time. Likewise, placing the Sun at the center of the solar system may be based on extra-empirical considerations, or on intentionally biased accounts of a descriptive nature (see Mylius, 2018). Additionally, religious forms of anthropocentrism may perhaps be better characterized as *metaphysical anthropocentrism*, in that they postulate metaphysical causes for the ontological primacy of humans (e.g., humans are created after the image of a God). Ontological anthropocentrism, while conceptually (and historically) close to metaphysical anthropocentrism, does not necessarily entail metaphysical claims.

anthropocentrism "begins from, revolves around, focusses on, takes as its reference point, is centered around, or is ordered according to the species *Homo sapiens* or the category of 'the human'" (p. 168). Epistemological anthropocentrism represents a vast research theme shared across traditional and social epistemology, cognitive science, psychology, neurobiology, theory of mind, and more. For this reason alone, the definition hereby adopted is unlikely to encompass all existing formulations of epistemological (or epistemic) anthropocentrism identified by scholars. In the present context, it is only relevant to observe that (1) it is directly related, but not equivalent to perspectival/perceptual anthropocentrism; (2) it represent an unavoidable, but not immutable form of anthropocentrism (i.e., knowledge systems vary over time but remain *human* frameworks nevertheless); and (3) it may represent an epistemic obstacle if, and only if, enforced normatively (e.g., claiming that a determined human system of knowledge is *better* than any other human or non-human system of knowledge;[308] or that only *human* knowledge is *true* knowledge).

Ethical, perspectival/perceptual, ontological, and epistemological anthropocentrism represent four common types of anthropocentrism engendering discussions about the place of humans on the Earth. These should not be considered as conclusive, nor as reflecting all possible formulations of anthropocentrism recognized by scholars. Moreover, some authors (Dzwonkowska, 2018; Hayward, 1997; Mylius, 2018) warn that many of the discussions on anthropocentrism are substantially of a terminological nature: they depend on the semantic characterization and basic definition given to articulate discussions of anthropocentrism. Nevertheless, these considerations provide a basic conceptual toolkit for navigating criticism of the 'Anthropocene' based on claims of anthropocentrism.

It was perhaps natural for scholars enmeshed in anti-anthropocentric intellectual, political, and social agendas to express concerns about the idea of naming the latest epoch of the Earth's history after humanity. In practical terms, this skepticism has been fueled by translation of the 'Anthropocene' designation into the 'Age of Man,' 'Age of Humans,' or 'Human Age' – either by academics (e.g., Braje, 2016; Kress & Stine, 2017; Monastersky, 2015; Neimanis et al., 2015) or in the media (e.g., Kolbert, 2019; Sample, 2014) – and by its association with technology- and economic-oriented solutions proposed within the broader social and political arena to face the current environmental challenges (e.g., geoengineering, as originally advocated by Crutzen). Skepticism soon transformed into criticism and rejections of the 'Anthropocene' as a concept/discourse crystallizing anthropocentrism in geological terms. Here are some examples.

[308] This example touches on the vast research landscape conducted in the post-Kuhnian history and philosophy of science concerning the idea of scientific progress and the incommensurability of scientific theories. The term 'incommensurability' was popularized in the philosophy of science by the work of Thomas Kuhn and Paul Feyerabend. In short, the idea behind incommensurability is that different scientific theories, and especially successive theories, cannot be compared with one another because they share no common measure to allow comparison (see Hacking, 2012, pp. xxx-xxxiii). No scientific theory is, properly speaking, 'better' than another because they may have a different set of problems, methods, and language that do not provide rational and equal ground for preferring one over the other. Within this framework, epistemological anthropocentrism is considering one theory or hypothesis T_1 to be better than another T_2 based exclusively on the internal values of T_1 – which is equivalent to saying that T_1 is better than T_2 because it is T_1 (circular reasoning).

Crist (2013) argues that the 'Anthropocene' "has morphed into a discourse that is organizing the perception of a world picture (past, present, and future) through a set of ideas and prescriptions that is tenaciously anthropocentric" (p. 129). These ideas and prescriptions are articulated in a variety of ways among different knowledge contexts, from environmental ethics to the natural sciences. They emphasize the role of humanity (as a whole) in engendering today's environmental challenges, and promote techno-managerial solutions that adhere to the existing modes of production oriented toward economic growth and well-being. For Crist, these assumptions and prescriptions render the 'Anthropocene' concept/discourse fundamentally anthropocentric. She argues that

> this name [the 'Anthropocene'] is neither a useful conceptual move nor an empirical no-brainer, but instead a reflection and reinforcement of the anthropocentric actionable worldview that generated "the Anthropocene" – with all its looming emergencies […] By affirming the centrality of man – as both causal force and subject of concern – the Anthropocene shrinks the discursive space for challenging the domination of the biosphere, offering instead a techno-scientific pitch for its rationalization and a pragmatic plea for resigning ourselves to its actuality. The very concept of the Anthropocene crystallizes human dominion […] a name which has no added substantive content, no specific empirical or ethical overtones, no higher vision ensconced within it – beyond just Anthropos defining a geological epoch. (pp. 129, 141–142)

This criticism addresses a range of descriptive and normative facets that the concept/discourse of 'Anthropocene' seems to lack or obscure by promoting (an undifferentiated) *Anthropos* as central actor – both as causal agent and ultimate steward – of the 'Anthropo-stage.'

Similarly, environmental historian Timothy J. LeCain (2015) has argued that, "[w]hile perhaps not the intent of its creators and advocates, the term itself is unapologetically anthropocentric" (p. 3). In his paper "Against the Anthropocene," the author explores the concept/discourse of 'Anthropocene' from a neo-materialist perspective. Neo-materialism (or new materialism) is a type of post-humanist philosophy aiming at reconsidering materiality by challenging "the still dominant modernist belief that human culture is distinctly separate from the material world, suggesting that matter not only helps to create human intelligence, creativity, and culture, but may often be best understood as *constituting* these things" (p. 2). This stance considers human culture as a product of the material world, rather than as a dissociation from it. Consistent with this methodological assumption is a strong anti-anthropocentric agenda that rejects the traditional humanist philosophies (intended as human-centered systems of knowledge), but also rejects postmodern social constructivist theorizing.

Through this theoretical framework, LeCain argues that the 'Anthropocene' "tends to encourage the hubristic modernist faith in the human ability to fix the resulting problems" (p. 4). According to the historian, this tendency is exemplified by the 'Good vs. Bad Anthropocene' dispute that occurred between environmental journalist Andrew Revkin and philosopher Clive Hamilton (Hamilton, 2014a, 2014b;

Revkin, 2014a, 2014c).[309] LeCain considers the eco-pragmatist arguments[310] for a 'Good Anthropocene' "as a logical extension of the essential anthropocentrism of the concept itself" (p. 4), which is fundamentally possible by emphasizing humans' geological agency. By doing son, LeCain argues that "we begin to overestimate human power and agency, tending towards a celebratory stance even when the intent is to be critical" (ibid.).[311] This seemingly implicit celebratory stance parts ways with a neo-materialist perspective, which "argues that we humans derive much of what we like to think of as *our* power, intelligence, and creativity, from the material things around us" (ibid.). For LeCain, the intrinsic anthropocentrism of the 'Anthropocene' does not decentralize humans, but rather emphasizes their agency at the expense of the material world. If so, then other terminological substitutes, such as Carbocene or Thanatocene, may provide "a more modest understanding of the human place on the planet" (p. 23).[312]

In an essay published on the *Law & Liberty* website, environmental historian Paul Schwennesen (2020) criticizes the use of the term 'dominance' to address the relationship between humans and the Earth.[313] He argues that defining the 'Anthropocene' in terms of human dominance over planetary processes "does two things: first, it gratifies our aching human desire to believe in our own centrality. Second, it opens the lid to a Pandora's box of political controls – a field where *dominance* has more than abstract relevance." Our centrality is exalted if compared to the biological, chemical, and geological 'dominance' of organisms such as cyanobacteria, or by natural events such as volcanic eruptions which would have equal if not larger impact than human activity. For Schwennesen, the naming choice as well as the 'dominance' rhetoric are largely grounded on political convenience, so that "our 'unprecedented' impacts must be reined in by our governors, and quickly, there's no time to lose."

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[309] The dispute saw Revkin advocating for the possibility of envisioning a 'Good Anthropocene' – one driven by a positive attitude and amazement about the possibility of tackling the current environmental issues, thereby generating a brighter 'Anthropocene' future; and Hamilton considering the idea of a 'Good Anthropocene' delusional and "unscientific" (Hamilton, 2014a). The dispute is exquisitely narrativized in a paper by the geographer and environmental scholar Simon Dalby (2016).
[310] According to Hamilton (2014b), eco-pragmatism is a 'neogreen' movement gravitating around the Breakthrough Institute – an environmental research center and think tank based in Oakland, California, that emphasizes technical solutions to environmental problems. The movement is enthusiastic about technological and scientific progress, and about the possibility of achieving a 'Good Anthropocene' by means of economic growth, innovation, and scientific/technological development.
[311] This argument seems to suggest that attributing *Homo sapiens* geological agency is an overestimation of the species' geological relevance, and that necessarily implies a type of celebratory stance (exemplified by the eco-pragmatism movement and the 'Good Anthropocene' idea). While the latter point needs further consideration within the normative arena, overestimations of the geological significance of *Homo sapiens* are countered by distinguishing between geological *forces* and geological *agents*. This distinction (promoted in section 3.1.1) helps clarify what type of geological significance our species represents without falling into risk of overestimation.
[312] This criticism also suggests a problem of a nominalist nature. It is not solely the content of the 'Anthropocene' concept/discourse, but its signifier that represents an issue.
[313] Schwennesen is directly referring to an article published by Paul Crutzen and Christian Schwäger on the Yale School of the Environment website, where the authors define the Anthropocene as a reality characterized by "human dominance of biological, chemical and geological processes on Earth" (https://e360.yale.edu/features/living_in_the_anthropocene_toward_a_new_global_ethos, accessed on September 30, 2021).

The criticisms sampled here converge in arguing against the seemingly hubristic and anthropocentric connotation of the 'Anthropocene.' The following argument may summarize this type of criticism:

> **AA (Anthropocentrism Argument):** The concept/discourse of 'Anthropocene' promotes forms of ontological, epistemological, and ethical anthropocentrism by affirming the centrality of humans as a dominant (geological, biological, and ecological) force.

Two observations clarify the thesis advanced by AA. The first observation concerns the types of anthropocentrism that AA attributes to the 'Anthropocene.' Elevating the status of *Homo sapiens* to a geological force is problematic in several respects, as also argued in section 3.1.1. To further claim that humans have become a *dominant* geological force is, for critics of the term, an evident sign of ontological anthropocentrism. It is a way to help assuage "our sense of yawning insignificance" (Schwennesen, 2020) in light of the depth of geological time – of which *Homo sapiens* only occupies an infinitesimal fraction.

Epistemological anthropocentrism seemingly appears by humans' placement at the center of knowledge production about the 'Anthropocene.' This is partially inevitable because, as previously observed, humans cannot avoid generating *human* knowledge. However, the epistemic anthropocentrism of the 'Anthropocene' concept/discourse manifests itself in (1) neglecting more-than-human types of knowledge (Haraway, 2015; Swanson et al., 2015), (2) flattening different experiences of the Anthropocene (Chatterjee, 2020; Hecht, 2018; Kwai-Cheung & Yeung, 2019), and (3) framing the discourse exclusively in geological terms (Bostic & Howey, 2017; Ellis, 2016a).

Ethical anthropocentrism is closely tied to the seemingly hubristic rhetoric of stewardship – one that sees humans both as the fundamental threat to the Earth's stability and at the same time its ultimate solution by means of technology and human-focused well-being (Dalby, 2007b; Neimanis et al., 2015; Robin, 2018; Zylinska, 2014). Concerns over the ethical usefulness of the term are considered separately in section 5.1.4.

The second observation concerns the meaning of 'dominant force,' and more precisely the definition of 'dominant.' As also observed by Schwennesen (2020), the way 'dominance' is defined has several implications for what the 'Anthropocene' entails semantically. The Cambridge Dictionary[314] defines the verb 'to dominate' as "to have control over a place or person." Its etymology (from the Latin *dominus*: lord, master; and *dominat-*; ruled, governed) also suggests proximity with 'control,' generally to the advantage of the one who is dominating. These are common linguistic expressions in Anthropocene literature portraying the role and agency of humans with respect to the Earth System, climate change, the sixth extinction event, and in the geo-stratigraphical context. However, if exercising dominance with respect to something means *to be in control in a way that those exercising control are better off*, then humans (collectively) are clearly not dominating the Earth. The rationale is simple: if the 'Anthropocene' is a worse state for humans

[314] https://dictionary.cambridge.org/dictionary/english/dominate (accessed on July 5, 2021).

than what came before, and if the 'Anthropocene' is a product of human actions, then humans are not controlling (and thus not dominating) the Earth or the Earth System – because dominating requires those exercising control to be better off as a result. An example may illustrate this point: a drunken driver is neither dominating nor controlling their car, nor are they better off (in principle) in driving under the influence of alcohol – although they represent the primary causal (and eventually legal) agent of the present and possible future state of the car. Furthermore, if dominating (and controlling) requires consciousness of the act of dominating (and controlling), then humans have been only *indirectly* influencing the Earth System both from a historical and present viewpoint. Recent reactive and proactive responses from international agencies, NGOs, governments, and movements worldwide may be interpreted as a step toward controlling the Earth's status.

Linguistic digressions aside, humans *appear* dominant in the same way they appear as a geological *force*, while instead they are best represented as a geological *agent* – as also argued in section 3.1.1. Feasibly, the 'dominant' designation represents a figure of speech fraught with normative value. Nevertheless, this note is important to understand much of the criticism against the ontological status of humans advanced by AA.

Does criticism raised by AA also address the Anthropocene Hypothesis?

The distinction between different types of anthropocentrism raises important questions concerning the very nature of human knowledge, and requires a separate analysis beyond the scope of this research. In virtue of the evolutionary history and basic cognitive capabilities that define our species, it is reasonable to argue that it is unavoidable to incur some form of perspectival anthropocentrism. That is true for the Anthropocene Hypothesis as for any other form of human thought. However, the more pressing matter concerns forms of ontological and epistemological anthropocentrism of the 'Anthropocene,' and how these may reverberate in the formulation of the Anthropocene Hypothesis.

Is the Anthropocene Hypothesis ontologically anthropocentric? As observed, accusations of ontological anthropocentrism raised by AA largely gravitate around considerations of humans as a *dominant geological force*. Scientists and scholars around the AWG (and the broader environmental discourse) have themselves repeatedly portrayed humans as such (Crutzen & Stoermer, 2000; Robin & Steffen, 2007; Rockström et al., 2009b; Steffen et al., 2011b; Steffen et al., 2004b; Zalasiewicz et al., 2011b; Zalasiewicz et al., 2008b). As mentioned, this label is more often used as an informal and normative-oriented metaphor than a precisely defined epistemic category. However, there are reasons for arguing that the Anthropocene Hypothesis neither presupposes nor implies ontological anthropocentrism.

Firstly, because Claim 1 – that is, '*Homo sapiens* has left a discernible stratigraphic signature of significant magnitude in the recent geological history' – is a *descriptive* statement. If descriptive statements are in principle value-free, and if ontological anthropocentrism entails value judgements, then it follows that Claim 1 is in principle not (ontologically) anthropocentric. Nevertheless, being descriptive alone does not shield Claim 1 (and thus the hypothesis) from being anthropocentric *per se* because descriptive statements are not always value-free. In fact, there are always degrees and types of value entailed in any description because they are always part of a determined system of beliefs that is never purely 'neutral.' It is because *Homo sapiens* so happens to be the species that has left a discernible stratigraphic signature in the most recent geological history that makes it non-(ontologically) anthropocentric.[315] *Homo sapiens* is not attributed a certain status (in this case, geological agency) *because* of its being *Homo sapiens* (which is the characteristic sin of ontological anthropocentrism). Claim 1 could be reformulated as '*X* has left a discernible stratigraphic signature of significant magnitude in the recent geological history,' where *X* would represent any other species whose stratigraphic signature were substantial enough to delineate a boundary on the geological time scale (in which case, probably the designation '*Anthropo*-cene' would be replaced by '*X*-cene,' or by the standard stratotype designations for geological nomenclature).

A second reason why the Anthropocene Hypothesis neither presupposes nor implies ontological anthropocentrism is because the hypothesis considers *Homo sapiens* a geological *agent* rather than a geological *force*. This distinction avoids the issue of ontological anthropocentrism because it does not elevate humans to the same 'ontological class' as those geological forces that have been shaping the Earth for millions to billions of years. Furthermore, the Anthropocene Hypothesis does not strictly *require* humans to represent a geological force as a theoretical postulate to advance its core arguments. It so happens to assume this designation within the broader recognition of stratigraphic anthropogenic patterns observed across the globe. Whether or not humans are considered a geological force, the stratigraphic basis for upholding each of the three central claims of the Anthropocene Hypothesis is the empirical body required to support the arguments advanced by the hypothesis. The same is true for considering humans a dominant biological and ecological force. Naturally, this does not negate nor diminish the spectrum and gravity of anthropogenic disruption of the Earth, its biota, and its ecosystems.

A last reason concerns geologists' awareness of humans' existential contingency. This is particularly clear once *Homo sapiens* is placed in the context of geological and biological time – a time scale geologists are very accustomed with. A basic tenet of evolutionary biology is that the "morphological evolution in hominins was not special, but the product of genetic and developmental changes typical of other mammals and animals" (Carroll, 2003, p. 852). Darwin's famous narcissistic wound was only doubled by the discovery of geological time during the 20th century. Transcriptions of the 'Anthropocene' into the 'Age of Humans' (or similar variants) have been considered by the AWG to be "in some respects misleading" (Zalasiewicz et al., 2019b, p. 3) in framing the Anthropocene as a geological time unit, in that the epoch "is considered as an epoch of Earth time, just like all Earth's previous epochs" (ibid.). It is neither teleology nor necessity that defines the Anthropocene time unit – it "so happens its distinctive characteristics have up until now been driven largely by a variety of human actions" (ibid.). There is no ontological primacy ascribed to *Homo sapiens* in the Anthropocene Hypothesis, but rather observations of the stratigraphic effects of its (most recent) existence.

[315] It is important to note that the fact *Homo sapiens* so happens to be the species under scrutiny does not lead to any determinism. As historians have rightfully noted, it is not because of being *Homo sapiens* that certain social organizations, energy regimes, or modes of production have contributed (more than others) to the dawn of the 'Anthropocene.'

Is the Anthropocene Hypothesis epistemically anthropocentric? Criticism of epistemological anthropocentrism raises the questions on (1) what framework generates the very knowledge about the 'Anthropocene,' and on (2) the issue of reflexivity (i.e., humans studying human affairs) in assessing the stratigraphic footprint of our own species.

The former point concerns *who* is advancing the hypothesis. This criticism has been raised against the 'Anthropocene' in light of exclusion of particular knowledge systems – e.g., the 'African Anthropocene' (Hecht, 2018) or the 'Asian Anthropocene' (Chatterjee, 2020) – or criticism against 'White Geology' (Yusoff, 2019). This criticism does not so much attribute anthropocentrism to the category of *Homo sapiens* or *Anthropos*, but rather to the mostly 'Western,' male, and white-dominant epistemology informing and implementing these categories. These are complex issues stemming from recent scholarship in feminist, black, or indigenous epistemology. However, there has not been (as of March 2021) substantial empirical work of a sociological, psychological, or educational nature to assess how these epistemologies would affect the methodologies of stratigraphy[316] (e.g., how gender or ethnicity would affect the construction of the geological time scale and stratigraphic classification). This lack is reinforced by the general broader interest in the 'Anthropocene' rather than the Anthropocene Hypothesis, manifested in the humanistic engagement in Anthropocene Studies (also confirmed by the almost utter absence of a philosophy of science in the debating arena). Thus, any assessment on the matter would necessarily be premature – although crucial for a thorough analysis of the Anthropocene Hypothesis from multiple epistemologies.

The issue of reflexivity concerns *what* the hypothesis is arguing. The issue occurs in measuring the stratigraphic footprint of *Homo sapiens*. How are humans to measure their own stratigraphic signature without risking over- or underestimating its empirical and epistemological significance? One way that research on the Anthropocene Hypothesis has overcome this theoretical dilemma is by comparing quantitatively the products of human activity with those of natural processes – for instance, in terms of energy flow (Syvitski et al., 2020), material flow (Douglas & Lawson, 2001), denudation rates (Wilkinson, 2005), nitrogen fixation (Canfield et al., 2010), or niche-constructing activities of other species (Ersten et al., 2016; Kendal et al., 2011a, 2011b; Odling-Smee et al., 2003). These numerical proxies provide a basis for comparative analysis between human agency and geological (and biological) forces to assess the stratigraphic significance and importance of *Homo sapiens*. A second argument, which has been used both *for* and *against* the Anthropocene Hypothesis, is the 'future geologist argument' – that is, speculating how future geologists would assess present anthropogenic stratigraphic signatures. This argument is separately discussed in section 5.2.1.

If epistemological anthropocentrism "begins from, revolves around, focusses on, takes as its reference point, is centered around, or is ordered according to the species *Homo sapiens* or the category of 'the human'" (Mylius, 2018), it seems at first plausible to consider the Anthropocene Hypothesis (in virtue of its claims) epistemologically anthropocentric. However, as previously noted, it is precisely the adoption

[316] If compared, for instance, to the examples of primatology (see Godfrey-Smith, 2003, para. 9.3) or developmental psychology (e.g., Carol Gilligan's work on *In a Different Voice*, 1982).

of the evolutionary and taxonomical category of *Homo sapiens* that overcomes epistemological anthropocentrism of this kind. '*Homo sapiens*' provides a sufficient epistemic detachment that allows us to study it from a geological and stratigraphic viewpoint in the same way it allows evolutionary eco-biology or genetics to study ourselves as a species. From this viewpoint, the hypothesis provides evidence suggesting an objective stratigraphic pool of signals that cannot be ignored in stratigraphic classification. Consequently, there is nothing ontologically *special* about *Homo sapiens*, its geological agency, or its stratigraphic signals, but there are rather characteristics that make it geologically and stratigraphically interesting. This point is articulated by Ellis (2011a):

> Humans differ profoundly from every other species in the way we transform ecosystems, and our differences are partly responsible for our large populations. Three differences stand out. First, humans are ecosystem engineers – species like the beaver that alter their environment by mechanical or other means. Second, we are capable of manipulating a wide array of powerful tools in this effort, including fire. Third, we are social creatures capable of collective action and social learning in our ecosystem engineering and other activities. Separately, none of these capacities is novel in the history of the biosphere. It is their realization within a single species that has driven the rise and evolution of human systems that are far more complex, powerful and novel in the biosphere than even the sum of their billions of individual human parts. Even with a population of seven billion, *Homo sapiens* is not an entirely novel force of nature. But human systems are. (pp. 1011–1012)

Epistemological anthropocentrism is an issue that largely depends on terminology, and thus risks becoming a mere nominalistic dead end. What is important to highlight is that the Anthropocene Hypothesis does not seem to entail this type of anthropocentrism as long as the very epistemology upholding the hypothesis does not emphasize *Homo sapiens* solely *because* it happens to be the species we are, with implicit repercussions about *who* is advocating for the hypothesis, and *what* the hypothesis is advancing. While this may look trivial, the issue of reflexivity (which is often proportional to how close certain issues involving human affairs are to the present) is a problem that, while common in disciplines such as sociology, psychology, or history, is unprecedented in geological discourses.

Lastly, AA states that the 'Anthropocene' also entails forms of ethical anthropocentrism. This criticism does not hold for the Anthropocene Hypothesis because the hypothesis does not entail any type of normative-ethical statements, and thus cannot be ethically anthropocentric. Discussions of the broader social value of scientific ideas are always present, especially when these ideas cross with human affairs of primary importance, such as the current global environmental challenges. The 'Anthropocene' is situated at the intersection of this discourse between 'facts' and 'values' – promoting a name that would serve as a 'warning' to humanity in the geological arena. This argument has also been advanced by the AWG (Zalasiewicz et al., 2019b). Yet, it is important to distinguish the social utility of an idea from its epistemology. In the case of the Anthropocene Hypothesis, it is not its normative-ethical claims that directly support its empirical claims. Rejection or ratification of the hypothesis is likely to have some degree of normative-ethical implications, but these options are (and should be) assessed based on the epistemic virtues (e.g., explanatory power, intelligibility, empirical adequacy, etc.) of the evidence provided in its support. An argument against the *scientificity* of the hypothesis based on normative-political motifs seemingly behind the hypothesis is discussed in section 5.2.3.3.

Therefore, criticism raised by AA against the 'Anthropocene' does not seem to entirely address the Anthropocene Hypothesis as well – with the only exception of epistemological anthropocentrism, requiring further research concerning different epistemologies of geological time and how they would generate new useful knowledge.

5.1.3 The Historical Argument

A shared rationale underpinning both UAA and AA is the lack of historical soundness of the term 'Anthropocene' as used in the natural sciences discourses. This criticism has been repeatedly considered throughout the present work and largely overlaps with other lines of criticism observed so far. Thus, it is hereby only briefly summarized.

History became an important contributor to the semantics of the 'Anthropocene' during the late 2000s. The multi- and interdisciplinary atmosphere gravitating around the pioneering work of the IGBP and the Earth System Partnership ensured that historical research was not neglected in contextualizing the Earth System – as exemplified by the IHOPE (Integrated History and future Of People on Earth) project (Robin & Steffen, 2007, see also section 2.1.3.3). The 'Anthropocene' did not emerge as a historical object, but its connection with human history was latent since its inception. Crutzen and Stoermer's (2000) landmark article suggested the Industrial Revolution (a *historical* period) as a possible starting date for the Anthropocene.[317] The Great Acceleration (also a *historical* period) was shortly afterward connected to the term as well (Costanza et al., 2007), followed by the Nuclear Age (Waters et al., 2015) and other alternative starting dates from hundreds to thousands of years in the past. This is not trivial: stressing historical times was not merely a practical necessity, but was the first sign that the 'Anthropocene' represented an object of historical concern. As stated by historian Libby Robin and chemist Will Steffen (2007), the "Anthropocene defines the momentous and *historical* change in circumstances whereby the biophysical systems of the world are now no longer independent of the actions of people" (p. 1699). Chakrabarty's (2009) seminal paper *The Climate of History* argued that those circumstances deeply challenged the fundamental assumption of history "that our past, present, and future are connected by a certain continuity of human experience" (p. 197). His paper ignited a series of debates that have in particular engaged historians with the theses promoted – especially the convergence of human and natural (viz. geological) history through the 'Anthropocene.'

The 'Anthropocene' became an established object of historical (and broadly humanistic) interest after 2009. Thereafter, historical scholarship (especially environmental history) began to systematically explore and question the rationale of the 'Anthropocene' concept/discourse. Questions concerning the beginning of the Anthropocene – i.e., the Neolithic Revolution, the Industrial Revolution, or the Atomic

[317] Crutzen was also a contributor to the IHOPE project.

Age – engendered discussions of a historical rather than a geological nature. In the normative arena, these discussions raised further questions concerning the meaning and implications of selecting a beginning that have been fraught with political and historical significance. To this day, historians remain divided on the utility of the 'Anthropocene,' some showing suspicion towards its assumptions, rhetoric, and implications. In particular, advocates of the 'Capitalocene' idea (Moore, 2016a) have criticized the seemingly oblivious nature of the 'Anthropocene' concept to its real historical roots, which they locate in the 16th century CE. Skepticism against the seemingly unifying *Anthropos* (as in UAA), or which historical subject(s) to include in the 'Anthropocene' (Emmett & Lekan, 2016), has had several historians rejecting the seemingly all-inclusive notion of *Homo sapiens* used by the natural sciences to characterize the Anthropocene.

Criticism against the historically oblivious nature of the 'Anthropocene' transformed into criticism against the explanatory power of the term, and thus against epistemic utility. Bonneuil and Fressoz (2016) observe:

> The entry into the Anthropocene was intrinsically bound up with capitalism, with the commercial nation-state and the genesis of the British Empire, which dominated the world in the nineteenth century and forced other societies to serve its model or to seek to follow it. Similarly, the Great Acceleration *cannot be understood* [emphasis added] without the Second World War, the Cold War in which two blocs rivalled one another in the mobilization of the globe, and – since it emerged victorious – without American imperialism. (p. 289)

The Great Acceleration has been a key historical period in framing the 'Anthropocene' in the Earth System discourse. The period also coincides with the time window chosen by the AWG to locate a possible beginning of the Anthropocene as a geological time unit – that is, around the 1950s. If this time frame is insufficient to understand the deeper historical and social roots of the 'Anthropocene,' then the notion is epistemically insufficient. Delimiting the 'Anthropocene' concept/discourse to the Industrial Revolution or the Great Acceleration makes it fundamentally useless, if not historically inaccurate. This point is further reiterated by Malm (2014), who argues that "[t]heorists of the epoch have little to say about the actual causes of the rise of steam, but they do propound a general framework for understanding the transition to fossil fuels in the Industrial Revolution, which, for reasons of logical necessity, is deduced from human nature" (p. 63). Its lack of historical depth makes the 'Anthropocene' a term with little or no explanatory power concerning the causal mechanisms (e.g., social, political, cultural, economic, etc.) that engendered it. If so, then its epistemic utility is doubtful.

While criticism of historical kind merges with other lines of criticism (as seen in UAA and AA), its relevance in Anthropocene Studies deserves a separate formulation that can be expressed in the following argument:

> **HA (Historical Argument):** The lack of explanatory power concerning the deeper historical mechanisms of the 'Anthropocene' phenomenon makes the concept/discourse of 'Anthropocene' epistemically insufficient.

HA shares with UAA criticism against the epistemic utility of the 'Anthropocene' concept/discourse. Whereas UAA expresses historical, ethical, and epistemic concerns regarding the *Anthropos* postulated in the 'Anthropocene,' HA specifically addresses the lack of epistemic utility in relation to the historicity of the term. Because the concept/discourse does not explain the deeper historical mechanisms that engendered the Anthropocene, the term is considered to lack explanatory power – therefore providing an ahistorical, species-based narrative of the recent history of humanity and its relationship with the Earth. Ultimately, if the term lacks explanatory power, then it is epistemically insufficient because it fails to grasp the very thing it seeks to explain – that is, the impact of humans on the planet. This line of reasoning *assumes* historical research to be a necessary aspect of the geological, but also the broader natural sciences, discourse on the 'Anthropocene.'

Criticism connected to HA does not solely raise concerns regarding the historical validity of the term, it is also deeply embroiled in normative-ethical statements. It is crucial, critics argue, that historical mechanisms are properly discussed to frame subsequent questions of responsibility and attribution of recent anthropogenic environmental challenges. The question of identifying the historical causation behind the dawn of the 'Anthropocene' also means assigning historical and ethical responsibility. This argument is parallel to the ethical argument (EA), explored in the following section.

Does HA hold for the Anthropocene Hypothesis as well? A partial and preliminary answer to this question was anticipated in section 1.2.3 by proposing a complementary (rather than antagonistic) view on the historical and geological research. Based on this premise, section 4.2.2 further explored models in the philosophy of science that would best frame and represent the explanatory power and intelligibility of the hypothesis. While as a technical (viz. stratigraphic) term, the 'Anthropocene' lacks explanatory power (Renn, 2020; Rosol et al., 2017) because it only serves as a signpost for classifying geological time (in the same way the labels chosen for other geochronological time units do not entail explanatory power), it has been argued that the Anthropocene Hypothesis does on the contrary entail explanatory power. Three arguments have been promoted in support of this thesis, namely (1) the way that stratigraphic evidence for an 'Anthropocene' unit is presented – which has had historians and stratigraphers discussing a common object from complementary angles; (2) the multidisciplinary nature of the research group promoting the Anthropocene Hypothesis (i.e., the AWG); and (3) a comparative analysis of the explanatory power of the Alvarez Hypothesis. These arguments showed that historical considerations have not been absent in the theoretical forging and development of the Anthropocene Hypothesis. Rather, they complemented the necessary methodological deficiencies that stratigraphy, in virtue of its subject matter and epistemic context, cannot directly tackle. Thus, if the Anthropocene Hypothesis does entail explanatory power in the way highlighted, then the antecedent in HA is false, and the argument does not hold for the hypothesis.

It must be observed that considering the 'Anthropocene' *epistemically* insufficient (i.e., not achieving a particular epistemic goal, such as explanation or understanding of a phenomenon) is a statement that is not true or false *per se*. Any concept is either sufficient or insufficient based on the epistemological framework implementing it. Hence, it is plausible that the 'Anthropocene' is too broad a category for historians, who otherwise engage with the particular technological, scientific, environmental, economic, political, or other aspects that the 'Anthropocene' may too quickly condense into a single and stratigraphy-based conceptual unit. In the same way epistemic virtues such as explanatory power or intelligibility are always context dependent, being epistemically sufficient depends upon the specific epistemological framework in which one is situated. In the case of the Anthropocene Hypothesis, the empirical content (Chapter 3) and its epistemology (Chapter 4) are of a stratigraphic nature (although entailing multidisciplinary methods). Therefore, assessments of epistemic validity and utility of the hypothesis remain within this specific disciplinary and epistemic domain.

5.1.4 The Ethical Argument

A fourth (and here last) major line of criticism raised against the 'Anthropocene' comes from the normative-ethical research within Anthropocene Studies. Because one of the central premises of this research is that the descriptive and normative-methodological/functional nature of the Anthropocene Hypothesis neither entails nor presupposes normative-ethical claims, it follows that normative-ethical criticism against the 'Anthropocene' cannot equally hold against the Anthropocene Hypothesis. Hence, this section only outlines the inchoate landscape of ethical discussions about the 'Anthropocene.' Nevertheless, because scientific hypotheses are always part of societal contexts characterized by the existence of certain value systems (including scientific values), questions of a normative intent are raised in terms of what (if any) the ethical implications might be of the hypothesis and its surrounding discourse.

Ethical concerns inform much of UUA, AA, and HA. UUA considers *Anthropos* to be ethically irresponsible because it obfuscates questions of responsibility for the dawn of the Anthropocene. AA raises questions of anthropocentrism that include ethical anthropocentrism. HA implicitly stresses that, by lacking sufficient historical depth, the term necessarily fails to raise important questions of historical responsibility. These types of concerns have a longer history predating the dawn of the 'Anthropocene' debates. They originated in the increasing global environmental awareness that the second half of the 20th century witnessed through the formation of local and international institutions, think tanks, research programs, environmental movements, NGOs, and more. This global environmental movement has been championing initiatives to study, teach, prevent, and counteract the wide spectrum of social and environmental threats posed by anthropogenic activities. Because the 'Anthropocene' has been recently used as an umbrella term to frame this vast research and social landscape, it also absorbed the same ethical questions underpinning it.

For instance, the paleontologist and AWG member Reinhold R. Leinfelder (2013) argues that, from an ethical standpoint,

> the Anthropocene emphasizes that all of us – from individuals to states to the United Nations – are collectively *responsible* for the future of the world [...] As a conceptual framework, the Anthropocene

> could hence provide a solid basis for envisioning a *sustainable* human presence on Earth in which humans would no longer be "invaders" but rather participants in shaping the natural environment. (p. 9, emphases added)

This statement locates two central themes in the environmental discourses that have been shaping the 'Anthropocene' concept in the normative-ethical arena – that is, responsibility and sustainability. Invoking new responsibilities (Ellis, 2009), stewardship (AESS, 2014; Palsson et al., 2013; Steffen et al., 2011b), or ethical precepts (Polt & Wittrock, 2018; Zylinska, 2014) has transformed the 'Anthropocene' into more than merely a scientific term belonging to a discrete academic niche. The expression has become a vector for social change, used to inform the public about anthropogenic alteration of the globe through museum and gallery exhibitions, documentaries, and other forms of sensibilization and education.

However, some scholars have raised criticisms against the ethical validity of adopting this term to frame the present discussions on anthropogenic modifications of the Earth. For instance, the environmental scholar and ecofeminist Giovanna di Chiro (2017) argues that "the pan-humanism of the concept of Anthropocene reflects and shores up neoliberal, individualist, entrepreneurial forms of 'resilience', which trade on the notion that if 'we' (humans) are *all* to blame for the climate crisis, then *no one* is to blame and, therefore, *no one* is responsible, so we're all left to our own devices to become more resilient" (p. 489). Resilience is one of the key concepts in environmental literature that has engaged with the 'Anthropocene,' and thus needs some additional remarks.

'Resilience' is "[t]raditionally understood as a prevention of disasters or a capacity for individuals or systems to manage and rebound from a disruption" (Schwarz, 2018, p. 528), and has recently been embraced by a variety of disciplines, from psychology to national security and climate change. The term has also seen applications in ecology, originally defined as a "measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables" (Holling, 1973, p. 14). Dedicated research and initiatives have connected the 'Anthropocene' with ecological (or generally environmental) discourses on resilience (Fox et al., 2017; Grove & Chandler, 2017; Kareiva & Fuller, 2016; Robin, 2014b; Rockström et al., 2009a; Steffen et al., 2018). The Stockholm Resilience Centre (SRC) was founded in 2007 to "advance the scientific understanding of the complex, dynamic interactions of people and nature in the Biosphere, train the next generation of sustainability researchers and leaders, and engage in collaborations with change agents" (SRC, n.d.). A research project entitled 'Earth Resilience in the Anthropocene' was promoted by the SRC in conjunction with the European Research Council for the "analysis of nonlinearity and abrupt shifts, and informing global sustainability policy processes" (ERA, n.d.). One of the Future Labs (i.e., research themes) of the Potsdam Institute for Climate Impact Research addresses the theme 'Earth Resilience in the Anthropocene,' attempting "to develop a framework to characterize the resilience of the Earth System in the Anthropocene" (FutureLab, n.d.). A journal entitled *Resilience: A Journal of the Environmental Humanities* was founded in 2014, merging 'Anthropocene' themes with the topic of resilience. A special issue of *Resilience: International Policies, Practices and Discourses* entitled 'Resilience and the Anthropocene' was published by the journal in 2017 – a clear sign of interest in establishing a dialogue between these two terms. As part of the book series 'Routledge Research in the Anthropocene,' Routledge published *Resilience in the Anthropocene: Governance and Politics at the End of the World* in April 2020. These are examples witnessing the close link between the two concepts of 'Anthropocene' and resilience in recent scholarship.

Following di Chiro (2017), resilience – with its neoliberal, individualist, entrepreneurial connotations – favors an 'invisible hand' approach to the environmental challenges posed by humanity. This approach suggests that human systems (viz. the market) will eventually adapt to the stress they themselves impose on the Earth. Such adaptation will be an automatic response granted the way human societies (viz. the neoliberal market and technology) work. For di Chiro, such a narrative is supported by the 'Anthropocene' concept/discourse. The term does not reflect the realities of environmental justice and climate justice politics because it postulates an undifferentiated *Anthropos* that does not equally allocate responsibility, and thus does not assume a justice-based definition of resilience. Rather, it encourages 'bouncing back' to the *status quo* – the very same conditions that engendered the 'Anthropocene' in first place.

The environmental humanist and queer theorist Dana Luciano (2015) conceives the 'Anthropocene' as essentially "a political strategy, notwithstanding its scientific verifiability; its intent is not simply to carve humanity's name upon the stratigraphic map (humans, after all, invented the map in the first place), but to raise awareness of the *negative* planetary impact of certain human activities, with the intent of altering or mitigating them." Within the very stratigraphic agenda is a social message of political power, one linked to the determination of the impact of human activities that distinctively marked the beginning of the proposed epoch. Rather than raising a criticism, Luciano points out the political and ethical implications of selecting one among possible starting dates, from the colonization of the Americas to the Nuclear Age.

Adding to multiple lines of criticism, Crist (2013) argues that nothing about the 'Anthropocene' discourse, and much less the term itself, "offers an alternative to the civilizational revamping of Earth as a base of human operations and functional stage for history's uninterrupted performance" (p. 140). Adding neither an empirical nor ethical overtone, the concept fails to provide a basis for defining the Earth as something more than a managerial affair, instead insisting on a techno-scientific and rationalizing pitch that obstructs any other alternative ethical or social-oriented endeavor. Additionally, Crist criticizes the idea that the term would serve as a warning to the world, rhetorically asking "[w]hy (and how) would a term *with no content* other than the brazen face of 'anthropos' stamped over the face of the Earth, be a warning to the world?" (ibid., footnote 42).

Criticism of the term's utility in science and environmental communication has also been raised by Santana (2019b, discussed in section 4.1.3.2), who has challenged the idea that official recognition of the Anthropocene Epoch would increase environmental awareness in the public sphere. He considers this claim wishful thinking. This criticism addresses the utility of the term in science communication and is based on the premise that scientific consensus on anthropogenic alterations of the Earth does not reflect the public's environmental sensibility. Santana draws on the example of climate change discussions in the United States, "where the public is neither aware of the consensus nor in general agreement with it" because of (among other things) misinformation campaigns. This occurs despite the broad consensus and publicity that climate change research has achieved through "activists, professional scientific organizations, and government agencies." This fact alone suggests that the 'Anthropocene,' which has received far less attention in the public environmental discourse than climate change, would fail as an ethical device for science communication.

These excerpts provide a sufficient basis for formulating the ethical argument as follows:

> **EA (Ethical Argument):** The concept/discourse of 'Anthropocene' is ethically insufficient because (1) it promotes forms of ethical anthropocentrism and neoliberal responses to the environmental challenges it encompasses; (2) it dissolves questions of responsibility; and (3) it fails to convey any valuable and useful normative message in the public arena.

Criticism raised by EA addresses the 'Anthropocene' as generally portrayed by the discourse of natural scientists. As anticipated, EA intersects with the other arguments outlined in the previous sections. With them, EA contests the basic idea that the 'Anthropocene' could provide ethical as well as empirical content with broader normative utility, rather than representing a mere label or technical term of exclusively stratigraphic use. However, because the epistemological analysis of the Anthropocene Hypothesis so far conducted suggests that the hypothesis does not entail normative-ethical statements, EA does not apply to the Anthropocene Hypothesis.

Section 1.3.2 suggested that the statements that *Homo sapiens* has left a discernible stratigraphic signature of significant magnitude in recent geological history (Claim 1), and that this signature could be translated into the geological time scale (Claim 2) as a series/epoch (Claim 3), are not normative-ethical. Rather, Claim 1 is descriptive-observational (it states that something happens to be the case), whereas Claim 2 and Claim 3 are normative-methodological (they state how the division of the Quaternary should be rearranged in respect of the empirical evidence provided). The societal relevance of these statements is a different set of statements that *follows* from empirical and theoretical recognition of a certain state of affairs (in the same way anthropogenic climate change and the ozone layer represent social issues *after* they have been recorded and documented). As also stressed by the AWG (Zalasiewicz et al., 2019b), it is important to distinguish between the *scientific usefulness* and the *societal utility* of the Anthropocene Hypothesis:

> One is the potential usefulness for science, involving or facilitating a paradigm shift (and this is the matter to which the mandate of the AWG study is limited). The second is a broader societal relevance due to enhanced awareness raising (and therefore stretching into the sphere of political perception of the Anthropocene), and this is a fundamentally different consideration. (p. 39)

Because scientific usefulness is always context dependent, it is determined within the original epistemological context of the hypothesis (i.e., stratigraphy), and assessed by the epistemic actors affected by the acceptance or rejection of the hypothesis (e.g., a non-geologist can hardly assess whether the hypothesis is useful or not for geologists). The societal utility of the Anthropocene Hypothesis beyond the natural sciences has been considered by using the cases of international law (para. 1.4.3.1) and public health science (para. 1.4.3.2). However, this represents a different analysis from the ethical points raised by EA – that is, the *ethical* utility of the 'Anthropocene' concept.

Szerszynski (2012, p. 169) has argued that "[i]n terms of environmental ethics, one might say that geology is brutally consequentialist – it does not matter what one does, or why one did it, just what consequences it will leave behind" (p. 169). Similarly, the AWG (Zalasiewicz et al., 2021) has emphasized that "it is an important feature of the geological meaning of the Anthropocene in that it refers to the *manifestation* of human effects: the *consequence* in strata" (p. 6). This pragmatic tenet stresses the importance of the geological traces over the causal mechanisms that engender them in defining an Anthropocene Series in the stratigraphic record. Perhaps much of the ethical and historical controversy around the 'Anthropocene,' and raised by EA and HA, gravitates around the implications (and interpretations) of this statement. Nevertheless, whilst the ethical utility of the 'Anthropocene' remains an open question to be answered within ethical discourses in Anthropocene Studies, it has been shown how the Anthropocene Hypothesis can be approached as an epistemic entity avulsed from internal considerations of normative-ethical value.

5.2 Against the Anthropocene Hypothesis

Criticism against the Anthropocene Hypothesis reflects criticism against the evidence submitted, its stratigraphic significance, the proposed ~1950 boundary, the seemingly 'unorthodox' nature of the hypothesis and research methods of the AWG, and the overall utility of the Anthropocene in the scientific community. Such criticism has been advanced by scientists close, and even internal, to the Group. For instance, the archaeologist and AWG member Matt Edgeworth (2014b; Edgeworth et al., 2019; Edgeworth et al., 2015) has opposed a chronostratigraphic definition of the Anthropocene, advocating instead for a diachronous onset rather than a GSSP-based beginning. This view is shared by other AWG members, such as Ellis (2016a), who argues that "long-term reshaping of Earth systems by humans is being ignored in the group's discussions" (p. 192). An important voice in the debate has been the Quaternary geologist Philip Gibbard, also Secretary-General of the ICS and himself an AWG member. He has also opposed formal recognition of the Anthropocene, advancing a series of theses intersecting with several of the arguments highlighted in this section.

Other relevant figures in the geological community who have raised important criticism against the Anthropocene Hypothesis are the geologists Michael Walker (Professor Emeritus of Quaternary Science at the University of Wales, UK), Stan Finney (Professor of Geological Sciences at California State University, Long Beach, US), Martin J. Head (Vice-chair of the Subcommission on Quaternary Stratigraphy), Lucy Edwards (member of the United States Geological Survey), Whitney Autin (Professor of Geology at SUNY Brockport, US), John Holbrook (Professor of Geology at Texas Christian University, US), and William Ruddiman (paleoclimatologist at the University of Virginia, US). These figures of predominantly Anglophone provenance have contested the Anthropocene Hypothesis by advancing several types of critiques, publishing in geology-oriented academic platforms such as *GSA Today*, *The Holocene*, and *Quaternary International* as well as in newspapers and blogs. In turn, this mounting criticism has initiated a lively debate with promoters of the Anthropocene Hypothesis (i.e., the majority within the AWG) – who have absorbed or responded to criticism on several occasions (Zalasiewicz & al, 2012; Zalasiewicz et al., 2017b). Published journal articles from these figures represent the primary sources for surveying criticism against the hypothesis.

Aside from criticism of ideological science, most of the literature surveyed shares a common critique of the Anthropocene Hypothesis as a *stratigraphic* hypothesis. This pool of criticism differs from the critiques advanced against the 'Anthropocene,' in that the broader normative aspects of the hypothesis are not the primary object of concern for scientists rejecting the hypothesis. Rather, the epistemological aspects that represent the main hubs of discussion are the possibility, plausibility, and significance of the stratigraphic footprint of *Homo sapiens* from a present as well as future perspective (section 5.2.1);[318] the tension between diachronous and synchronous signals of the Anthropocene (section 5.2.2); the methodological and empirical consistency of the hypothesis in the context of stratigraphic classification (section 5.2.3); and the overall utility of the Anthropocene Hypothesis for and science (section 5.2.4). The disciplinary matrix (and thus content) of this type of criticism makes it substantially different than criticism against the 'Anthropocene' – despite the semantic overlap between the two theoretical entities (i.e., the 'Anthropocene' and the Anthropocene Hypothesis) that still occurs in scientific literature.

Criticism against the Anthropocene Hypothesis is surveyed in a descriptive fashion. Whilst section 5.1 aimed at assessing whether arguments against the 'Anthropocene' held equally against the Anthropocene Hypothesis, no such aim is pursued in overviewing this criticism – besides remarks emerging organically from the way the arguments are expressed. This is because the primary target is neither to defend nor attack the Anthropocene Hypothesis, but to consider criticism because of its epistemological value for science. Exclusion of criticism in an epistemological analysis of the hypothesis would result in a substantial and unjustified research vacuum. Furthermore, criticism has played an important role for the historical-conceptual development of the hypothesis. For instance, criticism against the GSSA methodology

[318] This section also explores an argument in favor of geological recognition of a human stratigraphic footprint (the Positive Future Geologist Argument). Delineating a profile of this argument aids an understanding of the arguments advanced against the plausibility that *Homo sapiens* will leave a discernible and significant stratigraphic mark from a future perspective.

persuaded AWG members to consider the GSSP a more suitable methodology for locating a possible beginning to the Anthropocene. Similarly, considerations over the diachronous nature of the Industrial Revolution shifted the attention to the more recent, and seemingly isochronous, signals of plutonium associated with the Atomic Age.

The only exception from this methodological choice of 'neutrality' is represented in the discussion of the Ideological Science Argument, tackled in section 5.2.3.3. The nature of the argument(s) advanced through this type of criticism makes it necessary to consider whether it holds against the Anthropocene Hypothesis because it undermines a fundamental premise of the present work – that is, that the Anthropocene Hypothesis constitutes a *scientific* hypothesis. Thus, a solely descriptive approach cannot be maintained in the section in question.

5.2.1 The Future Geologist Argument

One of the most recurrent and compelling discussions concerning the nature of the Anthropocene as a geological time unit is whether or not its (anthropogenic) stratigraphic base will be detectable in a geologically distant future. Researchers and scholars of a multidisciplinary matrix have widely implemented the future geologist perspective to discuss the geological signature of the 'Anthropocene' and its broader implications. Emblematic of this research interest is a recently formulated hypothesis – the Silurian Hypothesis (Schmidt & Frank, 2019)[319] – which aims to assess via a thought experiment the likelihood that an industrial civilization (e.g., humans) will be detectable in nature in future geological times.

There are several instances in extant literature showing the interest and importance of a future perspective. The climatologist and glaciologist Eric Wolff (2014) argues that the Anthropocene "has to be considered from the viewpoint of a geologist viewing sequences thousands or millions of years in the future" (p. 255, quoted in Santana, 2019a). Writing for *The Guardian,* Damian Carrington (2016) writes that "[t]he domestic chicken is a serious contender to be a fossil that defines the Anthropocene for future geologists." Geographer Noel Castree (2014a) notes that formalizing the Anthropocene requires "robust evidence of changes that might, thousands of years hence, be considered clear stratigraphic markers by future geologists" (p. 439). Anthropologist and archaeologist Todd Braje considers the term 'Anthropocene' useful for geologists "because it reflects a change in the Earth system so distinctive that future geologists, studying flora and fauna, ice cores, atmospheric records, stratigraphic layers and much more, will find clear human signatures" (p. 509). Braje and Erlandson (2013) write that "there is little question that the extinctions and translocations of flora and fauna will be easily visible to future scholars who study archaeological and paleoecological records worldwide" (p. 20). Environmental literary theorist

[319] The thought experiment was advanced by climatologist Gavin A. Schmidt and astrophysicist Adam Frank in a 2019 paper published in the *International Journal of Astrobiology*. The authors ask whether it would be "possible to detect an industrial civilization in the geological record" (Schmidt & Frank, 2019, p. 142). The term 'Silurian' draws from a 1970 episode of the science fiction TV show *Doctor Who*, where an ancient and Earthy species of the same name is awakened by humans.

Pieter Vermeulen (2017) considers the future geologist perspective "one of the most popular tropes in the Anthropocene imagination" (p. 867), and one altering the very function of literary narrative. Lastly, geologist Stanley Finney (2014) states that "projection into the future is implicit in the concept of the 'Anthropocene'" (p. 26). These examples show how much of a common *topos* the future geologist perspective has become in recent multidisciplinary scholarship on the 'Anthropocene' and the Anthropocene Hypothesis.

Whilst the future geologist perspective undertakes different trajectories, thus raising different questions reflecting different disciplinary takes, the question raised in the geochronological and stratigraphic domain is the following: *Will anthropogenic stratigraphic signals be substantial enough for a future geologist to discern a 'Human Stratum' event in stratigraphic records?* If answered positively, then there is no legitimate reason *not* to formalize the Anthropocene on the geological time scale *now* – provided that other necessary and sufficient epistemic requirements are met (e.g., empirical work, explanatory power, consistency, usefulness, etc.). In other words, it seems intuitive to formalize a time unit if its stratigraphic base will likely be detected by a future geologist. If answered negatively, there is no legitimate reason to formalize the epoch/series other than extra-scientific motives (e.g., political, normative-ethical, etc.). In this case, it seems unnecessary to formalize an infinitesimally short time unit if its stratigraphic base is uncertain or unlikely to be detected by a future geologist. In both cases, the future geologist perspective is adopted by both supporters and critics of the hypothesis in support of their respective arguments, which can be formulated as following:

> **FGA (Future Geologist Argument):** The range of stratigraphic evidence supporting a proposed lower boundary for an Anthropocene Epoch/Series at ~1950 *will/will not* be detectable by future geologists, thus *validating/invalidating* the proposal of formal ratification of the time unit on the geological time scale.

How is it possible for the same argument to support mutually exclusive theses? Besides how and for what purposes the argument is being formulated, much of the answer depends on the weight attributed to the *possibility*, *plausibility*, and *significance* of anthropogenic records to be preserved in strata.

The two existential categories 'possibility' and 'plausibility' require some preliminary definition. Let's define something *S* as *possible* if its existence does not entail an ontological contradiction, meaning that *S* may theoretically happen (e.g., it is impossible to throw a six-sided die and obtain more than six possible results, whilst it is possible that a meteorite might hit your car); and define *S* as *plausible* if there are reasons to believe that *S* will eventually be the case (e.g., it is possible to win the lottery, despite being very implausible).[320] Plausibility logically entails possibility, but not vice versa – meaning that everything that is plausible is also possible, but the opposite is not the case.

[320] A third existential category addresses the *probability* of *S* if there are ways to establish numerically the chances of *S* to eventually manifest (e.g., the probably of obtaining 'one' by throwing a six-sided die is 1/6). Given the non-mathematical nature of the 'Anthropocene' concept, it is difficult to attribute a numerical probability to the chances that anthropogenic signatures will or will not be preserved in the geological future.

To argue that it is *possible* that anthropogenic records will be preserved in strata means that such a claim is consistent with the observable natural world (i.e., it does not contradict known natural laws). Conversely, to argue that it is *impossible* that anthropogenic records will be preserved in strata means that such a claim is inconsistent with the natural world – that is, it entails a contradiction. Similarly, to argue that it is *plausible* that anthropogenic records will be preserved in strata means that there are reasons to believe that this will be the case – that is, a future geologist will observe a discernable human stratigraphic signature. Conversely, to argue that it is *implausible* that anthropogenic records will be preserved in strata means that a future geologist will be unlikely to observe a discernable human stratigraphic signature, or a signature substantial enough to define a unit of geological time.

There does not seem to be any contradiction (neither epistemic nor ontological) in claiming that humans may leave a stratigraphic footprint detectable in future geological records – not least because existing paleontological and stratigraphic records abundantly show that species may leave body[321] and trace fossils in the stratigraphic record. Thus, it is unlikely to be ontologically impossible for humans to leave a discernible stratigraphic mark. Further, critics of the Anthropocene Hypothesis do not deny the *possibility* that anthropogenic stratigraphic signals may exist – as later shown. Rather, their major point of criticism concerns the *plausibility* that anthropogenic strata will be discernible from a future geologist perspective, and their epistemic *significance*. More precisely, criticism address the plausibility that a clearly marked boundary at ~1950 CE will be detectable in future stratigraphic records.

Thus, from a theoretical standpoint, FGA gravitates around three hubs of discussion:

(1) The *plausibility* that anthropogenic signals will be discernible in future stratigraphic records. [322]
(2) The *plausibility* that a marked ~1950 boundary will be discernible in future stratigraphic records.
(3) The *significance* attributed to future anthropogenic stratigraphic records by a hypothetical future geologist.

The stance one assumes concerning these three discursive hubs determines the specific formulation of FGA – leading to 'positive' and 'negative' formulations of FGA. The labels 'positive' and 'negative' are not value judgements. Both arguments provide epistemically rich and useful considerations regarding the plausibility that humans will leave a stratigraphically significant marker in the geological history. The choice simply reflects the positive and negative stance concerning the plausibility and weight attributed to the future anthropogenic stratigraphic record.

The analysis of the 'positive future geologist argument' (P-FGA) draws on a thought experiment conducted by Zalasiewicz (2008) concerning how long the human geological footprint will last in the future.

[321] The possibility that body fossils will be discovered is nevertheless restricted. Schmidt and Frank (2019) observe that "[t]he fraction of life that gets fossilized is always extremely small and varies widely as a function of time, habitat and degree of soft tissue versus hard shells or bones […] species as short-lived as *Homo sapiens* (so far) might not be represented in the existing fossil record at all" (p. 143).

[322] Point (1) concerns both the plausibility that (a) anthropogenic signals will be detectable at all (this does not contradict the possibility of the existence of anthropogenic deposits, which could exist without being observed, from a philosophical realism viewpoint), or (b) that anthropogenic signals will be detectable as *anthropogenic* (rather than related to another species, for instance).

The thought experiment anticipated much of the extant debate on humans' geological legacy, and thus represents a valuable source when discussing FGA. It does not represent an argument *against* the Anthropocene Hypothesis, but rather (implicitly) in *favor* of it. Delineating it aims at clarifying opposing stances concerning the epistemic viewpoint of a hypothetical future observer.

The 'negative future geologist argument' (N-FGA) draws on the formulation of the argument provided by Santana (2019a) – a rare contribution from the philosophy of science in discussing the epistemology of the Anthropocene Hypothesis – and on criticism raised by geologists, stratigraphers, or researchers denying the plausibility of a 'Human Stratum' event in future geological records.

5.2.1.1 The Positive Future Geologist Argument

Prior to stratigraphic debates over the Anthropocene Hypothesis, the question of humans' geological legacy on the Earth had already been tackled by Zalasiewicz (2008) in *The Earth After Us*. The book provides a far-sighted thought experiment of great utility in framing the future geologist argument by asking what will remain of humans in geological records. The arguments it promotes suggest there will be traces of *Homo sapiens* in the distant future that an imaginative alien future civilization will be able to detect. The text does not engage with the 'Anthropocene' debate directly (which is only briefly addressed in just a few pages, i.e., pp. 154-157), but rather with the broader geological and stratigraphic significance of *Homo sapiens* and its appearance in the context of deep time. The arguments advanced anticipated some important theoretical aspects of the Anthropocene Hypothesis and the stratigraphic debates that ensued from its formulation. This is especially the case for assessing the *significance* of anthropogenic signals in future stratigraphic records. For this reason, the premises and arguments of the text provide a useful starting point for analyzing FGA.

The *Gedankenexperiment* proposed by Zalasiewicz (2008) is based on seven assumptions relating to the temporal and epistemological viewpoint of a hypothetical future observer. These can be summarized in the following six premises:

(**P1**) The future geologist studies the Earth in one hundred million years from the present (i.e., 2008 CE),[323] when *Homo sapiens* is extinct.

(**P2**) The future geologist is represented by an intelligent and inquisitive alien civilization equipped with sufficient geological knowledge to conduct geochronological- and stratigraphic-like research.

(**P3**) The future geologist applies existing (as of 2008 CE) geological principles "to studying the preservation potential of humans and their handiwork" (p. 4).

(**P4**) *Homo sapiens* is considered "from the standpoint of a future paleoecologist" (p. 5) because *Homo sapiens*, and less its cultures, will not be immediately detectable if extinct.

[323] The year 2008 represents the year the book was published, and it is accordingly used to define 'present' for the thought experiment.

(**P5**) Geological forces and processes that have acted in the past and are acting in the present will be equally acting in the geological future (Uniformitarianism Principle).

(**P6**) The geological records considered are based on *Homo sapiens*' cumulative geological footprint as of today (2008 CE).

Each one of these premises comports different theoretical aspects requiring further elucidation.

P1 postulates a conventional time frame that is geologically minute (only 2% of the Earth's geological history), yet significant enough in respect to the history of *Homo sapiens*. It also represents a time span adequate enough to browse and dive into stratigraphic records and geological time – which is mostly (though not solely) divided into million- and hundred-million-long time units (except for the sub-units of the Quaternary, which are hundreds of thousands to tens of thousands of years long). The premise implicitly hints that such a distant geological future represents a more suitable observation point to assess anthropogenic strata than any nearer future (e.g., a decade, a hundred years, or a thousand years). Interestingly, this point has often been evoked as an argument against the Anthropocene Hypothesis – that is, the idea that the stratigraphic consequences of human activities cannot be assessed in the present (especially if locating the lower boundary of the Anthropocene around 1950), but only in a geologically distant future. This point is further considered when discussing the negative interpretation of FGA.

P2 provides minimal epistemic features defining the future observer viewpoint. It is irrelevant for the purpose of the arguments advanced by Zalasiewicz (2008) whether the future geologist is an alien species or another Earthly being that evolved into a highly intelligent species capable of geological knowledge. Theoretically, it is also irrelevant whether the observer is a human being as long as the observer adheres to P3 – although the thought experiment postulates a post-human Earth. However, choosing an alien civilization allows the consideration of anthropogenic stratigraphic signals to be *objective* (in a weak sense) – that is, detectable from a non-human observer. This is an important theoretical consideration to avoid issues of ontological and epistemological anthropocentrism.

P3 provides the methodology adopted to investigate the potential of human remains to be recorded in stratigraphic material. The methodology chosen corresponds to extant principles in stratigraphic (and broader geological) research – especially radiometric dating, which "is something one can imagine as a standard inter-galactic technique" (p. 95) to determine the age of rocks and strata. Such methodology is projected onto the future alien civilization, meaning that the very same principles to study stratification and preservation of geological records (e.g., human fossils and technofossils) that apply now could be sufficient to detect human traces in stratigraphic records in one hundred million years.[324]

[324] Radiometric dating will be necessary (for the alien civilization) only to determine the absolute age of specific events. As explained in section 3.1, there exist several time-independent properties of strata successions that enable a relative geochronology. In this scenario, the alien civilization will perhaps only need knowledge of the Law of Superimposition (and will thus necessarily possess an understanding of gravity) and to observe certain properties (e.g., lithological, biostratigraphic) in sedimentary layers associated with the presence of *Homo sapiens*.

P4 postulates that a future paleoecologist will be able to discern *Homo sapiens* (or whatever possible designation chosen for our species by the observer) as a distinct species. This postulate is necessary for the thought experiment to work since it is not taken for granted that *Homo sapiens* will be either immediately or clearly detectable in fossil records. Hence, a future geologist would implement this knowledge to establish a correlation between the appearance of *Homo sapiens* and global and synchronous signals in stratigraphic records.

P5 – or the Uniformitarianism Principle – states that the very geological process that shape the Earth, and either destruct or allow preservation of geological records, will be invariantly active one hundred million years in the future. The principle is central in geology as well as in other natural sciences (e.g., physics, astronomy, chemistry), underpinning inferential strategies concerning reconstructions of the past (e.g., retrodiction) or predictions of the future (e.g., inductive reasoning). P5 is crucial to the thought experiment advanced. Without it, the very experiment would be unsubstantial, as it would be impossible to make any prediction or envision any universe inconsistent with known natural laws.

P6 postulates what time period of the history (viz. evolutionary history) of *Homo sapiens* is considered. Zalasiewicz selects ten thousand years' worth of stratigraphic section as a reasonable time span.[325] This "represents the span during which human activities can be said to have left a detectable imprint upon the geological record – an imprint beyond the odd vanishingly rare bone of an obscure bipedal hominid" (p. 120). It begins with the late Pleistocene megafauna extinction, "humanity's first real footprint upon the wider world" (ibid.) up to the present (2008 CE). However, Zalasiewicz also recognizes that "[t]he real global impact […] struck with the coming of the Industrial Revolution, when both human numbers and human exploitation of materials, energy, and land began to climb steeply" (ibid.), and that "[t]he longer the human species lasts, the deeper is likely to be the footprint" (p. 4). While necessarily relevant for assessing the stratigraphic significance of *Homo sapiens*, the future of humanity is not considered in the thought experiment.

These premises delimit a scenario where it is *possible* and *plausible* for *Homo sapiens* to represent a geologically significant episode in the Earth's history, and for a future geologist to assign epistemic (viz. stratigraphic) *significance* to anthropogenic signals. In fact, Zalasiewicz argues,

> The human empire may not represent a brief event, following which life on Earth, after our demise, goes back to normal. […] It represents a threshold, the transition between the world before humans and that to come afterwards. For our impact has been so great that we have already made Earth history. The world will, quite literally, never be the same again. (p. 125)

The main question is how this threshold event will be recorded. Geological processes such as plate tectonics or sea level changes will dramatically alter the geography of the planet, and with it its climate, biosphere,

[325] The selection of this time span does not reflect a preferred starting date for the Anthropocene at 10,000 ka – as similarly proposed by B. D. Smith and Zeder (2013) and Erlandson and Braje (2013). As anticipated, discussions on the Anthropocene Hypothesis had yet to fully develop in stratigraphic terms, and the 'Anthropocene' is not the primary concern of the text.

and so forth. Human artefacts, from skyscrapers and particle accelerators to everyday tools, will be mostly eroded and dissolved almost to their basic chemical components. No aspect of human civilization will be left unscathed (as of P1). This is especially the case for those artifacts exposed to the surface (and thus most subject to erosion), whereas other artefacts will be drowned by sea level rise that, if fast enough, may provide the conditions of possibility for preservation in geological time. Nevertheless, it is plausible that traces of anthropogenic activities will be recorded in complex signals – for instance, in pollen or fossil records:

> The sudden appearance of floods of identikit pollen of crop plants around large parts of the globe is unlikely to pass unnoticed by our future observers […] The [biota] changes may well soon encompass such commonly fossilized creatures as the bivalve molluscs and gastropods, sea urchins, limpets, and barnacles of seashore and shallow sea floors. There are also potential microfossils – planktonic single-celled organisms such as foraminifera and diatoms, with preservable skeletons of lime or silica, which sink to the sea floor and accumulate in their billions in the bottom sediments after the organisms themselves have died. These are the fossils that really characterize strata. It now seems likely that some will show clearly the impact of human activities, while others will provide barometers of wider oceanographic changes. (p. 130, 132)

The ongoing extinction events (Barnosky et al., 2011; Ceballos et al., 2015; Ceballos et al., 2017) will likely serve as valuable proxies for the Anthropocene. Most of the present extinctions will be geologically invisible (not insignificant), as they will "leave as little trace as the highland dinosaurs of the Jurassic have left – that is, virtually none" (Zalasiewicz, 2008, p. 133). However, watery sites such as coastal plains, deltas, river basins, lagoons, and ocean environments are likely to preserve fossilized remains of microbiota. The demise of coral reefs – hotspots of biological diversity and the center stage of many environmental discussions – "will leave an indelible and stark record in the Earth's strata, perhaps the most striking of all our signals to the future" (p. 134). This strata record will be "the clearest possible message in the Earth's strata: the simultaneous termination, worldwide, of the growth of massive white mountains of limy strata, and their replacement, and quite literally their burial, by layers of silicate mud and sand" (p. 138). These global extinctions in aquatic environments will not be as largely invisible as terrestrial extinctions. They are likely to be detected by the alien civilization depicted in P2.

Anthropogenic emissions of CO_2 in the atmosphere may also have consequences detectable from a future perspective. Oceans represent one of the Earth's major carbon sinks, where 'blue carbon' (i.e., carbon removed from the atmosphere by ocean ecosystems) is stored. CO_2 absorbed in the ocean reacts with seawater to form carbonic acid (H_2CO_3). In turn, carbonic acid interacts with water molecules to produce bicarbonate ions and hydrogen ions. Hydrogen ions interact with existing carbon in water to produce further bicarbonate ions, which eventually contributes to reducing ocean pH. Increased ocean acidity is offset by dissolution of calcium carbonate ($CaCO_3$) already present in the ocean. This has negative repercussions for shellfish and other aquatic organisms whose existence relies on the dissolved calcium carbonate for building and developing their shells and skeletons. As the anthropogenic carbon dioxide is further stored deeper in oceanic waters, calcium carbonate shells will dissolve and accumulate "as layers of ooze on the sea floor" (p. 143). This process will continue for several thousands of years until, "when a new chemical equilibrium is re-established, partly by this dissolution, and partly by the effects of weathering on land," and "when the settling of carbonate skeletons resumes, this will be on a sea floor which has been dissolved away to a depth of perhaps tens of centimeters" (ibid.). A widespread marker horizon will be visible in the strata of oceanic deep-sea floors by future geologists (in a P1 scenario, but the layer will eventually disappear as ocean floors are recycled through tectonic processes), witnessing an increase in atmospheric CO_2 concentrations.

Body fossils of *Homo sapiens* will be just as rare as same-size fossils from one hundred million years ago. As surface rather than marine animals, our fossils will be more subject to erosion, thus decreasing the fossilization potential (but leaving enough body fossils for postulating P5). However, multiple types of trace fossils (e.g., footprints, burrows, nests) connected to *Homo sapiens*' biological and cultural behaviors may be preserved in geological records. In fact, Zalasiewicz argues that *Homo sapiens* is "currently creating examples of the most amazing (and, in the far distant future, perhaps most puzzling) trace fossils likely to appear in the history of the planet" (p. 165). These 'trace fossils' or ichnofossils (i.e., fossilized traces) will not be classified "on the basis of the closeness of their relationship to other living organisms, but on the type of behaviour displayed" (p. 162).

Paleontologist Adolf Seilacher (1964) originally distinguished five main behavioral activities for the classification of trace fossils, namely, *Domichnia* (dwelling burrows), *Fodinichnia* (feeding burrows), *Pascichnia* (feeding trails), *Repichnia* (crawling trails), and *Cubichnia* (resting tracks).[326] The nomenclature parallels the binomial nomenclature used to classify of living organisms, but it is based on ethnological rather than biological principles. Ichnology (the study of trace fossils) uses this type of classification to reconstruct the behaviors of ancient (paleoichnology) and modern (neoichnology) species, complementing paleontological and stratigraphic research.

Ichnological principles and methods will provide future geologist-observers in a P1 scenario with epistemic tools sufficient to detect the presence of *Homo sapiens* through traces, rather than through direct observation of artefacts or skeletal remains (which will be much harder to find). A P2-type of observer will follow five principles of trace fossils (to add to the methodological toolkit postulated in P3), namely, (1) "a single type of organism can make many different traces" (Zalasiewicz, 2008, p. 160), (2) "the same structure [e.g., a burrow] may look different when formed in different types of sediment" (ibid.), (3) multiple organisms may contribute to the same structure over time, (4) "different types of organisms can make similar traces" (ibid.), and (5) "the same organism has different behaviors in different environments" (p. 163).[327]

Most trace fossils will be remnants of the 'Urban Stratum' – that is, the "novel sedimentary environments and structures" (Zalasiewicz et al., 2011a, p. 1038) related to the excavation, transportation,

[326] An overview of the taxonomical classification of trace fossils and other more recent classes is available on the Wikipedia page https://en.wikipedia.org/wiki/Trace_fossil_classification (accessed on March 17, 2021. Last revision: December 5, 2020, 08:49 CET by Monkbot).
[327] The fifth principle is created *ad hoc* by Zalasiewicz (2008) for his thought experiment, and it is "not necessarily used by paleontologists" (p. 163).

and deposition of material (new and old) for urbanization (Barnosky, 2014). While not a direct marker of the Anthropocene, they still represent possible stratigraphic evidence of the existence of *Homo sapiens* from a P1 perspective. Urban agglomerates (cities and megacities) will represent potential sites for preservation of geological traces, as cities develop upon old ones, hence forming thick accumulated sedimentary sections made of different types of materials such as concrete, cinder, glass, plastics, iron, steel, copper, and more (Zalasiewicz et al., 2019b, para. 2.5.2.1). These urban trace fossils will, "if buried in stratal successions, preserve distinctive structures, mineralogies and textures, and their nature and composition will provide a tool for distinguishing constructions from the Anthropocene from those that are older" (p. 65). These traces will be buried underground at different levels, depending on the pressure, temperature, region, and other variants contributing to the burial depth of anthropogenic sediments. Traces buried several kilometers in depth, and distant from orogenic regions, will have higher chances of preserving anthropogenic strata than those buried a few hundred meters below the surface. Those city remains observable by a P2 civilization will preserve "meters-thick layers of rubble, of compressed outlines of concrete buildings […] of softened brick structures; of irregular patches of iron oxides and sulphides representing former iron artefacts […] of darkened and opaque remnants of plastics; of white, devitrified fragments of glass jars and bottles; of carbonized structures of shaped wood" (Zalasiewicz, 2008, p. 189). Fossils of *Homo sapiens* will also appear in proximity to trace fossils (although in much less abundance), thus enabling a link between the Urban Stratum and our species.

Thus, trace fossils associated with *Homo sapiens* will leave for a P2 observer a sort of 'Human Event Stratum' that "will be a thin and patchy, albeit globe-encircling layer" (pp. 229–230). These fossil remains would gain significance once "set against the evidence of a perturbed global carbon cycle, of sudden global warming and sea level rise precisely synchronous with – as far as it will be possible to judge – the Human Event Stratum" (p. 230). Such a mark will have geological significance – being observable by a future geologist perspective.

Zalasiewicz's (2008) thought experiment provides a positive answer on whether or not humans will leave a distinct stratigraphic mark in the history of the Earth. The answer is not definitive. Predictions about humans' stratigraphic footprint are fraught with uncertainties, especially in a scenario as distant as postulated in P1. Nevertheless, based on P1-to-6, it seems *plausible* that a future geologist will be able to detect *significant* anthropogenic stratigraphic markers.

The thought experiment found academic ground in later years, when the AWG (Zalasiewicz et al., 2017b) stated that

> the most important question with respect to duration becomes: even if all anthropogenic forcings ceased tomorrow, would the defining characteristics of the present stratigraphic signal continue to be detectable in geological strata? That is, in addition to the unique attributes of the stratigraphic record already identified and documented, has the stratigraphic record been set on an irreversible trajectory? The answer is clearly yes. (p. 214)

Notably, the "important question" raised is equivalent to that raised by FGA, to which they provide a positive answer. Recent scientific literature has been endorsing this view, suggesting that "[h]umankind will remain a major geological force for many millennia, maybe millions of years, to come" (Steffen et al., 2007, p. 618); that "[i]n a deep-time perspective, long after humans have disappeared, sporadically distributed and exposed deep mine/boreholes traces in the strata of the far future might lie several kilometers stratigraphically below a stratified Anthropocene palaeosurface" (Zalasiewicz et al., 2014b, p. 7); that "[w]ith an ongoing source of CO_2, this state of the Earth System could persist for millions of years, as similarly warm states have in the past" (Steffen et al., 2016, p. 338, box 1); and that "[i]f in a hundred million years' time an alien civilization writes the history of the Universe, the Earth will be known as the Planet of the Humans" (Hamilton, 2017, p. 115). This literature leads to the formulation of the positive future geologist argument as follows:

> **P-FGA (Positive Future Geologist Argument):** It is *plausible* that *Homo sapiens* will leave a *significant* global signature in the stratigraphic record that will be detectable by a geologically distant observer.

It should be noted that P-FGA does not directly address the proposed boundary at ~1950, but rather the very *possibility* and *plausibility* of anthropogenic records to be preserved in strata (as body fossils, trace fossils, etc.). Zalasiewicz (2008) observes that "the human takeover of Earth was, in effect, accomplished in perhaps 10,000 years, and that interval, at a distance of 100 million years, will appear virtually instantaneous" (p. 213).[328] However, he also recognizes that "the takeover accelerated almost exponentially near the end of that brief span [i.e., since the Industrial Revolution], in that humanity has produced more body and (especially) trace fossils and environmental ripple effects in the last few centuries than in all of the preceding part of that span" (ibid.). While anthropogenic modifications spread slowly and diachronously during the Holocene, the last two decades saw accelerated changes reflected in the Earth System as well as in human energy regimes (Syvitski et al., 2020) that are an order of magnitude greater than any previous period in the history of humanity (Zalasiewicz et al., 2017b). Such changes are recorded in stratigraphic episodes of a qualitatively and quantitatively distinct nature than standard Holocene stratigraphy.

How does P-FGA relate, then, in any way to the Anthropocene Hypothesis? P-FGA elucidates the conditions of possibility for the formulation of Claim 1 (i.e., *Homo sapiens* has left a discernible stratigraphic signature of significant magnitude in the recent geological history) – a fundamental claim of the Anthropocene Hypothesis. P-FGA argues that humans *are capable* of leaving a stratigraphic footprint in geological records. The Anthropocene Hypothesis argues that humans *have already done so*. The hypothesis asks what lower boundary would best represent this signature in the present, rather than in the future. Selecting primary and secondary markers for a GSSP to be located at ~1950 represents an expression of

[328] As explained in section 5.2.2, the argument that, one hundred million years from now, the previous 10,000 years will appear instantaneous has been implemented *against* the Anthropocene Hypothesis.

our *present* knowledge of anthropogenic stratigraphic signals. It is a signpost that makes sense *now*, if P-FGA is true. AWG researchers have also indirectly stressed how P-FGA does not corroborate the Anthropocene Hypothesis *per se*. What corroborates the hypothesis is the *present* existence of anthropogenic stratigraphic signals:

> the key issue in determining whether or not the Anthropocene has begun is not how long epochs are, but whether the geological record that allows characterization and correlation of the Anthropocene is *already* sufficiently distinct and whether its distinctive features and their stratigraphic consequences will persist for at least many millennia […] We note here that the case being made for the Anthropocene rests solely on evidence documented within *existing* strata that represent *past* events, as it must. Deposits representing the Anthropocene, such as 'made-grounds,' are not imagined future deposits, but existing physical units that can be depicted on geological maps. (Zalasiewicz et al., 2017b, pp. 214, 218)

Thus, P-FGA is an argument indirectly supporting the Anthropocene Hypothesis. It is an argument supporting the *plausibility* (and thus *possibility*) that *Homo sapiens* will leave a *significant* geological signature in strata, and its significance as a global and synchronous threshold (from a geologically distant future). Formulated as such, it supports Claim 1 in warranting that the conditions for *Homo sapiens* to leave a significant signal in the geological record can occur in the first place.

5.2.1.2 The Negative Future Geologist Argument

It is an age-old view that humans invest much less significance in the natural domain than they attribute to themselves. Not a few thinkers throughout history have described human existence as transient, frail, and doomed to oblivion. This view of human existence has ancient roots in 'Western' culture and is manifested in various religious, philosophical, literary, and artistic forms throughout history. Perhaps an archetypical example can be found in the Book of Genesis: "By the sweat of your face you shall eat bread, till you return to the ground, for out of it you were taken; for you are dust, and to dust you shall return" (English Standard Version, 3:19). This oft-cited passage from the Old Testament foreshadows a theme still traceable in many recent and extant belief systems and cultural expressions – from the arts to philosophies such as cynicism, existentialism, and nihilism – the perception of human existence as insignificant, or mere 'dust.'

For instance, William Shakespeare has General Macbeth exclaim, upon hearing of the death of his wife:

> Tomorrow, and tomorrow, and tomorrow,
> Creeps in this petty pace from day to day,
> To the last syllable of recorded time;
> And all our yesterdays have lighted fools
> The way to dusty death. Out, out, brief candle,
> Life's but a walking shadow, a poor player

> That struts and frets his hour upon the stage
> And then is heard no more.
> It is a tale told by an idiot, full of sound and fury,
> Signifying nothing. (*Macbeth*, 5.5.18–27)

The 'dust' metaphor provides a rich exegesis of the human condition in the world as ephemeral, doomed to the abyss of entropy and deep time (and space). To be like dust, and to become dust, are vivid existential metaphors: humanity is but a blip in the history of the Earth and the universe, and its very own existence will leave no traces to safeguard its ontological mark upon reality.

Friedrich W. Nietzsche notoriously shared this view of humanity's place in the world. In the opening lines of the posthumously published *On Truth and Lie in an Extra-Moral Sense* (1977), he states:

> In some remote corner of the universe, poured out and glittering in innumerable solar systems, there once was a star on which clever animals invented knowledge. That was the highest and most mendacious minute of 'world history' – yet only a minute. After nature had drawn a few breaths the star grew cold, and the clever animals had to die.
>
> One might invent such a fable and still not have illustrated sufficiently how wretched, how shadowy and flighty, how aimless and arbitrary, the human intellect appears in nature. There have been eternities when it did not exist; and when it is done for again, nothing will have happened. (p. 42)

Literati and philosophers were not alone in considering the meaning of human existence. Science certainly contributed to toppling humans from their self-appointed pedestal, as Freud (2014) famously observed. The Copernican revolution showed that humans were not at the center of the solar system, and modern astrophysics and cosmology show that the Earth is one among 10^{15} to 10^{19} planetary bodies in the Milky Way – which is itself one among an estimated two hundred billion galaxies in the observable universe. Since Darwin, modern evolutionary biology has provided an explanatory framework for the evolution of biological species that includes *Homo sapiens* as one among millions of existing species. One could add to these 'narcissistic wounds' the modern revolution in geochronology, which defied humans' chronocentrism and teleologism by investing them with only an infinitesimal fraction of time in the Earth's 4.54-billion-year history.

This inclination toward the role and agency of *Homo sapiens* has recently found new ground in some environmental fringes. Clive Hamilton (2017) has recognized nihilistic tendencies in contemporary environmental literature, arguing that "a new kind of existential defeatism finds expression in the thought, now often voiced, that if humans disappear in the next century or two, then the history of *Homo sapiens* on Earth would be a mere blip in the planet's 10 [*sic*] billion-year history, whose signs would soon be erased by natural processes, and Nature would simply move on" (p. 115). These tendencies are vivid in radical social expressions in movements such as the Voluntary Human Extinction Movement, a group advocating for the extinction of *Homo sapiens* by abstaining from reproduction. In the 'Anthropocene' geological discourse, this view is occasionally expressed by pointing out the apparent insignificance of the human stratigraphic footprint in light of the Earth's deep history – thus denying the plausibility, or even the possibility, of an anthropogenic signature to be preserved in geological archives. The erosional effects of plate tectonics and other geological forces will reduce humans' traces to dust, rendering them a mere blip in the vastness of past and future geological time.

This deeply rooted tendency to deflate the importance (both ontological and ethical) of humans should not be directly linked to the negative interpretation of the future geologist argument. Such an argument (outlined later in this section) is not nihilistic in the sense of promoting the absence of *any* value concerning humanity's agency and ontological status. The argument does not deny humanity's role as a geological agent capable of dramatically altering the Earth System, nor does it discourage proactive and reactive measures to prevent its consequences. Rather, it reconsiders the *geological significance* of *Homo sapiens* in relation to deep time, and to the stratigraphic traces it will leave behind. It questions whether these will be abundantly detectable from a future geologist perspective to challenge the Anthropocene Hypothesis. Advancing this type of criticism is not just crucial in developing a transparent and scientifically sound framework for assessing the possibility and plausibility of a 'Human Stratum' in sedimentary records. It is a necessary filter against types of anthropocentrism that, historically, have proven to be a recurrent epistemic hindrance when addressing humans, their nature, and their place on Earth. Nevertheless, a common denominator among criticism against the Anthropocene Hypothesis has been skepticism against the *plausibility* that a future geologist will clearly distinguish an anthropogenic boundary horizon, and the *significance* the observer would attribute to it.

An insightful example of a negative future geologist perspective is offered by Santana (2019a) – partially discussed in section 4.1.3.2. The article briefly explores the methods of geochronology and stratigraphy before outlining a hypothetical future geologist's perspective – which is used to endorse an informal use of the term 'Anthropocene.' He notes that hypothesizing a future geologist perspective "is a radical shift for a historical science like geology, because it requires the historical science to become a science of prediction" (p. 1076). Likewise, Santana finds the Anthropocene Hypothesis to evidence this radical shift because "[w]ere the Anthropocene to be ratified, it would be the unique division in geological time to be based on 'projections into future millennia' rather than on evidence of the past" (ibid.). This he defines as the 'future geologist perspective,' which he contraposes to the 'synchronic perspective' – that is, posing the scientific as well as political question of formalization of the Anthropocene as a reflection of humans' relationship with the Earth.

The philosopher of science argues against fully endorsing the Anthropocene as a formal unit of geological time – and particularly as an epoch-level unit. A central assumption in Santana's arguments is that traditional stratigraphic methodologies cannot be applied for formalizing an Anthropocene Epoch/Series "since we're contemporaneous with the proposed epoch" (p. 1076). This requires considering extant stratigraphic signals from a future geologist perspective from thousands to millions of years in the future, and determine whether the future geologist will be able to detect anthropogenic signals substantial enough to warrant ratification of an anthropogenic epoch-level unit. From this future viewpoint, Santana rejects extant evidence submitted by the AWG as sufficient for warranting formal epoch-level recognition. This rejection grounds on three main arguments – namely,

> (1) Many of our geological impacts can be mitigated by future human behaviour. To the future geologist, this may make them relatively insignificant, brief anomalies.
> (2) Some anthropogenic activities are best conceived as continuations of processes that originated in the Holocene, so the future geologist will not see them as marking a new post-Holocene epoch. […]
> (3) Many clear examples of human impact will be seen by the future geologist as local catastrophes rather than geologic events of global reach and long-term impact. […] [E]pochs are typically defined by long-term global change. (p. 1078)

If none of these argument applies to a significant marker, "then a future geologist will still have grounds to ratify the Anthropocene" (ibid.). However, if the arguments apply for each of the evidence surveyed, then there are no sufficient reasons for formalizing an Anthropocene Epoch/Series.

No specific coordinates are explicitly provided by Santana concerning the temporal location of the future geologist (i.e., a hundred years, a thousand years, or millions of years from the present). Nevertheless, he seems to imply that the year 2500 CE is the observation point for the hypothesized future geologist.[329] Selecting this date is a substantially different premise from P1 as postulated in Zalasiewicz's (2008) thought experiment; it is a geologically minute time interval from the present, compared to one hundred million years from now. Logically, if in five hundred years a future geologist will not find sufficient evidence for warranting a post-Holocene epoch-level boundary, then there are no reasons to suspect that a more distant future geologist will detect such evidence. Furthermore, this also seems to imply that, if five hundred years is geologically irrelevant, then *present* geologists are also not justified in defining a post-Holocene Anthropocene Epoch – indeed, this being Santana's main thesis.

Besides preliminary conceptual implications, Santana (2019a) provides additional observations in support of his arguments. He considers whether or not common markers for the Anthropocene – that is, climate change, fossil records, human fossils, anthropogenic deposits, chemostratigraphic markers, and hydrological markers – are susceptible of (1) to (3). For instance, he notes that sea-level change and cryosphere loss associated with anthropogenic climate change "will leave clear markers in the sedimentary record" (p. 1079) that a future geologist will be able to observe. However, these markers will not reflect an epoch-scale change. For the first thing, sea-level changes exceeding current projections (Sweet et al., 2017)

[329] Indeed, when discussing the geological significance of anthropogenic climate change, Santana (2019b) writes: "Antarctica alone could contribute another fifteen meters of sea-level by 2500, if greenhouse emissions follow current trends. […] Nevertheless, we are not yet justified in predicting that the future geologist will see anthropogenic sea-level rise as epochal" (p. 1079). Later, he concludes the paragraph by stating: "Come 2500, if the sea level really is tens of metres higher than the present, we can revisit the question [i.e., formalizing the Anthropocene], but for now, let's treat that future as something within our power to prevent" (p. 1080). Likewise, the author also seems to refer to a geologically immediate future when addressing the fossil record as possible marker for the Anthropocene, suggesting that "whether the future geologist will see present-day extinctions as marking a new epoch will depend on our choices *in the coming decades* [emphasis added]" (p. 1081). Thus, the year 2500 CE can be reasonably assumed to be the standpoint of Santana's future observer.

have been documented in paleoclimate studies (e.g., Dumitru et al., 2021; Voris, 2000, quoted in Santana, 2019a). These changes do not define lower boundaries of epoch-level geological units. Second, projected sea-level changes will be largely dependent on future mitigation efforts, meaning that the respective stratigraphic traces will be less significant that one might expect. Likewise, future conservation efforts will determine the biostratigraphic signature of the Anthropocene. While the fossil record associated with the present extinction rates "will provide evidence of this to the future geologist" (Santana, 2019a, p. 1080), it is too soon to compare the present number of extinct species to past mass extinction events – which are characterized by a minimum of 75% of estimated species lost from observed genera (Barnosky et al., 2011; see also section 3.1.2.4). Body fossils of *Homo sapiens* cannot mark the onset of the Anthropocene, as its presence is part of the Holocene biota. However, ichnofossils associated with human civilizations (especially fossilized subways) will be "geochronologically significant because they evince novel animal behaviours" (Santana, 2019a, p. 1083). Nevertheless, ichnofossils will not be sufficient to define the base of the Anthropocene, in that they are an expression of human activities extending throughout the Holocene. Novel sedimentary material will represent too fine a grain for a future geologist to delimit a post-Holocene unit at ~1950. Furthermore, any future revolution in construction may deflate the lower boundary proposed by the Anthropocene Hypothesis. Hence, the proposed boundary is premature in respect to the future geologist observer. Lastly, the author grants that the chemostratigraphic marker associated with nuclear and thermonuclear bomb testing (especially ^{239}Pu and ^{240}Pu because of their relatively long half-lives) "will be an excellent candidate marker for the future geologist" (p. 1084). However, because no radical global change is associated with this marker, the future geologist will only be able to associate it with other human impacts, such as anthropogenic climate change or accelerated extinction rates – which are Holocene-type events.

How does Santana's analysis stand in terms of assessing the *possibility* and *plausibility* of anthropogenic signatures being recorded in stratigraphic sections? As shown, the scenario hypothesized by the philosopher admits that a future geologist will be able to detect distinct anthropogenic stratigraphic signals, from sea-level rise to plutonium fallout. This makes it plausible (and thus possible) for anthropogenic signals to be recorded in rocks and strata from a future perspective. The main point of divergence from P-FGA is the *significance* attributed to these signals. Santana argues that it is unlikely that "a future geologist would look back on humanity's geological influence and see anything that would justify differentiating an Anthropocene epoch from the Holocene" (p. 1086). That is because:

> Some of our activity lacks the impact of other epoch-defining processes. Other activity is more significant, but continues trends of the Holocene rather than breaking with them. The potentially most significant human geological effects, however, aren't inevitable. Mass extinction, nuclear winter, and geologically unprecedented global warming are all real possibilities, but it is still within our power to prevent them. (ibid.)

The arguments advanced by the author against recognition of an Anthropocene Epoch/Series also find motivation in broader social and political considerations. These are beyond the theoretical boundaries set by the future geologist scenario (and thus beyond the scope of the present analysis). Within these boundaries, a central argument against the Anthropocene Hypothesis is the seemingly *diachronous* nature of the markers used to define the proposed epoch.

As explained in section 3.1.2.6, synchronicity of signals is a requirement when determining the beginning of a chronostratigraphic unit, meaning that the events recorded in stratigraphic material should be approximately of the same age. However, researchers have observed that synchronicity is relative from a future observer standpoint. For instance, Braje (2016) notes that "[t]o geologists living a million years from now, it will make little difference whether the Anthropocene began in AD 1800, 10,000 years earlier or is marked by the invention of the steam engine or the first appearance of Neolithic tools" (p. 509). Similarly, LeCain (2015) rhetorically asks "what could justify doing so now based on changes that have occurred over the past 200 years, mere seconds in the vast ages of the Earth gone by?" (p. 19). Even AWG researchers (Waters et al., 2014b) recognize that "[v]irtually all stratigraphic boundaries are diachronous and spatially heterogenous to an extent that would make any of the potential Anthropocene bounding events seem effectively instantaneous, in a far-future perspective" (p. 15). As noted by Edgeworth et al. (2019), "the terms 'diachronous–synchronous' roughly correspond to the terms 'near–far' – not actually absolute terms with fixed meanings at all, but relative terms that can be applied to the same thing when viewed from variable distances away in time" (p. 338). Other than advancing an argument on diachronicity (explored in the next section), this literature suggests that a sharp ~1950 boundary will not be detected by a future geologist.

Thus, based on Santana's (2019a) thought experiment as well as similar literature, a way to concisely summarize the negative interpretation of FGA can be the following:

> **N-FGA (Negative Future Geologist Argument):** It is *implausible* that *Homo sapiens* will leave a *significant* global and synchronous signature (especially at ~1950 CE) in the stratigraphic record that a future geologist will be able to observe and use as a boundary horizon.

This argument does not deny the possibility that humans will not leave *any* stratigraphic record at all; nor does it minimize the overall environmental impact of humans on the planet (i.e., it is not a climate skepticism argument). Attributing *Homo sapiens* geological agency is a different discussion than defining a stratigraphic unit based on the human footprint on the planet, and critics of the Anthropocene Hypothesis too are aware of this distinction (Autin & Holbrook, 2012; Baskin, 2015; Brannen, 2019a; Santana, 2019a, 2019b). The core thesis of N-FGA is that it is implausible that *Homo sapiens* will leave a *significant* global and seemingly synchronous marker in the future stratigraphic record. If any trace will be observed by a future geologist, it will be unlikely to provide grounds for a chronostratigraphic boundary.

It is an epistemic requirement that chronostratigraphic units should be correlatable on a global scale, and that these units be synchronous. Markers of various types (e.g., biostratigraphic, magnetostratigraphic, etc.) ensure that each chronostratigraphic unit has a clearly distinct 'body' that makes it unique from other units, ensuring a consistent and gap-free reconstruction of the Earth's history. Versions of N-FGA deny that such a significant 'body' for justifying a clearly distinguishable Anthropocene stratigraphic unit will be detectable in future strata. An example is Visconti (2014), who argues that "[t]he basic assumption that Anthropocene is shaping the planet is challenged considering that natural processes are and will be operating on the planet and have the potential to obliterate any trace left by the human activity" (p. 381). Science journalist Peter Brannen (2019a) originally shared this view, stating that "[v]ery little of our handiwork will survive the obliteration of the ages. If 100 million years can easily wear the Himalayas flat, what chance will San Francisco or New York have?"[330] The term seemingly inflates humanity's geological agency "on an ever-churning planet that will quickly destroy – or conceal forever – even our most awesome creations" (ibid.). These arguments share a basic skepticism against the plausibility that humans will leave any significant stratigraphic trace in the geological record.

By denying the plausibility of preservation of a global and synchronous boundary horizon associated with *Homo sapiens* (against Claim 1), and by drastically diminishing its hypothetical epistemic significance for a future (and present) geologist (against Claims 2 and 3), N-FGA is in fact rejecting the central claims defining the Anthropocene Hypothesis. N-FGA is diametrically opposed to P-FGA: it denies that the conditions of possibility for preservation of anthropogenic strata are met. Thus, if it is unlikely that an anthropogenic boundary horizon in the stratigraphic record will be observed by a future geologist, or if it is simply too soon to make any such predictive statement (Wolff, 2014),[331] then there are no substantial reasons to formally recognize an Anthropocene unit at present.

The critical viewpoint raised by N-FGA does not solely address the ~1950 boundary, but the very idea that humans may leave a distinct and significant stratigraphic footprint upon the Earth's history. Consequently, this viewpoint also rejects alternative hypotheses attempting to translate anthropogenic activities into the domain of geochronological and stratigraphical classification.

While N-FGA adopts a future observer viewpoint to delegitimize present recognition of the Anthropocene, other arguments against the Anthropocene Hypothesis consider a present standpoint to reject one or more claims held by the hypothesis.

[330] The author changed his opinion on humans' stratigraphic footprint (Brannen, 2019b) after the AWG responded (Wing et al., 2019) to his initial criticism. See section 1.2.4.

[331] On whether or not it is too early to formalize an Anthropocene unit, Wolff (2014) has also argued "if it may be more sensible to describe ourselves as being firmly in the transition into the Anthropocene" (p. 262). A similar remark has been advanced by Ford et al. (2014), who argue that "the definition of type sections for anthropogenic deposits may be simpler in the distant future when they are preserved as rocks in the geological record and exposures are available for study" (p. 77). This particular expression of N-FGA does not argue that it is implausible that *Homo sapiens* will leave a global and synchronous mark, but rather that it is too early to define this mark.

5.2.2 The Diachronicity Argument

At least since the Ruddiman Hypothesis was formulated, critics of the Anthropocene Hypothesis have questioned whether the beginning of the Anthropocene should be dated much earlier than the Industrial Revolution, and the currently proposed ~1950 CE boundary. One line of questioning lies in the seemingly diachronous nature of anthropogenic signals – extending for thousands of years before the present.[332] This represents "one of the pervasive problems with the 'Anthropocene' concept" (Walker et al., 2015, p. 205) because the primary and secondary markers used for defining the base of a geological time unit need to be synchronous according to the GSSP methodology. The main line of argument is that anthropogenic signals typically used to define the proposed unit (e.g., increased extinction rates, ichnofossils, emissions of greenhouse gasses) extend throughout the Holocene, so that the Anthropocene is somewhat already encompassed in the Holocene. If so, then (1) the Anthropocene designation should remain informal (Ruddiman, 2013, 2018; Ruddiman et al., 2015), (2) a Holocene-Anthropocene unit could be officially recognized (Braje, 2016; Braje & Erlandson, 2013), or (3) there is neither practical nor theoretical utility for the scientific community in formalizing an Anthropocene unit (Walker et al., 2015). The argument is closely tied to N-FGA because the farther the future, the more diachronous anthropogenic signals will appear. However, it differs from N-FGA in arguing that diachronicity is already visible from a *present* perspective.

The earliest instance of attribution of diachronicity to the Anthropocene is traceable in the Ruddiman Hypothesis, originally advanced by Ruddiman in 2003.[333] The hypothesis, which suggests that anthropogenic changes of global significance preceded the Industrial Revolution (and later in the debate, the Atomic Age) by thousands of years, has been a major competitor of the Anthropocene Hypothesis by promoting an informal usage of the term. The debate between the majority of the AWG and Ruddiman (who declined an invitation to join the group) has spanned over a decade, and provides an illuminating example of the debate over the diachronous nature of the Anthropocene. Recently, the debate was articulated in a series of three articles published in *Progress in Physical Geography* where Ruddiman (2018) criticized the Anthropocene Hypothesis, the AWG (Zalasiewicz et al., 2019a) responded to criticism, and finally Ruddiman (2019) provided a further reply to the group.

In his first paper, Ruddiman (2018) highlights three main flaws in the Anthropocene Hypothesis. The first flaw is that its proposed boundary (i.e., ~1950) ignores millennia of anthropogenic changes of a greater cumulative magnitude. This argument draws on three major pre-Atomic Age changes of global reach: (1) the extinction across continents of large mammals in the Late Pleistocene associated with human migration, and the extensive forest clearance associated with spreading agricultural practices (< ~12 ka); (2) increased methane-emission associated with domesticated livestock and the spread of irrigated rice farming

[332] Another early proposal of diachronous attribution to the Anthropocene also appears in Periman (2006), who argues that "[t]he Anthropocene begins to emerge when we consider human-environmental activity at a local level, compounded by thousands of years, affecting vast areas of interlocking landscapes" (p. 562, quoted in Edgeworth, 2014b).

[333] See section 3.2.2.3.

across southern and southeast Asia (< 5 ka); and (3) the development of novel agricultural practices during the Industrial Revolution, such as the John Deere plow, the McCormick reaper, and later fossil-fuel based tractors. These changes represent the "largest transformations of Earth's surface to date by human activities" (p. 456). If the Anthropocene unit is defined by the impact of human activities, then there is no point in formalizing a unit that would not account for these massive transformations.

The second flaw is methodological. The AWG (Waters et al., 2018, also quoted in Ruddiman, 2018) has argued that "the choice of markers should not be to provide an indication of the start of anthropogenically driven effects, but to give the most pragmatic marker that will allow global correlation of the chosen boundary, being geographically extensive, temporally abrupt and providing a permanent record" (p. 381). This stance reflects the methodological requirements set by the stratigraphic community for locating a GSSP – whose primary marker needs regional and global correlation in *synchronous* outcrops. Within the methodological framework, the AWG has considered the ~1950 peak in radionuclides to be a suitable candidate for marking the beginning of the Anthropocene. This methodological choice also implied rejecting megafauna extinctions, domestication of livestock and crops, and the Industrial Revolution as markers for the Anthropocene because of their diachronous nature. Ruddiman (2018) has accused this methodological choice of neglecting millennia of significant and global anthropogenic changes. Rather than proposing a stratigraphy-based marker, Ruddiman has argued "against *any* formal definition of the Anthropocene precisely *because of* its basic time-transgressiveness" (p. 457). If a stratigraphy-based definition of the Anthropocene ignores millennia of anthropogenic alterations of the Earth, then it is more convenient to treat the Anthropocene (or 'anthropocene,' without capitalization, as Ruddiman proposes) as an informal designation.

The third flaw is practical: scientists will make little if any use at all of a formally designated Anthropocene unit. Ruddiman argues how this is already the case for some existing formal units, such as the stages dividing the Pleistocene Epoch – the Gelasian (2.588 Ma to 1.8 Ma), the Calabrian (1.8 Ma to 0.781 Ma), the Ionian (0.781 Ma to 0.126 Ma), and the Tarantian (0.126 Ma to 11.7 ka). Paleoclimate and paleoenvironmental research barely ever implement these terms in published research and textbooks. Improved radiometric techniques allow probing into recent (i.e., Quaternary) geological time with higher and higher precision, essentially bypassing the need for using recent formally recognized time units of low hierarchical status. Considering the extremely short time span of the unit advanced by the Anthropocene Hypothesis, Ruddiman concludes that "most practicing scientists will refer to the 'anthropocene' and its various [and diachronous] phases in an informal way and ignore any formal late-1900s 'Anthropocene' designation" (p. 459).

The AWG (Zalasiewicz et al., 2019a) responded to Ruddiman (2018) by considering a formal Anthropocene compatible with diachronous anthropogenic variants. First, the group argues that an early "Anthropocene as defined stratigraphically should *not* be equated with 'anthropogenic'. The Anthropocene […] is not synonymous with anthropogenic activity" (Zalasiewicz et al., 2019a, p. 325). This does not imply deflating the significance of millennia of anthropogenic impacts, but it denies them the status as the largest transformations of the Earth's surface – as recent global road network development, damming, or global loss of wildlife witness. The group considers the steady Holocene atmospheric CO_2 and CH_4 increase as natural rather than anthropogenic – contrary to what is argued by Ruddiman. Additionally, the group justifies a ~1950 boundary by recognizing it as a "marked *intensification* […] of anthropogenic change, taking the Earth System beyond the envelope of Holocene conditions" (p. 324). The boundary represents a *decisive* threshold concerning human alteration of the Earth System – an episode of unprecedented magnitude in human and Holocene history.

Second, the AWG denies that locating early anthropogenic impacts either in the Holocene or the Anthropocene diminishes or downgrades the historical and environmental importance of these impacts. An Anthropocene boundary at ~1950 is only consistent with the abundant stratigraphic evidence converging by that time, particularly geochemical markers, and the methodological necessities of grounding a proposed unit on global and synchronous signals. The mandate of the AWG is "to identify a practical stratal and time marker as point of reference in the formal classification of geological time" rather than providing "another prism through which to reinterpret human history and environmental impact" (Zalasiewicz et al., 2019a, p. 320). Thus, "whether a particular phenomenon lies above or below a chronostratigraphic boundary has no significance to its inherent or perceived worth or significance" (p. 327).

Third, the group claims it is not true that recent (i.e., Pleistocene) geological time units are largely useless and unused among scientific communities. The purpose of dividing time into geological units is to afford "effective means of arranging and communicating a wide range of phenomena within time and space on Earth" (ibid.). Scientists of different provenances will have different ideas of formal time periods (e.g., the Greenlandian, 11.7 ka to 8.186 ka), rather than adopting informal and ambiguous designations (e.g., Early Holocene). Contrary to Ruddiman, citation metrics show that formal geochronological/ chronostratigraphic units of recent time are "arguably more, and not less, widely used by scientists other than geologists" (p. 328). While paleoceanographers and paleoclimate researchers may use different reference frameworks for studying the recent geological past, correlation of frameworks with the geological time scale is a long and well-established practice among Earth science communities. Moreover, the group notes the Ionian and Tarantian (used by Ruddiman as examples) are not officially recognized by IUGS because they are not yet defined by a GSSP – hence why they have not seen much use among scientists.

Ultimately, the AWG states that Ruddiman's 'Anthropocene' represents a different theoretical entity from the Anthropocene Hypothesis. It is a concept representing "the time when human impact became significant, the definition of which can vary from author to author and the recognition of which can vary from place to place to reflect both individual interpretation of significance and the diachronous spread of human influence" (p. 330). This concept is different from the Anthropocene Hypothesis – a *geochronological* and *chronostratigraphic* interpretation of the 'Anthropocene.' If so, then the argument of diachronicity does not hold because it is attacking a straw man – that is, it attempts to confute a different argument than the one originally advanced by the Anthropocene Hypothesis.

Ruddiman's (2019) reply to the group (restricted by the journal editors to 2000 words) reiterates and clarifies some of the points advanced in his first article. The reply also appeals to the very research practices implicit in the AWG. For instance, it claims that "lead papers by multiple AWG authors did not mention several key publications that document large early anthropogenic changes" (p. 347), and that this "pattern" (ibid.) omits crucial research produced in recent years focusing on key anthropogenic transformations, while only selecting early criticism of Ruddiman (2003). Such criticism essentially attributes confirmation bias to research practices of the AWG. Another example concerns the mandate of the AWG. Ruddiman (2019) criticizes the *a priori* methodological stance of the group, setting a disciplinary limit that ignores or downgrades "viewpoints from other fields" (p. 349). This criticism seems to view the multidisciplinary face of the AWG as simply window-dressing, hiding the strictly geological mandate that the AWG in fact attributes itself. While the points raised in this reply represent a rich hub for sociological discourse, the main object of this paragraph is the question of diachronicity – which is not raised in the reply.

Another major instance of the diachronicity argument comes from archaeology. Archaeological research has been especially involved in underscoring the seemingly diachronous nature of the Anthropocene as a geological unit (Braje, 2016; Edgeworth, 2014a; Edgeworth et al., 2019; Edgeworth et al., 2015; González-Ruibal, 2018; Periman, 2006; Pétursdóttir, 2017). Archaeology (especially archaeological stratigraphy) and geology share an early history and practices, but increasing specialization of both disciplines led to a separation in their object of study – archaeology dealing with shallow deposits and time depths, and geology dealing with the underlying rocks in a time frame of a much greater order of magnitude. Nevertheless, this separation recently found renewed convergence in the Anthropocene Hypothesis debate – where the extremely recent nature of geological and stratigraphic evidence makes it also *archaeological* evidence.

The AWG member Matt Edgeworth (2014b) has located such convergence in the notion of artificial ground,[334] arguing that "for artificial ground to be reliably used to inform debate on the proposed new epoch, stratigraphical evidence from pre-industrial and even prehistoric periods should be included in its classification" (p. 93). Archaeological evidence associated with millennia of human–nature interaction leads to three conclusions: first, that Zalasiewicz's (2008) hypothetical future observer will detect a Human Stratum event of a diachronous nature (i.e., diachronicity from a FGA perspective); second, that this event should be "broadened out to include Neolithic tells, plaggen soils, sediment built up behind early dams, Roman occupation debris, mediaeval castle earthworks, and so on, together with later industrial age deposits" (Edgeworth, 2014b, p. 105); third, that from an archaeological (present) perspective, the lower boundary of the Anthropocene (identified by Edgeworth as 'Boundary A') identifies "the first surviving traces of human activity in the material record at any given location" (p. 106) – meaning that the Anthropocene represents a diachronous temporal unit.

[334] The AWG (Zalasiewicz et al., 2019b, para. 2.5.1) does not consider artificial grounds as a marker in itself for a chronostratigraphic Anthropocene.

The last point may appear as purely a matter of reference frameworks – that is, the 'Anthropocene' in archaeology differs from the 'Anthropocene' as a geological time unit, based on non-mutually exclusive methods of analysis and properties observed. In fact, this is the case for many scientific and humanistic variants of the 'Anthropocene,' each analyzing one or more specific aspects based on the framework adopted (e.g., historical, social, ethical, Earth System science, etc.). However, in addition to providing a new reference framework to approach the 'Anthropocene,' archaeological literature – and particularly literature authored by the Edgeworth (Edgeworth et al., 2019; Edgeworth et al., 2015) – seems to contest the very validity of a chronostratigraphic Anthropocene, and thus of the Anthropocene Hypothesis.

The main line of argument has been that anthropogenic stratigraphy reveals a diachronous beginning of the Anthropocene. Edgeworth et al. (2015) notice that a chronostratigraphic framework "contrasts with the diachronous character of much archaeological and geological evidence in the Earth's sedimentary record" (p. 2) – which stretches as far back as 13.8 ka (i.e., the Late Pleistocene megafauna extinction). The authors argue that, if a geochronological and chronostratigraphic boundary should reflect "a substantial change in the Earth system" (Zalasiewicz et al., 2015b, p. 197) recognizable in the different physical, chemical, and fossiliferous properties differing above and below the boundary, then this change is represented diachronously in "the lower boundary of anthropogenic deposits" (Edgeworth et al., 2015, p. 2), or Boundary A. This boundary defines the onset of a spectrum of anthropogenically modified grounds, such as "artificial ground of industrial date, archaeological strata, buried infrastructure, quarries, landfill deposits, agricultural soils and surface layers of relevant material irrespective of depth" (p. 8). These represent parts of a larger stratigraphic entity – the *archaeosphere* – whose "lower boundary [i.e., beginning] can be understood to be a largely continuous [viz. diachronous] allostratigraphic [[335]] surface extending over considerable areas" (ibid.). Boundary A represents the primary stratigraphic marker of the archaeosphere, associated with secondary markers related to the appearance of human artifacts relative to their deposits below, to fossils of domesticated animals, different physical and chemical composition of soils, and notable changes in the character and complexity of stratification. The archaeosphere varies in thickness and geographic extension, and lower boundaries include marine deposits (those with higher preservation potential) such as "[s]poil and other waste from mining activity, material dredged from harbours and estuaries, dumps of ballast from ships approaching harbour, rubbish tipped overboard from boats, plastic debris from multiple sources" (ibid.) – among others. Artifacts and technofossils of various origins also characterize the lower boundary of the archaeosphere. For instance, pottery represents a novel material of wide geographical distribution, just like 20th-century plastic. It first appeared in China at ~20–19 ka (Wu et al., 2012), in Europe at ~17.5–15 ka,[336] in the Middle East between 11 ka (Edgeworth, 2014b) and 9 ka (Gibbs, 2015), in Africa at 9.4 ka (Huysecom et al., 2009), and in South and Central America at 7–6 ka and 4 ka respectively (Edgeworth et al., 2015). As such, pottery represents a diachronous marker of the archaeosphere.

[335] See section 3.1.2.3, footnote 190, for the definition and purpose of allostratigraphy.
[336] Early instances of pottery were retrieved in 2006 in an archaeological site located at Vela Spila Cave, Croatia.

The diachronous nature of the archaeosphere or Boundary A reflects the diachronous nature of the Anthropocene if its lower boundary (1) represents changes in the Earth System detectable in stratigraphic records, and (2) includes the appearance of anthropogenically modified grounds. These are diachronous aspects which challenge "the rationale of imposing a precise and globally synchronous date onto processes that stratigraphic evidence indicates were – and still are – manifestly diachronous in onset and development" (2015, p. 19). This methodological choice (i.e., considering the Anthropocene as a diachronous lithostratigraphic unit whose beginning is defined by Boundary A) rejects a GSSP-based definition of the Anthropocene as a chronostratigraphic unit, considering a diachronous Anthropocene a more comprehensive and useful unit for archaeological as well as geological research. This criticism has been recently reiterated by Edgeworth et al. (2019) in a paper entitled "The chronostratigraphic method is unsuitable for determining the start of the Anthropocene."

The paper endorses and expands upon Ruddiman's (2018) 'three flaws' previously discussed in this section by questioning "the suitability of the chronostratigraphic method for the division of time on archaeological and historical timescales, which are several orders of magnitude shorter" (Edgeworth et al., 2019, p. 335). The authors argue that the emphasis placed on the chronostratigraphic method impinges on a stratigraphically sound characterization of the Anthropocene – one that would include anthropogenically modified ground (i.e., the archaeosphere). By defining the Anthropocene as a chronostratigraphic rather than a stratigraphic (viz. lithostratigraphic) unit with a lower boundary at ~1950, the Anthropocene Hypothesis inverts the traditional 'ground-up' or 'strata-led' characterization of stratigraphic units. As a result, the hypothesis is a "case of ideas imposing their authority on strata, using the material record only as an index (through the use of stratigraphic proxies), for the date of 1950 has already been decided upon for non-stratigraphic reasons" (p. 337). This date, whose selection follows the synchronicity requirement of chronostratigraphy, "will be effectively unmappable on the ground" (ibid.) because it would reflect a concept rather than actual material strata.

Furthermore, the authors note that diachronicity and synchronicity are relative, in that all GSSPs are somehow diachronous – entailing uncertainties of thousands to millions of years. The perceived diachronicity of the archaeosphere is only related to its proximity from the present perspective. If the GSSP method should be used to determine the beginning of the Anthropocene, then a diachronous lower boundary would be consistent with the average uncertainty of GSSPs – unless implementing *ad hoc* criteria for selecting a ~1950 boundary:

> different criteria are being applied to different sets of evidence used for boundary definition, according to how near or how far away these are in time from the chronostratigraphic observer in the present. […] [T]he closer the boundary is to the present, the greater the time-definition demanded and the more that so-called diachronous evidence (actually near-synchronous on a scale of deep time) is removed from consideration. […] The degree of time precision being asked of this latest boundary [i.e., the Anthropocene], within one decade, is over six orders of magnitude (10^6) greater than that of nearly all the boundaries marked by GSSPs in the earlier Phanerozoic. There has been a huge shift in the timescale of chronostratigraphic observations from deep geological time to the much shallower time frames used by archaeologists, historians, ecologists, geographers

> and other scholars investigating the dynamics of recent times, without any corresponding shift in methodological focus. (p. 339)

The argument here outlined is that the AWG is arbitrarily bending chronostratigraphic criteria to justify the ~1950 boundary without implementing complementary methodologies necessary for the very timescale considered by the Anthropocene Hypothesis. This arguments assumes chronostratigraphy (and stratigraphy in general) to be unequipped to deal with short timescales, especially when confronted with decade-long timescales. The selection of the ~1950 boundary reflects a seemingly synchronous and global signal (radionuclide fallout) that is *interpreted* by the AWG as a satisfactory chronostratigraphic marker. Edgeworth et al. (2019) contest this interpretation (and consequent methodological choice), arguing that the chronostratigraphic requirement of synchronicity hinders rather than improves a thorough and useful characterization of the Anthropocene in scientific discourses. Ultimately, the rejection of a chronostratigraphy-based Anthropocene translates into rejecting the formalization of the Anthropocene as a geological time unit (since this requires a chronostratigraphy-based boundary).

An interesting and relevant insight is offered by a thought experiment conducted by Schmidt and Frank (2019). The experiment – named the Silurian Hypothesis – is very similar to FGA in that it assesses the likelihood that a future civilization will be able to detect signs of an industrialized civilization in the geological record. The authors consider the stratigraphic markers of the Anthropocene and compare them to previous Paleozoic, Mesozoic, and Cretaceous events of geological significance – e.g., Paleocene–Eocene Thermal Maximum (PETM), Eocene Thermal Maximum 2 (ETM-2), oceanic anoxic events (OAEs), and extinction events from the Late Devonian (380–360 Ma) through the Carboniferous (305 Ma) to the end-Permian extinction event (252 Ma). They find "undoubted similarities between previous abrupt events in the geological record and the likely Anthropocene signature in the geological record to come" (p. 148) – such as warming, variations in atmospheric $\delta^{13}C$, disruption of the nitrogen cycle, carbon dioxide output, and the magnitude of changes. However, they question the possibility of detecting an Anthropocene event in a section only a few centuries old, so that "direct isolation of an industrial cause based only on apparent timing is also not conclusive" (p. 148). They do not deny that a clear signature of an Anthropocene event will be left in geological traces. In fact, they observe that multiple proxies (e.g., geochemical, biostratigraphic, lithological, mineralogical) of the Anthropocene located in ocean sediment layers will provide a unique combination demarcating "a clear transition of faunal taxa prior to the event compared with afterwards" (p. 146). Nevertheless, they note that, from a future perspective, "the Anthropocene will likely only appear as a section a few cm thick, and appear almost instantaneously in the record" (p. 144), and that its significance will likely depend on future scenarios.

Further instances of the diachronicity argument are detectable across the Anthropocene scientific literature. For instance, Autin and Holbrook (2012) observe that a "global marker could be diachronous across millennia if human-accelerated sedimentation were the specific attribute used to mark the basal Anthropocene" (p. 60). This is because "[a] distinct stratigraphic marker [for the Anthropocene] should have been forming since anthropogenic change began" (p. 60). While this point is questioned by the AWG (as delineated in the recent Ruddiman debate), the authors – writing roughly three years after the formation of the AWG – invoke the diachronous nature of anthropogenic signals as a possible epistemic hindrance to the Anthropocene Hypothesis. Geologists S. J. Gale and P. G. Hoare (2012) recognize "serious difficulties in using stratigraphic methods to define the base of the Anthropocene," partly because of the "worldwide diachroneity of human impact and the difficulty of establishing a single chronological datum for the epoch" (p. 1493). Similarly to Ruddiman (2018) and Edgeworth et al. (2015; 2019), defining a ~1950 boundary would be of little use in characterizing anthropogenic impact on the planet. Consequently, a stratigraphic Anthropocene would be mostly "unnecessary, constraining and arbitrary" (Gale & Hoare, 2012, p. 1494).

The literature surveyed in this section converges toward diachronicity as a central problem in the Anthropocene Hypothesis. This issue can be discretely analyzed as the following argument:

> **DA (Diachronicity Argument):** The diachronous nature of the stratigraphic markers characterizing anthropogenic impacts on the Earth makes any chronostratigraphic definition of the Anthropocene epistemically problematic or unnecessary.

Notably, DA expresses the problematic or unnecessary nature of *any* chronostratigraphic definition of the Anthropocene. Because extant geological research favors the GSSP method (a chronostratigraphic method) for determining the beginning of most geological units in the Phanerozoic (Salvador, 1994), rejecting a chronostratigraphy-based definition of the Anthropocene means rejecting *any* formal definition of the proposed unit as a geochronological/chronostratigraphic unit. Thus, DA does not solely criticize the Anthropocene Hypothesis and its proposed ~1950 boundary, but also (1) the very methodology chosen for defining it (i.e., chronostratigraphy), (2) any alternative date based on such methodology, and (3) the general utility of formal recognition for the broader geological and scientific community (this latter point is also discussed separately in section 5.2.4). For these reasons, researchers advancing DA have suggested the informal use of 'anthropocene' (non-capitalized), or abandoning the Anthropocene Hypothesis in the context of stratigraphic and chronostratigraphic classification.

As anticipated at the beginning of the section, DA is very close to FGA because from the latter viewpoint, any timespan as geologically 'short' as the appearance of *Homo sapiens* will appear almost synchronous from a hundred-million-years future perspective. Therefore, diachronicity and synchronicity are not absolute properties, being always dependent upon a given temporal reference framework. This is not unknown to the AWG (Waters et al., 2014b), who also recognize that "[v]irtually all stratigraphic boundaries are diachronous and spatially heterogenous to an extent that would make any of the potential Anthropocene bounding events seem effectively instantaneous, in a far-future perspective" (p. 15). However, DA does not require a future perspective (either hundreds or millions of years in the future) because it argues that diachronicity is already visible from the *present* perspective. This is possible by noting anthropogenic impacts on the Earth through time, and correlating them to significant biotic, environmental, and climate changes recorded in stratigraphic signals.

The rationale behind DA is that, if an Anthropocene time unit should be characterized by anthropogenic impacts globally detectable in stratigraphic layers, then millennia of anthropogenic modifications of land (associated with agriculture, livestock, urbanization, etc.) *should be* included in the definition of the unit. If not, then a selected chronostratigraphic boundary at ~1950 would create a seemingly 'empty' or 'thin' Anthropocene – not reflecting the (diachronous) signals that engendered it over the course of millennia of human history. While the AWG argues that this rationale does not mirror the practices of geochronology and chronostratigraphy, DA reiterates that such methodology is fundamentally incapable of dealing with the timespan it seeks to explain and translate in geological terms. In short, the epistemic gains of selecting a ~1950 boundary through a GSSP-based method are largely inferior compared to the gains of using an informal 'anthropocene' whose identity includes millennia of anthropogenic activities.

DA is a powerful argument against the Anthropocene Hypothesis, and many researchers on the 'Anthropocene' have endorsed this perspective – especially researchers involved in human history and paleohistory, where gradual, cumulative, and transformative changes (rather than sharp threshold events) are customary. Its importance for the Anthropocene Hypothesis as well as Anthropocene Studies is paramount – having ignited a range of intense and prolific debates over the nature of the 'Anthropocene' either as an Earth System singularity, geological time unit, or historical event.

5.2.3 The Unorthodoxy Argument

Another recurrent type of criticism against the Anthropocene Hypothesis concerns its methodological and procedural orthodoxy. The term 'orthodoxy' (ὀρθοδοξία) translates literally from the Greek as 'correct opinion,' and more generally as adherence to an established creed or norm. In this context, orthodoxy reflects adherence to the general protocols and norms established by the stratigraphic community, and criticism of unorthodoxy questions the adherence of the Anthropocene Hypothesis to such protocols or norms. This is an important line of criticism because it unveils the deeper normative-methodological aspects of the Anthropocene Hypothesis anticipated in section 1.3.1. Such criticism unfolds in several ways, from questioning the methods and practices of the AWG to disputing the *stratigraphic* nature of the evidence and claims supporting the hypothesis. The common denominator among this criticism is that the hypothesis (and the AWG) does not adhere to the traditional norms and procedures of geochronological and stratigraphic research (*contra* the AWG's self-proclaimed adherence to such norms). In the words of environmental activist Kierán Suckling (2014), the 'Anthropocene' "immediately stands out as an anomaly." If so, then the seemingly 'unorthodox' nature of the Anthropocene Hypothesis casts doubts on the *stratigraphic* nature of the hypothesis. Such an argument can be summarized in the following way:

UnA (Unorthodoxy Argument): The Anthropocene Hypothesis is not a stratigraphic hypothesis because it does not reflect the standard methods, practices, and evidence of stratigraphic classification.

UnA represents a pool of diversified criticism rather than a single line of argument. This section explores three selected accusations of 'unorthodoxy' of particular relevance in debating the Anthropocene Hypothesis, namely, (1) the seemingly wrong and misleading choice of the term 'Anthropocene' (Bonneuil, 2015; Gale & Hoare, 2012; Gibbard & Lewin, 2016; Gibbard & Walker, 2014; Walker et al., 2015); (2) the unorthodox nature of Anthropocene evidence and scientific procedure (Finney & Edwards, 2016; Gibbard & Walker, 2014); and (3) the hidden activist and political agendas pursued within the call for formalization of the epoch (i.e., Claim 2) on the geological time scale (Finney & Edwards, 2016; Schneider, 2020; Visconti, 2014).

5.2.3.1 The Naming Argument

Accusations of a terminological fault are abundant in 'Anthropocene' literature.[337] The humanities and social sciences have primarily been concerned that the implicit *Anthropos* in the 'Anthropocene' term may have important implications for the way humanity is portrayed in engendering the proposed epoch. However, humanists also take notice of the seemingly unorthodox naming choice for geological research. For instance, LeCain (2015) observes that "none of the other officially recognized geological periods are named for a specific class or order of creatures, much less one species" (p. 19). Similarly, Bonneuil (2015) notes that "the naming practice is an anomaly in the stratigraphic nomenclature: until now, geological divisions were named after their main flora and fauna composition, not after any causal agent" (p. 19).[338] Foster (2018) also notes that "[i]f the nomenclature for the proposed new epoch were to stick with the tradition of mentioning only *effects*, then the anthropos should receive no explicit mention" (p. 24). This criticism suggests an unorthodox naming practice that breaks with the traditional norms of geochronological nomenclature.

Within the geological community, researchers have advanced similar and additional criticism against the term. Walker et al. (2015) identify two reasons why the terminological choice is misleading. First,

[337] For a interesting insight on the philosophy of geological nomenclature, see Davis (2011).

[338] Bonneuil's observation seems to confuse *defining* (in stratigraphic terms; see Murphy & Salvador, 2000, p. 235) geological units with *naming* them. Chronostratigraphic units are *defined* based on (preferably) marine fossiliferous records that reflect a given flora and fauna composition in a given time, but are not technically *named* after that composition (e.g., the *terms* 'Jurassic,' 'Quaternary,' and 'Holocene' are not chosen after species composition; see also Salvador, 1994, section 3.B.3). The confusion may arise from the fact that Bonneuil is probably considering Cenozoic epochs (i.e., Paleocene, Eocene, Oligocene, Miocene, Pliocene, Pleistocene, and Holocene), which are *defined* on the relative abundance of molluscan taxa, and have historically established names that reflect this abundance in stratigraphic sequences. Yet, the ISG does not require the *naming* to follow the fauna and flora composition of a given fossiliferous stratigraphic sequence. In fact, it recommends naming a series after "a geographic feature in the vicinity of its stratotype or type area" (Salvador, 1994, p. 81). Nevertheless, Bonneuil is correct in noticing that no geological unit is named after a causal agent.

they suggest that the etymology of the term 'Anthropocene' (from ἄνθρωπος, 'anthropos,' meaning 'human'; and καινός, 'kainos,' meaning 'new') "makes no sense at all" (p. 205) once literally translated into 'human-new.' The suffix '-cene' has been used to characterize Cenozoic epochs (< 66 Ma), and are indicative of the relative abundance of molluscan taxa in stratigraphic records. Hence, terms like 'Oligocene' ('few new'), 'Pleistocene' ('most new'), or 'Holocene' ('entirely new') reflect species composition in rocks. However, the authors note that, following this naming praxis, the term 'Anthropocene' suggests an epoch named after the appearance of *Homo sapiens* in stratigraphic records. This is incorrect for two reasons: first, because anatomically modern humans have a long biological history dating at least to the Late Pleistocene (~300 ka); and second, because discernible anthropogenic forcings are already included in the definition of the Holocene. Similar observations concerning the misleading etymology of the term have been raised by Visconti (2014), who notes that the "etymology of the word is not consistent with the meaning of other geologic epochs" (p. 381).

A second reason why the term 'Anthropocene' is considered misleading concerns its seemingly self-appointed status of epoch implicit in the '-cene' suffix. Virtually ever since Crutzen's seminal IGBP intervention and article, researchers have been treating the Anthropocene as an *epoch*, rather than any other lower hierarchical unit (e.g., sub-epoch, stage, sub-stage). This initial trend was further reinforced by the work of the AWG, which also assigned the Anthropocene the status of epoch as the most suitable hierarchical level to represent the scale and magnitude of the proposed period.[339] Walker et al. (2015) contend that "[n]o consideration is given to the possibility that the 'Anthropocene' might be designated a unit of lesser rank, i.e. of stage, age, or even sub-stage/sub-age status," and that "there is no question for Zalasiewicz et al. [2015] to consider regarding the status of the 'Anthropocene'; the decision has already been taken" (p. 205).

This type of accusation is very common among scientific literature critical of the Anthropocene Hypothesis, and often follows criticism over the chosen geological rank. For instance, Gale and Hoare (2012) note that "there would appear to be strong grounds for reviewing the accepted stratigraphic status [i.e., epoch] of the unit" (p. 1494, note 1). Gibbard and Walker (2014) also observe that the suffix '-cene' implies, unwittingly or intentionally, that "the term would have Series or Epoch status" (p. 32). Regarding this epistemic assumption, they object that

> a change of this magnitude is not supported by the geological evidence, the Anthropocene episode being too limited in duration when viewed from the perspective of the present, and with too variable a global stratigraphic signature to justify its elevation to a time-stratigraphic unit of Series or Epoch rank within the internationally agreed geological timescale. (ibid.)

[339] During a personal interview with Zalasiewicz held on occasion of the ten-year anniversary of the Rachel Carson Center (personal interview, November 21, 2019), it transpired that the AWG is willing to consider the Anthropocene as an age/stage – if deemed appropriate by the larger geoscientific community. Nevertheless, the majority of the group holds to the idea that the epoch level best reflects the nature of the Anthropocene as a geological time unit.

Head and Gibbard (2015) add to this criticism by stating that "it would make more sense to define the 'Anthropocene' at the rank of stage or substage (if formalized at all), as this would maintain the Holocene in its useful, entire, traditional and historical contexts" (p. 33). As such, the 'Anthropocene' should be renamed with the '-ian' or '-an' suffix typical of age-level units (e.g., Meghalayan, Gelasian, Piacenzian, etc.). Different members of the stratigraphic community have expressed criticism against the implicit hierarchical status of the Anthropocene, suggesting a stage or substage definition, or simply as an event or episode of the Holocene.[340]

An argument summarizing this type of criticism can be formulated as following:

> **NA (Naming Argument):** The term 'Anthropocene' is not consistent with the naming of traditional geological time units, and reflects an *a priori* methodological choice concerning the status and rank of the proposed geological unit that is epistemically misleading.

As observed, the *a priori* methodological choice is reflected in the adoption of the '-cene' suffix, which leads to the assumption that the Anthropocene should be treated as an epoch-level time unit. NA argues this choice to be epistemically misleading because rank level is assigned only *after* a substantial and justified stratigraphic profile has been defined and characterized for the proposed unit. The proposed Anthropocene unit, critics argue, seems to have undergone the opposite transformation – from geochronological to stratigraphic unit. This unorthodox practice has also been noted by Barnosky (2014):

> Past definitions began with recognizing distinctive features of the material rock record, primarily the fossils contained therein and their implications for defining biostratigraphic and chronostratigraphic units. From those stratigraphic entities, geochronological units (epochs) were then recognized. The development of the Anthropocene has gone in exactly the opposite direction. An arbitrary unit of time (a geochronological unit), characterized as the time of intensified human impacts, was first proposed (Crutzen 2002a, b, c; Steffen et al. 2007), and now the material 'rock' record – deposits that have accumulated in the past few centuries – is being scoured for distinctive signs that could provide an objective material basis for an epoch. (p. 151)

The AWG (Zalasiewicz et al., 2017b) has acknowledged that the term 'Anthropocene' is "not a carefully constructed neologism" (p. 208), but rather a spur-of-the-moment word that maintained its terminological integrity and impetus after Crutzen's original formulation. Nevertheless, they also observe that "geological time unit terms in general are not the most rigorously constructed or consistent items of language" (ibid.) – using the case of the Silurian and Ordovician (named after Welsh tribes) as examples.

Additionally, the AWG argues that 'Anthropocene' is a well-established term, citing bibliometric figures (i.e., citation scores) and inclusion of the term in English dictionaries. The ISG (Salvador, 1994, section 3.B.3, requirement g) allows tolerance and flexibility in choosing names for stratigraphic units,

[340] Biologist Valentí Rull (2018) provides useful insight through personal communication with geologists who have opposed the Anthropocene Hypothesis.

including the preservation of well-established names. Both advocates and critics of the Anthropocene Hypothesis agree that (for better or worse) the term 'Anthropocene' has become widely adopted in scientific communities as well as the humanities, the social sciences, and the broader popular and political discourse. If popularity is a synonym of well-established, then it seems that the current linguistic expression of 'Anthropocene' is consistent with the ISG naming guidelines. However, popularity alone may not suffice to consider 'Anthropocene' well-established. The ISG does not provide a rigorous definition of 'well-established,' leaning instead toward an interpretation of 'well-established' as holding a long-standing history. After more than twenty years, one could make the case that the 'Anthropocene' term can be ascribed such status.[341]

Nevertheless, being well-established (either by popularity or historical tradition) does not immediately warrant formal recognition as an epoch. If the Anthropocene were to be discussed (or formalized) as an Age/Stage, then the '-cene' suffix should accordingly be replaced by '-ian' or '-an' to avoid unnecessary epistemic confusion. What NA argues is that such *discussion* is not considered *because* the terminology implicitly assumes the Anthropocene to be treated and discussed as an epoch. If the term 'Anthropocene' is epistemically misleading, then so is the Anthropocene Hypothesis. This is not merely because of the terminology it reiterates, but because it is a central claim of the hypothesis that the proper unit level reflecting the magnitude of the stratigraphic signature of *Homo sapiens* is that of epoch/series (Claim 3). It is possible that the content of Claim 3 may change with future research, perhaps attributing the 'Anthropo-unit' a lower rank than epoch (unlikely a higher one). Indeed, the main argument advanced by NA is not against the selected rank, but rather the selection of the epoch level implicit in the term's suffix – suggesting an already widely established rank. While the majority of the AWG agrees on the epoch level, criticism surveyed shows that evidence is not conclusive in this direction. Ultimately, it often follows from NA that the term should be treated informally, given its seeming inconsistency with stratigraphic nomenclature protocols.

5.2.3.2 The Unorthodox Evidence Argument

Evidence for the Anthropocene Hypothesis ranges from traditional stratigraphic evidence and Earth System science to archaeology, history, and biology. In the context of formal ratification of the Anthropocene as a possible time unit, stratigraphic evidence represents evidence of primary importance, and thus the primary object of debate. Such debate is focused around two main discursive hubs, namely, (a) that the evidence submitted does not sufficiently warrant recognition of a distinct stratigraphic and chronostratigraphic unit; and (b) that the evidence submitted is not *stratigraphic* in a traditional sense.

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[341] It should be noted that both popularity and history are relative parameters – relying on factors such as language and discipline. The term 'Anthropocene' may be popular in some languages (notably English) while not in others, and popular in some domains (notably the environmental humanities) and not in others. The central question is assessing popularity and history within the stratigraphic context – the defining context of the Anthropocene Hypothesis.

Hub (a) is defined by several arguments advanced against the evidence submitted by the AWG.[342] As also observed by Zalasiewicz et al. (2017b), most criticism of this type accuses the spatial and temporal scale of the Anthropocene to be too insignificant to allow correlation and recognition as a distinct unit. In his contribution to *A Stratigraphic Basis for the Anthropocene* (Waters et al., 2014a), Finney (2014) questions "how human-induced material bodies of an 'Anthropocene' will be shown on medium- and small-scale [geological] maps, if at all" (p. 26), given the extremely thin and recent nature of anthropogenic deposits. Finney and Edwards (2016) consider the 1945 boundary[343] (and by association the 1950 boundary) as stratigraphically negligible. They also argue that most of the stratigraphic evidence supporting the Anthropocene Hypothesis is based on predictions of preservation of future records. In the present, this evidence (bioturbation, excavation, human stratum, etc.) cannot yet be used for defining a stratigraphic and chronostratigraphic unit. Anthropogenic records preserved in depositional settings such as lakes, marshes, speleothems, coasts, ice cores, and more, are only a few centimeters thick, making them hard to distinguish from the lower Holocene stratigraphic profile. Likewise, Gibbard and Walker (2014) consider the Anthropocene to be too limited in terms of its temporal span to demarcate a post-Holocene unit, and it is thus uncertain whether the proposed anthropogenic markers for the Anthropocene could distinctly and adequately represent a Holocene-Anthropocene boundary. This view is shared by Autin and Holbrook (2012), who consider an Anthropocene global marker "at best a bit premature" (p. 60). This discursive hub imputes the evidence for an Anthropocene stratigraphic and chronostratigraphic unit not to be sufficient for effectively (and usefully) recognizing a new time unit.

Hub (b) encompasses criticism against the nature of the evidence submitted – primarily claims that the evidence supporting the Anthropocene Hypothesis is not consistent with the 'standard' evidence used in stratigraphic classification, or that such evidence is simply not *stratigraphically* relevant. For instance, early criticism against the hypothesis from Autin and Holbrook (2012) challenged the stratigraphic content of the proposed unit by claiming that "we are left to map a unit conceptually rather than conceptualizing a mappable stratigraphic unit" (p. 61). This criticism contested that the evidence so far advanced provided any substantial *stratigraphic* evidence for supporting claims of formal recognition on the geological time scale. A few years later, Finney and Edwards (2016) asserted that "[h]uman structures, excavations, boreholes, bioturbation of soils (agriculture) and the sea floor (drag net fishing) are not strata" (p. 7) and should therefore not be considered (and less treated) as such. This criticism seems to develop along the same conceptual line – that is, what is promoted as evidence by the AWG does not in fact represent *stratigraphic* evidence (and thus the 'Anthropocene' should be treated informally in a non-stratigraphic context, as many critics conclude).

[342] It must be noted that the debate is still ongoing, and most geological literature criticizing the Anthropocene Hypothesis has been written during developmental stages of the hypothesis (as seen in literature criticizing the proposal of using the GSSA method over the GSSP; see for instance Walker et al., 2015; Head & Gibbard, 2015). Hence, a systematic review of the evidence submitted by the group is still due (as of April 2021). Nevertheless, this comprehensive summary includes evidence already debated by critics of the hypothesis.

[343] The 1945 boundary was originally suggested by Zalasiewicz et al. (2015b). See section 3.2.4.1.

Based on this sample literature, criticism of unorthodox evidence may be summarized in the following argument:

> **UEA (Unorthodox Evidence Argument):** The evidence submitted in support of the Anthropocene Hypothesis does not warrant stratigraphic recognition because (a) it is largely unsubstantial and premature, and/or (b) is not relevant in stratigraphic research.

The question of what does constitute stratigraphic 'evidence' is complicated, and is located at the intersection of history, sociology, and philosophy of science. This represents a meeting point yet to mature in extant scholarship. Nevertheless, one could feasibly conjecture that geologists and stratigraphers working within certain periods of the Earth's history make use of different types of methods, and consider different types of evidence for interpreting and reconstructing the past. For instance, Quaternary stratigraphy makes vast use of (among other things) paleoclimatic research, radiocarbon dating (especially useful for the dating of organic material from the past 50,000 to 70,000 years), and optically stimulated luminescence (OSL, a technique for dating quartz minerals used in late Quaternary research[344]) to reconstruct the history of the past 2.588 million years. Not all of these techniques are applicable for much older time periods, which implement new methods and work on different types of evidence for reconstructing the past.[345] This fact alone suggests that contextual factors of a sociological nature need to be considered in representing the epistemic category of 'evidence' in stratigraphic research.

In the context of the Anthropocene, stratigraphic evidence has been recognized in the appearance of new human-mediated minerals, novel chemical compounds (radionuclide fallout from atomic bomb testing), or those anthropogenic activities connected to the formation of a Human Stratum (see section 3.1.1 and 5.2.1). Because most of these signals are new both ontologically (i.e., are not naturally produced[346]) and epistemologically (i.e., are unprecedented evidence in stratigraphic classification), their epistemic status in stratigraphic classification, and particularly chronostratigraphy and geochronology, poses a challenge to traditional stratigraphic research – a field mostly unaccustomed with interpreting anthropogenic impacts in the context of reconstructing geological time. The fact that chemostratigraphic signals represent the primary marker adopted by the Anthropocene Hypothesis for basing a GSSP (despite chemostratigraphy not being recognized as an independent stratigraphic method), and the fact that the International Mineralogical Association Commission on New Minerals and Mineral Names does not officially recognize anthropogenic rocks as minerals, are examples of such epistemic challenges to traditional stratigraphy. They also confirm

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[344] See http://www.usu.edu/geo/luminlab/whatis.html for a short explanation of OSL (accessed on April 19, 2021).

[345] That is not to say that older time units are not defined within the general classification protocol for stratigraphic units. Indeed, fossil records provide evidence for life and changes in fauna and flora composition all throughout the Phanerozoic. The remark hereby advanced is that there exist different 'cultures' or perceptions of what represents geological evidence according to the specific time frame considered.

[346] This statement does not imply that humans are not *ontologically* part of nature, but merely that some materials are unprecedented in nature before they were produced and distributed by humans.

the normative-methodological nature of the hypothesis (which implicitly asks for these aspects to be fully recognized as *stratigraphic* evidence).

5.2.3.3 The Ideological Science Argument

NA and UEA question the orthodoxy of the Anthropocene Hypothesis in a way that denies it the status of a *stratigraphic* hypothesis, particularly in terms of establishing a formal Anthropocene geochronological and chronostratigraphic unit. In addition, critics have also expressed skepticism about the very *scientificity* of the hypothesis. This skepticism is grounded in the belief that political and ideological rather than genuine scientific motivations are major drivers behind recognition of the Anthropocene as a geological time unit. More specifically, such criticism considers Claim 2 ('The stratigraphic signature left by *Homo sapiens* could be translated into a geochronological and chronostratigraphic unit of time') to be a claim motivated by the broader environmental activist agenda rather than genuine scientific research.

This type of criticism is part of a larger and longer debate between scientists and humanists (and social scientists) concerning the role of science in society. These debates manifest in different topics, such as relationships between scientists and their personal beliefs (e.g., political, religious), between methods and meaning of research, between epistemic truth and social good, or the nature of scientific knowledge. These topics of a social, philosophical, and historical nature informed conversations about science throughout the second half of the 20th century (especially in the 1990s, during the so-called 'science wars'), and remain major topics of discussion in current international and interdisciplinary scholarship about science (especially in disciplines such as STS). Amidst these discussions, a hotspot for debate is establishing a boundary between politics, ideologies, and activism on the one hand, and scientific research on the other. This question can be briefly condensed as following: a hypothetical researcher working on any topic of scientific as well as social and political interest (e.g., anthropogenic global warming, cigarette smoke–induced cancer, the relationship between gender and sex, etc.) should not allow their own beliefs (e.g., religious, political, etc.) to interfere with the practices and methods of science – lest violating basic epistemic tenets of scientific research such as neutrality, objectivity, and truth. While this may appear trivial, the fact that scientists are always enmeshed within a socio-political and economic context, and may (legitimately) hold political and/or religious views influencing or conflicting with a given subject matter,[347] makes any sharp threshold between scientific research and social values much harder to delineate. Accusations of ideological science or activist-driven agendas against the Anthropocene Hypothesis stem from this cultural, intellectual, and historical background.

As noted by Jedediah Purdy (2015), law scholar and author of *After Nature: A Politics for the Anthropocene*, "the Anthropocene is a political and ethical gambit" as much as a scientific concept. The fact

[347] Epistemic issues arising from this type of influence or conflict may take the form of different types of biases (selection bias, reporting bias, confirmation bias, funding bias, etc.).

that the term 'Anthropocene' has been widely adopted by environmental narratives and agendas within and outside academia corroborates this assertion. Criticism against the normative usefulness of the term surveyed throughout section 5.1 further proves that the 'Anthropocene' has been invested with a political overtone. However, a fundamental premise of this work states that the Anthropocene Hypothesis does not entail the same type of normative-ethical (and likewise social and political) statement otherwise entailed in the 'Anthropocene' concept. Based on this premise, normative criticism, including the political meaning and implications of the 'Anthropocene' concept, seems not to equally hold for the Anthropocene Hypothesis. Yet, criticism has also accused the Anthropocene Hypothesis of prioritizing political over scientific considerations. It is thus paramount to understand whether or not criticism of ideological research levied against the 'Anthropocene' equally holds against the Anthropocene Hypothesis. A few instances of this criticism are hereby surveyed.

Autin and Holbrook (2012) express criticism based on the nature and scientific credibility of stratigraphic research. They argue that "[s]cientific disciplines maintain their reputation by providing the credible voice a scientific community needs in public debate" (p. 61). The ISC and the discipline of stratigraphy provide credibility by meticulously assessing the scientific relevancy of stratigraphic terms based on a set of scientifically grounded guidelines (i.e., the ISG or the Code). Accordingly, grounding scientific concepts on motives beyond established and corroborated guidelines implies loss of credibility. If the Anthropocene Hypothesis were to be accepted by the stratigraphic community, this acceptance should be based exclusively on its scientific content and utility rather than the broader social message it conveys. However, the authors comment that scientists and environmental activists embracing the 'Anthropocene' (and the Anthropocene Hypothesis) base their motives on the assertation that the "Anthropocene creates public awareness and formalizes the concept of human-induced environmental change" (ibid.). Against this motive, they contend that the term "may have greater importance in pop culture than to serious scientific research," and that "pop culture does not have an interest in the stratigraphic implications of this debate" (ibid.).

A notorious accusation of politically motivated research comes from Finney and Edwards (2016), who published an article in *GSA Today* provocatively entitled "The 'Anthropocene' epoch: Scientific decision or political statement?" They argue that the term has received wide attention, but that its value in chronostratigraphic research has been largely misinterpreted and left undiscussed. Because evidence is considered by the authors inconclusive for officially recognizing a chronostratigraphic unit (following UEA), they suspect whether the true motives behind formal recognition are political rather than scientific:

> When we explain the fundamental difference of the Anthropocene from the chronostratigraphic units established by the International Commission on Stratigraphy to proponents for its recognition, they often reply that the human impact on the Earth system must be officially recognized, if for no other reason than to make the public and governmental agencies aware of that impact. Or, as the editorial in *Nature* (2011)[348] argued, official recognition would encourage cross-disciplinary science

[348] The authors are addressing the stance of *Nature* (2011) concerning the normative-social value of the Anthropocene Hypothesis. The editorial argues that "the Anthropocene does deserve proper recognition. It reflects a grim reality on

> and a "mindset" to understand and to take control of the current transformation. […] Is the role of the ICS to make such a political statement? Would official recognition of the term Anthropocene as a unit of the ICS Chart realistically have any effect on promoting cross-disciplinary science or recognizing that we are in the driver's seat as *Nature* editorialized? […] Perhaps promotion of the Anthropocene is anthropocentric as well as political? (p. 9)

Similarly to Autin and Holbrook (2012), this excerpt hints that broader social utility (i.e., increasing environmental awareness) is implemented as an epistemic parameter among proponents of the Anthropocene Hypothesis. A first thesis advanced is that such a parameter should not be implemented in assessing the *stratigraphic* validity of the term – which Finney and Edwards (2016) question. That is because the Anthropocene Hypothesis should be considered exclusively on its scientific content, rather than its normative implications. A second thesis questions whether official recognition of an Anthropocene unit on the geological time scale / international chronostratigraphic chart would have any substantial effect in terms of increasing awareness of the impact of human activities among governments, environmental agencies, and the public. This thesis has also seen support by Santana (2019b), as well as by authors rejecting the ethical value and utility of the term 'Anthropocene' based on EA.

A 'radical' example further proves the strong antagonism that the 'Anthropocene' and the Anthropocene Hypothesis have received from critics. In an article published in the journal *The Market of Ideas*, economist Henrique Schneider (2020) considers the Anthropocene Hypothesis[349] to be "indicative of how activism is permeating academia, and even science; transforming both from an institutionalized skeptical method of discovery and creation of knowledge to a process of rationalization of opinions." The author argues that the "separation of belief and science, or rather, the missing separation between them, lies at the heart of the Anthropocene fallacy," considering the 'Anthropocene' a way to confirm the *belief* in climate change on geological grounds.[350] His criticism goes so far as considering the 'Anthropocene' discourse a "totalitarian, or oppressive, project," in that it undermines the axiom of skepticism that defines science by postulating truths of and about the 'Anthropocene' with a political rather than scientific drive.

Based on these excerpts from the literature, this type of criticism against the scientificity of the Anthropocene Hypothesis can be summarized in the following argument:

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the ground, and it provides a powerful framework for considering global change and how to manage it" (*Nature*, 2011, p. 254).

[349] The linguistic expression used by the author is 'Anthropocene' rather than Anthropocene Hypothesis. However, because he is accusing the concept of promoting politically motivated *science*, it seems implicit that he is not simply addressing the 'Anthropocene' boundary object, but the very stratigraphic hypothesis.

[350] Schneider's (2020) equation between climate change and the geological 'Anthropocene' is dubious in some respects. First, anthropogenic climate change mostly (though not exclusively) relates to the discourse on global warming and emissions of greenhouse gasses. These only represent a minor aspect of the stratigraphic profile of the proposed epoch, as illustrated throughout section 3.1. This common conflation of the Anthropocene and climate change has also been noted by Thomas et al. (2020), who hold that "[t]he Anthropocene is sometimes held to be effectively synonymous with – or even merely to represent a repackaging of – the science of global warming. It is not that, and indeed in some respects global warming might be said to be – for now – a relatively minor, if rapidly growing, part of the array of phenomena that make up the Anthropocene" (p. 69). Second, the 'Anthropocene' concept stems from Earth System science rather than climate change studies. Climate change represents a fundamental component of the Earth System, but does not equate to it.

> **ISA (Ideological Science Argument):** The arguments supporting the Anthropocene Hypothesis, and particularly its appeal for formal recognition (Claim 2), are primarily of an ideological and political nature rather than genuinely scientific.

Implicit in ISA is the fundamental idea that science should be separated from ideologies or personal beliefs insofar as the latter are implemented as *epistemic* parameters for the production of scientific knowledge. This separation is traditionally understood as a cardinal aspect of science. On a macro-level, it warrants *in principle*[351] that the production of scientific knowledge is not biased, ideologically manipulated, politically manufactured, or obstructed on a *structural* level for purposes outside the scope and aims of science. This separation is also considered to be beneficial for society overall. On a micro-level, it provides scientists with a prescriptive set of norms to conduct scientific research that delimits the discussions of scientific ideas, hypotheses, or theories within certain epistemic parameters (e.g., neutrality, objectivity, pursuit of truth) traditionally considered beneficial for (if not distinctive of) scientific knowledge. If such a separation holds true, then considerations of broader social utility (e.g., increasing environmental awareness) should not be used to assess the stratigraphic validity of the Anthropocene Hypothesis. Because ISA imputes such consideration in assessing the epistemic validity of the Anthropocene Hypothesis, it follows that the hypothesis violates a basic tenet of science, and therefore that the hypothesis is not scientific.

Not all criticism of an ideological nature follows the thesis advanced in ISA. For instance, sociologist Jeremy Baskin (2014, 2015) has argued that the Anthropocene Hypothesis "is not simply a neutral characterisation of a new geological epoch, but it is also a particular way of understanding the world and a normative guide to action" (Baskin, 2015, p. 10). However, because the hypothesis "provides the ideational underpinning for a particular view of the world, which it, in turn, it helps to legitimate," (pp. 10–11), the proposal is best understood as an ideology dressed as scientific discourse. Rather than a *political* ideology, the Anthropocene represents a *scientific* ideology based on a partial notion of humanity, on an anthropocentric worldview, on an uncritical technological and scientific vocabulary, and on a legitimatizing normative discourse promoting planetary management and technical fixes to the 'climate emergency.' Contrary to ISA, it is the *absence* of the social and political sphere that makes the Anthropocene Hypothesis an ideological discourse.

Similarly, Santana (2019a) – himself a critic of the normative and scientific value of the hypothesis – has argued that a strong separation between 'political' and 'epistemic' parameters in scientific research is untenable. Grounded in literature from the sociology of science, he states that "we are *sometimes* [emphasis added] justified in including political motivations among our reasons to adopt a scientific position" (p. 1088). What makes it the case that the Anthropocene Hypothesis *should* include a political dimension, according to the philosopher, is the fact the hypothesis touches upon issues of primary social relevance. As he writes, "[s]ince the environmental crisis is the most significant political situation humanity has ever faced,

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[351] In practice, scientific research has always been part of a social and political context that influences (even positively) how research is conducted.

we can't tackle relevant scientific questions without considering the political dimensions" (ibid.). Thus, if it is the case that the Anthropocene Hypothesis *should* involve epistemic parameters of a political nature, then ISA does not hold because political claims do not necessarily undermine the scientificity of hypotheses.

Does, then, ISA hold for the Anthropocene Hypothesis? Three considerations may help in answering this question.

First, ISA-type criticism (i.e., arguments imputing the Anthropocene Hypothesis of being ideological science) exhibits a common semantic overlap between the two theoretical entities identified at the beginning of the present research – namely, the 'Anthropocene' concept, adopted and embraced also by the broader intellectual and activist environmental movement, and the Anthropocene Hypothesis of the AWG. As observed in Chapter 2, the term 'Anthropocene' was invested with strong normative and political significance during the last decade, transitioning from a loose scientific concept to an umbrella term for environmental discourse and activism in a very short period of time. During the same time period, the concept also developed independently in the stratigraphic context as the Anthropocene Hypothesis. Reasonably, scientists (especially geoscientists in the Holocene and Quaternary stratigraphy community) upholding a separation between science and political activism grew concerned or suspicious of the term because (1) it reflected normative messages (propagated by scientists as well) about broader social concerns rather than a stratigraphic hypothesis; (2) it received media and public 'approval' prior to any discussion and eventual ratification within the stratigraphic community;[352] and because (3) geologists and stratigraphers did not (and perhaps could not) immediately and thoroughly identify the discrete existence of (and thus differences between) an 'Anthropocene' boundary object and the stratigraphic Anthropocene Hypothesis. Thus, it is plausible that ISA-type criticism addresses the 'Anthropocene' rather than the Anthropocene Hypothesis.

A second point relates to the implications of stating that political considerations should not overlap with epidemic parameters of a scientific nature. This separation implies that *there are* some parameters delimiting the boundaries of scientific knowledge, and that these parameters are *legitimate*. Defining such parameters is not easy, in that it fundamentally means defining what science and scientific knowledge is – a vast and open topic of fundamental historical, philosophical, and sociological interest. Section 4.2 illustrated how traditional epistemic virtues in the philosophy of science, such as explanatory power, intelligibility, and utility, can be implemented to develop a reference framework capable of assessing the epistemological status of the Anthropocene Hypothesis. The analysis conducted showed that the hypothesis is in fact invested with a certain kind of explanatory power (as a historical hypothesis), it delivers scientific understanding of a certain set of phenomena, and it can thus potentially represent a useful *scientific* hypothesis (also *contra* criticism of its utility, discussed in the following section). While these aspects only cover epistemological virtues ascribed by traditional philosophy of science, they suggest that the hypothesis satisfies basic epistemic requirements for being considered a *scientific* hypothesis – regardless of one's

[352] An emblematic example of this informal approval in the media context is an article from *The Guardian* with the (misleading) title "The Anthropocene epoch: Scientists declare dawn of human-influenced age" (Carrington, 2016).

personal consideration of the hypothesis. If so, then ISA does not hold because 'genuinely scientific' parameters used to assess the scientificity of the hypothesis corroborate its scientific nature.

Another consideration concerns the relationship between political beliefs and scientific statements. In principle, statements such as "*Homo sapiens* has left a discernible stratigraphic signature of significant magnitude in the recent geological history" (Claim 1) may be broadly considered *scientific* because they are based on certain established scientific methods and practices for verifiability (e.g., empirical evidence, inferential strategy, methodological consistency, adherence to established norms, peer reviewing, etc.) implemented in a given scientific community (in the case of the Anthropocene Hypothesis, the stratigraphic community). These methods and practices also serve to validate the truth and falsity of any given scientific statement, such as Claim 1. Advocating the truth or falsity of Claim 1 *based on* political or other beliefs unrelated to, or disconnected from, the established epistemic criteria makes the statement unjustified, and likely unscientific. This is also the case for corroborated facts such as 'the Earth is round' or 'the heart pumps blood through the human body.' For instance, to claim that 'the Earth is round' is true because it is politically convenient to consider it true does not make the statement actually true – simply because there is neither logical nor semantic entailment between political convenience and the statement 'the Earth is round' (while there is such entailment in general relativity). Likewise, there is neither logical nor semantic entailment between political convenience and the stratigraphic signature of *Homo sapiens* – a statement (i.e., Claim 1) requiring stratigraphic criteria to be regarded as true or false. While this consideration may appear trivial, the fact that recent proposals concerning the beginning of the Anthropocene are also *based on* political and social commitments (Maslin & Lewis, 2020) reveals the necessity of clarifying the relationship between political beliefs and scientific statements.

The claim that scientific statements *should not* be based on political beliefs does not imply that scientific ideas, hypotheses, or theories do not have political or broader societal implications. This is a very well-established circumstance, demonstrated by the virtually all-encompassing influence of science and technology throughout the history of human societies. Nor does it imply that scientists should not pursue scientific aims considered to be of broader social utility. Much scientific research in the healthcare and pharmaceutical sector is pursued (and funded) primarily for its broader social aims. Yet, the *implications* and *motivations* of pursuing a certain scientific idea should not be confused with the epistemic parameters assessing its legitimacy – an overlap not uncommon among ISA-type criticism (possibly due to the acceptance of the term 'Anthropocene' by the public and in academic discourse prior to an in-depth stratigraphic analysis). Positive and socially oriented motivations, and political implications, do not warrant sufficient justification *per se* for determining the truth and/or utility of a scientific hypothesis – such as the Anthropocene Hypothesis.

The AWG (Zalasiewicz et al., 2019b, para. 1.4.4) has expressed opinions that may help in further discussing this latter consideration (see also Luciano, 2019; Zalasiewicz et al., 2017b). They suggest a key distinction between the broader societal relevance and the scientific utility of formalizing the Anthropocene in stratigraphic terms, and the scope of the Group. They state:

> The phrase 'the scientific and societal utility' of formalising the Anthropocene refers in fact to two profoundly different matters: One is the potential usefulness for science, involving or facilitating a paradigm shift (and this is the mater to which the mandate of the AWG study is limited). The second is a broader societal relevance due to the enhanced awareness raising (and therefore stretching into the sphere of political perception of the Anthropocene), and this is a fundamentally different consideration […] What is the point of the formalisation exercise for the society at large? – that is the question of *societal relevance*, which is a beyond the scope of, and independent of, the AWG mandate. (Zalasiewicz, Waters, Williams, et al., 2019, p. 39)

The Group does not deny that formalizing (or, conversely, rejecting) the Anthropocene Hypothesis will hold political resonance. Yet, the members distinguish between the implications of the hypothesis, and the motives behind it – which they claim to be purely scientific:

> The final consideration here relates to the responsibility of stratigraphers in specific and scientists in general, when faced with geologically relevant evidence of change, to record that change and, if appropriate, to formalise it. Geologists, thus, would be in error if they saw a scientifically demonstrable, significant and substantial change and did not give it commensurate recognition. (p. 40)

This statement seems to clarify concerns raised by ISA regarding the political *motivations* (rather than implications) of the Anthropocene Hypothesis (concerns which often quote *Nature*, 2011, as written proof of a politically motivated agenda, e.g., Finney & Edwards, 2016; Santana, 2019b; Schneider, 2020).

Thus, if stratigraphic motivations lead the research behind the Anthropocene Hypothesis, and if stratigraphic methods and evidence is adduced to support its claims, then ISA-type accusations against the scientificity of the hypothesis do not hold. If this is the case, then the Anthropocene Hypothesis is a *scientific* hypothesis rather than a hidden political agenda.

5.2.4 The Utility Argument

One last and crucial argument advanced against the Anthropocene Hypothesis to be discussed in this chapter is its utility within stratigraphic research. Such criticism negates that an Anthropocene stratigraphic unit, and particularly a chronostratigraphic unit with a lower boundary at ~1950 CE, is a useful addition to stratigraphic and geological classification, and consequently to the geological time scale.

Utility is a central parameter in the acceptance or rejection of a scientific theory or hypothesis. Not uncommonly in science, usefulness can be regarded as a more decisive parameter than truth itself for accepting or rejecting a scientific idea. Indeed, scientific theories or hypotheses may be fundamentally conjectural, less accurate, or even wrong to some measure, yet they are maintained as long as they enable scientists to tackle and solve certain problems or answer certain questions of epistemic significance. A textbook example of such a circumstance is classical mechanics – considered an incorrect description of the universe according to quantum theory and general relativity (both held to be true), yet still used for dealing with a certain class of phenomena because of its simplicity (and thus utility). This fact alone witnesses the important of usefulness as an epistemic parameter for assessing the legitimacy of hypotheses and theories in science. Therefore, if the Anthropocene Hypothesis is to be accepted by the stratigraphic (or broadly scientific) community, it must prove itself to be a useful hypothesis.

Section 4.2.2.3 marginally mentioned an intellectual relationship between US-American pragmatism and US-American geologists by the end of the 19th century. While geographically delimited, this relationship hinted at a broader intellectual proximity between the epistemic values (including utility) uphold by pragmatism, and the praxis-oriented philosophy implicitly informing geological research. If such a relationship exists (at least theoretically), then considerations concerning the utility of the Anthropocene Hypothesis should appear in critical literature. This is in fact the case, as illustrated by some examples hereby discussed. Notably, much of the criticism advanced stems from other arguments delineated throughout section 5.2, so that the utility argument is interwoven with different lines of critique of the hypothesis.

In discussing the stratigraphic status of the Anthropocene, Gale and Hoare (2012) observe that "[a]ny definition of the start of the new epoch must ultimately pass the test of utility; does it have value to those working in the field?" (p. 1494). The authors answer this question in the negative by arguing that the stratigraphic approach for defining an Anthropocene unit "may eventually prove of limited practical use in studies of human environmental impact" (ibid.). This is because such a stratigraphy-based approach would exclude sources traditionally beyond stratigraphic research, such as "tree rings, landscape art and documentary records" (p. 1493). These environmental sources (of a diachronous nature) provide a more useful approach in defining the Anthropocene beyond the theoretical and methodological constraints of stratigraphy. Such an argument is linked to DA in advocating against the utility of the Anthropocene Hypothesis – that is, it criticizes a GSSP-based view over the beginning of the epoch by advocating for its diachronous nature, and consequently rejects the chronostratigraphic (and stratigraphic) utility of the hypothesis.

Autin and Holbrook (2012) endorse UEA by criticizing the empirical content of the proposed Anthropocene unit.[353] They argue that the proposed unit only reflects a conceptual stratigraphic unit rather than a mappable unit. Since geological research overall heavily relies on geological mapping (i.e., the mapping of rock units or strata to show salient properties such as lithology or age), the usefulness of a 'conceptual' rather than 'practical' unit is questioned. Indeed, the authors state that the "Anthropocene provides eye-catching jargon, but terminology alone does not produce a useful stratigraphic concept" (p. 61). Similar criticism is also shared by Head and Gibbard (2015), who observe that truncating the Holocene (and consequently revisiting geological mapping) would be impractical and would diminish the utility of the Holocene, with many surficial deposits by necessity being labeled 'Holocene–Anthropocene'" (p. 33).

Gibbard and Walker (2014) have considered a formal definition of Anthropocene of little stratigraphic value, considering the 'Anthropocene' to be more useful as an informal designation:

[353] Criticism expressed by Autin and Holbrook (2012) is representative of early critique of the Anthropocene Hypothesis, which had been formulated only a few years before that. This criticism should be an object of revision in light of the recent summary of evidence provided by the Group (Zalasiewicz et al., 2019b).

> There is no doubt that the term 'Anthropocene' has caught the popular imagination […] However, the question remains as to whether or not the utility of the term will be as an informal designation for the period of recent enhanced human activity, or whether it can be defined in a geological sense as a formal time-stratigraphic unit of the GTS […] At best, the Anthropocene might become another name for the later Holocene (with a usage similar, perhaps, to 'Dark Ages' or 'Middle Ages'), but in a geological context the term would remain informal. Indeed, this view has now been reinforced by the Geological Society of America, who have rejected the term from their 2012 Geological Time Scale because it has no 'internationally sanctioned standing.' (p. 35)[354]

This view does not question the utility of the 'Anthropocene' as a normative and descriptive concept mirroring the influence of humans on the Earth System. The authors are aware of the environmental pressures represented by human societies, and of the social message the term 'Anthropocene' has been invested with to encompass these pressures. Rather, they address the utility for stratigraphic classification of formally recognizing a stratigraphic unit less than a hundred years old (a geologically insignificant time span) and, consequently, of truncating the Holocene. This is also considered a major issue for Walker et al. (2015), who question the "practical value of a formally defined chronostratigraphic unit that began less than a single human lifetime ago" (p. 206). Its extremely short nature makes such a unit "effectively unresolvable in most marine sedimentary sequences" (ibid.), and no enhanced understanding of anthropogenic records is provided by a discrete chronostratigraphic unit. These precarious epistemic conditions make the term 'Anthropocene' more useful as an informal category, rather than a stratigraphy- and chronostratigraphy-based term.

Finney (2014) considers the utility of the Anthropocene geochronological/chronostratigraphic unit one of the fundamental issues that the AWG needs to tackle. The geologist notes that a vast number of significant events in the Earth System history are not reflected as distinguished units in the geological time scale / international chronostratigraphic chart. The evolution and continental spread of vascular land plants is an example of organism-induced upheaval in the Earth System (vastly outweighing the impact of *Homo sapiens* throughout its history) that is not represented as a geochronological/chronostratigraphic unit. If such far-reaching changes do not define the base of any existing time unit, "[w]hy should human impact on the Earth system be different? Might the desire to establish the 'Anthropocene' as a formal unit be anthropocentric?" (p. 27). These rhetorical questions cast doubts on the practical utility (and epistemic validity) of an Anthropocene time unit as well as its basic epistemic assumptions.[355]

Smith and Zeder (2013, see section 3.2.2.1), proponents of an early Anthropocene hypothesis, have contested the utility of placing the beginning of the Anthropocene at ~1950 CE. Their hypothesis locates the beginning of the Anthropocene at ~11–9 ka, coinciding with increasing human niche construction activities such as plant and animal domestication. The authors suggest that, "[i]n considering the practical

[354] While the Anthropocene did not appear in the 2012 geological time scale (nor in the later 2018 version, see https://www.geosociety.org/GSA/Education_Careers/Geologic_Time_Scale/GSA/timescale/home.aspx, accessed on July 5, 2021), the proposed epoch was included in the two-volume 2020 edition of *Geological Time Scale*, edited by Felix M. Gradstein, James G. Ogg, Mark Schmitz, and Gabi Ogg.

[355] A similar argument is advanced by Foster (2018), who also uses the case of the planetary changes caused by cyanobacteria as an example of a dramatic event with no linked chronostratigraphic unit.

or utility value of designating a new Anthropocene epoch, the emphasis […] should be placed on gaining a greater understanding of the long-term and richly complex role played by human societies in altering the earth's biosphere" (p. 12). This criticism is similar to the issues raised by DA. It states that a ~1950 CE boundary would dismiss millennia of human activities and impacts on the Earth, and would consequently be largely useless for framing the stratigraphic footprint of humanity on rock records.

Based on this literature, criticism of usefulness can be summarized through the following argument:

> **UtA (Utility Argument):** The empirical body, rationale, and purpose of the proposed Anthropocene stratigraphic and geochronological/chronostratigraphic unit make it of little practical value in the context of stratigraphic classification.

The argument is straightforward: geoscientists, and especially Quaternary and Holocene geologists, would find little utility in defining the beginning of a new series/epoch at ~1950 CE. Notably, UtA is specifically restricted to stratigraphic classification, and to geochronology and chronostratigraphy. It does not negate nor diminish any value (scientific or not) that the term 'Anthropocene' may hold in other knowledge domains. In fact, most critics seem to agree that the term may still have value in the broader social and environmental arena as an *informal* designation for the present time period (Edgeworth et al., 2019; Edgeworth et al., 2015; Finney & Edwards, 2016; Gibbard & Walker, 2014; Ruddiman, 2018). The term is widely used in disciplinary contexts such as Earth System science, where it reflects a dramatic transition of the Earth System associated with socio-economic trends; in evolutionary biology and ecology, where the term is associated with accelerated anthropogenic extinctions and increased human niche construction activities (Ceballos et al., 2015; Ellis, 2016b); and in archaeological research, where the term expresses the diachronous onset of the Human Stratum or Boundary A (Edgeworth et al., 2015). A shared feature among these knowledge domains is that the 'Anthropocene' is not bounded to the issue of formal ratification, representing indeed an informal threshold-event of broader semantic reach.

The question of the utility of the Anthropocene has been tackled by the AWG (Zalasiewicz et al., 2019b, para. 1.4.1). As discussed in section 4.2.3, the Group has advocated for the social, stratigraphic, and theoretical utility of the Anthropocene as a geological time unit. The stratigraphic (and broadly geological) utility of the proposed unit lies in the possibility of mapping anthropogenic deposits – both on a local scale (i.e., for engineering geology) and a global one (i.e., the Human Stratum developed by human dwellings) – in a way that reflects their significance and the magnitude of this sedimentary record. In other words, the Anthropocene would 'explain' (*sensu lato*) anthropogenic signals in stratigraphic terms – granted that this signature exhibits properties of unavoidable interest for geological research. Such a unit would reflect major short and long-term anthropogenic changes in the Earth System, from physical records of a lithostratigraphic nature to climate and, more permanently, the Earth's biota. These changes "can already be reasonably said to be of long-term significance to the geological record," making the Anthropocene "geologically 'real' both as a unit of time and process and as a distinctive stratal unit across a large range of environment" (p. 33).

Ultimately, the question of *scientific* utility is largely a social affair – that is, it is assessed within a certain community considering the hypothesis worth accepting or not. The history of the 'Anthropocene' concept shows that some scientific communities, such as Earth System science and water sciences, have found epistemic as well as practical utility in the term. It defined a time threshold after which natural systems (e.g., river systems, biogeochemical cycles, etc.) operate differently due to the overwhelming presence and impact of humans. As such, the term was perceived as *useful* in describing a particular state of affairs. In stratigraphy, and particularly chronostratigraphic classification, the AWG has advocated for the utility of formally recognizing the proposed time unit, but the hypothesis has not been unanimously accepted (not even by some members of the group). Validating the *broader* utility of the hypothesis will be assessed during the process of formal ratification of geological units set by the *Guide*, which lies in the judgment of the SQS, ICS, and finally IUGS.

CONCLUSIONS

This research attempted a historical and philosophical study of the birth and epistemology of the Anthropocene Hypothesis.

A central goal of this endeavor was to legitimize and articulate a conceptual distinction between the 'Anthropocene' as a boundary object, and the Anthropocene Hypothesis as the scientific, and specifically stratigraphic, interpretation of the 'Anthropocene.' Arguments for legitimatizing this distinction both theoretically and practically have been advanced, particularly in respect to delimiting the epistemological identity of the Anthropocene Hypothesis, and in providing a solution to the issue of definition. Such a distinction would be beneficial for all parties involved in Anthropocene Studies, providing a conceptual and linguistic roadmap helpful for navigating heated and socially relevant debates over the nature, meaning, and scope of the 'Anthropocene' as concept and as a proposed geochronological and chronostratigraphic unit. This roadmap does not hinder any possible future analysis on the relationship between the 'Anthropocene' and the Anthropocene Hypothesis, nor does it aim to dissolve the semantic potential of the 'Anthropocene' exclusively into its stratigraphic variant. On the contrary, by clarifying the conceptual and semantic relationship between these, the research attempted to deliver a toolkit for 'Anthropocene' scholars, researchers, and students alike to approach and/or contribute to this highly debated scientific hypothesis

A related goal was to answer the questions *What is the Anthropocene Hypothesis?* and *What does it mean for the Anthropocene Hypothesis to represent a* scientific *hypothesis?*

The first question was answered by probing the historical, empirical, epistemological, and social context of the Anthropocene Hypothesis. This inquiry characterized the epistemology of the Anthropocene Hypothesis as the epistemology of a *scientific* hypothesis. This seemingly trivial statement is in fact very informative: it answers what the Anthropocene Hypothesis represents not solely amidst the theoretical impasse of defining the 'Anthropocene,' but also in light of accusations of politically motivated science or of being a pop culture phenomenon, and amidst otherwise ambiguous criticism (i.e., against the 'Anthropocene' and/or the Anthropocene Hypothesis). Indeed, the research showed that attributes typical of scientific knowledge production are defining characteristics of the Anthropocene Hypothesis.

The second analogous question was answered by scrutinizing the theoretical implications of characterizing the Anthropocene Hypothesis as a scientific hypothesis. In terms of conceptual history, the predominantly scientific characterization of the 'Anthropocene' idea has been retrieved by surveying early research literature. Authors, texts, and communities within the *natural sciences* were the primary drivers in the survival, spread, and evolution of the 'Anthropocene' concept. The research correlated this predominantly scientific history of the 'Anthropocene' concept to the birth of the Anthropocene Hypothesis. In philosophical terms, considering the hypothesis as a scientific hypothesis means that it should exhibit those epistemic virtues traditionally ascribed to scientific thought. The research showed that the hypothesis, as a *historical* hypothesis (viz. dealing with past events), exhibits epistemic virtues not solely related to empirical adequacy or adherence to the standard norms of stratigraphic classification, but also in terms of explanatory power and intelligibility. These epistemic aspects of vast philosophical interest might need proper consideration when a formal proposal is submitted in the years ahead.

The conceptual differences between the 'Anthropocene' and the Anthropocene Hypothesis, and the development of an epistemological identity of the latter, were delineated throughout each chapter. This was done by tackling salient aspects of the Anthropocene Hypothesis in terms of its core claims, its history, its empirical body, its epistemological structure, and the debate surrounding it. Here, the main findings of each chapter are highlighted.

The analysis conducted in Chapter 1 framed the broader academic and intellectual scenario engendered by Anthropocene Studies. It showed that many research trajectories, often overlapping, but also differentiating from one another, gravitate around the 'Anthropocene' concept. These research trajectories transformed the term from much more than mere technical jargon of a geochronological and chronostratigraphic provenance. Indeed, over the past two decades, the term has assumed different nuances unified by the basic assumption and belief that humans have become an environmental force and geological agent to be reckoned with. While extremely beneficial in approaching the 'Anthropocene' as a polysemantic object, this multidisciplinary surge in interest caused an intrinsic challenge – that is, the issue of definition. This issue pertains to the formulation of an 'Anthropocene' concept that (1) is not simply reduced to personal interpretations, (2) is not restricted to a single disciplinary domain, and (3) is a shared category providing functional knowledge across disciplinary domains and fields of knowledge.

A way to face this challenge is considering the conceptual history of the 'Anthropocene.' The statement 'history of the Anthropocene' is ambiguous, and opens up various interpretative avenues depending on the emphasis and nuance given to 'history' or 'Anthropocene.' Among the research areas that evolved within this semantic ambiguity, one in particular is useful for framing the stratigraphic variant of the 'Anthropocene' – namely, the history of the 'Anthropocene' as a concept and idea. Within this approach, scholars have been divided between 'continuists' and 'discontinuists,' with the former advocating for a genealogical understanding of the 'Anthropocene' and the latter arguing for a seemingly theoretical singularity that the concept entails, broken off from previous conceptual antecedents. It has been observed that both stances provide interesting insights into the conceptual history and nature of the 'Anthropocene.' However, they fail to properly recognize the 'Anthropocene' concept as a *discrete instance of geological reflexivity* – that is, a discrete and autonomous idea that subscribes to a meta-historical tradition of anthropogenically defined geological time units – by separating between a *paleo-history*, *pre-history*, and *modern history* of the 'Anthropocene' concept. This framework enables the reconstruction of the birth of the Anthropocene Hypothesis by looking at the *modern history* of the 'Anthropocene' concept as a discrete occurrence of geological reflexivity over the stratigraphic footprint of humanity, and by reconsidering a historical period (i.e., 2000–2009) particularly valuable for this endeavor.

The analysis further distinguished between normative and descriptive research in Anthropocene Studies. Approaching the concept this way allowed the separation of the 'Anthropocene' as a broader social category fraught with ethical, political, and aesthetic values, and the Anthropocene Hypothesis as the descriptive and normative-methodological stratigraphic formulation of the 'Anthropocene.' Three central claims were identified as characteristic of the hypothesis – namely, Claim 1, '*Homo sapiens* has left a discernible stratigraphic signature of significant magnitude in recent geological history'; Claim 2, 'The stratigraphic signature left by *Homo sapiens* could be translated into a geochronological and chronostratigraphic unit of time'; and Claim 3, 'The proper unit level reflecting the magnitude of the stratigraphic signature of *Homo sapiens* in the geological time scale and international chronostratigraphic chart is that of epoch/series.' These represent the 'hardcore' (to borrow terminology from philosopher Imre Lakatos) of the Anthropocene Hypothesis. They condense the central aims and epistemic context of the hypothesis, and distinguish it in purpose and content from its parent concept of the 'Anthropocene.' The separation between the 'Anthropocene' and the Anthropocene Hypothesis is considered beneficial for overcoming the issue of definition, avoiding diatribes over the 'true meaning' of the 'Anthropocene,' defining the object of analysis that philosophers of science should consider, and resolving naming-related issues raised by humanists and social scientists. In addition to these broader benefits, this distinction facilitates a discrete analysis of the Anthropocene Hypothesis, focalizing the relevant epistemological features pertaining to stratigraphic research (e.g., empirical evidence, epistemic context, debates, etc.).

The birth of the Anthropocene Hypothesis was explored in Chapter 2 by using complementary quantitative and qualitative methods. In particular, this analysis required focusing on the early modern history of the 'Anthropocene' concept, and on how the academic context that emerged engendered the evolution of its stratigraphic variant. It was recognized that a genealogical approach is the predominant trend in reconstructing the history of the 'Anthropocene' concept. While of undoubtable value, this approach has largely overseen the more recent history of the term, particularly the 2000–2009 decade – a time span encompassing the birth, survival, spread, and evolution of the 'Anthropocene' idea. This time frame was considered of primary value and interest for reconstructing the birth of the Anthropocene Hypothesis. In analyzing literature produced within this time span, the research brings previously unexplored literature into discussions over the genesis of the 'Anthropocene' idea. It also reconsiders the roles of individual disciplinary domains in engendering the 'Anthropocene' idea and in defining the preconditions for the birth of the Anthropocene Hypothesis.

Text mining techniques focusing on the appearance of the term 'Anthropocene' in early research literature (i.e., 2000–2009) were implemented for the quantitative approach. This method allowed the survey of a corpus of 670 written records based on the relative frequency of the term 'Anthropocene' for each record. This numerical value was used as a proxy for authors' engagement with the term, and to separate between a 'central' and 'peripheral' literature. Additionally, the corpus was divided based on publication year, field of knowledge, discipline, format, and language – all clusters considered useful in reconstructing the early modern history of the 'Anthropocene.' The corpus is considered semi-complete, meaning that it is comprehensive enough to faithfully represent how early research literature assimilated and disseminated the term 'Anthropocene' (i.e., no 'hidden literature').

Findings show that the term spread relatively slowly during its first decade of existence, while it surged remarkably in the following decade. The natural sciences were by a substantial margin the predominant field of knowledge where the term spread (483 records), followed by the social sciences (233), applied sciences (46), and humanities (34). Consistently with this finding, scientific disciplines were the primary branches of knowledge where the term appeared in the literature, particularly in geology (99), Earth System science (87), oceanography (76), climatology (71), and ecology (61) – among others. Among the social sciences, environmental studies (82) stands out as the discipline with the most records by a factor of two, followed by sustainability studies (41), human geography (27), history (26), sociology (24), and political science (23). Resource management (17) and engineering (13) were the primary recipients of the 'Anthropocene' among applied sciences. In the humanities, ecocriticism (12) and philosophy (12) are the disciplines with the most records, representing more than two-thirds of all humanistic engagement.

The vast majority of records are of English-language provenance (637), although non-English records (33) cannot be fully considered as emblematic of language- or geography-based assimilations of the term. Journal articles (411) were the primary academic vehicle for transmission and spread of the term by an outstanding margin, followed by book sections (108), books (37), book reviews (36), and abstracts (25). The vast majority of literature composing the corpus is recognized as *peripheral literature* (587), whilst only a minority constitutes *central literature* (83). Lastly, the disciplines most representative of the central literature (i.e., with high *normalized engagement factor per discipline*, ($E_n(D)$)) are geology ($E_n(D) = 2.12$), Earth System science ($E_n(D) = 1.72$), environmental science (($E_n(D) = 1.54$), soil science ($E_n(D) = 1.43$), chemistry ($E_n(D) = 1.36$), political science ($E_n(D) = 1.30$), oceanography ($E_n(D) = 1.18$), history ($E_n(D) = 1.15$), climatology ($E_n(D) = 1.13$), and human geography ($E_n(D) = 1.11$).

These quantitative findings suggest that the early modern history of the 'Anthropocene' idea can be treated as the history of an informal *scientific* concept. The large (though not exclusive) presence of the natural sciences as a field of knowledge, and consequently the prevalence of scientific disciplines as main vectors in absorbing and spreading the term, corroborate this argument. The fact that seven of ten disciplines with highest $E_n(D)$ are natural sciences further proves the scientific origins and evolution of the term. An interesting finding concerns the substantially low engagement that humanities had during the first decade – a trend perhaps almost completely reversed during the 2010–2019 decade. This low engagement may explain why the term was mostly left unproblematized, with only a handful of publications addressing the 'Anthropocene' in terms of 'narrative' or 'discourse.' Another finding concerns the role of water sciences – namely, oceanography (76 records), hydrology (35), and limnology (31). The combined value for this macro-discipline amounts to 142, hinting at the pivotal position that the water science community had in absorbing and popularizing the term. This fact is also confirmed by analyzing the literature from a qualitative viewpoint. An additional important finding concerns geological literature, standing with the highest value in terms of records per discipline as well as normalized engagement factor. This is considered as a preliminary historical and intellectual factor in the evolution of the 'Anthropocene' into a stratigraphic hypothesis through the formation of a geological Working Group on the Anthropocene. In other words, it made it possible for the 'Anthropocene' concept to be an object worth considering in stratigraphic terms.

The qualitative analysis explored the records through discourse analysis, focusing on records, authors, organizations, conferences, and other epistemic contexts from a chronological viewpoint. This analysis was based on selected records considered to be of notable historical and conceptual value. These records were selected primarily based on their respective relative frequency of the term 'Anthropocene.' However, records were also considered based on other salient factors, such as the *context* where the term appeared (e.g., journal, discipline, workshop, publication year, etc.), or *how* the term appeared (e.g., position in text, definition given, etc.). This literature was considered emblematic of some ways the term was perceived, conceived, and implemented across disciplines and epistemic actors. In particular, it was shown that the term was implemented for the most part as an informal scientific designation to delimit a time threshold related to certain aspects of human impacts. This type of use is recurrent in the peripheral literature, where the term mostly appeared 'passively' in the introduction or conclusions of research material as a background notion. In the central literature, the term saw more 'active' engagement from authors who used it as an *epistemic category*. This use of the 'Anthropocene' manifested in different ways, from designating a time boundary ranging from 1750 years to 1950 (anticipating discussions over the beginning of the 'Anthropocene'), to identifying and framing a new transitional phase of the Earth pushing towards new methods, models, and objects of analysis.

A further interesting finding is the early vertical and horizontal reach of the 'Anthropocene' concept. Propelled by Crutzen's highly esteemed academic figure, the 'Anthropocene' navigated as a neologism, concept, idea, and epistemic category across prestigious organizations, conferences, and workshops – such as the Dahlem Workshop, the Pontifical Academy of Sciences meetings, events and projects around the International Geosphere-Biosphere Programme, and more. Simultaneously, the term appeared in preeminent journals such as *Science* and *Nature* as well as in scientific graduate university textbooks, and it began to be mentioned and used by established figures across various disciplines, from sustainability and environmental studies to soil science, oceanography, Earth System science, and more.

This vertical reach of the term was paralleled by its remarkably extended horizontal reach across fields of knowledge. While the term had an undeniable scientific imprint, it also aroused multidisciplinary interest for its captivating connotation – being able to condense and express in a simple and elegant semantic unit the array of anthropogenic impacts and forcings upon the Earth. Indeed, during the 2000–2009 decade, the term began quickly to be absorbed into pre-existing discourses on sustainability, global change, and the Great Acceleration, transforming into a normative category in addition to retaining its descriptive connotation. The remarkable horizontal extension of the 'Anthropocene' is also visible linguistically (e.g., appearing in Chinese literature as early as 2001) and societally (i.e., appearing in non-academic sources such as newspaper articles, nonfiction books, and websites, and across a different range of academic sources besides journal articles). These findings suggest that the use of the term was not restricted to a geographic region or confined to a disciplinary cohort of scholars and researchers. On the contrary, the term had substantial international reach as well as visibility among the public (although not as much as in the following decade). The vertical and horizontal success of the term, especially in the geoscientific community, can be treated as a historical and intellectual precondition for the geologists of the Stratigraphy Commission of the Geological Society of London to take interest in the term on stratigraphic grounds.

After reconstructing the early history of the 'Anthropocene' and the birth of the Anthropocene Hypothesis, Chapter 3 dissected the empirical substrate of the hypothesis. This was accomplished by surveying, examining, and meticulously discussing the evidence (of a primarily stratigraphic drive) that the AWG has gathered so far in support of formal recognition of an Anthropocene geochronological and chronostratigraphic unit. In framing the Anthropocene Hypothesis, a useful preliminary distinction between a *geological claim* and a *stratigraphic claim* was advanced. This distinction was intended to parse out the primary epistemic goal of the hypothesis – namely, to assess whether *Homo sapiens* has left a discernible stratigraphic footprint that may be used to define the beginning of a new geological time unit, and not whether *Homo sapiens* has become a geological *force*. Then, it was suggested that *Homo sapiens* be understood as a geological *agent* rather than *force* because of an ontological asymmetry between geological forces and the actions of humans. These preliminary remarks were considered beneficial epistemic clarifications of the meaning, scope, and purpose of the Anthropocene Hypothesis.

Subsequently, the chapter explored the empirical context and evidence for the hypothesis. From a contextual viewpoint, the *International Stratigraphic Guide* and the Code of the North American Commission on Stratigraphic Nomenclature (NACSN) were used to delineate the epistemological standards of stratigraphic classification. These guidelines for stratigraphic procedures worldwide are used to frame the epistemological requirements that the Anthropocene Hypothesis must accommodate. As such, they also delimit the scientific debate on the hypothesis, distinguishing it from the broader debate arena on the 'Anthropocene.' In terms of evidence, a wide spectrum was discussed – in particular lithostratigraphic, magnetostratigraphic, pedostratigraphic, biostratigraphic, chemostratigraphic, and chronostratigraphic evidence. This pool of stratigraphic evidence engenders the proposed Anthropocene stratigraphic unit.

Surveying the context and evidence of the hypothesis shows a fundamental adherence to the norms of stratigraphic classification, further corroborating the epistemic identity of the Anthropocene Hypothesis as an entity distinct from the 'Anthropocene.' However, by emphasizing anthropogenic signals and markers of an extremely recent geological nature, it was shown that the empirical evidence poses some challenges to traditional understandings of 'geological records' in stratigraphic praxis. This is the case, for instance, with human-mediated mineral-like compounds used as lithostratigraphic evidence, when these compounds are not recognized by the International Mineralogical Association Commission on New Minerals and Mineral Names as 'minerals.' Similarly, chemostratigraphic units (and thus chemostratigraphic markers, such as the radionuclide signal associated with nuclear and thermonuclear bomb testing) are not recognized as independent units by the *Guide* nor by the Code.

The analysis of the empirical body of the hypothesis was followed by a reconnaissance of the alternative and competing hypotheses gravitating around the 'Anthropocene' as a scientific category. These hypotheses differ from the Anthropocene Hypothesis in locating a different starting date to the 'Anthropocene' – either as a geochronological and chronostratigraphic unit or as a broader scientific term designating the earliest global impact of humans. In doing so, they challenge the proposed ~1950 CE boundary by implementing different scientific research methods (also beyond stratigraphy), by emphasizing the stratigraphic value of early anthropogenic signals, or by questioning the scientific value of a geochronological and chronostratigraphic characterization of the 'Anthropocene.' These hypotheses were divided into Paleoanthropocene hypotheses, Early Anthropocene hypotheses, Modern Anthropocene hypotheses, and Contemporary Anthropocene hypotheses.

Locating a beginning of a proposed unit is a necessary requirement for the formulation of new geochronological and chronostratigraphic units through a Global Boundary Stratotype Section and Point (GSSP). However, the discourse on the beginning of the 'Anthropocene' has ignited broader discussion of a historical and ethical nature. This discourse has raised questions about the meaning and implications of selecting a specific event or historical period (e.g., the Neolithic Revolution, the Colombian Exchange, the Industrial Revolution) in terms of historical responsibility and broader societal significance. As such, the beginning of the 'Anthropocene' represents one of the densest hubs of conversation in Anthropocene Studies. Chapter 3 built on preexisting research by providing a detailed analysis of the main alternative and competing hypotheses in engendering the 'Anthropocene' as a scientific term. Beyond the practical value of visualizing the landscape of proposed starting dates, this roadmap can easily foster further comparative as well as individual studies in respect to this pool of existing hypotheses.

Treating the Anthropocene Hypothesis as a scientific hypothesis has certain implications concerning the analysis of its epistemology (*sensu stricto*). Chapter 4 discussed these implications in terms of the epistemic virtues the hypothesis holds that are familiar to philosophical analyses of scientific ideas. This analysis borrowed concepts and methods from the philosophy of science, attempting to develop a contribution amidst a field of knowledge that has had very little interaction with the 'Anthropocene' and the Anthropocene Hypothesis.

First, the chapter explored how philosophy has perceived and assimilated the notion of the 'Anthropocene.' It was recognized that ethics and aesthetics were the branches of philosophy that have displayed the most interest in the term. In ethics, and particularly environmental ethics, the term signifies a range of human-induced pressures on the planet that raise questions of an ethical drive. Related literature on the matter was surveyed, showing how the 'Anthropocene' as an ethical category converged with questions concerning the task of philosophy, and demonstrating which ethical models best provide solutions to the ethical dilemmas and challenges raised by the dawn of this new phase of the Earth. It was argued that ethics represented the philosophical field of analysis that most successfully translated the 'Anthropocene' into an object of interest, but also of criticism. This argument was not solely supported historically by surveying the earliest instance of philosophical interest in the 'Anthropocene,' but also by assessing how philosophy's role was perceived in the context of the 'Anthropocene.' This perception was largely that philosophy is a discipline tasked with normative-ethical concerns.

In aesthetics, the 'Anthropocene' encompasses a range of artistic expressions – from art installations to museum exhibitions and documentaries – sharing the fundamental goal of representing this anthropogenic epoch from a visual standpoint. As such, the term was assimilated and connected to discourses of visual culture and the philosophy of art, igniting interest as well as criticism among theorists within this knowledge domain. This research landscape engendered the 'Anthropocene' as an aesthetic category at the intersection of art, politics, visual culture, society, and the environment.

A central finding was the almost utter absence of the voice of philosophy of science in debates surrounding either the 'Anthropocene' or the Anthropocene Hypothesis. Because the latter represents a *scientific* hypothesis, it falls necessarily within the range of interest of philosophers of science. Consequently, one would expect such scholars to show a certain degree of participation in these debates – not least because of the widespread media attention and international recognition the term 'Anthropocene' has received. Nevertheless, a surprising research vacuum was identified in philosophical literature on science concerning the Anthropocene Hypothesis. Reasons for this vacuum were provided. In particular, it was advanced that an underlying research trend in philosophy seeing physics as the exemplar of science has had consequences for the assimilation of geology into philosophical research. In turn, this resulted in the lack of an institutional philosophy of geology, and therefore the absence of prompt philosophical responses to the Anthropocene Hypothesis. Besides these considerations, three noteworthy contributions from philosophers of science concerning the Anthropocene Hypothesis were discussed, highlighting the main theses and arguments. Two of these contributions raise criticism against the hypothesis – a type criticism of particular value in framing the perception of the hypothesis in philosophical discourses on science.

After surveying the research landscape of the 'Anthropocene' and the Anthropocene Hypothesis in philosophical scholarship, Chapter 4 went on to develop an epistemology of the Anthropocene Hypothesis as a *historical* type of scientific hypothesis. This analysis showed that, indeed, the hypothesis exhibits a certain set of epistemic virtues traditionally ascribed to scientific knowledge – in particular, *explanatory power* and *intelligibility* (as in, providing scientific understanding of certain phenomena). These epistemic virtues, generally assumed as *desiderata* for scientific knowledge, were considered through influential models of scientific explanation and scientific understanding in philosophy of science scholarship. While historically oriented scholarship has often raised the issue of the intrinsic lack of explanatory power the hypothesis entails, the chapter advanced that a complementary view of the *network* of research gravitating around the hypothesis renders this criticism null. In particular, the chapter argued that the explanatory power and intelligibility of the stratigraphic variant of the 'Anthropocene' is assessed in relation to the epistemic goals and expectations of the stratigraphic community, as well as its protocols and procedures. This emerged by analyzing the *aim* and *methods* in relation to the tension between stratigraphy-oriented aims and multidisciplinary methods of the research gravitating around the AWG. These findings further corroborate and elucidate the nature of the Anthropocene Hypothesis as a *scientific* hypothesis. This has two implications. First, the hypothesis demonstrates certain epistemological aspects common to scientific knowledge, *regardless* of its ultimate fate – that is, whether an Anthropocene unit is formalized or not. Second, the hypothesis does not represent ideological or politically motivated science (Finney & Edwards, 2016). While politics and ideologies play a permeating role in virtually all aspects of human society, the fact that the hypothesis can be arguably ascribed certain virtues characteristic of scientific knowledge make it a scientific statement rather than a politically motivated one.

Lastly, Chapter 5 attempted a schematic outline of the major lines of critique against both the 'Anthropocene' and the Anthropocene Hypothesis advanced by recent Anthropocene Studies scholarship. The chapter showed that the separation between the 'Anthropocene' and Anthropocene Hypothesis can be beneficial in clarifying and organizing the arguments that have been advanced against either theoretical entity in the broader 'Anthropocene' research agenda. It was argued that criticism should be separated in respect to the two theoretical entities in question. Based on this premise, it was maintained that the main critiques against the 'Anthropocene' as a broader conceptual entity (i.e., the *Undifferentiated* Anthropos *Argument*, the *Anthropocentrism Argument*, the *Historical Argument*, and the *Ethical Argument*) do not equally hold against the Anthropocene Hypothesis. This is because they do not unfold within the epistemological ground of stratigraphic classification, but rather address aspects outside the mandate of the AWG, and thus of the theoretical reach of the Anthropocene Hypothesis. No judgement has been expressed toward this criticism, which was surveyed in order to extrapolate its core arguments and assess its limits.

Criticism against the Anthropocene Hypothesis was mapped based on four major arguments – namely, the *Future Geologist Argument* (formulated differently both by advocates and detractors of the hypothesis), the *Diachronicity Argument*, the *Unorthodoxy Argument* (embodied by three sub-arguments: the *Naming Argument*, the *Unorthodox Evidence Argument*, and the *Ideological Science Argument*), and the *Utility Argument*. These critiques stemmed from the geological and broader scientific community, highlighting one or more particular epistemic aspects that the Anthropocene Hypothesis seemingly lacks. While this criticism was generally surveyed in a descriptive fashion, one particular line of critique – namely, the Ideological Science Argument – needed further normative considerations. This criticism denies the Anthropocene Hypothesis the status of *scientific* hypothesis by considering it a product of ideological and activist agendas dressed up as science. The relationship between science, politics, and society has historically been complex, often giving rise to cultural and intellectual tensions between socially oriented disciplines in the humanities and social sciences on the one hand, and the natural sciences on the other. Chapter 5 advanced that legitimate scientific claims inform the Anthropocene Hypothesis regardless of both one's personal ideological beliefs and one's personal view about the formalization of an Anthropocene time unit. These claims can be verified or falsified (in a broad sense) based on scientific methodologies, in particular by assessing the adherence of the hypothesis to the norms and practices of stratigraphic classification, and by weighting the epistemic significance of the evidence submitted. This is ultimately a task to be undertaken by the relevant epistemic community – that is, stratigraphy in particular, and geology in general. Additionally, Chapter 4 showed that the Anthropocene Hypothesis manifests epistemic virtues that enable a treatment of the hypothesis as a *scientific* hypothesis. Thus, the empirical and theoretical outline of the hypothesis corroborates its scientific – rather than ideological or political – nature.

The research overall showed that separating between the 'Anthropocene' as a boundary object and the Anthropocene Hypothesis as the stratigraphic variant of the 'Anthropocene' is not only theoretically possible, but also useful, and thus encouraged for 'Anthropocene' researchers. At its core, this distinction overcomes the issue of definition afflicting a multidisciplinary framework for Anthropocene Studies. If the 'Anthropocene' phenomenon calls for multi- and interdisciplinary attention of a descriptive and normative nature, then it is crucial that, first and foremost, disciplines are able to communicate using a common conceptual framework. This does not imply that there should be *one* vocabulary that all disciplines should adopt. This would contradict the very intent of multi- and interdisciplinary engagement in the 'Anthropocene' and the Anthropocene Hypothesis. However, without a minimally shared conceptual background, communication and cooperation amongst knowledge domains becomes difficult, if not incompatible and conflicting (Toivanen et al., 2017). This might lead the 'Anthropocene' to become an object of solipsistic interpretation, an undefined macro-category encompassing an undistinguished amalgam of phenomena and, ultimately, a floating signifier. Considering that the 'Anthropocene' concept has been at the forefront of key environmental narratives attempting to raise social and political awareness, it is paramount that its semantics, purpose, and scientific substrate are clarified. This research attempted to do so by focusing on the Anthropocene Hypothesis – perhaps the most relevant and debated variants of the 'Anthropocene' in Anthropocene Studies.

In achieving the target of separating between the 'Anthropocene' and Anthropocene Hypothesis, the research delineated an 'epistemological profile' of the Anthropocene Hypothesis as a *scientific*, and specifically *stratigraphic*, hypothesis. The absence of substantial scholarship from the philosophy of science (and the philosophy of geology) on the 'Anthropocene' and its stratigraphic variant was a major methodological obstacle toward this goal. However, this academic vacuum also provided fertile ground for experimenting with an interdisciplinary philosophical analysis of this scientific hypothesis. This analysis considered the conceptual history, empirical body, epistemic virtues, and key ingredients of the debate in considering the epistemology of the Anthropocene Hypothesis as a scientific formulation. As such, the research is posited as a contribution not solely to the history and philosophy of science, but also to interdisciplinary research in general.

Furthermore, this analysis paves the way for further complementary research trajectories, particularly in the sociology of science, but also in scientometrics (e.g., through an in-depth analysis of the means of spread of the 'Anthropocene' and the Anthropocene Hypothesis) and in the history of knowledge (e.g., relating the 'Anthropocene' idea to the broader intellectual, social, and political climate of the 21st century). Some of the aspects tackled along the way also give rise to further research questions – for instance, on the *prehistory* of the 'Anthropocene' in Soviet scientific literature; on the seminal role of NASA in developing Earth System science; on the nature and extent of human geological agency; on the underrepresentation of geology in 20th-century philosophy of science; on the history of the 'Anthropocene' concept term between 2010 and 2019; or on the future of the 'Anthropocene' if the hypothesis does not find approval by the broader geostratigraphic community. These aspects entail important underlying factors in framing the birth and epistemology of the Anthropocene Hypothesis, and have the potential to jump-start further research venues in the study of the 'Anthropocene' concept, and its stratigraphic variant, within and beyond Anthropocene Studies. The present analysis encourages contributions in these directions with the aim of achieving an all-around understanding of the hypothesis and the epistemic mechanisms informing it.

Whether or not the Anthropocene will see formal ratification as a geological time unit, the Anthropocene Hypothesis has undeniably placed geology, stratigraphy, and the geological time scale under the spotlight over the past years. This privileged position has allowed some ancient themes buried deep within 'Western' culture to reemerge under a different, stratigraphic guise. In particular, one may argue that at the heart of the hypothesis lies a deeper philosophical question, one situated at the very heart of religious, philosophical, and cultural thought: *What is our place on the Earth?*

The Book of Genesis (3:19) famously states that we are dust, and to dust we shall return. It does not fall to science to answer questions of a metaphysical or existential drive. Nevertheless, science is part of the collective enterprise we name 'human knowledge'; it has unavoidable effects on the way humans attribute meaning to reality, and on the answers to the questions they formulate. The Anthropocene Hypothesis argues that the stratigraphic footprint of *Homo sapiens* may be an indelible sign of the human enterprise in the history of the Earth, bearing witness to the geological agency of a single species with impacts on future civilizations, future species, and the future of the planet itself – before its inevitable end. As such, the hypothesis provides an answer – limited and circumscribed to a specific epistemic domain – to the ontological question of the place that humans are *now* invested with.

Perhaps *Homo sapiens* – this "clever animal" who "invented knowledge" in "some remote corner of the universe, poured out and glittering in innumerable solar systems" (Nietzsche, 1977, p. 42) – may be no more significant than dust when compared to the rise and fall of mountains, to the movement of oceans and continents, or to the inscrutable abyss of geological time.

Still, as a Japanese proverb states, even dust if piled can become a mountain.

DEUTSCHE ZUSAMMENFASSUNG

FORSCHUNGSTHEMA

Die folgende Untersuchung ist eine historische und philosophische Studie über die Entstehung und die Epistemologie einer wissenschaftlichen Hypothese - der Anthropozän-Hypothese.

Die Anthropozän-Hypothese ist eine vor kurzem formulierte wissenschaftliche Hypothese, die von der Anthropocene Working Group (AWG) aufgestellt wurde, einer stratigrafisch orientierten Forschungsgruppe mit multidisziplinär-arbeitenden Mitgliedern, die im Sommer 2009 von der Subcommission on Quaternary Stratigraphy (SQS) gegründet wurde. Die Gruppe wurde zusammengestellt, um zu beurteilen, ob ausreichend stratigrafische Beweise vorliegen, die eine formelle Ratifizierung einer Anthropozän-Zeiteinheit in der geologischen Zeitskala und der internationalen chronostratigrafischen Tabelle rechtfertigen. Eine solche Einheit würde durch den stratigrafischen Fußabdruck des *Homo sapiens* in den geologischen Aufzeichnungen definiert und charakterisiert werden. Die von der Gruppe vertretene Hypothese lautet, dass tatsächlich genügend stratigrafische Marker anthropogenen Ursprungs vorhanden sind, um die formale Anerkennung einer Anthropozän-Epoche/-Serie zu gewährleisten. Dies würde auch das Ende der Holozän-Epoche (und damit des Meghalayum-Zeitalters) bedeuten - der derzeitigen und offiziell anerkannten geologischen Epoche. Der vorgeschlagene Beginn dieser postholozänen Epoche würde etwa in den 1950er Jahren liegen. Dieser Zeitrahmen deckt sich mit einer Reihe von stratigrafischen Markern, insbesondere geochemischen Markern, die mit nuklearen und thermonuklearen Atombombentests in Verbindung gebracht werden und in Kernproben aus Umweltarchiven auf der ganzen Welt nachweisbar sind. Die Hypothese hat in der Wissenschaft und in der Öffentlichkeit eine Vielzahl von Debatten über die Bedeutung, die Gültigkeit, den Nutzen und die umfassenderen sozialen und ethischen Auswirkungen der Formalisierung des Anthropozäns als anthropogen verursachte geologische Zeiteinheit ausgelöst.

Die Anthropozän-Hypothese ist die stratigrafische Formulierung oder „Variante" des umfassenderen ‚Anthropozän'-Konzepts. Der Begriff ‚Anthropozän' hat eine lange Vorgeschichte (und Paläogeschichte), aber in seiner heutigen Verwendung wurde er erstmals Ende Februar 2000 von dem Chemiker und Nobelpreisträger Paul Crutzen während einer Sitzung des wissenschaftlichen Ausschusses des Internationalen Geosphären-Biosphären-Programms in Cuernavaca, Mexiko, geprägt. Der Begriff setzte sich allmählich in der akademischen Welt durch, bis er ab 2009 eine Welle des Interesses auslöste, die sich in einer Vielzahl von Veröffentlichungen, Initiativen, Konferenzen, Universitätskursen, Ausstellungen, künstlerischen Ausdrucksformen und vielem mehr niederschlug, die sich auf das ‚Anthropozän' bezogen. Zahlreiche Wissenschaftler, vor allem in den Geistes- und Sozialwissenschaften, haben sich mit dem Begriff auseinandergesetzt, indem sie seine Bedeutung, seine Annahmen und seine Rhetorik analysierten und dekonstruierten. Einige haben den Begriff unter verschiedenen terminologischen Varianten neu formuliert, z. B. als ‚Kapitalozän', ‚Novozän', ‚Pyrozän' oder ‚Technozän' - um nur einige zu nennen. Ein fruchtbarer Aspekt dieses wachsenden Interesses ist, dass die aus dieser multidisziplinären Interaktion hervorgegangene Forschung ein breites Spektrum an Gesichtspunkten für die Untersuchung des ‚Anthropozän' als polysemantisches Objekt bietet. Allerdings ist es dadurch auch problematisch geworden, das ‚Anthropozän' in einer multifunktionalen Weise zu definieren. Dies ist ein besonders relevantes Problem, wenn man es in den breiteren Diskurs über eine kulturelle Kluft zwischen den Geistes- und Sozialwissenschaften auf der einen und den Naturwissenschaften auf der anderen Seite einordnet - eine Kluft, die dem ähnelt, was der Physiker und Schriftsteller Charles Percy Snow in den späten 1950er Jahren mit den Worten „zwei Kulturen" beschrieben hat. In der Tat haben ‚Anthropozän'-Wissenschaftler bereits Formen des Rückzugs, der Isolation oder des Antagonismus beobachtet, die diese intellektuelle und kulturelle Segregation zu wiederholen scheinen.

FORSCHUNGSFRAGEN

In dieser Untersuchung wird eine Lösung für dieses Problem vorgeschlagen. Die Lösung besteht in der Unterscheidung zwischen dem ‚Anthropozän' als Grenzobjekt und der Anthropozän-Hypothese: Ersteres entspricht einem Grenzobjekt von multidisziplinärer Bedeutung und Verwendung, während letzteres die besondere stratigrafische (oder geologische) Formulierung des ‚Anthropozän' darstellt. In der jüngeren Forschung (Thomas et al., 2020; Zalasiewicz et al., 2018; Zalasiewicz et al., 2019b; Zalasiewicz et al., 2021) wurde eine ähnliche Unterscheidung getroffen, um den Zweck und die Bedeutung des „geologischen Anthropozäns" oder des „stratigrafischen Anthropozäns" als eine diskrete und abgegrenzte Forschungsagenda zu klären. Es wird jedoch eingeräumt, dass diese Unterscheidung und die ihr innewohnende semantische Spannung noch nicht gründlich untersucht worden sind - insbesondere vom Standpunkt der philosophischen Analyse wissenschaftlichen Wissens aus betrachtet.

Diese Unterscheidung bildet den Rahmen für den zentralen Analysegegenstand der vorliegenden Untersuchung, nämlich die Anthropozän-Hypothese. Diese Unterscheidung so zu begründen und zu artikulieren, dass sie sowohl im akademischen als auch im öffentlichen Diskurs nützlich und nachvollziehbar ist, ist eines der Hauptziele der vorliegenden Arbeit. Die Studie implementiert diese Unterscheidung als Prämisse und erläutert gleichzeitig die eepistemischen Vorteile und den praktischen Nutzen einer solchen Haltung.

Der Versuch, eine theoretische Trennung zwischen ‚Anthropozän' und der Anthropozän-Hypothese zu legitimieren und abzugrenzen, ist das erste Ziel dieser Untersuchung. Das zweite Ziel ist die Beantwortung zweier miteinander verbundener Fragen, die sich aus dem ersten Ziel ergeben, nämlich: Was ist die Anthropozän-Hypothese? Was bedeutet es, dass die Anthropozän-Hypothese eine wissenschaftliche Hypothese darstellt?

Die erste Frage ergibt sich ganz natürlich aus der getroffenen Unterscheidung. Wenn die Hypothese als eine eigenständige theoretische Einheit behandelt werden soll, die mit dem ‚Anthropozän' zusammenhängt, sich aber konzeptionell von ihm unterscheidet, dann müssen die epistemischen Eigenschaften, die die Anthropozän-Hypothese als eigenständige Einheit definieren, identifiziert werden. Diese Eigenschaften sollten notwendige und hinreichende Gründe dafür liefern, die Anthropozän-Hypothese als ein eigenständiges theoretisches Objekt zu behandeln, das sich vom ‚Anthropozän' unterscheidet und nicht nur eine Interpretation des Letzteren darstellt.

Die zweite Frage bezieht sich auf die Natur der Anthropozän-Hypothese. Es wird argumentiert, dass die Hypothese eine wissenschaftliche Hypothese darstellt, insbesondere eine stratigrafische Hypothese. Als wissenschaftliche Hypothese weist sie epistemische Tugenden auf (z. B. Verständlichkeit, Nützlichkeit, Erklärungskraft), die traditionell von Wissenschaftsphilosophen diskutiert, definiert und der wissenschaftlichen Praxis und dem wissenschaftlichen Denken zugeschrieben werden. Als stratigrafische Hypothese spiegelt sie die Produktion wissenschaftlicher Ideen in dem spezifischen epistemischen Kontext wider, in dem die Hypothese steht - also in der stratigrafischen Forschung. Dies sind einige der epistemischen Merkmale, die die Anthropozän-Hypothese vom ‚Anthropozän'-Konzept unterscheiden und die die Hypothese zu einem Gegenstand des Interesses der Wissenschaftsphilosophie machen - insbesondere der Philosophie der Geologie. Dies ist ein wichtiger Punkt, da die Wissenschaftsphilosophie sowohl in der Debatte um das ‚Anthropozän' als auch um die Anthropozän-Hypothese im Grunde nur eine Nebenrolle spielt. In gewisser Weise ermutigt diese Forschung die Wissenschaftsphilosophie zu weiterer Auseinandersetzung mit der Epistemologie der stratigrafischen Klassifizierung und der Anthropozän-Hypothese als wissenschaftlicher Idee.

FORSCHUNGSMETHODIK

Die Untersuchung der Entstehung und der Epistemologie der Anthropozän-Hypothese gilt als geeignete Strategie, um zufriedenstellende Antworten auf beide Fragen zu geben. Aber was genau bedeutet es, die „Geburt" und „Epistemologie" der Anthropozän-Hypothese zu untersuchen? Wie können diese Aspekte dazu beitragen, die oben gestellten Fragen zu beantworten?

Um die Entstehung der Hypothese zu rekonstruieren, müssen die Umstände ermittelt werden, die eine Gruppe von Geologen dazu veranlassten, das ‚Anthropozän'
, auf stratigrafischer Grundlage zu definieren. Dies erfordert eine Untersuchung des historischen, intellektuellen, disziplinären und sozialen Kontextes, in dem die Hypothese entstanden ist. Wie erwartet,

stellt die Anthropozän-Hypothese eine besondere Interpretation des Konzepts ‚Anthropozän' dar. Um die Ursprünge der Anthropozän-Hypothese zu verstehen, muss man wissen, wie sich das Konzept ‚Anthropozän' in den ersten Jahren seines Bestehens in der akademischen und insbesondere in der wissenschaftlichen Landschaft entwickelt hat. Außerdem muss man den breiteren Kontext verstehen, den das ‚Anthropozän' im letzten Jahrzehnt hervorgebracht hat, nämlich den neuen Wissensbereich der Anthropozän-Studien. Dass die Anthropozän-Hypothese eine eigenständige theoretische Einheit darstellt, bedeutet nicht, dass sie völlig losgelöst von den breiteren Diskursen ist, die sich um das ‚Anthropozän' ranken. Im Gegenteil, man kann sagen, dass die Hypothese im Epizentrum eines solchen Diskurses und einer solchen Debatte angesiedelt ist. Daher ist es wichtig, den Kontext, der die Anthropozän-Hypothese umgibt und ihr vorausgeht, zu erfassen, um das Wesen und die Bedeutung der Hypothese als wissenschaftliche und stratigrafische Hypothese zu verstehen.

Die Epistemologie der Anthropozän-Hypothese zu untersuchen, bedeutet, die zentralen Wissensaussagen zu beschreiben, die die Identität der Hypothese untermauern, und zu bestimmen, welche epistemischen Tugenden die Hypothese charakterisieren (wenn überhaupt). Diese Wissensaussagen können aus dem Forschungsmaterial extrapoliert werden, das den methodischen, theoretischen und empirischen Rahmen der Hypothese absteckt, und dann in philosophischen Begriffen neu formuliert werden. Sie werden in verschiedenen Formen ausgedrückt, von normativ-methodisch (z. B. was geologische Beweise für die Hypothese darstellen; welche Normen der stratigrafischen Klassifizierung die Hypothese befolgt oder in Frage stellt usw.) bis hin zu deskriptiv-beobachtend (z. B. empirische Beweise). Die Analyse dieser Aussagen gewährt einen tieferen Einblick in ihre logischen und semantischen Implikationen und bietet neben der begrifflichen und semantischen Klärung auch kritische Gesichtspunkte von methodologischem und theoretischem Nutzen. Die Beurteilung, ob eine bestimmte Reihe von epistemischen Tugenden identifiziert werden kann, gewährleistet die theoretische Legitimität (sensu lato) der Hypothese als wissenschaftliche Hypothese. Dies ist besonders wichtig, weil die Wissenschaftlichkeit der Hypothese sowohl von außen als auch innerhalb der stratigrafischen und geologischen Gemeinschaft in Frage gestellt wurde. Die Untersuchung versucht zu zeigen, dass die Hypothese tatsächlich einige epistemische Tugenden aufweist, die es erlauben, sie (von einem philosophischen Standpunkt aus) als wissenschaftliche Hypothese zu charakterisieren.

Die philosophische Analyse in Form einer begrifflichen und sprachlichen Analyse ist das primäre Mittel, um die in dieser Untersuchung gesetzten Ziele zu erreichen. Wie der Philosoph Wesley Salmon (1982) jedoch einmal feststellte, „läuft die Philosophie, die nicht in Kontakt mit anderen Disziplinen steht, Gefahr, ziemlich steril zu werden" (1982, S. 282). Das bedeutet, dass die Philosophie allein nicht in der Lage ist, das Spektrum der Faktoren, die die Anthropozän-Hypothese als wissenschaftliche Hypothese charakterisieren, gründlich zu untersuchen, ohne Gefahr zu laufen, in abstrakte, von der „praktischen" Struktur wissenschaftlicher Erkenntnis losgelöste Wissenschaftsvorstellungen zu verfallen. Die Hypothese ist Teil eines sozialen, historischen und wissenschaftlichen Kontextes, der sowohl ihre Formulierung als auch ihren wissenschaftlichen Status mitbestimmt und beeinflusst. Ein interdisziplinärer Ansatz bestimmt daher die Arbeitsweise der vorliegenden Untersuchung. Diese Methode umfasst die quantitative und qualitative Linguistik, Methoden der stratigraphischen und geologischen Klassifizierung, die Begriffsgeschichte und die Wissenschaftsgeschichte. Jede dieser Disziplinen stellt Methoden zur Verfügung, die als angemessene Mittel zur Untersuchung der Entstehung und der Epistemologie der betreffenden Hypothese angesehen werden. Die verwendeten Methoden und die mit ihnen angegangenen Probleme werden in den jeweiligen Kapiteln und Abschnitten erörtert.

Der Grundton dieser Untersuchung ist in erster Linie deskriptiv. Sie versucht, die Ursprünge und das Wesen der Anthropozän-Hypothese als wissenschaftliche Hypothese auf der Grundlage sorgfältig geprüfter Daten zu untersuchen. Es wird nicht darüber geurteilt, ob die vorgeschlagene Epoche formalisiert werden sollte oder nicht, oder ob die formale Ratifizierung einer Anthropozän-Einheit für die Wissenschaft und die Gesellschaft im Allgemeinen von Vorteil wäre. Da jedoch völlige Objektivität methodisch unerreichbar ist, werden in begrenzten Teilen der Forschung Behauptungen aufgestellt, deren Absicht über eine Beschreibung hinausgeht. Dies gilt insbesondere für den Vorwurf der ideologischen Wissenschaftlichkeit der Anthropozän-Hypothese, aber auch für die Zuschreibung bestimmter epistemischer Tugenden an die Hypothese, den Umfang und das Ziel der Hypothese, ihre Neuartigkeit in der geologischen Forschung und ihre allgemeine Legitimität als wissenschaftliche Hypothese. Im Folgenden werden einige Argumente angeführt, die für die Anerkennung der Anthropozän-Hypothese als legitime und in ihrer Art noch nie dagewesene wissenschaftliche Hypothese sprechen. Außerdem werden die Auswirkungen dieses Standpunkts erörtert.

FORSCHUNGSSTRUKTUR

Die Untersuchung gliedert sich in fünf Kapitel, gefolgt von der Schlussfolgerung und einem Anhang. Jedes Kapitel wirft Fragen auf, deren Antworten für die Erreichung der zentralen Ziele dieser Untersuchung unerlässlich sind.

Kapitel 1 bildet den breiteren multidisziplinären Rahmen der Anthropozän-Hypothese. Es werden die folgenden Fragen aufgeworfen: Was ist das ‚Anthropozän'? Wodurch unterscheidet es sich von der Anthropozän-Hypothese? Welchen Sinn hat es, zwischen dem ‚Anthropozän' und der Anthropozän-Hypothese zu unterscheiden? Um diese Fragen zu beantworten, werden in diesem Kapitel das kürzlich eingerichtete Feld der Anthropozän-Studien und die wichtigsten Forschungsrichtungen, die ihm zugrunde liegen, untersucht. Die Anthropozän-Studien stellen ein multi- und interdisziplinäres Wissensgebiet dar, das in der Untersuchung des ‚Anthropozän' als globales Phänomen anthropogener Natur zusammenläuft. Nach der Erkundung der primären Forschungsrichtungen, die diesem im Entstehen begriffenen Forschungsfeld zugrunde liegen, wird eine theoretische und praktische Unterscheidung zwischen dem ‚Anthropozän' als Grenzobjekt und der Anthropozän-Hypothese als stratigrafische Variante vorgenommen. Diese Trennung untermauert den Rest der Forschung, indem sie den Untersuchungsrahmen auf die Anthropozän-

Hypothese eingrenzt, aber auch eine Analyse der semantischen Spannungen zwischen diesen beiden theoretischen Einheiten ermöglicht.

Kapitel 2 rekonstruiert die Entstehung der Anthropozän-Hypothese durch ergänzende quantitative und qualitative Analysen. Dabei werden die folgenden Fragen aufgeworfen: Was geschah in der frühen Geschichte des ‚Anthropozän'-Konzepts? Wie wurde der Begriff verwendet, und von wem? Wie hat das ‚Anthropozän' zur Entstehung der Anthropozän-Hypothese beigetragen? Um diese Fragen zu beantworten, wird in diesem Kapitel die frühe Geschichte des ‚Anthropozän' untersucht, indem ein Korpus von Literatur gesichtet wird, in der der Begriff in den ersten zehn Jahren seines Bestehens (d. h. 2000-2009) verwendet wurde. Aus quantitativer Sicht werden in der Untersuchung Textmining-Techniken eingesetzt, um herausragende Eigenschaften eines Korpus von 670 schriftlichen Aufzeichnungen zu ermitteln. Diese Analyse bietet einen quantitativen Überblick über die frühe Geschichte des Konzepts ‚Anthropozän' in der wissenschaftlichen Literatur. Aus qualitativer Sicht wird ein ausgewählter Pool von Texten mittels Diskursanalyse untersucht. Diese Texte gelten als emblematisch für die Art und Weise, wie der Begriff ‚Anthropozän' wahrgenommen, assimiliert und verwendet wurde. Darüber hinaus stützt sich die qualitative Analyse auf die persönliche Kommunikation mit Autoren, die bei der Übernahme und Popularisierung des Begriffs eine Rolle gespielt haben. Die Rekonstruktion der frühen Geschichte des ‚Anthropozän' wird als notwendige Voraussetzung für die Rekonstruktion der Entstehung der Anthropozän-Hypothese angesehen.

In Kapitel 3 wird der empirische Korpus, der die Anthropozän-Hypothese zu einer stratigraphischen Hypothese macht, untersucht und diskutiert, und es werden alternative und konkurrierende Hypothesen geprüft. Es werden die folgenden Fragen aufgeworfen: Was ist der empirische Korpus der Anthropozän-Hypothese? Welche alternativen stratigraphischen und allgemeineren wissenschaftlichen Vorschläge gibt es für ein wissenschaftlich sinnvolles ‚Anthropozän'? Zur Beantwortung der ersten Frage werden die neuesten wissenschaftlichen Erkenntnisse aus der Forschung im Umfeld der AWG untersucht. Parallel dazu werden die grundlegenden Definitionen, Prinzipien und Verfahren der stratigraphischen Klassifizierung untersucht, die die Erkenntnistheorie der Anthropozän-Hypothese bestimmen. Anschließend wird das Panorama der bestehenden wissenschaftlichen Hypothesen über das ‚Anthropozän' und seinen Beginn erörtert. Die Lokalisierung des Beginns der vorgeschlagenen Einheit ist einer der meist diskutierten Aspekte der Anthropozän-Hypothese. Daher wird die Erörterung des Spektrums alternativer Vorschläge als ein notwendiger Bestandteil der Epistemologie des von der AWG vorgelegten Vorschlags angesehen.

In Kapitel 4 wird ein erkenntnistheoretischer Abriss der Anthropozän-Hypothese skizziert. Dabei werden die folgenden Fragen aufgeworfen: Welche erkenntnistheoretischen Implikationen hat es, die Anthropozän-Hypothese als wissenschaftliche Hypothese zu betrachten? Welche epistemischen Tugenden (wenn überhaupt) weist die Anthropozän-Hypothese auf, die traditionell von Wissenschaftsphilosophen definiert werden? Was hat die bestehende philosophische Wissenschaft über das ‚Anthropozän' und die Anthropozän-Hypothese zu sagen? Zur Beantwortung dieser Fragen muss zunächst die Rezeption des

‚Anthropozän' in der bestehenden philosophischen Forschung untersucht werden, um festzustellen, in welchen philosophischen Bereichen das ‚Anthropozän' als philosophische Kategorie aufgenommen wurde. Besonderes Augenmerk gilt dabei dem offensichtlichen Desinteresse der Wissenschaftsphilosophie am ‚Anthropozän' oder der Anthropozän-Hypothese. Nachdem Gründe für diesen Umstand genannt werden, werden einige Beiträge aus der Wissenschaftsphilosophie diskutiert. Anschließend werden einflussreiche Modelle der Wissenschaftsphilosophie herangezogen, um festzustellen, ob die Anthropozän-Hypothese erkenntnistheoretische Merkmale aufweist, von denen gemeinhin gesagt wird, dass sie Wissenschaft und wissenschaftliches Wissen definieren. Diese Modelle konzentrieren sich in erster Linie auf die Epistemologie historischer Hypothesen sowie auf das Wesen wissenschaftlicher Erklärung und wissenschaftlichen Verstehens.

Kapitel 5 schließlich befasst sich mit den kritischen Debatten über das Konzept ‚Anthropozän' und die Anthropozän-Hypothese, die in den letzten zehn Jahren entstanden sind. Dabei werden die folgenden Fragen aufgeworfen: Welche Argumente wurden gegen das ‚Anthropozän' und seine stratigraphische Interpretation vorgebracht? Was ist der Unterschied zwischen den Argumenten gegen das ‚Anthropozän' und denen gegen die Anthropozän-Hypothese? Welche Aspekte der Hypothese sind besonders umstritten? Diese Fragen werden beantwortet, indem unabhängige Kritiklinien zu einzelnen und leicht identifizierbaren Argumenten zusammengeführt und vereinheitlicht werden. Das Kapitel untersucht, wie sich jedes dieser identifizierten Argumente auf das ‚Anthropozän' oder die Anthropozän-Hypothese bezieht, und bietet so einen Fahrplan, um sich in den vielfältigen Kritiklinien der Anthropozän-Studien zurechtzufinden. Dies ist ein nützliches Unterfangen, nicht nur um die konzeptionelle Trennung zu verstärken, die in dieser Untersuchung vorgenommen wurde, sondern auch um zu fragen, ob die Argumente gegen das ‚Anthropozän' auch für die Anthropozän-Hypothese gelten. Insbesondere werden die Argumente gegen die Anthropozän-Hypothese im Hinblick auf ihre Rolle bei der Verhandlung der Beweise und im Lichte der breiteren Epistemologie der Hypothese untersucht und diskutiert.

FORSCHUNGSWERT

Die Forschung soll vor allem zu drei Bereichen der akademischen Wissenschaft beitragen. Erstens ist sie ein Beitrag zur Wissenschaftsgeschichte und -philosophie, wofür sie einen doppelten Zweck erfüllt. Zum einen handelt es sich um eine Fallstudie über die Entstehung und die Erkenntnistheorie einer wissenschaftlichen Hypothese, insbesondere einer stratigrafischen Hypothese. Daraus lassen sich mehrere Anwendungen ableiten - zum Beispiel durch Vergleiche mit der Entstehung ähnlicher wissenschaftlicher Hypothesen oder durch Einordnung in größere wissenschaftstheoretische Diskurse. Andererseits werden Wissenschaftler der Wissenschaftsgeschichte und -philosophie ermutigt, sich an der Debatte über die Anthropozän-Hypothese zu beteiligen. Auf diese Weise wird auch das Interesse an der Philosophie der Geologie gefördert, einer Disziplin, die in der bestehenden Wissenschaftsphilosophie weitgehend unterrepräsentiert ist. In der Tat wird dieser Wissensbereich als entscheidend für die Entwicklung philosophischer Analysen der Anthropozän-Hypothese angesehen, da er sich auf die Epistemologie der Geologie konzentriert. Dennoch bleibt dieser Bereich ein weitgehend unerforschtes Gebiet.

Zweitens stellt es einen Beitrag zu den Anthropozän-Studien dar, einem im Entstehen begriffenen Forschungsgebiet, das sich um das ‚Anthropozän' als zentrales Konzept für die gegenwärtigen anthropogenen Auswirkungen auf den Planeten rankt. Der Begriff hat sich sowohl in der Wissenschaft als auch in der Öffentlichkeit als erfolgreiche Kategorie etabliert, was darauf schließen lässt, dass der Begriff unabhängig vom endgültigen Ergebnis der Anthropozän-Hypothese auf Dauer Bestand haben könnte. Wenn dies der Fall ist, dann kann eine Analyse, die die begriffliche Beziehung zwischen dem ‚Anthropozän' und der Anthropozän-Hypothese klärt, nur von Nutzen sein, um Instrumente zur weiteren Erforschung der semantischen Gebiete bereitzustellen, die dieser Begriff zu bieten hat.

Der dritte Beitrag betrifft die interdisziplinäre Forschung. Die hier angewandten interdisziplinären Untersuchungsmethoden machen das gesamte Vorhaben zu einem Beispiel für interdisziplinäre Arbeit - und hoffentlich zu einem erfolgreichen. Obwohl die interdisziplinäre Forschung „weithin als Treibhaus für Innovationen und als einzig plausibler Ansatz für komplexe Probleme wie den Klimawandel gilt" (Bromham et al., 2016, S. 684), steht sie immer noch vor großen Schwierigkeiten, die vor allem mit den Finanzierungsmöglichkeiten zusammenhängen. Die Trennung der Disziplinen an den Universitäten und die Probleme bei der Entwicklung funktionaler Modelle der Interdisziplinarität (Heikkurinen et al., 2016; Inkpen & DesRoches, 2019; Toivanen et al., 2017) sind ebenfalls große Hindernisse für die Durchführung interdisziplinärer Projekte. Inmitten dieser praktischen und theoretischen Schwierigkeiten ist das beste Mittel vielleicht Versuch und Irrtum. Daher wird in dieser Studie versucht, interdisziplinäre Analysemethoden zusammenzuführen. Dies geschieht nicht mit dem Ziel, einen interdisziplinären Rahmen zu entwickeln, sondern als Experiment, das Methoden und Theorien der Disziplinen zusammenführt, die an der Spitze der Forschung zum ‚Anthropozän' und zur Anthropozän-Hypothese stehen.

Abschließend ist anzumerken, dass die Geschichte der Anthropozän-Hypothese noch im Entstehen begriffen ist. Die AWG ist noch dabei, Erkenntnisse und Ergebnisse zur Unterstützung der Hypothese vorzulegen, und ein formeller Vorschlag an die Internationale Kommission für Stratigraphie steht noch aus. Die Forschung über die Anthropozän-Hypothese und das ‚Anthropozän' im Allgemeinen wird derzeit noch durchgeführt. Dies macht diese Gesamtanstrengung notwendigerweise etwas unvollständig, was das endgültige Schicksal des Vorschlags einer formellen stratigraphischen Anerkennung einer Anthropozän-Epoche (oder anderer Einheitsebenen) angeht. Dennoch ist aus der Anthropozän-Hypothese eine Fülle empirischer und theoretischer Forschungen hervorgegangen, die eine diskrete Analyse der Hypothese nicht nur möglich, sondern auch nützlich - wenn nicht sogar notwendig - machen. Die vorliegende Arbeit baut auf diesem breiten Spektrum an Forschungsliteratur auf.

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APPENDIX

The following table provides data concerning each of the 670 records composing the corpus analyzed and discussed in Chapter 2. The columns include the following information: author(s), year, title, journal, volume, issue, pages, publisher, place published, field(s) of knowledge, discipline(s), relative frequency (F_n), designation as central literature (CL) or peripheral literature (PL), language (LNG), and format.

The records are listed in chronological order, from 2000 to 2009 (day and/or month of publication are not considered). Because the vast majority of records are labelled as journal articles, this format, and consequently 'volume,' 'issue,' and 'pages,' are given separate columns. Records that do not have this information because they constitute different formats (e.g., book, book section, conference paper) are marked with a double slash in the appropriate cell. This also applies for any other information that is not pertinent to a given record (e.g., place published, publisher, journal).

The F_n column lists the relative frequency value of each of the records. Notably, each record is also labelled as central or peripheral literature in the adjacent column to the right. While this information is redundant, in that it is already suggested by the record's specific F_n value, it ensures that the division of the corpus into central and peripheral literature is error-free.

Lastly, languages are abbreviated according to the ISO 639-1 nomenclature, whereas discipline, field of knowledge, and format are labelled according to the categories defined in Chapter 2.

AUTHOR(S)	YEAR	TITLE	JOURNAL	VOL.	ISSUE	PAGES	PUBLISHER	PLACE PUBLISHED	FIELD(S) OF KNOWLEDGE	DISCIPLINE(S)	Fn	CL/PL	LNG	FORMAT
H. Ducklow	2000	ASLO Elections - candidature statement	ASLO Bulletin	9	1	2-11	//	//	Natural Sciences	Limnology, Oceanography	787	PL	EN	Pamphlet
K. R. Lassey; D. C. Lowe; B. Allan; M. Manning	2000	How has the Global Methane Source Inventory Evolved over the Anthropocene?	//	81	48	//	Eos Trans. AGU	//	Natural Sciences	Atmospheric science	3101	CL	EN	Abstract
B. Moore	2000	Global Climate Change: Current Challenges in Research and Scientific Leadership," Sustaining Earth's Life Support Systems -the Challenge for the Next Decade and Beyond"	//	81	48	//	Eos Trans. AGU	//	Natural Sciences	Earth System science	1653	PL	EN	Abstract
P. G. Falkowski; R. J. Scholes; E. Boyle; J. Canadell; D. Canfield; J. Elser; N. Gruber; K. Hibbard; P. Högberg; S. Linder; F. T. Mackenzie; B. Moore III; T. F. Pedersen; Y. Rosenthal; S. Seitzinger; V. Smetacek; W. Steffen	2000	The Global Carbon Cycle: A Test of Our Knowledge of Earth as a System	Science	290	5490	291-296	//	//	Natural Sciences	Earth System science	128	PL	EN	Journal Article
P. J. Crutzen; V. Ramanathan	2000	The ascent of Atmospheric science	Science	290	5490	299-304	//	//	Natural Sciences	Atmospheric science	151	PL	EN	Journal Article
P. J. Crutzen; E. Stoermer	2000	The "Anthropocene"	IGBP Global Change Newsletter	//	41	17-18	IGBP	//	Natural Sciences	Earth system science	2269	CL	EN	Journal Article
M. Nyström; C. Folke	2001	Spatial Resilience of Coral Reefs	Ecosystems	4	5	406-417	//	//	Natural Sciences	Ecology	232	PL	EN	Journal Article
J. Jäger; P. A. Matson; B. Moore III; F. Oldfield; K. Richardson; J. Schellnhuber; W. Steffen; B. Turner II; P. Tyson; R. J. Wasson	2001	Global Change and the Earth System: A Planet Under Pressure	Science Series	4	//	//	IGBP	//	Natural Sciences	Earth System science	489	PL	EN	Book
L. A. Codispoti; J. A. Brandes; J. P. Christensen; A. H. Devol; S. W. Naqvi; H. W. Paerl; T. Yoshinari	2001	The oceanic fixed nitrogen and nitrous oxide budgets: Moving targets as we enter the anthropocene?	Scientia Marina	65	Suppl. 2	85-105	//	//	Natural Sciences	Oceanography	504	PL	EN	Journal Article
F. Zhu	2001	现代地质学的新名词———人类世	Marine Geology Letters	//	8	24	//	//	Natural Sciences	Oceanography, geology	2008	CL	CN	Journal Article
M. Meybeck	2001	River basin under anthropocene conditions	Science and Integrated Coastal Management	//	85	275-294	Dahlem University Press	Berlin	Natural Sciences	Oceanography	1331	PL	EN	Book Section

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E. Ehlers; T. Krafft	2001	Understanding the Earth System - From Global Change Research to Earth System science	Understanding the Earth System: Compartments, Processes and Interactions	//	//	16-29	Springer-Verlag	Berlin, Heidelberg	Natural Sciences	Earth System science	340	PL	EN	Book Section
H. Lotze-Campen	2001	A Sustainability Geoscope – Observing, Understanding and Managing the Sustainability Transition	//	//	//	//	//	Berlin, Hotel Intercontinental, Germany	Natural Sciences	Earth System science	135	PL	EN	Conference Proceedings
W. Lucht; C. C. Jaeger	2001	The Sustainability Geoscope: a proposal for a global observation instrument for the anthropocene	Contributions to Global Change Research: A Report by the German National Committee on Global Change Research	//	//	138-144	//	Bonn	Natural Sciences, Social Sciences	Sustainability studies, Environmental science	1852	PL	EN	Book Section
T. McMichael	2001	Human frontiers, environments and disease: Past patterns, uncertain futures	//	//	//	//	Cambridge University Press	Cambridge	Social Sciences	Anthropology, Human geography	19	PL	EN	Book
H. J. Schellnhuber	2001	Earth System Analysis and Management	Understanding the Earth System: Compartments, Processes and Interactions	//	//	18-55	Springer-Verlag	Heidelber	Natural Sciences	Earth System science	82	PL	EN	Book Section
A. Berger; M.-F. Loutre	2001	The Past and Future Climate at the Astronomical Time Scale: The anthropocene, a transition between the Quaternary and the Quinternary	V Reun. Quat. Ibérico (REQUI) e I Congr. Quat. Paises Ling. Port. (CQPLI)	//	//	//	//	Lisbon	Natural Sciences	Geology, Climatology	132	PL	EN	Conference Paper
D. K. C. Jones	2001	The Evolution of Hillslope Processes	Geomorphological Processes and Landscape Change	//	//	61-89	Wiley-Blackwell	Oxford	Natural Sciences	Geology	209	PL	EN	Book Section
P. Caesau	2002	De la boucle ouverte « pression-État-réponse »... à la boucle complète « nature-société »	Nature Sciences Sociétés	10	1	80-84	//	//	Social Sciences	Environmental studies	365	PL	FR	Journal Article
P. Caesau	2002	La crise du progrès et le nécessaire changement d'échelle	Editions scientifiques et medicales Elsevier SAS	10	3	46-47	//	//	Social Sciences	History, environmental studies	638	PL	FR	Journal Article
M. D. Karl	2002	Nutrient dynamics in the deep blue sea	Trends in Microbiology	10	9	410-418	//	//	Natural Sciences	Biology, oceanography	261	PL	EN	Journal Article
F. Biermann	2002	Green Global Governance": Weltpolitik im Anthropozän"	GAIA	11	1	38-40	//	//	Social Sciences	Political science	1234	PL	DE	Journal Article
P. J. Crutzen	2002	The "anthropocene"	Journal de Physique IV (Proceedings)	12	10	1-5	//	//	Natural Sciences	Earth System science	3638	CL	EN	Journal Article
P. D. Tyson; G. R. J. Cooper; T. S. McCarthy	2002	Millennial to multi-decadal variability in the climate of southern Africa	International Journal of Climatology	22	9	1105-1117	//	//	Natural Sciences	Climatology	132	PL	EN	Journal Article
P. J. Crutzen	2002	The Effects of Industrial and Agricultural Practices on Atmospheric Chemistry and Climate during the Anthropocene	Journal of Environmental science and Health, Part A	37	4	423-424	//	//	Natural Sciences	Environmental science, climatology	2833	CL	EN	Journal Article
M. Saarnisto; K. Strand; M. Nuttall; B. Riffenburgh	2002	'The Arctic on Thinner Ice': First International Symposium of the Nordic Arctic Research Programme Thule Institute, University of Oulu, Finland, 10–11 May 2001	Polar Record	38	206	193	//	//	Natural Sciences, Social Sciences	Arctic studies, environmental studies	2392	CL	EN	Journal Article

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E. W. Sanderson; M. Jaiteh; M. A. Levy; K. H. Redford; A. V. Wannebo; G. Woolmer	2002	The Human Footprint and the Last of the Wild	BioScience	52	10	891-904	//	//	Natural Sciences	Environmental science	103	PL	EN	Journal Article
M. Meybeck	2002	Riverine quality at the Anthropocene: Propositions for global space and time analysis, illustrated by the Seine River	Aquatic Sciences	64	4	376-393	//	//	Natural Sciences	Limnology	1107	PL	EN	Journal Article
P. K. Haff	2002	Neogeomorphology	Eos, Transactions American Geophysical Union	83	29	310	//	//	Natural Sciences	Geology	846	PL	EN	Journal Article
E. A. Oberlander; C. A. M. Brenninkmeijer; P. J. Crutzen; N. F. Elansky; G. S. Golitsyn; I. G. Granberg; D. H. Scharffe; R. Hofmann; I. B. Belikov; H. G. Paretzke; P. F. J. van Velthoven	2002	Trace gas measurements along the Trans-Siberian railroad: The TROICA 5 expedition	Journal of Geophysical Research	107	D14, 4206	//	//	//	Natural Sciences	Geology	159	PL	EN	Journal Article
P. Jöckel	2002	The seasonal cycle of cosmogenic14CO at the surface level: A solar cycle adjusted, zonal-average climatology based on observations	Journal of Geophysical Research	107	D22	//	//	//	Natural Sciences	Geology	79	PL	EN	Journal Article
A. Berger; M.-F. Loutre	2002	An Exceptionally Long Interglacial Ahead?	Science	297	5585	1287-1288	//	//	Natural Sciences	Geology, Climatology	415	PL	EN	Journal Article
Y. Malhi; P. Meir; S. Brown	2002	Forests, carbon and global climate	Philos Trans A Math Phys Eng Sci	360	1797	1567-91	//	//	Natural Sciences	Ecology, Environmental science	235	PL	EN	Journal Article
Y. Malhi	2002	Carbon in the atmosphere and terrestrial biosphere in the 21st century	Philosophical Transactions of The Royal Society A Mathematical Physical and Engineering Sciences	360	1801	2925-2945	//	//	Natural Sciences	Atmospheric science	195	PL	EN	Journal Article
P. J. Crutzen	2002	Geology of Mankind	Nature	415	//	23	//	//	Natural Sciences	Geology, Earth System science	5800	CL	EN	Journal Article
LOICZ	2002	Coastal Change and the Anthropocene	LOICZ Synthesis & Futures Meeting	//	22	5	LOICZ Newsletter	Miami, USA	Natural Sciences	Oceanography	230	PL	EN	Conference Proceedings
H. Lotze-Campen; W. Lucht	2002	How to observe and model transitions towards sustainability: the Geoscope initiative	Berlin Conference on the Human Dimensions of Global Environmental Change	//	//	//	//	Berlin	Social Sciences, Natural Sciences	Sustainability studies, Environmental science	907	PL	EN	Conference Paper
IGBP	2002	Regional Studies and Global Change / Summary and Conclusions	Global-Regional Linkages in the Earth System	//	//	1-2, 186-190	Springer-Verlag	Berlin, Heidelberg	Natural Sciences, Social Sciences	Earth System science, environmental studies	346	PL	EN	Book Section

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P. J. Crutzen	2002	Atmospheric Chemistry in the "Anthropocene"	Challenges of a Changing Earth: Proceedings of the Global Change Open Science Conference, Amsterdam, The Netherlands, 10–13 July 2001	//	//	45-48	Springer-Verlag	Berlin, Heidelberg	Natural Sciences	Atmospheric science, Earth System science	990	PL	EN	Book Section
K. Y. Kondratyev; V. F. Krapivin; G. Phillips, W.	2002	Global Environmental Change: Modelling and Monitoring	//	//	//	//	Springer-Verlag	Berlin, Heidelberg	Natural Sciences	Earth System science	8	PL	EN	Book
P. Fabian	2002	Leben im Treibhaus: Unser Klimasystem—und was wir daraus machen	//	//	//	//	Springer-Verlag	Berlin/Heidelberg	Natural Sciences	Climatology	11	PL	DE	Book
F. S. Chapin III; P. A. Matson; H. A. Mooney	2002	Principles of Terrestrial Ecosystem Ecology	//	//	//	//	Springer	New York, USA	Natural Sciences	Ecology	156	PL	EN	Book
D. M. Etheridge; C. Trudinger; D. C. Lowe; K. R. Lassey; A. M. Smith; L. P. Steele; R. L. Langenfelds; R. J. Francey; M. Battle	2002	Evolution of Atmospheric Methane During The Anthropocene From Methane Isotopic Measurements of Firn Air From Two Antarctic Sites	EGS XXVII General Assembly	//	//	//	//	Nice	Natural Sciences	Geology, Atmospheric science	1333	PL	EN	Conference Paper
H. Lotze-Campen; W. Lucht; C. C. Jaeger	2002	A Sustainability Geoscope: defining an integrated information base for interdisciplinary modeling of global change	Fifth Annual Conference fo Global Economic Analysis	//	//	//	//	Taipei	Social Sciences, Natural Sciences	Sustainability studies, Environmental science	811	PL	EN	Conference Paper
K. R. Lassey; D. C. Lowe; D. Etheridge	2002	Reconstructing the Evolving Global Methane Budget Through the Anthropocene	//	//	//	//	American Geophysical Union: Western Pacific Geophysics Meeting	//	Natural Sciences	Atmospheric science	1887	PL	EN	Abstract
C. C. Jaeger; H. Lotze-Campen; W. Lucht	2002	The Development of a Sustainability Geoscope: An Interim Report	//	//	//	//	Deutsches Nationalkomitee für Global Change-Forschung (NKGCF)	//	Natural Sciences, Social Sciences	Eart System science, Sustainability studies	148	PL	EN	Report
C. D. Butler	2002	Inequality and Sustainability	//	//	//	555	The Australian National University	//	Social Sciences	Political science, Sustainability studies	32	PL	EN	Thesis
B. Bolin	2003	Geophysical and Geochemical Aspects of Environmental Degradation	Environmental Degradation and Institutional Responses	1	//	7-59	Elsevier	//	Natural Sciences, Social Sciences	Geology, environmental studies	42	PL	EN	Book Section
M. Meybeck	2003	Global Occurrence of Major Elements in Rivers	Treatise on Geochemistry, Volume 5: Surface and Ground Water, Weathering, and Soils	5	5	207-223	Elsevier	//	Natural Sciences	Limnology	103	PL	EN	Book Section

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B. Venkateswararao	2003	Information and Announcements: Refresher Course on Earth Sciences, 3 November-15 November 2003	//	8	3	105-106	Resonance	Kukatpally campus, Hyderabad	Natural Sciences	Earth System science	1330	PL	EN	Pamphlet
W. H. Schlesinger	2003	Introduction to Volume 8	Treatise on Geochemistry	8	//	xv-xix	Elsevier	//	Natural Sciences	Geology	509	PL	EN	Book Section
A. Berger; M.-F. Loutre; M. Crucifix	2003	The Earth's Climate in the Next Hundred Thousand Years (100 kyr)	Surveys in Geophysics	24	//	117-138	//	//	Natural Sciences	Climatology, geology	117	PL	EN	Journal Article
R. Dirzo; P. H. Raven	2003	Global State of Biodiversity and Loss	Annual Review of Environment and Resources	28	1	137-167	//	//	Natural Sciences	Ecology	58	PL	EN	Journal Article
C. Folke	2003	Reserves and resilience--from single equilibrium to complex systems	Ambio	32	6	379	//	//	Natural Sciences	Ecology	989	PL	EN	Journal Article
P. J. Crutzen; W. Steffen	2003	How Long Have We Been In The Anthropocene Era?	Climatic Change	61	3	251-257	//	//	Natural Sciences	Earth System science	2556	CL	EN	Journal Article
W. F. Ruddiman	2003	The Anthropogenic Greenhouse Era Began Thousands Of Years Ago	Climate Change	61	3	261-293	//	//	Natural Sciences	Climatology	229	PL	EN	Journal Article
U. Aswathanarayana	2003	Technologies for utilizing natural resources create new job opportunities in the geosciences in developing countries	Eos	84	36	354	//	//	Social Sciences	Science and technology studies, environmental studies	387	PL	EN	Journal Article
M. Meybeck	2003	Global analysis of river systems: from Earth system controls to Anthropocene syndromes	Philos Trans R Soc Lond B Biol Sci	358	1440	1935-55	//	//	Natural Sciences	Limnology, hydrology	1779	PL	EN	Journal Article
L. Gordon; M. Dunlop; B. Foran	2003	Land cover change and water vapour flows: learning from Australia	Philos Trans R Soc Lond B Biol Sci	358	1440	1973-84	//	//	Natural Sciences	Ecology, hydrology	108	PL	EN	Journal Article
C. Folke	2003	Freshwater for resilience: a shift in thinking	Philos Trans R Soc Lond B Biol Sci	358	1440	2027-36	//	//	Natural Sciences	Ecology, hydrology	626	PL	EN	Journal Article
Nature	2003	Welcome to the Anthropocene	Nature	424	6950	709	//	//	Natural Sciences	Climatology, Environmental science	5634	CL	EN	Journal Article
J. Finnegan	2003	Earth System science in the Early Anthropocene	IGBP Global Change Newsletter	//	55	8-11	IBGP	//	Natural Sciences	Earth System science	1020	PL	EN	Journal Article
B. de Vries; R. A. Marchant; J. de Greef	2003	Exploring the Past: on Methods and Concepts	Mappae Mundi: Humans and their Habitats in a Long-Term: Socio-Ecological Perspective: Myths, Maps and Models	//	//	111-147	Amsterdam University Press	Amsterdam	Social Sciences, Natural Sciences	Human Geography, ecology	142	PL	EN	Book Section
D. J. Wuebbles; G. Brasseur; H. Rodhe	2003	Changes in the Chemical Composition of the Atmosphere and Potential Impacts / An Integrated View of the Causesand Impacts of Atmospheric Changes	Atmospheric Chemistry in a Changing World: An Integration and Synthesis of a Decade of Tropospheric Chemistry Research	//	//	//	Springer-Verlag	Berlin, Heidelberg	Natural Sciences	Atmospheric science, chemistry	69	PL	EN	Book Section
S. E. Manahan	2003	Toxicological Chemistry and Biochemistry	//	//	//	//	CRC Press	Boca Raton,	Natural Sciences	Chemistry	23	PL	EN	Book
S. J. DeCanio	2003	Introduction	Economic Models of Climate Change, A Critique	//	//	//	Palgrave McMillan	New York	Social Sciences	Economics	178	PL	EN	Book Section
J. Goldammer	2003	Fire ecology of the recent anthropocene	2nd International Wildland Fire Ecology and Fire Management Congress	//	//	//	//	Orlando, Florida, USA	Natural Sciences	Ecology	184	PL	EN	Conference Proceedings

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R. Bradley	2003	Paleoclimatic perspectives on the Anthropocene	XVI INQUA Congress	//	//	//	//	Reno	Natural Sciences	Climatology	3425	CL	EN	Conference Paper
G. P. Brasseur; P. Artaxo; L. A. Barrie; R. J. Delmas; I. Galbally; W. M. Hao; R. C. Harriss; I. S. A. Isaksen; D. J. Jacob; C. E. Kolb; M. Prather; H. Rodhe; D. Schwela; W. Steffen; D. J. Wuebbles	2003	An Integrated View of the Causes and Impacts of Atmospheric Changes	Atmospheric Chemistry in a Changing World: An Integration and Synthesis of a Decade of Tropospheric Chemistry Research	//	//	330	Springer-Verlag	//	Natural Sciences	Atmospheric science	59	PL	EN	Book Section
F. Oldfield; K. D. Alverson	2003	The Societal Relevance of Paleoenvironmental Research	Paleoclimate, Global Change and the Future	//	//	1-11	//	//	Natural Sciences	Earth System science, Environmental science	453	PL	EN	Journal Article
R. Bradley; K. D. Alverson; T. F. Pedersen	2003	Challenges of a Changing Earth: Past Perspectives, Future Concerns	Paleoclimate, Global Change and the Future	//	//	163-167	//	//	Natural Sciences	Climatology, Earth System science	557	PL	EN	Journal Article
W. E. H. Blum; H. Eswaran	2004	Editorials: soils and sediments in the Anthropocene	Journal of soils and sediment	4	2	71	//	//	Natural Sciences	Soil science	4281	CL	EN	Journal Article
S. Chu; S. Elliott; M. Maltrud	2004	Ecodynamic and Eddy-Admitting Dimethyl Sulfide Simulations in a Global Ocean Biogeochemistry/ Circulation Model	Earth Interactions	8	11	1-25	//	//	Natural Sciences	Oceanography, chemistry	105	PL	EN	Journal Article
R. Pienitz; M. S. V. Douglas; J. P. Smol	2004	Paleolimnological research in polar regions: An introduction	Long-term Environmental Change in Arctic and Antarctic Lakes	8	//	1-18	Springer	Dordrecht	Natural Sciences	Limnology, arctic studies, Environmental science	129	PL	EN	Book Section
B. Allenby	2004	Infrastructure in the Anthropocene: Example of Information and Communication Technology	Journal of infrastructure systems	10	3	79-86	//	//	Applied Sciences	Engineering	335	PL	EN	Journal Article
C. Zielhofer; D. Faust; R. B. Escudero; F. D. del Olmo; A. Kadereit; K.-M. Moldenhauer; A. Porras	2004	Centennial-scale late-Pleistocene to mid-Holocene synthetic profile of the Medjerda Valley, northern Tunisia	The Holocene	14	6	851-861	//	//	Natural Sciences	Geology	117	PL	EN	Journal Article
S. Gupta; M. C. Porwal; P. S. Roy	2004	Human Modification of the Tropical Rain Forest of Nicobar Islands: Indicators From Land Use Land Cover Mapping	Journal of Human Ecology	16	3	163-171	//	//	Natural Sciences	Ecology	236	PL	EN	Journal Article
L. Tung sheng	2004	Demand of anthropocene study in the new stage of geoscience: in honor of late geologist Huang Jiqing for his innovative spirit	Quaternary Science (Chinese)	24	4	369—378	//	//	Natural Sciences	Geology	1283	PL	CN	Journal Article
M. Rycroft	2004	Book reveiw: Earth System Analysis for Sustainability	Surveys in Geophysics	25	5-6	539-541	//	//	Natural Sciences, Social Sciences	Earth System science, Sustainability studies	1215	PL	EN	Journal Article
T. O'Riordan	2004	Environmental science, sustainability and politics	Transactions of the Institute of British Geographers	29	2	234-247	//	//	Social Sciences, Natural Sciences	Environmental science, political science	114	PL	EN	Journal Article

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L. Talaue-McManus	2004	LOICZ: Coastal Change and the Anthropocene	//	32	//	B32A-03	American Geophysical Union	AGU Abstract Browser	Natural Sciences	Oceanography	2237	CL	EN	Abstract
B. Kjellén	2004	Pathways to the Future: The New Diplomacy for Sustainable Development	IDS Bulletin	35	3	107-113	//	//	Social Sciences	Sustainability studies, sociology	933	PL	EN	Journal Article
J. Luhmann	2004	Die Zukunft der Fauna im Anthropozän - Betrachtungen zum neuen Buch von Edward O. Wilson	Naturschutz und Landschaftsplanung: Zeitschrift für angewandte Ökologie	36	4	126	//	//	Natural Sciences, Social Sciences	Biology, sociology	651	PL	DE	Journal Article
M. Hoppema	2004	Weddell Sea turned from source to sink for atmospheric CO2 between pre-industrial time and present	Global and Planetary Change	40	3-4	219-231	//	//	Natural Sciences	Climatology, oceanography	355	PL	EN	Journal Article
S. T. Jarnagin	2004	Regional and Global Patterns of Population, Land Use, and Land Cover Change: An Overview of Stressors and Impacts	GIScience and Remote Sensing	41	3	207-227	//	//	Natural Sciences	Ecology	206	PL	EN	Journal Article
O. Koji	2004	Conference Report	International Union for Quaternary Research, XVI International Congress	43	2	139-163	The Quaternary Research	Reno	Natural Sciences	Geology	80	PL	JP	Conference Proceedings
W. Steffen; M. O. Andreae; B. Bolin; P. M. Cox; P. J. Crutzen; U. Cubasch; H. Held; N. Nakidenovic; R. J. Scholes; L. Talaue-mcmanus; B. L. Turner	2004	Abrupt Changes: The Achilles' Heels of the Earth System	Environment: Science and Policy for Sustainable Development	46	3	8-20	//	//	Natural Sciences	Earth System science	135	PL	EN	Journal Article
M. Meybeck	2004	The global change of continental aquatic systems: dominant impacts of human activities	Water Science and Technology	49	7	73-83	//	//	Natural Sciences	Earth System science	2221	CL	EN	Journal Article
H. Kreutzmann	2004	Ellsworth Huntington and his perspective on Central Asia. Great game experiences and their influence on development thought	GeoJournal	59	1	27-31	//	//	Social Sciences	Human Geography	632	PL	EN	Journal Article
U. Riebesell	2004	Effects of CO2 Enrichment on Marine Phytoplankton	Journal of Oceanography	60	4	719-729	//	//	Natural Sciences	Oceanography	125	PL	EN	Journal Article
M. J. Higginson; M. A. Altabet; D. W. Murray; R. W. Murray; T. D. Herbert	2004	Geochemical evidence for abrupt changes in relative strength of the Arabian monsoons during a stadial/interstadial climate transition	Geochimica et Cosmochimica Acta	68	19	3807-3826	//	//	Natural Sciences	Geology	71	PL	EN	Journal Article
R. Showstack	2004	In Brief: Entering the ``Anthropocene era''; Bush administration defends environmental policies	Eos, Transactions American Geophysical Union	85	5	46	//	//	Natural Sciences	Geology	2088	CL	EN	Journal Article
H. N. Pollack	2004	Book review: Global Change and the Earth System	Eos, Transactions American Geophysical Union	85	35	333	//	//	Natural Sciences	Earth System science	459	PL	EN	Journal Article

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D. Tchernov; M. Y. Gorbunov; C. de Vargas; S. N. Yadav; A. J. Milligan; M. Häggblom; P. G. Falkowski	2004	Membrane lipids of symbiotic algae are diagnostic of sensitivity to thermal bleaching in corals	Proceedings of the National Academy of Sciences	101	37	13531-13535	//	//	Natural Sciences	Biology, oceanography	253	PL	EN	Journal Article
H. H. Janzen	2004	Carbon cycling in earth systems—a soil science perspective	Agriculture, Ecosystems & Environment	104	3	399-417	//	//	Natural Sciences	Earth System science, soil science	105	PL	EN	Journal Article
A. Murakami; J. Inoue; S. Yoshikawa; H. Yamazaki	2004	The fossil fuel combustion and fire history in Osaka city by analyzing spheroidal carbonaceous particles (SCPs) and charcoal of the Osaka Castle moat sediments	The Journal of the Geological Society of Japan	110	1	11-18	//	//	Natural Sciences	Geology	685	PL	JP	Journal Article
E. Ehlers	2004	Geographie im Anthropozän	Petermanns geographische Mitteilungen : PGM ; Zeitschrift für Geo- und Umweltwissenschaften	148	6	79-88	//	//	Social Sciences	Human Geography	2345	CL	DE	Journal Article
C. L. Sabine; R. A. Feely; N. Gruber; R. M. Key; K. Lee; J. L. Bullister; R. Wanninkhof; C. S. Wong; D. W. R. Wallace; B. Tilbrook; F. J. Millero; T.-H. Peng; A. Kozyr; T. Ono; A. F. Rios	2004	The Oceanic Sink for Anthropogenic CO2	Science	305	5682	367-371	//	//	Natural Sciences	Oceanography	2258	CL	EN	Journal Article
G. Ramstein; Y. Donnadieu; Y. Goddéris	2004	Les glaciations du Protérozoïque	Comptes Rendus Geoscience	336	7-8	639-646	//	//	Natural Sciences	Geology	238	PL	FR	Journal Article
Y. Malhi; O. L. Phillips	2004	Tropical forests and global atmospheric change: a synthesis	Philos Trans R Soc Lond B Biol Sci	359	1443	549-55	//	//	Natural Sciences	Climatology, ecology	180	PL	EN	Journal Article
W. Steffen; A. Sanderson; P. D. Tyson; J. Jäger; P. A. Matson; B. Moore III; F. Oldfield; K. Richardson; H. J. Schellnhuber; B. L. Turner II; R. J. Wasson	2004	Global Change and the Earth System: A Planet Under Pressure	The IGBP Series	//	//	346	Springer-Verlag	Berlin, Heidelberg	Natural Sciences	Earth System science	181	PL	EN	Book
M. Meybeck; C. Vörösmarty; R. E. Schulze; A. Becker	2004	Conclusions: Scaling Relative Responses of Terrestrial Aquatic Systems to Global Changes	Vegetation, Water, Humans and the Climate: A New Perspective on an Interactive System	//	//	//	Springer-Verlag	Berlin, Heidelberg	Natural Sciences	Earth System science, hydrology	1148	PL	EN	Book Section

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C. Vörösmarty; M. Meybeck	2004	Responses of Continental Aquatic Systems at the Global Scale: New Paradigms, New Methods	Vegetation, Water, Humans and the Climate: A New Perspective on an Interactive System	//	//	//	Springer-Verlag	Berlin, Heidelberg	Natural Sciences	Earth System science, limnology	50	PL	EN	Book Section
P. M. Cox; N. Nakicenovic	2004	Assessing and Simulating the Altered Functioning of the Earth System in the Anthropocene	Earth System Analysis for Sustainability	//	//	//	MIT Press	Cambridge	Natural Sciences	Earth System science	2216	CL	EN	Book Section
W. Steffen; M. O. Andreae; B. Bolin; P. M. Cox; P. Crutzen; U. Cubasch; H. Held; N. Nakicenovic; L. Talaue-McManus; B. L. Turner II	2004	Group Report: Earth System Dynamics in the Anthropocene	Earth System Analysis for Sustainability	//	//	//	MIT Press	Cambridge	Natural Sciences	Earth System science	2040	CL	EN	Book Section
P. J. Crutzen; V. Ramanathan	2004	Atmospheric Chemistry and Climate in the Anthropocene	Earth System Analysis for Sustainability	//	//	//	MIT Press	Cambridge	Natural Sciences	Earth System science, Atmospheric science	1643	PL	EN	Book Section
C. Clark; P. J. Crutzen; H. J. Schellnhuber	2004	Science for Global Sustainability: Toward a New Paradigm	Earth System Analysis for Sustainability	//	//	//	MIT Press	Cambridge	Natural Sciences, Social Sciences	Earth System science, Sustainability studies	962	PL	EN	Book Section
W. Lucht; R. K. Pachauri	2004	The Mental Component of the Earth System	Earth System Analysis for Sustainability	//	//	//	MIT Press	Cambridge	Natural Sciences	Earth System science	730	PL	EN	Book Section
A. J. Watson; V. Brovkin; M. Claussen; P. Falkowski; H. Held; A. Payne; S. Rahmstorf; R. J. Scholes; D. P. Schrag; F. Sirocko	2004	Group Report: Possible States and Modes of Operation of the Quaternary Earth System	Earth System Analysis for Sustainability	//	//	//	MIT Press	Cambridge	Natural Sciences	Earth System science, climatology	302	PL	EN	Book Section
B. L. Turner II; S. R. McCandless	2004	How Humankind Came to Rival Nature: A Brief History of the Human-Environment Condition and the Lessons Learned	Earth System Analysis for Sustainability	//	//	//	MIT Press	Cambridge	Humanities, Social Sciences	Anthropology, human geography	272	PL	EN	Book Section
S. Rahmstrof; F. Sirocko	2004	Modes of Oceanic and Atmospheric Circulation during the Quaternary	Earth System Analysis for Sustainability	//	//	//	MIT Press	Cambridge	Natural Sciences	Atmospheric science, Earth System science, oceanography	171	PL	EN	Book Section
M. Clausen; H. Held; D. P. Schrag	2004	What Do We Know about Potential Modes of Operation of the Quaternary Earth System?	Earth System Analysis for Sustainability	//	//	//	MIT Press	Cambridge	Natural Sciences	Earth System science	150	PL	EN	Book Section
W. Steffen; A. Sanderson; P. D. Tyson; J. Jäger; P. A. Matson; B. Moore III; F. Oldfield; K. Richardson; H. J. Schellnhuber; B. L. Turner II; R. J. Wasson	2004	Global Change and the Earth System: A Planet Under Pressure. Executive Summary	IBGP Series	//	//	//	IGBP Secretariat	Stockholm, Sweden	Natural Sciences	Earth System science	1484	PL	EN	Book

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B. L. Turner II; E. Moran; R. Rindfuss	2004	Integrated Land-Change Science and Its Relevance to the Human Sciences	Land Change Science: Observing, Monitoring and Understanding Trajectories of Change on the Earth's Surface	//	//	431-447	Springer	//	Social Sciences, Natural Sciences	Human Geography, Environmental science	205	PL	EN	Book Section
P. J. Crutzen	2004	Anti-Gaia	Global Change and the Earth System: A Planet Under Pressure	//	//	72, box 2.7	Springer-Verlag	//	Natural Sciences, Social Sciences	Earth System science, Sustainability studies	288	PL	EN	Book Section
S. Lange; U. Schimank	2004	Governance und gesellschaftliche Integration	//	//	//	//	Springer-Verlag	//	Social Sciences	Political science	241	PL	DE	Book
M. Wallström; B. Bolin; P. Crutzen; W. Steffen	2004	A global crisis : The Earth's life-support system is in peril	The New York Times	//	//	//	//	//	Natural Sciences, Social Sciences	Environmental science, environmental studies	833	PL	EN	Newspaper Article
C. I. Millar	2004	Session Overview: Climate and Landscape Change Over Time1	Proceedings of the Sierra Nevada Science Symposium: Science for Management and Conservation, October 7-10, 2002	Gen. Tech. Rep. PSW-GTR-193	//	//	Pacific Southwest Research Station	Kings Beach	Natural Sciences	Climatology, ecology	273	PL	EN	Conference Proceedings
M. K. Hughes	2004	Interannual-scale to Century-scale Climate Variability in Western North America1	Sierra Nevada Science Symposium, October 7–10, 2002	Proceedings of the Sierra Nevada Science Symposium	//	//	USDA Forest Service Gen. Tech. Rep. PSW-GTR-193.	Kings Beach, California, US	Natural Sciences	Climatology	994	PL	EN	Conference Proceedings
P. J. Richerson; R. L. Bettinger; R. Boyd	2005	Evolution on a Restless Planet: Were Environmental Variability and Environmental Change Major Drivers of Human Evolution?	Handbook of Evolution: The Evolution of Living Systems (Including Hominids)	2	//	233-242	Wiley-VHC	//	Natural Sciences	Biology	115	PL	EN	Book Section
A. van Amstel	2005	Integrated assessment of climate change with reductions of methane emissions	Environmental sciences	2	2-3	315-326	//	//	Natural Sciences	Environmental science, climatology	342	PL	EN	Journal Article
GWSP	2005	The Global Water System Project: Science Framework and Implementation Activities	//	3	//	//	Global Water System Project	//	Natural Sciences	Earth System science, hydrology	81	PL	EN	Report
U. Lohmann; J. Feichter	2005	Global indirect aerosol effects: a review	Atmospheric Chemistry and Physics	5	3	715-737	//	//	Natural Sciences	Atmospheric science	52	PL	EN	Journal Article
P. K. Patra; S. K. Behera; J. R. Herman; S. Maksyutov; H. Akimoto; Y. Yamagata	2005	The Indian summer monsoon rainfall: interplay of coupled dynamics, radiation and cloud microphysics	Atmospheric Chemistry and Physics	5	8	2181-2188	//	//	Natural Sciences	Climatology	179	PL	EN	Journal Article

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A. P. Karageorgis; M. S. Skourtos; V. Kapsimalis; A. D. Kontogianni; N. T. Skoulikidis; K. Pagou; N. P. Nikolaidis; P. Drakopoulou; B. Zanou; H. Karamanos; Z. Levkov; C. Anagnostou	2005	An integrated approach to watershed management within the DPSIR framework: Axios River catchment and Thermaikos Gulf	Regional Environmental Change	5	2-3	138-160	//	//	Natural Sciences	Environmental science, oceanography	349	PL	EN	Journal Article
D. Archer; B. Buffett	2005	Time-dependent response of the global ocean clathrate reservoir to climatic and anthropogenic forcing	Geochemistry, Geophysics, Geosystems	6	3	//	//	//	Natural Sciences	Earth System science, oceanography	148	PL	EN	Journal Article
J. Kaplan	2005	From the Holocene to the Anthropocene: Climate of the last 1,000 Years	PAGES news	13	3	25	//	//	Natural Sciences	Climatology, geology	2681	CL	EN	Journal Article
A. G. Bunn; L. A. Waggoner; L. J. Graumlich	2005	Topographic mediation of growth in high elevation foxtail pine (Pinus balfouriana Grev. et Balf.) forests in the Sierra Nevada, USA	Global Ecology and Biogeography	14	2	103-114	//	//	Natural Sciences	Ecology	114	PL	EN	Journal Article
D. P. Turner	2005	Thinking at the global scale	Global Ecology and Biogeography	14	6	505-508	//	//	Social Sciences, Natural Sciences	Ecology, history	651	PL	EN	Journal Article
E. Keys; W. J. McConnell	2005	Global change and the intensification of agriculture in the tropics	Global Environmental Change	15	4	320-337	//	//	Social Sciences	Human Geography	152	PL	EN	Journal Article
M. Meybeck	2005	Looking for water quality	Hydrological Processes	19	1	331-338	//	//	Natural Sciences	Hydrology	780	PL	EN	Journal Article
K. Matsumoto; N. Gruber	2005	How accurate is the estimation of anthropogenic carbon in the ocean? An evaluation of the ΔC* method	Global Biogeochemical Cycles	19	3	//	//	//	Natural Sciences	Oceanography, Environmental science	88	PL	EN	Journal Article
H. H. Dürr; M. Meybeck; S. H. Dürr	2005	Lithologic composition of the Earth's continental surfaces derived from a new digital map emphasizing riverine material transfer	Global Biogeochemical Cycles	19	4	//	//	//	Natural Sciences	Geology	355	PL	EN	Journal Article
P. J. Crutzen	2005	Human Impact on Climate Has Made This the "Anthropocene Age"	New Perspectives Quarterly	22	2	14-16	//	//	Natural Sciences	Earth System science	4579	CL	EN	Journal Article
B. H. Luckman	2005	Dendrochronology and Human Dimensions Issues in Global Change	Dendrochronologia	22	3	131-134	//	//	Natural Sciences, Social Sciences	Physical geography, human geography	475	PL	EN	Journal Article
A. Körtzinger; J. Schimanski; U. Send	2005	High Quality Oxygen Measurements from Profiling Floats: A Promising New Technique	Journal of Atmospheric and Oceanic Technology	22	3	302-308	//	//	Natural Sciences	Oceanography, Atmospheric science	236	PL	EN	Journal Article
J. Byrne; L. Glover	2005	Ellul and the Weather	Bulletin of Science, Technology & Society	25	1	4-16	//	//	Humanities	Law	207	PL	EN	Journal Article
D. Liu	2005	人与自然和谐发展	Air Land Geography	28	2	//	//	//	Social Sciences, Natural Sciences	Human Geography, Ecology	5385	CL	CN	Journal Article
K. Gaston	2005	Biodiversity and extinction: species and people	Progress in Physical Geography Earth and Environment	29	2	239-247	//	//	Natural Sciences	Biology, physical geography	174	PL	EN	Journal Article
A. A. Stierle; D. B. Stierle	2005	Bioprospecting in the Berkeley pit: Bio active metabolites from acid mine waste extremophiles	Studies in Natural Products Chemistry	32	Part L	1123-1175	//	//	Natural Sciences	Chemistry, ecology	59	PL	EN	Journal Article
B. R. Gurjar; J. Lelieveld	2005	New Directions: Megacities and global change	Atmospheric Environment	39	2	391-393	//	//	Natural Sciences, Social Sciences	Atmospheric science, environmental studies	654	PL	EN	Journal Article

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C. F. Chyba; K. P. Hand	2005	Astrobiology: The Study of the Living Universe	Annual Review of Astronomy and Astrophysics	43	1	31-74	//	//	Natural Sciences	Biology, astronomy	84	PL	EN	Journal Article
T. Volk	2005	Hope for mind on earth. Book review: Earth System Analysis for Sustainability.	BioScience	55	12	1088-1090	//	//	Natural Sciences, Social Sciences	Earth System science, Sustainability studies	1233	PL	EN	Journal Article
M. Claussen; V. Brovkin; R. Calov; A. Ganopolski; C. Kubatzki	2005	Did Humankind Prevent a Holocene Glaciation?	Climatic Change	69	2-3	409-417	//	//	Natural Sciences	Climatology	688	PL	EN	Journal Article
J. Syvitski; C. Vörösmarty; A. Kettner	2005	Impact of Humans on the Flux of Terrestrial Sediment to the GlobalCoastal Ocean	//	86	18	//	Eos Trans. AGU	//	Natural Sciences	Hydrology, Oceanography	5714	CL	EN	Abstract
A. F. Spilhaus	2005	Ocean Biogeochemistry and Climate Studies	Eos	86	34	314	Eos	Princeton University	Natural Sciences	Oceanography, climatology	398	PL	EN	Call for Applications
J. P. Smol; A. P. Wolfe; H. J. B. Birks; M. S. V. Douglas; V. J. Jones; A. Korhola; R. Pienitz; K. Rühland; S. Sorvari; D. Antoniades; S. J. Brooks; M.-A. Fallu; M. Hughes; B. Keatley; T. E. Laing; N. Michelutti; L. Nazarova; M. Nyman; A. M. Paterson; B. Perren; R. Quinlan; M. Rautio; É. Saulnier-Talbot; S. Siitonen; N. Solovieva; J. Weckström	2005	Climate-driven regime shifts in the biological communities of arctic lakes	Proceedings of the National Academy of Sciences	102	12	4397-4402	//	//	Natural Sciences	Climatology	419	PL	EN	Journal Article

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H. J. W. de Baar; W. Philip; K. H. Coale; M. R. Landry; A. Tsuda; P. Assmy; D. C. E. Bakker; Y. Bozec; R. T. Barber; M. A. Brzezinski; K. O. Buesseler; M. Boyé; P. L. Croot; F. Gervais; M. Y. Gorbunov; P. J. Harrison; W. T. Hiscock; P. Laan; C. Lancelot; C. S. Law; M. Levasseur; M. Adrian; F. J. Millero; J. Nishioka; Y. Nojiri; T. van Oijen; U. Riebesell; M. J. A. Rijkenberg; H. Saito; S. Takeda; K. R.	2005	Synthesis of iron fertilization experiments: From the Iron Age in the Age of Enlightenment	Journal of Geophysical Research	110	C9	//	//	//	Natural Sciences	Geology	48	PL	EN	Journal Article
A. Ridgwell; R. Zeebe	2005	The role of the global carbonate cycle in the regulation and evolution of the Earth system	Earth and Planetary Science Letters	234	3-4	299-315	//	//	Natural Sciences	Earth System science	185	PL	EN	Journal Article
A. J. Andersson; F. T. Mackenzie; A. Lerman	2005	Coastal ocean and carbonate systems in the high CO2 world of the Anthropocene	American Journal of Science	305	9	875-918	//	//	Natural Sciences	Oceanography	1066	PL	EN	Journal Article
J. P. Syvitski; C. J. Vorosmarty; A. J. Kettner; P. Green	2005	Impact of humans on the flux of terrestrial sediment to the global coastal ocean	Science	308	5720	376-80	//	//	Natural Sciences	Oceanography, Hydrology	1242	PL	EN	Journal Article
M. Meybeck; C. Vörösmarty	2005	Fluvial filtering of land-to-ocean fluxes: from natural Holocene variations to Anthropocene	Comptes Rendus Geoscience	337	1-2	107-123	//	//	Natural Sciences	Limnology, oceanography	2482	CL	EN	Journal Article
G. de Marsily	2005	Eaux continentales / Continental Waters	Comptes Rendus Geoscience	337	1-2	1-7	//	//	Natural Sciences	Hydrology	209	PL	EN, FR	Journal Article
M.-F. Loutre; A. Berger	2005	Insolation, CO2 et précipitations en période interglaciaire	Comptes Rendus Geoscience	337	1-2	69-78	//	//	Natural Sciences	Geology	154	PL	FR	Journal Article
S. E. van der Leeuw; A. R. Team	2005	Climate, hydrology, land use, and environmental degradation in the lower Rhone Valley during the Roman period	Comptes Rendus Geoscience	337	1-2	9-27	//	//	Natural Sciences, Social Sciences	Hydrology, Environmental science, environmental studies	232	PL	EN	Journal Article
F. Sirocko; K. Seelos; K. Schaber; B. Rein; F. Dreher; M. Diehl; R. Lehne; K. Jager; M. Krbetschek; D. Degering	2005	A late Eemian aridity pulse in central Europe during the last glacial inception	Nature	436	7052	833-6	//	//	Natural Sciences	Geology	294	PL	EN	Journal Article

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RealClimate	2005	Debate over the Early Anthropogenic Hypothesis	RealClimate: Climate Science from Climate Scientists	2019	//	//	RealClimate	http://www.realclimate.org/index.php/archives/2005/12/early-anthropocene-hyppothesis/ (Accessed on July 29, 2021)	Natural Sciences	Climatology	4561	CL	EN	Web Page
M. Meybeck	2005	Origins and Behaviours of Carbon Species in World Rivers	Soil Erosion and Carbon Dynamics	//	//	//	CR Press	Boca Raton	Natural Sciences	Limnology	817	PL	EN	Book Section
A. Cianciullo	2005	Book review: Benvenuti nell'Antropocene!" L'uomo ha cambiato il clima. La Terra entra in una nuova era"."	//	//	//	//	PeaceLink	https://www.peacelink.it/ecologia/a/10462.html (Accessed on July 29, 2021)	Natural Sciences, Social Sciences	Earth System science, environmental studies	1429	PL	IT	Book Review
C. J. Barrow	2005	Environmental Management and Development	//	//	//	//	Tayler & Francis	London	Social Sciences, Natural Sciences	Environmental studies, Sustainability studies	9	PL	EN	Book
P. J. Crutzen	2005	Benvenuti nell'Antropocene! L'uomo ha cambiato il clima. La Terra entra in una nuova era	//	//	//	//	Mondadori	Milan	Natural Sciences, Social Sciences	Earth System science, environmental studies	1138	PL	IT	Book
H. G. Hengeveld	2005	Climate Change – Past, Present and Future	Encyclopedia of Hydrological Sciences	//	//	//	Wiley	New Jersey	Natural Sciences	Hydrology, climatology	72	PL	EN	Encyclopedia
F. Oldfield	2005	Environmental Change: Key Issues and Alternative Perspectives	//	//	//	//	Cambridge University Press	New York, USA	Natural Sciences	Earth System science, Environmental science	249	PL	EN	Book
T. Flannery	2005	The Weather Makers: How Man Is Changing the Climate and What It Means for Life on Earth	//	//	//	//	Grove Press	New York, USA	Natural Sciences, Social Sciences	Environmental studies, climatology	96	PL	EN	Book
S. Killops; V. Killops	2005	Introduction to Organic Geochemistry	//	//	//	//	Blackwell Publishing	Padstow	Natural Sciences	Geology, chemistry	5	PL	EN	Book
B. Allenby	2005	Reconstructing Earth: Technology and Environment in the Age of Humans	//	//	//	//	Island Press	Washington, DC, USA	Natural Sciences, Social Sciences	Earth System science, environmental studies	145	PL	EN	Book
H. G. Hengeveld	2005	The Science of Changing Climates	Climate Change and Managed Ecosystems	//	//	17-43	CRC Press	//	Natural Sciences	Climatology, Environmental science	82	PL	EN	Book Section
R. W. Arnold	2005	Future of Soil Science: Role of Soils	Encyclopedia of Soil Science	//	//	//	CRC Press Book	//	Natural Sciences	Soil science	788	PL	EN	Encyclopedia
T. Oki	2005	The Hydrologic Cycles and Global Circulation	Encyclopedia of Hydrological Sciences	//	//	//	John Wiley & Sons	//	Natural Sciences	Hydrology	465	PL	EN	Book Section
H. Lotze-Campen; H.-J. Schellnhuber	2005	Global environmental change as projected by IPCC and its impact on food availability	Food and Nutrition Security in the Process of Globalization	//	//	//	LIT	//	Natural Sciences, Social Sciences	Climatology, Sustainability studies	241	PL	EN	Book Section
C. J. Crossland; H. H. Kremer; H. J. Lindeboom; J. I. M. Crossland; M. D. A. Le Tissier	2005	Coastal Fluxes in the Anthropocene: The Land-Ocean Interactions in the Coastal Zone Project of the International Geosphere-Biosphere Programme	The IGBP Series	//	//	//	Springer-Verlag	//	Natural Sciences	Oceanography	33	PL	EN	Book
LOICZ	2005	Land–Ocean Interactions in the Coastal Zone: Science Plan and Implementation Strategy	//	//	IGBP Report 51 / IHDP Report 18	//	IGBP Secretariat	Stockholm	Natural Sciences	Oceanography	211	PL	EN	Report
J. P. M. Syvitski; A. J. Kettner; A. Correggiari; B. W. Nelson	2005	Distributary channels and their impact on sediment dispersal	Marine Geology	222-223	//	75-94	//	//	Natural Sciences	Oceanography, geology	404	PL	EN	Journal Article

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L. Kullman; R. W. Battarbee; W. Francke; D. E. Goldberg; P. G. Jarvis; R. H. Marrs; B. J. Philogène; M. V. Price; P. H. Zedler	2006	Transformation of alpine and subalpine vegetation in a potentially warmer future, the Anthropocene era. Tentative projections based on long-term observations and paleovegetation records.	Current Trends in Ecology	1	1	1-16	//	//	Natural Sciences	Ecology, Environmental science	300	PL	EN	Journal Article
B. Allenby	2006	Macroethical systems and sustainability science	Sustainability Science	1	1	7-13	//	//	Social Sciences, Humanities	Sustainability studies, philosophy	2648	CL	EN	Journal Article
W. Steffen	2006	The Anthropocene, global change and sleeping giants: where on Earth are we going?	Carbon Balance and Management	1	1	//	//	//	Natural Sciences, Social Sciences	Earth System science, environmental studies	899	PL	EN	Journal Article
K. Matsumoto	2006	A psychological effect of having a potentially viable sequestration strategy	Carbon Balance Manag	1	//	4	//	//	Social Sciences, Natural Sciences	Political science, geology	686	PL	EN	Journal Article
J. A. Dearing	2006	Climate-human-environment interactions: resolving our past	Climate of the Past	2	2	187-203	//	//	Social Sciences, Natural Sciences	Human Geography, climatology	162	PL	EN	Journal Article
J. H. Bédard	2006	Book review: Plates, Plumes, and Paradigms	Elements	2	5	298	//	//	Natural Sciences	Geology	970	PL	EN	Journal Article
L. A. Codispoti	2006	An oceanic fixed nitrogen sink exceeding 400 Tg N a−1 vs the concept of homeostasis in the fixed-nitrogen inventory	Biogeosciences Discussions	3	4	1203-1246	//	//	Natural Sciences	Oceanography	280	PL	EN	Journal Article
A. Berger	2006	Les causes astronomiques des grandes variations du climat au Quaternaire	Comptes Rendus Palevol	5	1-2	21-26	//	//	Natural Sciences	Climatology	216	PL	EN	Journal Article
M. Zalewski	2006	Fritz Schiemer - a positive driving force in the development of Ecohydrology	Ecohydrology & Hydrobiology	6	1-4	3-4	//	//	Natural Sciences	Hydrology, ecology	1435	PL	EN	Journal Article
E. Kolbert	2006	One Big Fix	Conservation	7	3	48-49	//	//	Applied Sciences	Geoengineering	2079	CL	EN	Journal Article
R. Edwards; P. Sedwick; V. Morgan; C. F. Boutron	2006	Iron in ice cores from Law Dome: A record of atmospheric iron deposition for maritime East Antarctica during the Holocene and Last Glacial Maximum	Geochemistry, Geophysics, Geosystems	7	12	//	//	//	Natural Sciences	Geology	339	PL	EN	Journal Article

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F. S. Chapin; G. M. Woodwell; J. T. Randerson; E. B. Rastetter; G. M. Lovett; D. D. Baldocchi; D. A. Clark; M. E. Harmon; D. S. Schimel; R. Valentini; C. Wirth; J. D. Aber; J. J. Cole; M. L. Goulden; J. W. Harden; M. Heimann; R. W. Howarth; P. A. Matson; A. D. McGuire; J. M. Melillo; H. A. Mooney; J. C. Neff; R. A. Houghton; M. L. Pace; M. G. Ryan; S. W. Running; O. E. Sala; W. H. Schlesinger; E. D.	2006	Reconciling Carbon-cycle Concepts, Terminology, and Methods	Ecosystems	9	7	1041-1050	//	//	Natural Sciences	Ecology	264	PL	EN	Journal Article
J. E. Chaplin	2006	Benjamin Franklin and Science, Continuing Opportunities for Study	Perspectives on Science	14	2	232-251	//	//	Social Sciences	Science and Technology studies, history	122	PL	EN	Journal Article
A. Machado	2006	Book review of 'Reconstructing Earth: Technology and Environment in the Age of Humans' by Braden Allenby	Journal for Nature Conservation	14	3-4	264-265	//	//	Social Sciences, Natural Sciences	Science and technology studies, Earth System science	1372	PL	EN	Journal Article
D. K. A. Barnes; D. A. Hodgson; P. Convey; C. S. Allen; A. Clarke	2006	Incursion and excursion of Antarctic biota: past, present and future	Global Ecology and Biogeography	15	2	121-142	//	//	Natural Sciences	Ecology, biology, physical geography	107	PL	EN	Journal Article
B. Allenby	2006	The Real Death of Environmentalism	Environmental Quality Management	16	1	1-9	//	//	Social Sciences	Environmental studies	390	PL	EN	Journal Article
F. Marret	2006	Book review: Environmental change: key issues and alternative perspectives	The Holocene	16	3	463	//	//	Social Sciences, Natural Sciences	Environmental studies	1093	PL	EN	Journal Article
B. L. Otto-Bliesner; R. Tomas; E. C. Brady; C. Ammann; Z. Kothavala; G. Clauzet	2006	Climate Sensitivity of Moderate- and Low-Resolution Versions of CCSM3 to Preindustrial Forcings	Journal of Climate	19	11	2567–2583	//	//	Natural Sciences	Climatology	106	PL	EN	Journal Article
A. J. Andersson; F. T. Mackenzie; A. Lerman	2006	Coastal ocean CO2-carbonic acid-carbonate sediment system of the Anthropocene	Global Biogeochemical Cycles	20	1	//	//	//	Natural Sciences	Earth System science, oceanography	1380	PL	EN	Journal Article
M. Meybeck; H. H. Dürr; C. J. Vörösmarty	2006	Global coastal segmentation and its river catchment contributors: A new look at land-ocean linkage	Global Biogeochemical Cycles	20	1	//	//	//	Natural Sciences	Oceanography	522	PL	EN	Journal Article
E. Y. Kwon; F. Primeau	2006	Optimization and sensitivity study of a biogeochemistry ocean model using an implicit solver and in situ phosphate data	Global Biogeochemical Cycles	20	4	//	//	//	Natural Sciences	Chemistry, oceanography	109	PL	EN	Journal Article

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T. Frändberg; G. A. Swanson	2006	The Earth: beyond the levels of life	Systems Research and Behavioral Science	23	3	437-440	//	//	Natural Sciences	Earth System science	506	PL	EN	Journal Article
P. P. Smolka	2006	Book review: Early Hominin Landscapes in Northern Pakistan: Investigations in the Pabbi Hills	Quaternary Science Reviews	25	3-4	393-396	//	//	Natural Sciences	Earth System science	312	PL	EN	Journal Article
C. Zhirong	2006	Anthroposphere, Noosphere, Anthropocene	Quaternary Science (Chinese)	26	5	872-878	//	//	Natural Sciences	Geology, Earth System science	2530	CL	CN	Journal Article
B. Dresp	2006	Restoring is believing	Ecological Engineering	28	1	11-13	//	//	Natural Sciences, Applied Sciences	Ecology, engineering	435	PL	EN	Journal Article
J. Aronson; J. N. Blignaut; S. J. Milton; A. F. Clewell	2006	Natural capital: The limiting factor	Ecological Engineering	28	1	1-5	//	//	Social Sciences	Economics, environmental studies	2384	CL	EN	Journal Article
J. Farley; H. Daly	2006	Natural capital: The limiting factor. A reply to Aronson, Blignaut, Milton and Clewell	Ecological Engineering	28	1	6-10	//	//	Social Sciences	Economics, environmental studies	744	PL	EN	Journal Article
A. M. Mannion	2006	Book review: Environmental Change. Key Issues and Alternative Approaches	Environmental Conservation	33	1	84-84	//	//	Social Sciences, Natural Sciences	Environmental studies	1036	PL	EN	Journal Article
W. Steffen	2006	The Arctic in an Earth System Context: From Brake to Accelerator of Change	AMBIO: A Journal of the Human Environment	35	4	153-159	//	//	Natural Sciences, Social Sciences	Earth System science, environmental studies	899	PL	EN	Journal Article
P. Verburg	2006	The need to correct for the Suess effect in the application of δ13C in sediment of autotrophic Lake Tanganyika, as a productivity proxy in the Anthropocene	Journal of Paleolimnology	37	4	591-602	//	//	Natural Sciences	Limnology, geology	679	PL	EN	Journal Article
J. McCarthy	2006	Book review: Environmental change: key issues and alternative approaches	Polar Record	42	4	373-375	//	//	Natural Sciences, Social Sciences	Earth System science, environmental studies	771	PL	EN	Journal Article
P. McFedries	2006	Technically Speaking: Changing Climate, Changing Language	IEEE Spectrum	43	8	60	//	//	Humanities	Linguistics	1208	PL	EN	Journal Article
C. N. H. Doll; J.-P. Muller; J. G. Morley	2006	Mapping regional economic activity from night-time light satellite imagery	Ecological Economics	57	1	75-92	//	//	Social Sciences	Economics	98	PL	EN	Journal Article
R. M. May	2006	Address of the President, Lord May of Oxford OM AC FRS, given at the Anniversary Meeting on 30 November 2005 Threats to tomorrow's world	Notes and Records of the Royal Society	60	1	109-130	//	//	Social Sciences, Natural Sciences	History, Environmental science	155	PL	EN	Journal Article
K. Reise; S. Olenin; D. W. Thieltges	2006	Are aliens threatening European aquatic coastal ecosystems?	Helgoland Marine Research	60	2	77-83	//	//	Natural Sciences	Oceanography, ecology	171	PL	EN	Journal Article
T. Blaschke	2006	The role of the spatial dimension within the framework of sustainable landscapes and natural capital	Landscape and Urban Planning	75	3-4	198-226	//	//	Applied Sciences	Landscape architecture	55	PL	EN	Journal Article
L. V. Pivovarova; T. G. Korzhenevskaya; M. V. Gusev	2006	The role of science and education in the formation of biological competence	Herald of the Russian Academy of Sciences	76	1	27-33	//	//	Social Sciences	Pedagogy, science and technology studies	173	PL	EN	Journal Article
R. J. Cicerone	2006	Geoengineering: Encouraging Research and Overseeing Implementation	Climatic Change	77	3-4	221-226	//	//	Applied Sciences	Geoengineering	386	PL	EN	Journal Article
P. J. Crutzen	2006	Albedo Enhancement by Stratospheric Sulfur Injections: A Contribution to Resolve a Policy Dilemma?	Climatic Change	77	3-4	211-220	//	//	Natural Sciences, Applied Sciences	Atmospheric science, geoengineering	218	PL	EN	Journal Article

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A. A. Kokhanovsky	2006	Modeling of light depolarization by cubic and hexagonal particles in noctilucent clouds	Atmospheric Research	79	2	175-181	//	//	Natural Sciences	Atmospheric science	274	PL	EN	Journal Article
L. A. James; W. A. Marcus	2006	The human role in changing fluvial systems: Retrospect, inventory and prospect	Geomorphology	79	3-4	152-171	//	//	Natural Sciences	Physical geography, geology	67	PL	EN	Journal Article
N. L. Poff; B. P. Bledsoe; C. O. Cuhaciyan	2006	Hydrologic variation with land use across the contiguous United States: Geomorphic and ecological consequences for stream ecosystems	Geomorphology	79	3-4	264-285	//	//	Natural Sciences	Hydrology, geology	64	PL	EN	Journal Article
A. U. Igamberdiev; P. J. Lea	2006	Land plants equilibrate O2 and CO2 concentrations in the atmosphere	Photosynth Res	87	2	177-94	//	//	Natural Sciences	Climatology, ecology	166	PL	EN	Journal Article
P. Falkowski; S. Seitzinger	2006	How do continental shelves store organic carbon?	//	87	36	//	Eos Trans. AGU	//	Natural Sciences	Oceanography	2611	CL	EN	Abstract
L. E. Band	2006	Ecohydrologic pattern optimization at the hillslope scale:Implications for ecosystem management and restoration in the Anthropocene	//	87	52	//	Eos Trans. AGU	//	Natural Sciences	Ecology, Hydrology	2033	CL	EN	Abstract
J. L. Florsheim; M. D. Dettinger; F. Malamud-Roam	2006	Geomorphic Response to Global Warming in the Anthropocene:Levee Breaches in California's Sacramento-San Joaquin Watershed	//	87	52	//	Eos Trans. AGU	//	Natural Sciences	Hydrology, Geology	1721	PL	EN	Abstract
R. A. Dahlgren	2006	Biogeochemical processes in soils and ecosystems: From landscape to molecular scale	Journal of Geochemical Exploration	88	1-3	186-189	//	//	Natural Sciences	Soil science, ecology, chemistry	366	PL	EN	Journal Article
M. Singh; A. K. Singh	2006	Bibliography of environmental studies in natural characteristics and anthropogenic influences on the Ganga River	Environ Monit Assess	129	1-3	421-32	//	//	Natural Sciences, Social Sciences	Environmental studies, limnology	104	PL	EN	Journal Article
C. S. Larsen	2006	The agricultural revolution as environmental catastrophe: Implications for health and lifestyle in the Holocene	Quaternary International	150	1	11-20	//	//	Social Sciences	Anthropology, archaeology	167	PL	EN	Journal Article
J. Mills; A. Sobel; L. Durvin	2006	Book review: The Weather Makers: How Man Is Changing the Climate and What It Means for Life on Earth	Science News	169	7	111	//	//	Natural Sciences, Social Sciences	Environmental studies	818	PL	EN	Journal Article
H. Fan; H. Huang; T. Zeng	2006	Impacts of Anthropogenic Activity on the Recent Evolution of the Huanghe (Yellow) River Delta	Journal of Coastal Research	224	//	919-929	//	//	Natural Sciences	Hydrology, Environmental science	226	PL	EN	Journal Article
T. Oki; S. Kanae	2006	Global Hydrological Cycles and World Water Resources	Science	313	5790	1068-1072	//	//	Natural Sciences	Hydrology, Earth System science	201	PL	EN	Journal Article
S. L. Lewis	2006	Tropical forests and the changing earth system	Philos Trans R Soc Lond B Biol Sci	361	1465	195-210	//	//	Natural Sciences	Earth System science, ecology	141	PL	EN	Journal Article
F. T. Mackenzie; L. Abraham	2006	Carbon in the Geobiosphere — Earth's Outer Shell —	Topics in Geobiology	//	25	412	Springer	Dordrecht	Natural Sciences	Geology, Earth System science	189	PL	EN	Book
T. Bai	2006	人类世:挑战科技储备	Journal of Dalian Nationalities University	//	35	//	//	//	Social Sciences	Science and technology studies	9127	CL	CN	Journal Article
H. Graßl	2006	Climate and Environment	Utilization of Space: Today and Tomorrow	//	//	91-110	Springer-Verlag	Berlin, Heidelberg	Natural Sciences	Earth System science	106	PL	EN	Book Section
R. W. Arnold	2006	Concepts of soils	Soils: Basic Concepts and Future Challenges	//	//	1-10	Cambridge University Press	Cambridge	Natural Sciences	Soil science	211	PL	EN	Book Section

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G. Winter	2006	Introduction	Multilevel Governance of Global Environmental Change: Perspectives from Science, Sociology and the Law	//	//	1-33	Cambridge University Press	Cambridge	Social Sciences, Natural Sciences, Humanities	Law, political science, Environmental science	75	PL	EN	Book Section
G. Certini; R. Scalenghe	2006	Soil formation on Earth and beyond: the role of additional soil-forming factors	Soils: Basic Concepts and Future Challenges	//	//	193-210	Cambridge University Press	Cambridge	Natural Sciences	Soil science	131	PL	EN	Book Section
Z. Chladná; E. Moltchanova; M. Obersteiner	2006	Prevention of Surprise	Extreme Events in Nature and Society	//	//	//	Springer-Verlag	Center for Frontier Sciences, Germany	Natural Sciences, Social Sciences	Environmental science	121	PL	EN	Book Section
J. Herget	2006	Extreme Events in the Geological Past	Extreme Events in Nature and Society	//	//	//	Springer-Verlag	Center for Frontier Sciences, Germany	Natural Sciences	Geology	113	PL	EN	Book Section
A. M. Mannion	2006	Carbon and its Domestication	//	//	//	//	Springer	Dordrecht	Social Sciences, Natural Sciences	History, Environmental science	8	PL	EN	Book
R. Trabucchi	2006	Nell'era dell'antropocene la paura ci fa compagnia	//	//	//	//	Manageritalia	https://www.manageritalia.it/content/download/Informazione/Giornale/Marzo_2006/pag_24.pdf (Accessed on December 5, 2020)	Social Sciences, Humanities	Environmental studies	703	PL	IT	Web Page
R. E. Zeebe	2006	A lesson on carbon release and sequestration from the past	//	//	//	//	Goldschmidt Conference	Melbourne (Australia)	Natural Sciences	Oceanography	4902	CL	EN	Abstract
E. Ehlers; T. Krafft	2006	Earth System science in the Anthropocene. Emerging Issues and Problems	//	//	//	//	Springer	Meppel, The Netherlands	Natural Sciences	Earth System science	578	PL	EN	Book
R. Scalenghe; G. Certini	2006	Soils: Basic Concepts and Future Challenges	//	//	//	//	Cambridge University Press	New York, USA	Natural Sciences	Soil science	18	PL	EN	Book
D. I. Lyuri; N. A. Karavaeva; T. G. Nefedova; B. D. Konyushkov; S. V. Goryachkin	2006	Self-Restoration of Post-Agrogenic Soils: Recent Process of Late Antropocene	18th World Congress of Soil Science: Panel 1.0B: Soil Change in Anthropocence	//	//	//	//	Philadelphia	Natural Sciences	Soil science	2268	CL	EN	Conference Paper
B. A. Kennedy	2006	Inventing the Earth: Ideas on Landscape Development since 1740	//	//	//	//	Blackwell Publishing	Replika	Social Sciences	History	61	PL	EN	Book
B. Fry	2006	Stable Isotope Ecology	//	//	//	//	//	Springer	Natural Sciences	Ecology, chemistry	35	PL	EN	Book
W. Steffen; E. Lambin	2006	Earth System Functioning in the Anthropocene: Human Impacts on the Global Environment	Interactions between Global Change and Human Health: 31 October - 2 November 2004	//	//	//	The Pontifical Academy of Sciences,	Vatican City	Natural Sciences	Earth System science	1652	PL	EN	Conference Proceedings
M. Meybeck	2006	Global Changes in Aquatic Systems and their Interrelations with Human Health	Interactions between Global Change and Human Health: 31 October - 2 November 2004	//	//	//	The Pontifical Academy of Sciences,	Vatican City	Natural Sciences	Hydrology, limnology	659	PL	EN	Conference Proceedings
M. O. Andreae; U. E. C. Confalonieri; A. J. McMichael; D. E. Bloom; D. L. Heymann; P. Martens; W. Steffen; M. E. Wilson	2006	Global Environmental Change and Human Health	Interactions between Global Change and Human Health: 31 October - 2 November 2004	//	//	//	The Pontifical Academy of Sciences,	Vatican City	Natural Sciences, Social Sciences	Environmental studies, Environmental science	287	PL	EN	Conference Proceedings

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J. J. Ibáñez	2006	Future of soil science	The Future of Soil Science	//	//	//	International Union of Soil Sciences.	Wageningen	Natural Sciences	Soil science	765	PL	EN	Book Section
R. B. Cathcart; M. M. Ćirković	2006	Extreme Climate Control Membrane Structures	Macro-Engineering: A Challenge for the Future	//	//	151-174	Springer	//	Applied Sciences	Geoengineering	338	PL	EN	Book Section
S. Kapur; E. Akça; B. Kapur	2006	Migration: an irreversible impact of land degradation in Turkey	Desertification in the Mediterranean Region. A Security Issue	//	//	291-301	Springer	//	Natural Sciences, Social Sciences	Soil science, Sustainability studies	737	PL	EN	Book Section
A. Stajano	2006	Research, Quality, Competitiveness: European Union Technology Policy for the Knowledge-based Society	//	//	//	//	Springer	//	Social Sciences	Science and technology studies, sociology	14	PL	EN	Book
C. J. Barrow	2006	Environmental Management for Sustainable Development	Routledge Environmental Management	//	//	//	//	//	Applied Sciences, Social Sciences	Resource management, Sustainability studies	9	PL	EN	Journal Article
J. Grinevald	2006	La révolution industrielle à l'échelle de l'histoire humaine de la biosphère	Revue européenne des sciences sociales	//	XLIV-134	139-167	//	//	Social Sciences	History	65	PL	FR	Journal Article
P. J. Crutzen	2006	The Anthropocene: the current human-dominated geological era	Paths of Discovery	Acta 18	//	//	Pontifical Academy of Sciences	Vatican City	Natural Sciences	Geology	5255	CL	EN	Conference Proceedings
B. Allenby	2006	Ethical Systems in an Age of Accelerating Technological Evolution	2006 IEEE International Symposium on Electronics and the Environment	Proceedings of the 2006 IEEE International Symposium on Electronics and the Environment	//	42-44	Institute of Electrical and Electronics Engineers	Scottsdale	Social Sciences, Humanities	Philosophy, Science and technology studies	2572	CL	EN	Conference Proceedings
R. D. Periman	2006	Visualizing the Anthropocene: Human Land Use History and Environmental Management	USDA Forest Service Proceedings	RMRS-P-42CD	//	//	//	//	Social Sciences, Applied Sciences	History, Resource management	3718	CL	EN	Journal Article
S. Dalby	2007	Anthropocene Geopolitics: Globalisation, Empire, Environment and Critique	Geography Compass	1	1	103-118	//	//	Social Sciences	Political science, human geography	3141	CL	EN	Journal Article
G. B. Goodrich	2007	Multidecadal Climate Variability and Drought in the United States	Geography Compass	1	4	713-738	//	//	Natural Sciences	Physical geography, climatology	84	PL	EN	Journal Article
P. J. Crutzen	2007	La géologie de l'humanité : l'Anthropocène	Ecologie & politique	1	34	143-145	//	//	Natural Sciences, Social Sciences	Geology, Earth System science	1478	PL	FR	Journal Article
J. Grinevald	2007	L'Anthropocène et la révolution thermo-industrielle	Ecologie & politique	1	34	146-148	//	//	Social Sciences	History	679	PL	FR	Journal Article
K. D. Alverson	2007	Paleoclimate	Handbook of Paleoanthropology	1	//	357-382	//	//	Natural Sciences	Climatology	235	PL	EN	Book Section
Y. Malhi	2007	Carbon in the Atmosphere and Terrestrial Biosphere in the Early Anthropocene	Advances in Earth Science: From Earthquakes to Global Warming	2	//	25-50	Imperial College Press	London, UK	Natural Sciences	Atmospheric science, Earth System science	508	PL	EN	Book Section

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J. Grosskurth	2007	Ambition and reality in modeling: a case study on public planning for regional sustainability	Sustainability: Science, Practice and Policy	3	1	3-11	//	//	Social Sciences	Sustainability studies	141	PL	EN	Journal Article
S. L. Brantley; M. B. Goldhaber; K. V. Ragnarsdottir	2007	Crossing Disciplines and Scales to Understand the Critical Zone	Elements	3	5	307-314	//	//	Natural Sciences	Geology	135	PL	EN	Journal Article
R. Amundson; D. D. Richter; G. S. Humphreys; E. G. Jobbágy; J. Gaillardet	2007	Coupling between Biota and Earth Materials in the Critical Zone	Elements	3	5	327-332	//	//	Natural Sciences	Ecology, Soil science	362	PL	EN	Journal Article
L. A. Codispoti	2007	An oceanic fixed nitrogen sink exceeding 400 Tg Na−1 vs the conceptof homeostasis in the fixed-nitrogen inventory	Biogeosciences	4	//	233-253	//	//	Natural Sciences	Oceanography, chemistry	372	PL	EN	Journal Article
L. Robin; W. Steffen	2007	History for the Anthropocene	History Compass	5	5	1694-1719	//	//	Social Sciences	History	3266	CL	EN	Journal Article
E. F. DeLong	2007	Modern microbial seascapes	Nature Reviews Microbiology	5	10	755-757	//	//	Natural Sciences	Oceanography, biology	315	PL	EN	Journal Article
D. M. Karl	2007	Microbial oceanography: paradigms, processes and promise	Nat Rev Microbiol	5	10	759-69	//	//	Natural Sciences	Oceanography	84	PL	EN	Journal Article
M. Zalewski	2007	Ecohydrology in the face of the Anthropocene	Ecohydrology & Hydrobiology	7	2	99-100	//	//	Natural Sciences	Ecology, hydrology	3565	CL	EN	Journal Article
E. J. K. Nilsson; M. S. Johnson; F. Taketani; Y. Matsumi; M. D. Hurley; T. J. Wallington	2007	Atmospheric deuterium fractionation: HCHO and HCDO yields in the CH2DO+O2 reaction	Atmospheric Chemistry and Physics Discussions	7	4	10019-10041	//	//	Natural Sciences	Atmospheric science	147	PL	EN	Journal Article
H. Rolston III	2007	The Future of Environmental Ethics	Teaching Ethics	8	1	1-27	//	//	Humanities	Philosophy	93	PL	EN	Journal Article
A. Cowie; U. A. Schneider; L. Montanarella	2007	Potential synergies between existing multilateral environmental agreements in the implementation of land use, land-use change and forestry activities	Environmental science & Policy	10	4	335-352	//	//	Humanities, Natural Sciences	Law, Environmental science	253	PL	EN	Journal Article
P. E. O'Connell; J. Ewen; G. O'Donnell	2007	Is there a link between agricultural land-use management and flooding?	Hydrology and Earth System sciences	11	1	96-107	//	//	Natural Sciences	Hydrology, Earth System science	121	PL	EN	Journal Article
R. E. Zeebe; J. C. Zachos	2007	Ocean acidification in the early Eocene and Anthropocene	//	11	//	OS14A-04	American Geophysical Union	AGU Abstract Browser	Natural Sciences	Oceanography	3984	CL	EN	Abstract
C. Folke; L. Pritchard; F. Berkes	2007	The Problem of Fit between Ecosystems and Institutions: Ten Years Later	Ecology and Society	12	1	//	//	//	Natural Sciences, Social Sciences	Ecology, sociology	93	PL	EN	Journal Article
S. Dalby	2007	Ecology, Security, and Change in the Anthropocene	The Brown Journal of World Affairs	13	2	155–164	//	//	Natural Sciences, Social Sciences	Ecology, international studies	2242	CL	EN	Journal Article
B. Allenby; D. Allen; C. Davidson	2007	Sustainable engineering: From myth to mechanism	Environmental Quality Management	17	1	17-26	//	//	Social Sciences, Applied Sciences	Engineering, pedagogy	181	PL	EN	Journal Article
M. J. Kotchen; O. R. Young	2007	Meeting the challenges of the anthropocene: Towards a science of coupled human–biophysical systems	Global Environmental Change	17	2	149-151	//	//	Natural Sciences	Environmental science	3099	CL	EN	Journal Article

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N. N. Rabalais; R. E. Turner; B. K. Sen Gupta; E. Platon; M. L. Parsons	2007	Sediments Tell the History of Eutrophication and Hypoxia in the Northern Gulf Mexico	Ecological Applications	17	5	129-143	//	//	Natural Sciences	Soil science, oceanography	433	PL	EN	Journal Article
n/a	2007	Fuel for Thought	Energy & Environment	18	5	647-704	//	//	Social Sciences	Political science, sociology	35	PL	EN	Journal Article
D. Kirchman; C. Pedrós-Alió	2007	Predictions for the Future of Microbial Oceanography	Oceanography	20	2	166-171	//	//	Natural Sciences	Oceanography, biology	234	PL	EN	Journal Article
E. A. Laws	2007	Climate Change, Oceans, and Human Health	Ocean Yearbook Online	21	1	129-175	//	//	Natural Sciences, Applied Sciences	Environmental science	26	PL	EN	Journal Article
A. R. Jacobson; S. E. Mikaloff Fletcher; N. Gruber; J. L. Sarmiento; M. Gloor	2007	A joint atmosphere-ocean inversion for surface fluxes of carbon dioxide: 2. Regional results	Global Biogeochemical Cycles	21	1	//	//	//	Natural Sciences	Oceanography	83	PL	EN	Journal Article
S. Dalby	2007	Ecological Intervention and Anthropocene Ethics	Ethics & International Affairs	21	3	//	//	//	Humanities	Philosophy	4496	CL	EN	Journal Article
F. Chambers	2007	Book review: Environmental change: key issues and alternative approaches	Journal of Quaternary Science	22	1	97-98	//	//	Natural Sciences	Earth System science, Environmental science	486	PL	EN	Journal Article
R. Murtugudde; R. Seager; P. Thoppil	2007	Arabian Sea response to monsoon variations	Paleoceanography	22	4	//	//	//	Natural Sciences	Oceanography, climatology	108	PL	EN	Journal Article
A. Free; N. H. Barton	2007	Do evolution and ecology need the Gaia hypothesis?	Trends Ecol Evol	22	11	611-9	//	//	Natural Sciences	Biology, ecology	130	PL	EN	Journal Article
S. Harrison	2007	Book review: Nature	Journal of Rural Studies	23	4	//	//	//	Humanities	Ecocriticism	1266	PL	EN	Journal Article
J. P. M. Syvitski; A. J. Kettner	2007	On the flux of water and sediment into the Northern Adriatic Sea	Continental Shelf Research	27	3-4	296-308	//	//	Natural Sciences	Limnology	178	PL	EN	Journal Article
R. Scalenghe	2007	Some effects of a buried electricity transmission cable on bulk soil	Bioelectromagnetics	28	8	667-71	//	//	Applied Sciences, Natural Sciences	Soil science, engineering	599	PL	EN	Journal Article
S. C. Doney; D. S. Schimel	2007	Carbon and Climate System Coupling on Timescales from the Precambrian to the Anthropocene	Annual Review of Environment and Resources	32	1	31-66	//	//	Natural Sciences	Geology, climatology	187	PL	EN	Journal Article
C. D. Arp; J. C. Schmidt; M. A. Baker; A. K. Myers	2007	Stream geomorphology in a mountain lake district: hydraulic geometry, sediment sources and sinks, and downstream lake effects	Earth Surface Processes and Landforms	32	4	525-543	//	//	Natural Sciences	Geology	88	PL	EN	Journal Article
J. L. Florsheim; M. D. Dettinger	2007	Climate and floods still govern California levee breaks	Geophysical Research Letters	34	22	//	//	//	Natural Sciences	Geology	288	PL	EN	Journal Article
N. Mahowald	2007	Anthropocene changes in desert area: Sensitivity to climate model predictions	Geophysical Research Letters	34	L18817	//	//	//	Natural Sciences	Geology	554	PL	EN	Journal Article
J. P. Obbard	2007	Carbon in the Geobiosphere: Earth's Outer Shell	Journal of Environment Quality	36	5	//	//	//	Natural Sciences	Geology, biology	1825	PL	EN	Journal Article
W. Steffen; P. J. Crutzen; J. McNeill	2007	The Anthropocene: Are Humans Now Overwhelming The Great Forces Of Nature?	Ambio	36	8	614-621	//	//	Natural Sciences	Geology	2810	CL	EN	Journal Article

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J. Liu; T. Dietz; S. R. Carpenter; C. Folke; M. Alberti; C. L. Redman; S. H. Schneider; E. Ostrom; A. N. Pell; J. Lubchenco; W. W. Taylor; Z. Ouyang; P. Deadman; T. Kratz; W. Provencher	2007	Coupled Human and Natural Systems	Ambio	36	8	639-649	//	//	Natural Sciences	Earth System science	83	PL	EN	Journal Article
W. T. Anderson	2007	Knowledge in evolution	Futures	39	8	915-919	//	//	Social Sciences	Sociology	779	PL	EN	Journal Article
I. Šlaus	2007	Building a knowledge-based society: The case of South East Europe	Futures	39	8	986-996	//	//	Humanities, Social Sciences	Law, sociology	192	PL	EN	Journal Article
M. A. Largent	2007	Book review: Plows, Plagues & Petroleum: How Humans Took Control of Climate	Journal of the History of Biology	40	1	185-206	//	//	Social Sciences	History	360	PL	EN	Journal Article
A. J. Kettner; B. Gomez; J. P. M. Syvitski	2007	Modeling suspended sediment discharge from the Waipaoa River system, New Zealand: The last 3000 years	Water Resources Research	43	7	//	//	//	Natural Sciences	Limnology	278	PL	EN	Journal Article
W. F. Ruddiman	2007	The early anthropogenic hypothesis: Challenges and responses	Reviews of Geophysics	45	4	//	//	//	Natural Sciences	Geology	34	PL	EN	Journal Article
L. Brussaard; M. M. Pulleman; É. Ouédraogo; A. Mando; J. Six	2007	Soil fauna and soil function in the fabric of the food web	Pedobiologia	50	6	447-462	//	//	Natural Sciences	Soil science	105	PL	EN	Journal Article
X. Li; X. Zhou; J. Zhou; J. Dodson; H. Zhang; X. Shang	2007	The earliest archaeobiological evidence of the broadening agriculture in China recorded at Xishanping site in Gansu Province	Science in China Series D: Earth Sciences	50	11	1707-1714	//	//	Natural Sciences	Physical geography, geology	914	PL	EN	Journal Article
X. Li; X. Zhou; H. Zhang; J. Zhou; X. Shang; J. Dodson	2007	The record of cultivated rice from archaeobiological evidence in northwestern China 5000 years ago	Chinese Science Bulletin	52	10	1372-1378	//	//	Natural Sciences	Geology, climatology	207	PL	EN	Journal Article
D. R. Jones	2007	University Sustainability League Tables: Institutionalising 'Nature Deficit Disorder'?	Greener Management International	57	28	104-131	//	//	Social Sciences	Sustainability studies, environmental studies	210	PL	EN	Journal Article
H. Wang; Z. Yang; Y. Saito; J. P. Liu; X. Sun; Y. Wang	2007	Stepwise decreases of the Huanghe (Yellow River) sediment load (1950–2005): Impacts of climate change and human activities	Global and Planetary Change	57	3-4	331-354	//	//	Natural Sciences	Limnology	140	PL	EN	Journal Article
J. P. M. Syvitski; Y. Saito	2007	Morphodynamics of deltas under the influence of humans	Global and Planetary Change	57	3-4	261-282	//	//	Natural Sciences	Limnology	127	PL	EN	Journal Article
M. Rees	2007	Grounds for Optimism	Bulletin of the Atomic Scientists	63	1	32	//	//	Social Sciences	Science and Technology studies	1081	PL	EN	Journal Article
C. Ohl; K. Krauze; C. Grünbühel	2007	Towards an understanding of long-term ecosystem dynamics by merging socio-economic and environmental research	Ecological Economics	63	2-3	383-391	//	//	Natural Sciences, Social Sciences	Economics, Environmental science	512	PL	EN	Journal Article

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M. E. Gorman	2007	Cognition, Environment and the Collapse of Civilizations	Model-Based Reasoning in Science, Technology, and Medicine	64	//	217-227	Springer	Berlin, Heidelberg	Applied Sciences	Engineering	239	PL	EN	Book Section
V. O. Targulian; P. V. Krasilnikov	2007	Soil system and pedogenic processes: Self-organization, time scales, and environmental significance	Catena	71	3	373-381	//	//	Natural Sciences	Soil science	149	PL	EN	Journal Article
A. Kleidon	2007	Thermodynamics and environmental constraints make the biosphere predictable – a response to Volk	Climatic Change	85	3-4	259-266	//	//	Natural Sciences	Environmental science	229	PL	EN	Journal Article
R. Lindsay	2007	Book review: With Speed and Violence: Why Scientists Fear Tipping Points in Climate Change	Bulletin of the American Meteorological Society	88	12	1983-1992	//	//	Social Sciences, Natural Sciences	Environmental studies, climatology	332	PL	EN	Journal Article
M. K. Hughes; M. W. Salzer	2007	Twentieth Century Bristlecone Pine Tree Rings Near Upper Tree Limit Wider Than in Recent Millennia	Eos Trans. AGU	88	52	//	//	//	Natural Sciences	Environmental science	2519	CL	EN	Abstract
S. Duan; T. S. Bianchi; T. P. Sampere	2007	Temporal variability in the composition and abundance of terrestrially-derived dissolved organic matter in the lower Mississippi and Pearl Rivers	Marine Chemistry	103	1-2	172-184	//	//	Natural Sciences	Limnology	243	PL	EN	Journal Article
C. E. Miller; D. Crisp; P. L. DeCola; S. C. Olsen; J. T. Randerson; A. M. Michalak; A. Alkhaled; P. Rayner; D. J. Jacob; P. Suntharalingam; D. B. A. Jones; A. S. Denning; M. E. Nicholls; S. C. Doney; S. Pawson; H. Boesch; B. J. Connor; I. Y. Fung; D. O'Brien; R. J. Salawitch; S. P. Sander; B. Sen; P. Tans; G. C. Toon; P. O. Wennberg; S. C. Wofsy; Y. L. Yung; R. M. Law	2007	Precision requirements for space-based data	Journal of Geophysical Research: Atmospheres	112	D10	//	//	//	Natural Sciences	Atmospheric science	74	PL	EN	Journal Article
S. E. Schwartz	2007	Heat capacity, time constant, and sensitivity of Earth's climate system	Journal of Geophysical Research	112	D24	//	//	//	Natural Sciences	Climatology, Earth System science	193	PL	EN	Journal Article
N. Michelutti; A. P. Wolfe; J. P. Briner; G. H. Miller	2007	Climatically controlled chemical and biological development in Arctic lakes	Journal of Geophysical Research: Biogeosciences	112	G3	//	//	//	Natural Sciences	Limnology, biology, climatology	797	PL	EN	Journal Article
E. Crist	2007	Beyond the Climate Crisis: A Critique of Climate Change Discourse	Telos	141	Winter 2007	29-55	//	//	Humanities	Ecocriticism	1511	PL	EN	Journal Article

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J. T. Mills	2007	Time series modelling of two millennia of northern hemisphere temperatures: long memory or shifting trends?	Journal of the Royal Statistical Society Series A (Statistics in Society)	170	1	83-94	//	//	Natural Sciences	Climatology	196	PL	EN	Journal Article
D. D. Richter	2007	Humanity's Transformation of Earth's Soil: Pedology's New Frontier	Soil Science	172	12	957-967	//	//	Natural Sciences	Soil science	451	PL	EN	Journal Article
Y. Copard; P. Amiotte-Suchet; C. Di-Giovanni	2007	Storage and release of fossil organic carbon related to weathering of sedimentary rocks	Earth and Planetary Science Letters	258	1-2	345-357	//	//	Natural Sciences	Earth System science	118	PL	EN	Journal Article
R. M. May	2007	Preface	Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences	365	1853	879-881	//	//	Natural Sciences	Climatology	875	PL	EN	Journal Article
D. A. King	2007	Introduction: energy for a sustainable future	Philos Trans A Math Phys Eng Sci	365	1853	883-95	//	//	Social Sciences	Sustainability studies	185	PL	EN	Journal Article
C. Deutsch; J. L. Sarmiento; D. M. Sigman; N. Gruber; J. P. Dunne	2007	Spatial coupling of nitrogen inputs and losses in the ocean	Nature	445	7124	163-7	//	//	Natural Sciences	Oceanography	183	PL	EN	Journal Article
E. M. Georgieva; W. S. Heaps; E. L. Wilson	2007	Differential Radiometers Using Fabry-Perot Interferometric Technique for Remote Sensing Determination of Various Atmospheric Trace Gases	2007 IEEE International Geoscience and Remote Sensing Symposium	//	//	3862-3865	IEEE	Barcelona	Natural Sciences	Atmospheric science	361	PL	EN	Conference Proceedings
F. Pearce	2007	With Speed and Violence: Why Scientists Fear Tipping Points in Climate Change	//	//	//	//	Beacon Press	Boston	Natural Sciences, Social Sciences	Climatology, environmental studies	169	PL	EN	Book
K. Keller; S.-R. Kim; J. Baehr; D. F. Bradford; M. Oppenheimer; M. E. Schlesinger; H. S. Kheshgi; J. Smith; F. C. de la Chesnaye; J. M. Reilly; T. Wilson; C. Kolstad	2007	What is the economic value of information about climate thresholds?	Human-Induced Climate Change	//	//	343-354	Cambridge University Press	Cambridge	Social Sciences	Economics, environmental studies	117	PL	EN	Book Section
J. A. Dearing; L. J. Graumlich; R. H. Grove; A. Grübler; H. Haberl; F. Hole; C. Pfister; S. van der Leeuw	2007	Group Report: Integrating Socioenvironmental Interactions over Centennial Timescales	Sustainability or Collapse? An Integrated History and Future of People on Earth	//	//	//	MIT Press	Cambridge, Massachusetts, USA	Social Sciences	Environmental studies, Sustainability studies	149	PL	EN	Book Section
S. Van der Leeuw	2007	Information Processing and Its Role in the Rise of the European World System	Sustainability or Collapse? An Integrated History and Future of People on Earth	//	//	//	MIT Press	Cambridge, Massachusetts, USA	Social Sciences	Sociology, Sustainability studies	76	PL	EN	Book Section

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H. G. Brauch	2007	Environment and Security in the Middle East: Conceptualizing Environmental, Human, Water, Food, Health and Gender Security	Integrated Water Resources Management and Security in the Middle East	//	//	121-161	Springer	Dordrecht	Social Sciences	Environmental studies	113	PL	EN	Book Section
K. Krauze; I. Wagner	2007	An ecohydrological approach for the protection and enhancement of ecosystem services	Use of Landscape Sciences for the Assessment of Environmental Security	//	//	177-207	Springer & NATO Public Diplomacy Division	Dordrecht, The Netherlands	Natural Sciences	Hydrology, ecology	167	PL	EN	Book Section
J. Grinevald	2007	La Biosphère de l'Anthropocène: Climat et pétrole, la double menace	//	//	//	//	Georg Editeur	Geneva (Switzerland)	Social Sciences	History	372	PL	FR	Book
R. B. Spies; T. Cooney; A. M. Springer; T. Weingartner; G. H. Kruse	2007	Long-Term Changes in the GOA: Properties and Causes	Long-Term Ecological Change in the Northern Gulf of Alaska	//	//	521-560	Elsevier	Italy	Natural Sciences	Ecology, oceanography	58	PL	EN	Book Section
A. E. Nilsson	2007	A Changing Arctic Climate: Science and Policy in the Arctic Climate Impact Assessment	//	//	//	271	Linköping Studies in Arts and Science	Linköping, Sweden	Social Sciences, Natural Sciences	Political science, environmental studies, arctic studies	24	PL	EN	Book
B. Allenby	2007	Sustainable Engineering Education: Translating Myth to Mechanism	IEEE International Symposium on Electronics and the Environment, 1998	//	//	//	IEEE	Orlando	Social Sciences, Applied Sciences	Engineering, pedagogy	244	PL	EN	Conference Proceedings
P. H. Liotta; A. W. Shearer	2007	Gaia's Revenge: Climate Change and Humanity's Loss	//	//	//	//	Praeger Publishers	Westport, Connecticut, USA	Social Sciences	Political science, environmental studies	1042	PL	EN	Book
V. Ramanathan	2007	Global and regional climate change: the next few decades	Mountains Witnesses of Global Changes Research in the Himalaya and Karakoram: Share-Asia Project	//	//	9-11	Elsevier	//	Natural Sciences	Environmental science	844	PL	EN	Book Section
C. De Vargas; M.-P. Aubry; I. Probert; J. Young	2007	Origin and Evolution of Coccolithophores: From Coastal Hunters to Oceanic Farmers	Evolution of Primary Producers in the Sea	//	//	251-285	Elsevier	//	Natural Sciences	Biology, oceanography	51	PL	EN	Book Section
J. W. C. White; D. F. Ferretti; J. B. Miller; D. M. Etheridge; K. R. Lassey; D. C. Lowe; C. M. MacFarling; M. F. Dreier; C. M. Trudinger; T. van Ommen	2007	The Global Methane Budget over the Last 2000 Years: CH413 Reveals Hidden Information	Stable Isotopes as Indicators of Ecological Change	//	//	235-248	//	//	Natural Sciences	Atmospheric science, ecology	132	PL	EN	Book Section
L. F. Pitelka; J. G. Canadell; D. E. Pataki	2007	Global Ecology, Networks, and Research Synthesis	Terrestrial Ecosystems in a Changing World	//	The IGBP Series	1-21	Springer-Verlag	Berlin, Heidelberg	Natural Sciences	Earth System science	135	PL	EN	Book Section
T. J. Dalton	2008	Book review: Common Wealth: Economics for a Crowded Planet	Journal of Natural Resources Policy Research	1	1	117-123	//	//	Social Sciences	Economics	1157	PL	EN	Journal Article
B. Allenby	2008	Educating Engineers in the Anthropocene	2008 IEEE International Symposium on Electronics and the Environment	1	//	//	Institute of Electrical and Electronics Engineers	San Francisco, USA	Social Sciences, Applied Sciences	Pedagogy, engineering	2003	CL	EN	Conference Proceedings

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J. Hansen; M. Sato; P. Kharecha; D. Beerling; R. Berner; V. Masson-Delmotte; M. Pagani; M. Raymo; D. L. Royer; J. C. Zachos	2008	Target Atmospheric CO2: Where Should Humanity Aim?	The Open Atmospheric science Journal	2	1	217-231	//	//	Natural Sciences, Social Sciences	Atmospheric science, environmental studies	199	PL	EN	Journal Article
C. Brown	2008	Emergent Sustainability: The Concept of Sustainable Development in a Complex World	Globalization and Environmental Challenges: Reconceptualizing Security in the 21st Century	3	//	//	Springer Verlag	Berlin, Heidelberg	Social Sciences	Sustainability studies	309	PL	EN	Book Section
H. G. Brauch	2008	Securitization of Space and Referent Objects	Globalization and Environmental Challenges: Reconceptualizing Security in the 21st Century	3	//	//	Springer Verlag	Berlin, Heidelberg	Social Sciences	International studies	251	PL	EN	Book Section
U. Albrecht; H. G. Brauch	2008	Security in Peace Research and Security Studies	Globalization and Environmental Challenges: Reconceptualizing Security in the 21st Century	3	//	//	Springer Verlag	Berlin, Heidelberg	Social Sciences	International studies	119	PL	EN	Book Section
Ú. O. Spring; H. G. Brauch	2008	Reconceptualizing Security in the 21st Century: Conclusions for Research and Policy-making	Globalization and Environmental Challenges: Reconceptualizing Security in the 21st Century	3	//	//	Springer Verlag	Berlin, Heidelberg	Social Sciences	Political sciences, sociology	106	PL	EN	Book Section
H. G. Brauch	2008	From a Security towards a Survival Dilemma	Globalization and Environmental Challenges: Reconceptualizing Security in the 21st Century	3	//	//	Springer Verlag	Berlin, Heidelberg	Social Sciences	International studies	89	PL	EN	Book Section
H. G. Brauch	2008	Introduction: Globalization and Environmental Challenges: Reconceptualizing Security in the 21st Century	Globalization and Environmental Challenges: Reconceptualizing Security in the 21st Century	3	//	//	Springer Verlag	Berlin, Heidelberg	Social Sciences	Environmental studies	84	PL	EN	Book Section
S. J. Kao; K. K. Liu; S. C. Hsu; Y. P. Chang; M. H. Dai	2008	North Pacific-wide spreading of isotopically heavy nitrogen from intensified denitrification during the Bølling/Allerød and post-younger dryas periods: evidence from the Western Pacific	Biogeosciences Discussions	5	2	1017-1033	//	//	Natural Sciences	Atmospheric science, geology	146	PL	EN	Journal Article

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A. van Buuren; L. Gerrits	2008	Understanding and managing a complex estuary: the process towards more congruence between the physical system characteristics and the management system of the Westerschelde (Netherlands)	Hydrology and Earth System sciences Discussions	5	3	1371-1405	//	//	Natural Sciences	Oceanography	86	PL	EN	Journal Article
S. A. Wooldridge	2008	Mass extinctions past and present: a unifying hypothesis	Biogeosciences Discussions	5	3	2401-2423	//	//	Natural Sciences	Biology	239	PL	EN	Journal Article
E. Diczfalusy	2008	A brave new world for brave old men	Journal of Men's Health	5	3	A7-A8	//	//	Applied Sciences	Medicine	1327	PL	EN	Journal Article
P. R. Halloran; I. R. Hall; E. Colmenero-Hidalgo; R. E. M. Rickaby	2008	Evidence for a multi-species coccolith volume change over the past two centuries: understanding a potential ocean acidification response	Biogeosciences	5	6	1651-1655	//	//	Natural Sciences	Earth System science	297	PL	EN	Journal Article
A. Kock; S. Gebhardt; H. W. H. W. Bange	2008	Methane emissions from the upwelling area off Mauritania (NW Africa)	Biogeosciences	5	//	1119-1125	//	//	Natural Sciences	Chemistry, geology	385	PL	EN	Journal Article
J. Mukherjee; L. E. Llewellyn; E. A. Evans-Illidge	2008	A tropical marine microbial natural products geobibliography as an example of desktop exploration of current research using web visualisation tools	Mar Drugs	6	4	550-77	//	//	Natural Sciences	Oceanography, biology	106	PL	EN	Journal Article
M. Keller; D. S. Schimel; W. W. Hargrove; F. M. Hoffman	2008	A continental strategy for the National Ecological Observatory Network	Frontiers in Ecology and the Environment	6	5	282-284	//	//	Natural Sciences	Ecology	1388	PL	EN	Journal Article
W. E. H. Blum	2008	Forms of energy involved in soil and sediment processes	Journal of Soils and Sediments	8	1	1-2	//	//	Natural Sciences	Soil science	1347	PL	EN	Journal Article
N. H. Hussain; S. S. Al-Noor; F. M. Mutlak; I. M. Al-Sudani; A. M. Mojer; A. J. Toman; M. A. Abdad	2008	Declaration on Sustainable Floodplain Management — change of perspective	Ecohydrology & Hydrobiology	8	2-4	105-106	//	//	Social Sciences, Natural Sciences	Sustainability studies, hydrology	1081	PL	EN	Journal Article
M. Zalewski	2008	Rationale for the "Floodplain Declaration" from environmental conservation toward sustainability science	Ecohydrology & Hydrobiology	8	2-4	107-113	//	//	Natural Sciences, Social Sciences	Hydrology, ecology, Sustainability studies	1034	PL	EN	Journal Article
J. C. Stephens; M. E. Hernandez; M. Román; A. C. Graham; R. W. Scholz	2008	Higher education as a change agent for sustainability in different cultures and contexts	International Journal of Sustainability in Higher Education	9	3	317-338	//	//	Social Sciences	Pedagogy, Sustainability studies	188	PL	EN	Journal Article
B. G. Mackey; J. E. M. Watson; G. Hope; S. Gilmore	2008	Climate change, biodiversity conservation, and the role of protected areas: An Australian perspective	Biodiversity	9	3-4	11-18	//	//	Social Sciences	Environmental studies	119	PL	EN	Journal Article
E. Saxon	2008	Noah's Parks: A partial antidote to the Anthropocene extinction event	Biodiversity	9	3-4	5-10	//	//	Natural Sciences	Ecology	683	PL	EN	Journal Article
K. K. Goldewijk	2008	Holocene = Anthropocene? The HYDE database for integrated global change research over the past 12,000 years	//	11	//	GC11A-0662	American Geophysical Union	AGU Abstract Browser	Natural Sciences	Environmental science, geology	6024	CL	EN	Abstract

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M. G. Davis; D. S. Chapman	2008	Warming of the Continents in the Anthropocene	//	11	//	GC11A-0666	American Geophysical Union	AGU Abstract Browser	Natural Sciences	Geology, climatology	4024	CL	EN	Abstract
M. A. Kruge	2008	Organic Chemostratigraphic Markers Characteristic of the (Informally Designated) Anthropocene Epoch	//	11	//	GC11A-0675	American Geophysical Union	AGU Abstract Browser	Natural Sciences	Chemistry, geology	14148	CL	EN	Abstract
C. Hakkenberg	2008	Biodiversity and Sacred Sites: Vernacular Conservation Practices in Northwest Yunnan, China	Worldviews: Global Religions, Culture, and Ecology	12	1	74-90	//	//	Social Sciences	Human geography	140	PL	EN	Journal Article
C. Turley	2008	Book review: The world without us	Limnology and Oceanography Bulletin	17	1	20-21	//	//	Natural Sciences	Oceanography, limnology	480	PL	EN	Journal Article
M. Glaser; G. Krause; B. Ratter; M. Welp	2008	Human/Nature Interaction in the Anthropocene: Potential of Social-Ecological Systems Analysis	GAIA - Ecological Perspectives for Science and Society,	17	1	77-80	//	//	Social Sciences	Environmental studies, sociology	1246	PL	EN	Journal Article
N. Rolland; I. Larocque; P. Francus; R. Pienitz; L. Laperrière	2008	Holocene climate inferred from biological (Diptera: Chironomidae) analyses in a Southampton Island (Nunavut, Canada) lake	The Holocene	18	2	229-241	//	//	Natural Sciences	Climatology	109	PL	EN	Journal Article
M. Morgan	2008	The year in microbiology and infectious diseases; a tale of two conferences	Expert Opinion on Therapeutic Patents	18	2	241-252	//	//	Natural Sciences	Biology	103	PL	EN	Journal Article
J. Zalasiewicz; M. Williams; A. Smith; T. L. Barry; A. L. Coe; P. R. Bown; P. Brenchley; D. Cantrill; A. Gale; P. Gibbard; F. J. Gregory; M. W. Hounslow; A. C. Kerr; P. Pearson; R. Knox; J. Powell; C. Waters; J. Marshall; M. Oates; P. F. Rawson; P. Stone	2008	Are we now living in the Anthropocene?	GSA Today	18	2	4-8	//	//	Natural Sciences	Geology	2397	CL	EN	Journal Article
R. Agnihotri; S. Kurian; M. Fernandes; K. Reshma; W. D'Souza; S. W. A. Naqvi	2008	Variability of subsurface denitrification and surface productivity in the coastal eastern Arabian Sea over the past seven centuries	The Holocene	18	5	755-764	//	//	Natural Sciences	Oceanography	795	PL	EN	Journal Article
D. Rose	2008	Love in the Time of Extinctions	The Australian Journal of Anthropology	19	1	81-84	//	//	Humanities	Ecocriticism	2574	CL	EN	Journal Article
K. Charman	2008	False Starts and False Solutions: Current Approaches in Dealing with Climate Change	Capitalism Nature Socialism	19	3	29-47	//	//	Social Sciences	Environmental studies	174	PL	EN	Journal Article
J. Tamir	2008	Book review: Children of the Sun: A History of Humanity's Unappeasable Appetite for Energy	Journal of World History	19	4	556-558	//	//	Social Sciences	History, environmental studies	792	PL	EN	Journal Article

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R. L. Edgeman; L. A. Fraley	2008	A System of Profound Consciousness: Building beyond Deming	Total Quality Management & Business Excellence	19	7-8	683-707	//	//	Applied Sciences	Resource management	102	PL	EN	Journal Article
P. Dukes	2008	Book review: The American Mission and the 'Evil Empire': The Crusade for a 'Free Russia' since 1881	Revolutionary Russia	21	2	203-226	//	//	Social Sciences	History	868	PL	EN	Journal Article
T. Garrison	2008	Book review: Our Changing Planet: The View from Space	Oceanography	21	3	107-108	//	//	Natural Sciences	Oceanography	720	PL	EN	Journal Article
R. E. Dunlap	2008	Promoting a Paradigm Change	Organization & Environment	21	4	478-487	//	//	Social Sciences	Sociology, environmental studies	372	PL	EN	Journal Article
Q. Tang; T. Oki; S. Kanae; H. Hu	2008	Hydrological Cycles Change in the Yellow River Basin during the Last Half of the Twentieth Century	Journal of Climate	21	8	1790-1806	//	//	Natural Sciences	Hydrology	117	PL	EN	Journal Article
A. Körtzinger; U. Send; D. W. R. Wallace; J. Karstensen; M. DeGrandpre	2008	Seasonal cycle of O2 and pCO2 in the central Labrador Sea: Atmospheric, biological, and physical implications	Global Biogeochemical Cycles	22	1	//	//	//	Natural Sciences	Atmospheric science, Earth System science	97	PL	EN	Journal Article
A. Oschlies; K. G. Schulz; U. Riebesell; A. Schmittner	2008	Simulated 21st century's increase in oceanic suboxia by CO2-enhanced biotic carbon export	Global Biogeochemical Cycles	22	4	//	//	//	Natural Sciences	Oceanography	152	PL	EN	Journal Article
W. Steffen; P. J. Crutzen; J. McNeill; K. A. Hibbard	2008	Stages of the Anthropocene: Assessing the Human Impact on the Earth System	//	22	//	GC22B-01	American Geophysical Union	AGU Abtract Browser	Natural Sciences	Earth System science	13333	CL	EN	Abstract
Y. Joo; A. Lerman	2008	Pre-Anthropocene nitrogen cycle: balanced mass and isotope fluxes	//	23	//	B23A-0391	American Geophysical Union	AGU Abstract Browser	Natural Sciences	Earth System science	9091	CL	EN	Abstract
C. Ballantyne	2008	Book review: Darkening peaks. Glacier retreat, science and society	Journal of Quaternary Science	23	6-7	704-705	//	//	Natural Sciences	Geology	1065	PL	EN	Journal Article
R. Bryant	2008	Book review: A New Diplomacy for Sustainable Development: The Challenge of Global Change	Political Geography	27	7	817-820	//	//	Social Sciences	Human geography	598	PL	EN	Journal Article
S. Vavrus; W. F. Ruddiman; J. E. Kutzbach	2008	Climate model tests of the anthropogenic influence on greenhouse-induced climate change: the role of early human agriculture, industrialization, and vegetation feedbacks	Quaternary Science Reviews	27	13-14	1410-1425	//	//	Natural Sciences	Climatology	87	PL	EN	Journal Article
G. M. Von Furstenberg	2008	Performance Measurement under Rational International Overpromising Regimes	Journal of Public Policy	28	3	261-287	//	//	Social Sciences	Political science	97	PL	EN	Journal Article
A. Paulmier; D. Ruiz-Pino; V. Garcon	2008	The oxygen minimum zone (OMZ) off Chile as intense source of CO2 and N2O	Continental Shelf Research	28	20	2746-2756	//	//	Natural Sciences	Atmospheric science	107	PL	EN	Journal Article
P. Ainley	2008	Education and climate change – some systemic connections	British Journal of Sociology of Education	29	2	213-223	//	//	Social Sciences	Pedagogy, environmental studies	140	PL	EN	Journal Article
W. deBuys	2008	Welcome to the Anthropocene	Rangelands	30	5	31-35	//	//	Applied Sciences	Ecology	977	PL	EN	Journal Article
M. Hulme	2008	Geographical work at the boundaries of climate change	Transactions of the Institute of British Geographers	33	1	5-11	//	//	Social Sciences	Human geography	382	PL	EN	Journal Article
J. M. Fernández-Palacios; R. J. Whittaker	2008	The Canaries: an important biogeographical meeting place	Journal of Biogeography	35	3	379-387	//	//	Natural Sciences	Biology, physical geography	136	PL	EN	Journal Article
D. S. Ellsworth; D. T. Tissue	2008	Foreword: Measuring impacts of climate change on plants	Functional Plant Biology	35	6	iii-iv	//	//	Natural Sciences	Biology, climatology	454	PL	EN	Journal Article

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J. J. O'Brien; J. K. Hiers; M. A. Callaham, Jr.; R. J. Mitchell; S. B. Jack	2008	Interactions among overstory structure, seedling life-history traits, and fire in frequently burned neotropical pine forests	Ambio	37	7-8	542-7	//	//	Applied Sciences, Social Sciences	Resource management, history	345	PL	EN	Journal Article
W. Steffen	2008	Looking back to the future	Ambio	37	Spec No 14	507-13	//	//	Social Sciences	Environmental studies	173	PL	EN	Journal Article
D. Brandstrom	2008	The 2007 Royal Colloquium, Narsaq, Greenland: in summary	Ambio	37	Spec No 14	517-20	//	//	Natural Sciences	Arctic studies	386	PL	EN	Journal Article
H. Scholz	2008	Some comments on the genus Bromus (Poaceae) and three new species	Willdenowia	38	2	411-422	//	//	Natural Sciences	Biology	538	PL	EN	Journal Article
W. Fritsche	2008	Überlastetes Ökosystem Erde. Wie der Mensch über seine Verhältnisse lebt	Biologie in unserer Zeit	38	6	390-399	//	//	Natural Sciences	Ecology	528	PL	DE	Journal Article
R. E. Dunlap	2008	The New Environmental Paradigm Scale: From Marginality to Worldwide Use	The Journal of Environmental Education	40	1	3-18	//	//	Social Sciences	Environmental studies	272	PL	EN	Journal Article
S. Brothers; J. C. Vermaire; I. Gregory-Eaves	2008	Empirical models for describing recent sedimentation rates in lakes distributed across broad spatial scales	Journal of Paleolimnology	40	4	1003-1019	//	//	Natural Sciences	Biology, limnology	297	PL	EN	Journal Article
P. Salonius	2008	Book review: Sustainability or Collapse? An Integrated History and Future of People on Earth	Futures	40	9	847-848	//	//	Social Sciences	History	562	PL	EN	Journal Article
W. M. Adams	2008	Conservation, carbon and transition to sustainability	Oryx	42	4	//	//	//	Social Sciences	Human geography, Sustainability studies	1034	PL	EN	Journal Article
J.-P. Maréchal	2008	Le réchauffement climatique: un dilemme du prisonnier aux conséquences catastrophiques	Géoéconomie	46	3	107-127	//	//	Social Sciences	Economics, environmental studies	313	PL	FR	Journal Article
W. R. Kelly; S. V. Panno	2008	Some considerations in applying background concentrations to ground water studies	Ground Water	46	6	790-2	//	//	Natural Sciences	Limnology	465	PL	EN	Journal Article
A. A. Leiserowitz; L. O. Fernandez	2008	Toward a New Consciousness: Values to Sustain Human and Natural Communities	Environment: Science and Policy for Sustainable Development	50	5	62-69	//	//	Social Sciences	Environmental studies	135	PL	EN	Journal Article
S. A. Heckathorn; J. Chen	2008	Plants and global environmental change: a special issue highlighting younger scientists	J Integr Plant Biol	50	11	1337-8	//	//	Natural Sciences	Biology, Environmental science	718	PL	EN	Journal Article
G. Bologna	2008	Global Environmental Change and the Challenge of Sustainability	Development	51	3	338-343	//	//	Social Sciences	Environmental studies, Sustainability studies	636	PL	EN	Journal Article
R. J. Berg	2008	Governing in a World of Climate Change	Development	51	3	387-389	//	//	Social Sciences	Political science	628	PL	EN	Journal Article
M. Lauer; S. Aswani	2008	Integrating indigenous ecological knowledge and multi-spectral image classification for marine habitat mapping in Oceania	Ocean & Coastal Management	51	6	495-504	//	//	Social Sciences, Natural Sciences	Anthropology, oceanography	127	PL	EN	Journal Article
B. Allenby	2008	The Anthropocene as Media	American Behavioral Scientist	52	1	107-140	//	//	Social Sciences	Science and technology studies	1531	PL	EN	Journal Article
O. Slaymaker	2008	Sediment budget and sediment flux studies under accelerating global change in cold environments	Zeitschrift für Geomorphologie, Supplementary Issues	52	1	123-148	//	//	Natural Sciences	Geology	123	PL	EN	Journal Article
K. O. Doyle	2008	Introduction: "Thinking Differently" About the New Media	American Behavioral Scientist	52	1	3-7	//	//	Social Sciences	Sociology	825	PL	EN	Journal Article

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F. De Vleeschouwer; M. Ibanez; N. Mattielli; C. Mattielli; N. Fagel	2008	Geochemical And Pb Isotopic Signature Of peaty Sediments From Central-South Chile : Identification Of Particle Supplies Over The Holocene	Journal of the Chilean Chemical Society	53	3	1640-1649	//	//	Natural Sciences	Geology, Chemistry	133	PL	EN	Journal Article
Y. Y. Li; L. P. Zhou; H. T. Cui	2008	Pollen indicators of human activity	Science Bulletin	53	9	1281-1293	//	//	Natural Sciences	Physical geography	102	PL	EN	Journal Article
Y. Y. Li; L. Zhou; H. T. Cui	2008	人类活动的孢粉指示体	Chinese Science Bulletin	53	9	991-1002	//	//	Natural Sciences	Physical geography	90	PL	CN	Journal Article
P. Crook	2008	The New Eugenics? The Ethics of Bio-Technology	Australian Journal of Politics & History	54	1	135-143	//	//	Humanities, Social Sciences	Philosophy, science and technology studies	393	PL	EN	Journal Article
A. Y. Glikson	2008	Milestones in the evolution of the atmosphere with reference to climate change	Australian Journal of Earth Sciences	55	2	125-139	//	//	Natural Sciences	Atmospheric science	228	PL	EN	Journal Article
GDCh	2008	Kolloquien der Ortsverbände	Nachrichten aus der Chemie	56	1	92-96	//	//	Natural Sciences	Atmospheric science	166	PL	DE	Pamphlet
C. N. Drummond; J. M. Markin	2008	An Analysis of the Bachelor of Science in Geology Degree as Offered in the United States	Journal of Geoscience Education	56	2	113-119	//	//	Social Sciences	Pedagogy	282	PL	EN	Journal Article
M. C. MacCracken	2008	Prospects for Future Climate Change and the Reasons for Early Action	Journal of the Air & Waste Management Association	58	6	735-786	//	//	Social Sciences	Environmental studies	60	PL	EN	Journal Article
B. Osmond; T. Neales; G. Stange	2008	Curiosity and context revisited: crassulacean acid metabolism in the Anthropocene	J Exp Bot	59	7	1489-502	//	//	Natural Sciences	Biology	2057	CL	EN	Journal Article
S. Zhang; X. X. Lu; D. L. Higgitt; C.-T. A. Chen; J. Han; H. Sun	2008	Recent changes of water discharge and sediment load in the Zhujiang (Pearl River) Basin, China	Global and Planetary Change	60	3-4	365-380	//	//	Natural Sciences	Limnology	500	PL	EN	Journal Article
T. Haine	2008	What did the Viking discoverers of America know of the North Atlantic Environment?	Weather	63	3	60-65	//	//	Social Sciences	History	241	PL	EN	Journal Article
J. Plant; A. R. McKinlay; N. Voulvoulis	2008	Endocrine disrupting substances in the late anthropocene and breast and prostate cancer	Mineralogical Magazine	72	1	487-487	//	//	Applied Sciences	Medicine	4415	CL	EN	Journal Article
V. H. Garrison	2008	Aerobiogeochemistry perturbations of the Anthropocene Epoch Or - What does this stuff in the air do to the world?	Goldschmidt Abstracts 2008- G	72	12	A287-A338	Geochimica et Cosmochimica Acta	//	Natural Sciences	Chemistry, climatology	2652	CL	EN	Conference Paper
A. Newton; J. Icely	2008	Land Ocean Interactions in the Coastal Zone, LOICZ: Lessons from Banda Aceh, Atlantis, and Canute	Estuarine, Coastal and Shelf Science	77	2	181-184	//	//	Natural Sciences	oceanography	799	PL	EN	Journal Article
W. C. Dennison	2008	Environmental problem solving in coastal ecosystems: A paradigm shift to sustainability	Estuarine, Coastal and Shelf Science	77	2	185-196	//	//	Natural Sciences	Environmental science	821	PL	EN	Journal Article
J. D. Restrepo	2008	Applicability of LOICZ catchment–coast continuum in a major Caribbean basin: The Magdalena River, Colombia	Estuarine, Coastal and Shelf Science	77	2	214-229	//	//	Natural Sciences	Limnology, geology	180	PL	EN	Journal Article
R. M. Baum	2008	Welcome To The Anthropocene	Chemical & Engineering News	86	5	3	//	//	Natural Sciences	Geology, chemistry	5529	CL	EN	Journal Article
P. L. Lomas; S. Alvarez; M. Rodriguez; C. Montes	2008	Environmental accounting as a management tool in the Mediterranean context: the Spanish economy during the last 20 years	J Environ Manage	88	2	326-47	//	//	Applied Sciences, Social Sciences	Resource management, economics	130	PL	EN	Journal Article

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H. D. Safford; J. L. Betancourt; G. D. Hayward; J. A. Wiens; C. M. Regan	2008	Land management in the Anthropocene: is history still relevant?: Incorporating historical ecology and climate change into land management; Lansdowne, Virginia, 22–25 April 2008	Eos, Transactions American Geophysical Union	89	37	343	//	//	Applied Sciences	Resource management	951	PL	EN	Journal Article
D. Schertzer	2008	Predictability and Uncertainties in Geophysics: from the ButterflyEffect to Ensemble Predictions, Multifractal Predictability and theAnthropocene	//	89	53	//	Eos Trans. AGU	//	Natural Sciences	Geology	2618	CL	EN	Abstract
P. Mortyn; M. A. Martinez-Boti; J. C. Herguera	2008	ENSO- and PDO-modulated SST Reconstructions From the Anthropocene Into the Last 2 Millennia: Planktonic Foraminiferal Mg/Ca Evidence at Inter-annual Resolution From San Lázaro Basin (NE Pacific)	//	89	53	//	Eos Trans. AGU	//	Natural Sciences	Oceanography, Climatology	1479	PL	EN	Abstract
C. N. Alpers; J. Z. Drexler; L. A. Neymark; J. B. Paces; H. E. Taylor	2008	Peat Deposits of the Sacramento-San Joaquin Delta, California: An Archive for Anthropogenic Contamination of Mercury, Lead, and Other Trace Metals	//	89	53	//	Eos Trans. AGU	//	Natural Sciences	Limnology, Geology	1420	PL	EN	Abstract
M. Manton	2008	Book review: Climate Variability and Extremes During the Past 100 Years	Eos	89	53	556	//	//	Natural Sciences	Climatology	925	PL	EN	Journal Article
T. C. Jennerjahn; K. Soman; V. Ittekkot; I. Nordhaus; S. Sooraj; R. S. Priya; N. Lahajnar	2008	Effect of land use on the biogeochemistry of dissolved nutrients and suspended and sedimentary organic matter in the tropical Kallada River and Ashtamudi estuary, Kerala, India	Biogeochemistry	90	1	29-47	//	//	Natural Sciences	Chemistry, limnology	78	PL	EN	Journal Article
D. Gerten	2008	Climatic Change, Aquatic Science, Multiple Shifts in Paradigms	International Review of Hydrobiology	93	4-5	397-403	//	//	Natural Sciences	Hydrology, climatology	544	PL	EN	Journal Article
J. Linton	2008	Is the Hydrologic Cycle Sustainable? A Historical–Geographical Critique of a Modern Concept	Annals of the Association of American Geographers	98	3	630-649	//	//	Natural Sciences, Social Sciences	Hydrology, history, human geography	217	PL	EN	Journal Article
J. B. C. Jackson	2008	Ecological extinction and evolution in the brave new ocean	Proceedings of the National Academy of Sciences	105	Supplement 1	11458-11465	//	//	Natural Sciences	Ecology, oceanography	110	PL	EN	Journal Article
C. Pottier; A. Turiel; V. Garcon	2008	Inferring missing data in satellite chlorophyll maps using turbulent cascading	Remote Sensing of Environment	112	12	4242-4260	//	//	Natural Sciences	Oceanography, Environmental science	90	PL	EN	Journal Article
A. Körtzinger; U. Send; R. S. Lampitt; S. Hartman; D. W. R. Wallace; J. Karstensen; M. G. Villagarcia; O. Llinás; M. D. DeGrandpre	2008	The seasonal pCO2 cycle at 49°N/16.5°W in the northeastern Atlantic Ocean and what it tells us about biological productivity	Journal of Geophysical Research	113	C4	//	//	//	Natural Sciences	Oceanography, geology	99	PL	EN	Journal Article
C. Ballantyne	2008	Book review: Geography: a Very Short Introduction	Scottish Geographical Journal	124	4	300-305	//	//	Social Sciences, Natural Sciences	Human geography, physical geography	737	PL	EN	Journal Article
L. A. Borrero	2008	The archaeology of the Neotropics	Quaternary International	180	1	152-157	//	//	Natural Sciences	Geology	629	PL	EN	Journal Article

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NewScientist	2008	Have humans created a new geological epoch?	New Scientist	197	2641	//	//	//	Natural Sciences	Geology	2172	CL	EN	Journal Article
P. Gabrielli; C. Barbante; J. M. C. Plane; C. F. Boutron; J. L. Jaffrezo; T. A. Mather; B. Stenni; V. Gaspari; G. Cozzi; C. Ferrari; P. Cescon	2008	Siderophile metal fallout to Greenland from the 1991 winter eruption of Hekla (Iceland) and during the global atmospheric perturbation of Pinatubo	Chemical Geology	255	1-2	78-86	//	//	Natural Sciences	Geology, Chemistry	229	PL	EN	Journal Article
M. D. Iglesias-Rodriguez; P. R. Halloran; R. E. M. Rickaby; Ian R. Hall; E. Colmenero-Hidalgo; J. R. Gittins; D. R. H. Green; T. Tyrrell; S. J. Gibbs; P. von Dassow; E. Rehm; E. V. Armbrust; K. P. Boessenkool	2008	Phytoplankton Calcification in a High-CO2 World	Science	320	5874	336-340	//	//	Natural Sciences	Biology, oceanography	352	PL	EN	Journal Article
L. Skinner	2008	Facing future climate change: is the past relevant?	Philos Trans A Math Phys Eng Sci	366	1885	4627-45	//	//	Natural Sciences	Climatology	105	PL	EN	Journal Article
A. Hare; G. A. Stern; R. W. Macdonald; Z. Z. Kuzyk; F. Wang	2008	Contemporary and preindustrial mass budgets of mercury in the Hudson Bay Marine System: the role of sediment recycling	Sci Total Environ	406	1-2	190-204	//	//	Natural Sciences	Atmospheric science, Environmental science	84	PL	EN	Journal Article
D. Bevan	2008	Continental Philosophy: A Grounded Theory Approach and the Emergence of Convenient and Inconvenient Ethics	Cutting-edge Issues in Business Ethics: Continental Challenges to Tradition and Practice	//	24	131-152	Springer Netherlands	Dordrecht	Humanities	Philosophy	184	PL	EN	Book Section
M. Gad-el-Hak	2008	The art and science of large-scale disasters	Large-Scale Disasters	//	//	5-68	Cambridge University Press	Cambridge	Social Sciences	Sociology	60	PL	EN	Book Section
P. A. Victor	2008	Managing Without Growth	//	//	//	//	Edward Elgar Publishing	Cheltenham, Northampton	Social Sciences	Environmental studies, economics	31	PL	EN	Book
W. Steffen	2008	The Future of Australia's Environment in the Anthropocene	Ten Commitments: Reshaping the Lucky Country's Environment	//	//	//	CSIRO Publishing	Collingwood, Australia	Social Sciences	Environmental studies	7132	CL	EN	Book Section
E. Ehlers	2008	Das Anthropozän: die Erde im Zeitalter des Menschen	//	//	//	//	Wissenschaftliche Buchgesellschaft	Darmstadt, Germany	Natural Sciences	Earth System science	583	PL	DE	Book
K. Krauze; I. Wagner	2008	An ecohydrological approach for the protection and enhancement of ecosystem services	Use of Landscape Sciences for the Assessment of Environmental Security	//	//	//	Springer	Dordrecht	Natural Sciences	Ecology, hydrology	90	PL	EN	Book Section

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K. Soyez; H. Graß	2008	Climate Change and Technological Options: Basic facts, Evaluation and Practical Solutions	//	//	//	//	Springer	Germany	Natural Sciences, Social Sciences	Environmental studies, Environmental science	15	PL	EN	Book
R. Pease	2008	An Epoch in the making	BBC News	//	//	//	BBC Radio Science Unit	http://news.bbc.co.uk/2/hi/science/nature/7223663.stm (Accessed on July 22, 2021)	Natural Sciences	Geology	1598	PL	EN	Newspaper Article
J. Zalasiewicz; C. Waters; F. J. Gregory; T. L. Barry; P. R. Bown; P. Brenchley; A. L. Coe; A. Gale; P. Gibbard; A. C. Kerr; R. Knox; J. Marshall; M. Oates; P. Pearson; J. Powell; A. Smith; P. Stone; P. F. Rawson	2008	The Anthropocene Epoch: today's context for governance and public policy	//	//	//	//	Geological Society of London	https://www.geolsoc.org.uk/Geoscientist/Letters/2008/The-Anthropocene-Epoch-todays-context-for-governance-and-public-policy (Accessed on July 22, 2021)	Social Sciences, Natural Sciences	Environmental science, political science	12500	CL	EN	Web Page
R. R. Britt	2008	Humans Force earth into new geologic epoch	//	//	//	//	Livescience	https://www.livescience.com/9557-humans-force-earth-geologic-epoch.html (Accessed on July 22, 2021)	Natural Sciences	Geology	2790	CL	EN	Web Page
A. Seabrook	2008	Welcome to the Anthropocene Epoch	National Public Radio	//	//	//	//	https://www.npr.org/transcripts/19120204 (Accessed on July 29, 2021)	Natural Sciences	Geology	9814	CL	EN	Newspaper Article
University of Portsmouth	2008	Man's Impact On The Planet Brings About New Epoch In Earth's History	ScienceDaily	//	//	//	//	https://www.sciencedaily.com/releases/2008/01/080125100314.htm (Accessed on July 22, 2021)	Natural Sciences	Geology	8290	CL	EN	Newspaper Article
B. Kjellén	2008	A New Diplomacy for Sustainable Development: The Challenge of Global Change	//	//	//	//	Routledge	London, UK	Social Sciences	Sustainability studies	114	PL	EN	Book
N. Nakicenovic	2008	Foreword	Globalization as Evolutionary Process: Modeling global change	//	//	//	Routledge	Milton Park	Natural Sciences, Social Sciences	Biology, sociology	1592	PL	EN	Book Section
J. Zalasiewicz	2008	The Earth After Us	//	//	//	//	Oxford University Press	Oxford, UK	Natural Sciences	Geology	91	PL	EN	Book
M. Newson	2008	Land, Water and Development: Sustainable and Adaptive Management of Rivers	//	//	//	474	Routledge	Oxon, UK	Natural Sciences, Social Sciences	Limnology, Sustainability studies	129	PL	EN	Book
M. Dudley-Flores	2008	Global Warming, Earthly Disasters, the Moon and Mars: Transfers of Knowledge (TOK). The American Problem	46th AIAA Aerospace Sciences Meeting and Exhibit	//	//	//	American Institute of Aeronautics and Astronautics	Reno	Social Sciences	Environmental studies, sociology	1974	PL	EN	Conference Proceedings
J. Zalasiewicz; A. Haywood; E. C. Ellis	2008	Stratigraphy of the Anthropocene	//	//	//	//	American Geophysical Union	//	Natural Sciences	Geology	9960	CL	EN	Abstract

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R. W. Battarbee	2008	Holocene climate variability and global warming	Natural Climate Variability and Global Warming	//	//	//	Blackwell Publishing	//	Natural Sciences	Climatology, geology	784	PL	EN	Book Section
H. J. B. Birks	2008	Holocene climate research – progress, paradigms, and problems	Natural Climate Variability and Global Warming	//	//	//	Blackwell Publishing	//	Natural Sciences	Geology, climatology	277	PL	EN	Book Section
H. J. B. Birks	2008	Paleoecology	Encyclopedia of Ecology	//	//	2623-2634	Elsevier	//	Natural Sciences	Ecology	156	PL	EN	Encyclopedia
A. H. Devol	2008	Denitrification Including Anammox	Nitrogen in the Marine Environment	//	//	263-301	Elsevier	//	Natural Sciences	Oceanography	104	PL	EN	Book Section
V. O. Targulian; R. W. Arnold	2008	Pedosphere	Encyclopedia of Ecology	//	//	2665-2670	Elsevier	//	Natural Sciences	Soil science	1194	PL	EN	Encyclopedia
GSA	2008	Final Announcement & Call for Papers: Northeastern 43rd Annual Meeting, Hyatt Regency Buffalo, Buffalo, New York, 27–29 March 2008	//	//	//	//	GSA	//	Natural Sciences	Geology	408	PL	EN	Pamphlet
P. Larcombe; D. J. Morris; C. M. O'brien	2008	In Recognition of Inevitable Uncertainties: From Fisheries Management to Managing Marine Resources	Advances in Fisheries Science: 50 years on from Beverton and Holt	//	//	491-533	Wiley-Blackwell	//	Applied Sciences	Resource management	90	PL	EN	Book Section
F. Oldfield	2008	The Role of People in the Holocene	Natural Climate Variability and Global Warming	//	//	58-97	Wiley-Blackwell	//	Natural Sciences, Social Sciences	Physical geography, history	118	PL	EN	Book Section
C. Jaeger	2008	Noosphere	Encyclopedia of Ecology	//	//	2533-2536	//	//	Natural Sciences, Social Sciences	History, ecology	659	PL	EN	Encyclopedia
S. Van der Leeuw	2008	Durabilité et archéologie environnementale	Archeopages (Hors-série 1)	//	//	97-102	//	//	Social Sciences	Archaeology	234	PL	FR	Journal Article
S. Byravan; S. C. Rajan	2008	The Social Impacts of Climate Change in South Asia	SSRN Electronic Journal	//	//	//	//	//	Social Sciences	Sociology, environmental studies	419	PL	EN	Journal Article
R. Murtugudde	2009	Regional Earth System prediction: a decision-making tool for sustainability?	Current Opinion in Environmental Sustainability	1	1	37-45	//	//	Natural Sciences	Earth System science	420	PL	EN	Journal Article
M. Marien	2009	Book review: Common Wealth: Economics for a Crowded Planet	World Futures Review	1	1	76-81	//	//	Social Sciences	Economics	313	PL	EN	Journal Article
T. J. Doherty	2009	The Rediscovery of Ecopsychology	Ecopsychology	1	3	105-109	//	//	Natural Sciences, Social Sciences	Ecology, psychology	499	PL	EN	Journal Article
E. Struyf; A. Smis; S. Van Damme; P. Meire; D. J. Conley	2009	The Global Biogeochemical Silicon Cycle	Silicon	1	4	207-213	//	//	Natural Sciences	Earth System science	165	PL	EN	Journal Article

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B. Allenby	2009	The Ethics of Emerging Technologies: Real Time Macroethical Assessment	2009 IEEE International Symposium on Sustainable Systems and Technology	1	//	1-3	2009 IEEE International Symposium on Sustainable Systems and Technology, ISSST '09 in Cooperation with 2009 IEEE International Symposium on Technology and Society, ISTAS.	Phoenix, USA	Humanities	Philosophy	1491	PL	EN	Conference Proceedings
S. C. Doney; V. J. Fabry; R. A. Feely; J. A. Kleypas	2009	Ocean acidification: the other CO2 problem	Ann Rev Mar Sci	1	//	169-92	//	//	Natural Sciences	Oceanography, chemistry	136	PL	EN	Journal Article
A. Rechkemmer; L. von Falkenhayn	2009	The human dimensions of global environmental change: Ecosystem services, resilience, and governance	The European Physical Journal Conferences	1	//	3-17	//	//	Social Sciences, Applied Sciences	Environmental studies, resource management	122	PL	EN	Journal Article
M. Lapka; E. Cudlinova	2009	Any Lesson from the History of Sustainable Development?	Journal of Landscape Ecology	2	2	5-17	//	//	Humanities, Social Sciences	History, philosophy	150	PL	EN	Journal Article
G. Bridge	2009	Material Worlds: Natural Resources, Resource Geography and the Material Economy	Geography Compass	3	3	1217-1244	//	//	Social Sciences	Human geography, economics	147	PL	EN	Journal Article
F. Minoletti; M. Hermoso; V. Gressier	2009	Separation of sedimentary micron-sized particles for palaeoceanography and calcareous nannoplankton biogeochemistry	Nat Protoc	4	1	14-24	//	//	Natural Sciences	Oceanography, chemistry	151	PL	EN	Journal Article
B. Allenby; C. F. Murphy; D. Allen; C. Davidson	2009	Sustainable engineering education in the United States	Sustainability Science	4	1	7-15	//	//	Social Sciences, Applied Sciences	Pedagogy, engineering	572	PL	EN	Journal Article
P. J. Rasch; J. Latham; C.-C. Chen	2009	Geoengineering by cloud seeding: influence on sea ice and climate system	Environmental Research Letters	4	4	//	//	//	Applied Sciences	Geoengineering	203	PL	EN	Journal Article
Ú. O. Spring; H. G. Brauch; S. Dalby	2009	Linking Anthropocene, HUGE and HESP: Fourth Phase of Environmental Security Research	Facing Global Environmental Change Environmental, Human, Energy, Food, Health and Water Security Concepts	4	//	//	Springer Verlag	Berlin, Heidelberg	Social Sciences	International studies, environmental studies	1499	PL	EN	Book Section

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H. G. Brauch	2009	Summary and Results: Facing Global Environmental Change and Sectorialization of Security	Facing Global Environmental Change Environmental, Human, Energy, Food, Health and Water Security Concepts	4	//	//	Springer Verlag	Berlin, Heidelberg	Social Sciences	International studies, political sciences	863	PL	EN	Book Section
H. G. Brauch	2009	Securitizing Global Environmental Change	Facing Global Environmental Change Environmental, Human, Energy, Food, Health and Water Security Concepts	4	//	//	Springer Verlag	Berlin, Heidelberg	Social Sciences	International studies, environmental studies	438	PL	EN	Book Section
H. G. Brauch	2009	Human Security Concepts in Policy and Science	Facing Global Environmental Change Environmental, Human, Energy, Food, Health and Water Security Concepts	4	//	//	Springer Verlag	Berlin, Heidelberg	Social Sciences	Political science, International studies	413	PL	EN	Book Section
H. G. Brauch	2009	Introduction: Facing Global Environmental Change and Sectorialization of Security	Facing Global Environmental Change Environmental, Human, Energy, Food, Health and Water Security Concepts	4	//	//	Springer Verlag	Berlin, Heidelberg	Social Sciences	International studies, environmental studies	388	PL	EN	Book Section
Ú. O. Spring	2009	A HUGE Gender Security Approach: Towards Human, Gender, and Environmental Security	Facing Global Environmental Change Environmental, Human, Energy, Food, Health and Water Security Concepts	4	//	//	Springer Verlag	Berlin, Heidelberg	Social Sciences	International studies, gender studies	220	PL	EN	Book Section
W. D. Blümel	2009	Natural Climatic Variations in the Holocene: Past Impacts on Cultural History, Human Welfare and Crisis	Facing Global Environmental Change Environmental, Human, Energy, Food, Health and Water Security Concepts	4	//	//	Springer Verlag	Berlin, Heidelberg	Natural Sciences	Climatology	134	PL	EN	Book Section
H. G. Brauch; Ú. O. Spring	2009	Towards Sustainable Peace for the 21st Century	Facing Global Environmental Change Environmental, Human, Energy, Food, Health and Water Security Concepts	4	//	//	Springer Verlag	Berlin, Heidelberg	Social Sciences	International studies, Sustainability studies	120	PL	EN	Book Section
R. Leemans	2009	The Millennium Ecosystem Assessment: Securing Interactions between Ecosystems, Ecosystem Services and Human Well-being	Facing Global Environmental Change: Environmental, Human, Energy, Food, Health and Water Security Concepts	4	//	//	Springer Verlag	Berlin, Heidelberg	Applied Sciences, Social Sciences	resource management, Sustainability studies	186	PL	EN	Book Section

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K. W. Wirtz; K. Bernhardt; G. Lohmann; C. Lemmen	2009	Mid-Holocene regional reorganization of climate variability	Climate of the Past Discussions	5	1	287-326	//	//	Natural Sciences	Climatology	54	PL	EN	Journal Article
H. S. Lin	2009	Earth's Critical Zone and hydropedology: concepts, characteristics, and advances	Hydrology and Earth System sciences Discussions	6	2	3417-3481	//	//	Natural Sciences	Earth System science	38	PL	EN	Journal Article
J. L. Sarmiento; N. Gruber; M. Gloor; A. R. Jacobson; S. M. Fletcher; S. Pacala; K. Rodgers	2009	The changing carbon cycle	//	6	4	//	IOP Conference Series: Earth and Environmental science	//	Natural Sciences	Earth System science	2033	CL	EN	Abstract
N. N. Rabalais; R. J. Diaz; L. A. Levin; R. E. Turner; D. Gilbert; J. Zhang	2009	Dynamics and distribution of natural and human-caused coastal hypoxia	Biogeosciences Discussions	6	5	9359-9453	//	//	Natural Sciences	Biology, geology	59	PL	EN	Journal Article
B. H. Jakobsen	2009	Holocene climate change and environmental reconstruction in East Greenland	IOP Conference Series: Earth and Environmental science	6	7	//	//	//	Natural Sciences	Climatology, Environmental science	872	PL	EN	Journal Article
A. J. Gooday; F. Jorissen; L. A. Levin; J. J. Middelburg; S. W. A. Naqvi; N. N. Rabalais; M. Scranton; J. Zhang	2009	Historical records of coastal eutrophication-induced hypoxia	Biogeosciences	6	8	1707-1745	//	//	Natural Sciences	Oceanography	67	PL	EN	Journal Article
H. G. Brauch	2009	Climate change impacts on migration: Conflict and cooperation in the Mediterranean	IOP Conference Series: Earth and Environmental science	6	56	//	//	//	Social Sciences	Sociology, environmental studies, international studies	2230	CL	EN	Journal Article
D. Gerten	2009	The noosphere in earth system analysis	IOP Conference Series: Earth and Environmental science	6	57	//	//	//	Natural Sciences	Earth System science	1616	PL	EN	Journal Article
J. L. Sarmiento; M. Gloor; N. Gruber; C. Beaulieu; A. R. Jacobson; S. E. Mikaloff Fletcher; S. Pacala; K. Rodgers	2009	Trends and regional distributions of land and ocean carbon sinks	Biogeosciences Discussions	6	//	10583–10624	//	//	Natural Sciences	Earth System science	61	PL	EN	Journal Article
A. Oschlies	2009	Impact of atmospheric and terrestrial CO2 feedbacks on fertilization-induced marine carbon uptake	Biogeosciences	6	//	1603–1613	//	//	Natural Sciences	Atmospheric science, oceanography	123	PL	EN	Journal Article
S. Dupont; M. C. Thorndyke	2009	Impact of CO2-driven ocean acidification on invertebrates early life-history – What we know, what we need to know and what we can do	Biogeosciences Discussions	6	//	3109–3131	//	//	Natural Sciences	Oceanography, chemistry	133	PL	EN	Journal Article
A. M. Washburn	2009	Education for Exponential Times	Journal of Transformative Education	7	1	3-7	//	//	Social Sciences	Pedagogy	409	PL	EN	Journal Article

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J. Pretty; B. Adams; F. Berkes; S. F. de Athayde; N. Dudley; E. Hunn; L. Maffi; K. Milton; D. Rapport; P. Robbins; E. Sterling; S. Stolton; A. Tsing; E. Vintinnerk; S. Pilgrim	2009	The Intersections of Biological Diversity and Cultural Diversity: Towards Integration	Conservation and Society	7	2	//	//	//	Natural Sciences, Social Sciences	Biology, environmental studies	90	PL	EN	Journal Article
G. Cederlof; M. Rangarajan	2009	Predicaments of power and nature in India: An introduction	Conservation and Society	7	4	//	//	//	Social Sciences	History	169	PL	EN	Journal Article
M.-H. Depret; P. Le Masne; C. Merlin-Brogniart	2009	De la responsabilité sociale des acteurs	Marché et organisations	8	1	//	//	//	Social Sciences, humanities	Sustainability studies, environmental studies, philosophy	116	PL	FR	Journal Article
H. Thomas; L. Huang; M. Young; H. Ougham	2009	Evolution of plant senescence	BMC Evol Biol	9	//	163	//	//	Natural Sciences	Ecology	89	PL	EN	Journal Article
M. Martin; D. Pohler; K. Seitz; R. Sinreich; U. Platt	2009	BrO measurements over the Eastern North-Atlantic	Atmospheric Chemistry and Physics	9	//	9545–955 4	//	//	Natural Sciences	Atmospheric science, chemistry	423	PL	EN	Journal Article
D. Michalska-Hejduk; D. Kopeć; A. Drobniewska; B. Sumorok	2009	Comparison of physical and chemical properties of water and floristic diversity of oxbow lakes under different levels of human pressure: A case study of the lower San River (Poland)	Ecohydrology & Hydrobiology	9	2-4	183-191	//	//	Natural Sciences	Chemistry, hydrology	575	PL	EN	Journal Article
M. Schaefer	2009	Book review: Big questions in ecology and evolution	Basic and Applied Ecology	10	8	//	//	//	Natural Sciences	Ecology, biology	1513	PL	EN	Journal Article
L. R. Walker; R. Moral	2009	Lessons from primary succession for restoration of severely damaged habitats	Applied Vegetation Science	12	//	55-67	//	//	Natural Sciences	Ecology	120	PL	EN	Journal Article
G. P. J. Dijkema; L. Basson	2009	Complexity and Industrial Ecology	Journal of Industrial Ecology	13	2	157-164	//	//	Natural Sciences, Social Sciences	Ecology, Sustainability studies	233	PL	EN	Journal Article
B. Allenby	2009	The Industrial Ecology of Emerging Technologies: Complexity and the Reconstruction of the World	Journal of Industrial Ecology	13	2	168-183	//	//	Natural Sciences	Ecology	545	PL	EN	Journal Article
D. Koutsoyiannis; C. Makropoulos; A. Langousis; S. Baki; A. Efstratiadis; A. Christofides; G. Karavokiros; N. Mamassis	2009	HESS Opinions: "Climate, hydrology, energy, water: recognizing uncertainty and seeking sustainability"	Hydrology and Earth System sciences Discussions,	13	2	247-257	//	//	Natural Sciences	Climatology, hydrology	105	PL	EN	Journal Article

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J. Rockström; W. Steffen; K. Noone; Å. Persson; F. S. Chapin III; E. F. Lambin; T. M. Lenton; M. Scheffer; C. Folke; H. J. Schellnhuber; B. Nykvist; C. A. de Wit; T. Hughes; S. van der Leeuw; H. Rodhe; S. Sörlin; P. K. Snyder; R. Costanza; U. Svedin; M. Falkenmark; L. Karlberg; R. W. Corell; V. J. Fabry; J. Hansen; B. Walker; D. Liverman; K. Richardson; P. J. Crutzen; J. A. Foley	2009	Planetary Booundaries: Exploring the safe operating space for humanity	Ecology and Society	14	2	//	//	//	Natural Sciences	Earth System science	447	PL	EN	Journal Article
B. Karlberg; M. Grasserbauer; J. E. T. Andersen	2009	European analytical column no. 37 (January 2009) Division of Analytical Chemistry (DAC) of the European Association for Chemical and Molecular Sciences (EuCheMS)	Accreditation and Quality Assurance	14	6	337-340	//	//	Natural Sciences	Chemistry	671	PL	EN	Journal Article
L. Robin	2009	Book review: Global Environmental History 10,000 BC to AD 2000	Environment and History	15	2	245-263	//	//	Humanities, Social Sciences	History, ecocriticism	1013	PL	EN	Journal Article
C. Lemmen	2009	World distribution of land cover changes during Pre- and Protohistoric Times and estimation of induced carbon releases	Géomorphologie : relief, processus, environnement	15	4	303-312	//	//	Natural Sciences	Geology	380	PL	EN	Journal Article
A. Lerman	2009	Saline Lakes' Response to Global Change	Aquatic Geochemistry	15	1-2	1-5	//	//	Natural Sciences	Oceanography	364	PL	EN	Journal Article
S. Norra	2009	The astysphere and urban geochemistry-a new approach to integrate urban systems into the geoscientific concept of spheres and a challenging concept of modern geochemistry supporting the sustainable development of planet earth	Environ Sci Pollut Res Int	16	5	539-45	//	//	Natural Sciences	Geology	212	PL	EN	Journal Article
J. Treiner	2009	Pour un catastrophisme raisonné: réflexion sur l'identité de Kaya	Natures Sciences Sociétés	17	4	402-405	//	//	Natural Sciences, Social Sciences	climatology, Environmental studies	362	PL	FR	Journal Article
G. F. Ficetola; E. Padoa-Schioppa	2009	Human activities alter biogeographical patterns of reptiles on Mediterranean islands	Global Ecology and Biogeography	18	2	214-222	//	//	Natural Sciences	Biology, physical geography	306	PL	EN	Journal Article
E. Lövbrand; J. Stripple; B. Wiman	2009	Earth System governmentality: Reflections on science in the Anthropocene	Global Environmental Change	19	1	7-13	//	//	Social Sciences, Natural Sciences	Political science, Earth System science	3886	CL	EN	Journal Article
C. Folke; J. Rockström	2009	Turbulent times	Global Environmental Change	19	1	1-3	//	//	Social Sciences, Natural Sciences	Environmental studies, Environmental science	477	PL	EN	Journal Article

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J. Salick; N. Ross	2009	Traditional peoples and climate change	Global Environmental Change	19	2	137-139	//	//	Social Sciences	Anthropology, environmental studies	323	PL	EN	Journal Article
J. A. Matthews	2009	Book review: Natural climate variability and global warming: a Holocene perspective	The Holocene	19	5	806-808	//	//	Natural Sciences	Climatology, Environmental science	723	PL	EN	Journal Article
I. Larocque-Tobler; M. Grosjean; O. Heiri; M. Trachsel	2009	High-resolution chironomid-inferred temperature history since ad 1580 from varved Lake Silvaplana, Switzerland: comparison with local and regional reconstructions	The Holocene	19	8	1201-1212	//	//	Natural Sciences	Geology, climatology	124	PL	EN	Journal Article
A. S. Brierley; M. J. Kingsford	2009	Impacts of climate change on marine organisms and ecosystems	Curr Biol	19	14	R602-14	//	//	Natural Sciences	Biology, oceanography	81	PL	EN	Journal Article
J. Carruthers	2009	Book review: Griffith Taylor:Visionary, Environmentalist, Explorer	Historical Records of Australian Science	20	1	135-137	//	//	Social Sciences, humanities	Environmental studies	567	PL	EN	Journal Article
T. C. Hawes	2009	Origins and dispersal of the Antarctic fairy shrimp	Antarctic Science	21	5	477-482	//	//	Natural Sciences	Biology	227	PL	EN	Journal Article
L. Kump; T. Bralower; A. Ridgwell	2009	Ocean Acidification in Deep Time	Oceanography	22	4	94-107	//	//	Natural Sciences	Oceanography, geology	100	PL	EN	Journal Article
M. Krachler; J. Zheng; D. Fisher; W. Shotyk	2009	Global atmospheric As and Bi contamination preserved in 3000 year old Arctic ice	Global Biogeochemical Cycles	23	3	//	//	//	Natural Sciences	Geology, Atmospheric science	592	PL	EN	Journal Article
J. Pongratz; C. H. Reick; T. Raddatz; M. Claussen	2009	Effects of anthropogenic land cover change on the carbon cycle of the last millennium	Global Biogeochemical Cycles	23	4	//	//	//	Natural Sciences	Geology	94	PL	EN	Journal Article
S. Assonov; P. Taylor; C. A. Brenninkmeijer	2009	A system for high-quality CO2 isotope analyses of air samples collected by the CARIBIC Airbus A340-600	Rapid Commun Mass Spectrom	23	9	1347-63	//	//	Natural Sciences	Atmospheric science	80	PL	EN	Journal Article
S. Kurian; R. Agnihotri; D. V. Borole; S. W. A. Naqvi; A. M. Ferreira; C. Vale	2009	Possible solar control on primary production along the Indian west coast on decadal to centennial timescale	Journal of Quaternary Science	24	2	109-116	//	//	Natural Sciences	Geology	195	PL	EN	Journal Article
P. R. Ehrlich	2009	Cultural evolution and the human predicament	Trends in Ecology and Evolution	24	8	409-12	//	//	Social Sciences, Natural Sciences	human geography, ecology	268	PL	EN	Journal Article
M. E. Mann	2009	Do Global Warming and Climate Change Represent a Serious Threat to Our Welfare and Environment?	Social Philosophy and Policy	26	2	193-230	//	//	Social Sciences	Environmental studies	116	PL	EN	Journal Article
T. W. Luke	2009	Developing planetarian accountancy: Fabricating nature as stock, service, and system for green governmentality	Nature, Knowledge and Negation	26	//	129-159	//	//	Social Sciences, Applied Sciences	Political sciences, resource management	76	PL	EN	Book Section
M. C. MacCracken	2009	The Increasing Pace of Climate Change	Strategic Planning for Energy and the Environment	28	3	8-25	//	//	Social Sciences	Environmental studies	263	PL	EN	Journal Article
R. H. Bradbury; R. M. Seymour	2009	Coral reef science and the new commons	Coral Reefs	28	4	831-837	//	//	Natural Sciences, Applied Sciences	Ecology, resource management	2080	CL	EN	Journal Article
F. Schlütz; F. Lehmkuhl	2009	Holocene climatic change and the nomadic Anthropocene in Eastern Tibet: palynological and geomorphological results from the Nianbaoyeze Mountains	Quaternary Science Reviews	28	15-16	1449-1471	//	//	Natural Sciences	Climatology, geology	410	PL	EN	Journal Article

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W. R. Peltier	2009	Closure of the budget of global sea level rise over the GRACE era: the importance and magnitudes of the required corrections for global glacial isostatic adjustment	Quaternary Science Reviews	28	17-18	1658-1674	//	//	Natural Sciences	Geology, climatology	65	PL	EN	Journal Article
A. J. Kettner; J. P. M. Syvitski	2009	Fluvial responses to environmental perturbations in the Northern Mediterranean since the Last Glacial Maximum	Quaternary Science Reviews	28	23-24	2386-2397	//	//	Natural Sciences	Geology, oceanography	203	PL	EN	Journal Article
W. F. Ruddiman; E. C. Ellis	2009	Effect of per-capita land use changes on Holocene forest clearance and CO2 emissions	Quaternary Science Reviews	28	27-28	3011-3015	//	//	Natural Sciences	Climatology, geology	256	PL	EN	Journal Article
M. Hall	2009	Plant Autonomy and Human-Plant Ethics	Environmental Ethics	31	2	169-181	//	//	Humanities	Philosophy	145	PL	EN	Journal Article
S. Dalby	2009	Book review: A new diplomacy for sustainable development: the challenge of global change	Progress in Human Geography	33	2	295-296	//	//	Social Sciences	Political science, human geography	1560	PL	EN	Journal Article
S. J. Pyne	2009	The human geography of fire: a research agenda	Progress in Human Geography	33	4	443-446	//	//	Social Sciences, Humanities	Human geography	324	PL	EN	Journal Article
P. C. Sutton; S. J. Anderson; C. r. D. Elvidge; B. T. Tuttle; T. Ghosh	2009	Paving the planet: impervious surface as proxy measure of the human ecological footprint	Progress in Physical Geography: Earth and Environment	33	4	510-527	//	//	Social Sciences, Natural Sciences	Physical geography, environmental studies	273	PL	EN	Journal Article
E. L. Miles	2009	On the Increasing Vulnerability of the World Ocean to Multiple Stresses	Annual Review of Environment and Resources	34	1	17-41	//	//	Natural Sciences, Applied Sciences	Oceanography, resource management	59	PL	EN	Journal Article
M. T. Boykoff	2009	We Speak for the Trees: Media Reporting on the Environment	Annual Review of Environment and Resources	34	1	431-457	//	//	Social Sciences	Environmental studies	108	PL	EN	Journal Article
W. C. Vaughan; K. B. Briggs; K. Jin-Wook; T. S. Bianchi; R. W. Smith	2009	Storm-Generated Sediment Distribution Along the Northwest Florida Inner Continental Shelf	IEEE Journal of Oceanic Engineering	34	4	495-515	//	//	Applied Sciences, Natural Sciences	Engineering, Oceanography	68	PL	EN	Journal Article
D. Chakrabarty	2009	The Climate of History: Four Theses	The University of Chicago Press. Journals. Critical Inquiry	35	2	197-222	//	//	Social Sciences	History, environmental studies	2073	CL	EN	Journal Article
J. Lorimer; S. Whatmore	2009	After the 'king of beasts': Samuel Baker and the embodied historical geographies of elephant hunting in mid-nineteenth-century Ceylon	Journal of Historical Geography	35	4	668-689	//	//	Social Sciences	History, Human Geography	91	PL	EN	Journal Article
F. Saiano; R. Scalenghe	2009	An anthropic soil transformation fingerprinted by REY patterns	Journal of Archaeological Science	36	11	2502-2506	//	//	Natural Sciences	Soil science	609	PL	EN	Journal Article
A. Gunatilaka	2009	The Anthropocene– a 200 year record of human driven geological impacts: prelude to global climate changes and implications for South Asia	Journal of the National Science Foundation of Sri Lanka	37	1	3	//	//	Social Sciences, Natural Sciences	Environmental studies, Environmental science	2705	CL	EN	Journal Article
G. DeClue	2009	Book review: Common Wealth: Economics for a Crowded Planet	The Journal of Psychiatry & Law	37	4	449-456	//	//	Social Sciences	Economics	362	PL	EN	Journal Article
S. Sharma	2009	Why the marginalised protest: Environmental movements as a critique of dominant development discourse	Social Change	39	2	171-194	//	//	Social Sciences	Sociology	115	PL	EN	Journal Article
A. Cariapa	2009	Letter to Editor	Transactional Analysis Journal	39	3	262-264	//	//	Social Sciences	Sustainability studies	707	PL	EN	Journal Article

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C. Feltham	2009	Revolutionary Claims and Visions in Psychotherapy: An Anthropathological Perspective	Journal of Contemporary Psychotherapy	39	//	41-53	//	//	Social Sciences, Applied Sciences	anthropology, psychiatry	91	PL	EN	Journal Article
N. Castree	2009	Who's afraid of Charles Darwin?	Geoforum	40	6	941-944	//	//	Humanities, Social Sciences	Human geography, ecocriticism	223	PL	EN	Journal Article
P. Huges	2009	Book review: The cryosphere and global environmental change	Area	41	1	112-113	//	//	Natural Sciences	Climatology, Environmental science	579	PL	EN	Journal Article
J. Nadal; A. Pèlachs; D. Molina; J.-M. Soriano	2009	Soil fertility evolution and landscape dynamics in a Mediterranean area: a case study in the Sant Llorenç Natural Park (Barcelona, NE Spain)	Area	41	2	129-138	//	//	Natural Sciences	Physical geography	187	PL	EN	Journal Article
N. Castree	2009	Charles Darwin and the Geographers	Environment and Planning A: Economy and Space	41	10	2293-2298	//	//	Humanities, Social Sciences	Human geography, ecocriticism	565	PL	EN	Journal Article
M. T. Boykoff; A. Bumpus; D. Liverman; S. Randalls	2009	Theorizing the Carbon Economy: Introduction to the Special Issue	Environment and Planning A: Economy and Space	41	10	2299-2304	//	//	Social Sciences	Economics	941	PL	EN	Journal Article
X. Yang; A. Conacher	2009	Guest Editors' Introduction. Land Degradation and Rehabilitation in Ecologically Fragile Areas: Research Status and Perspectives	Geographical Research	47	1	1-3	//	//	Natural Sciences	Geology, ecology	1568	PL	EN	Journal Article
M. Rooney; R. Smith	2009	Australian Humanities Review	Australian Humanities Review	47	//	//	Australian National University Press	//	Humanities	Ecocriticism	5435	CL	EN	Journal Article
K. Rigby	2009	Writing in the Anthropocene: Idle Chatter or Ecoprophetic Witness?	Australian Humanities Review	47	//	173-187	//	//	Humanities	Ecocriticism	2177	CL	EN	Journal Article
J. Mazo	2009	Chapter One: Global Warming and Climate Change	The Adelphi Papers	49	409	15-42	//	//	Social Sciences	Environmental studies	439	PL	EN	Journal Article
A. E. Nilsson	2009	A Changing Arctic Climate: Science and Policy in the Arctic Climate Impact Assessment	Climate Governance in the Arctic	50	//	77-95	Springer	//	Social Sciences, Natural Sciences	Political science, environmental studies, arctic studies	204	PL	EN	Book Section
V. Galaz	2009	Pandemic 2.0: Can Information Technology Help Save The Planet?	Environment: Science and Policy for Sustainable Development	51	6	20-28	//	//	Social Sciences, Applied Sciences	Science and technology studies, medicine	163	PL	EN	Journal Article
Z. W. Kundzewicz; L. J. Mata; N. W. Arnell; P. DÖLl; B. Jimenez; K. Miller; T. Oki; Z. ŞEn	2009	REPLY to "Climate, hydrology and freshwater: towards an interactive incorporation of hydrological experience into climate research": Water and climate projections	Hydrological Sciences Journal	54	2	406-415	//	//	Natural Sciences	Hydrology, climatology	323	PL	EN	Journal Article
R. G. Taylor; A. D. Koussis; C. Tindimugaya	2009	Groundwater and climate in Africa—a review	Hydrological Sciences Journal	54	4	655-664	//	//	Natural Sciences	Limnology	143	PL	EN	Journal Article
N. Metzl	2009	Decadal increase of oceanic carbon dioxide in Southern Indian Ocean surface waters (1991–2007)	Deep Sea Research Part II: Topical Studies in Oceanography	56	8-10	607-619	//	//	Natural Sciences	Oceanography	93	PL	EN	Journal Article
M. Gad-el-Hak	2009	The art and science of large-scale disasters	Bulletin of the Polish Academy of Sciences: Technical Sciences	57	1	3-34	//	//	Applied Sciences	Engineering	65	PL	EN	Journal Article
N. Röling	2009	Professionals in context: How robust is the normative model?	Irrigation and Drainage	58	S2	S225-S230	//	//	Natural Sciences, Applied Sciences	Hydrology, engineering	287	PL	EN	Journal Article

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C. Taylor	2009	Casting Architecture in an Expanding Horizon: Atacama Lab: 07	Journal of Architectural Education	62	4	15-23	//	//	Social Sciences, Applied Sciences	Engineering, sociology	1058	PL	EN	Journal Article
R. Dirzo	2009	Anthropogenically Driven Contemporary Evolution: Lessons for Biodiversity Conservation	Evolution	63	11	3038-3041	//	//	Natural Sciences	Biology	2346	CL	EN	Journal Article
A. E. Kazdin	2009	Psychological science's contributions to a sustainable environment: extending our reach to a grand challenge of society	Am Psychol	64	5	339-56	//	//	Social Sciences, Applied Sciences	Psychology, environmental studies	126	PL	EN	Journal Article
C. J. Vörösmarty; J. Syvitski; J. Day; A. de Sherbinin; L. Giosan; C. Paola	2009	Battling to Save the World's River Deltas	Bulletin of the Atomic Scientists	65	2	31-43	//	//	Natural Sciences, Social Sciences	Limnology, environmental studies	331	PL	EN	Journal Article
L. von Gunten; M. Grosjean; U. Eggenberger; P. Grob; R. Urrutia; A. Morales	2009	Pollution and eutrophication history AD 1800–2005 as recorded in sediments from five lakes in Central Chile	Global and Planetary Change	68	3	198-208	//	//	Natural Sciences	Hydrology, Environmental science	336	PL	EN	Journal Article
A. A. Hezri; S. R. Dovers	2009	Australia's Indicator-Based Sustainability Assessments and Public Policy	Australian Journal of Public Administration	68	3	303-318	//	//	Social Sciences	Sustainability studies	111	PL	EN	Journal Article
K.-H. Erb; F. Krausmann; V. Gaube; S. Gingrich; A. Bondeau; M. Fischer-Kowalski; H. Haberl	2009	Analyzing the global human appropriation of net primary production — processes, trajectories, implications. An introduction	Ecological Economics	69	2	250-259	//	//	Social Sciences	economics, environmental studies	255	PL	EN	Journal Article
N. Rolland; I. Larocque; P. Francus; R. Pienitz; L. Laperrière	2009	Evidence for a warmer period during the 12th and 13th centuries AD from chironomid assemblages in Southampton Island, Nunavut, Canada	Quaternary Research	72	1	27-37	//	//	Natural Sciences	Climatology, geology	226	PL	EN	Journal Article
M. Henneberg	2009	Two interpretations of human evolution: Essentialism and Darwinism	Anthropological Review	72	1	66-80	//	//	Natural Sciences, Humanities	Biology, philosophy	136	PL	EN	Journal Article
L. Connor; S. Freeman; N. Higginbotham	2009	Not Just a Coalmine: Shifting Grounds of Community Opposition to Coal Mining in Southeastern Australia	Ethnos	74	4	490-513	//	//	Social Sciences	Environmental studies	90	PL	EN	Journal Article
G. Verstraeten; A. Lang; P. Houben	2009	Human impact on sediment dynamics — quantification and timing	Catena	77	2	77-80	//	//	Natural Sciences	Soil science	540	PL	EN	Journal Article
A. Paulmier; D. Ruiz-Pino	2009	Oxygen minimum zones (OMZs) in the modern ocean	Progress in Oceanography	80	3-4	113-128	//	//	Natural Sciences	Oceanography	126	PL	EN	Journal Article
M. Macdonald	2009	Book review: Security and environmental change	International Affairs	85	6	1249-1298	//	//	Social Sciences	International studies	688	PL	EN	Journal Article
I. Renberg; C. Bigler; B. Richard; N. Matilda; R. Johan; S. Ulf	2009	Environmental history: a piece in the puzzle for establishing plans for environmental management	J Environ Manage	90	8	2794-800	//	//	Social Sciences, Applied Sciences	History, resource management	307	PL	EN	Journal Article

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E. C. Ellis	2009	Earth Science in the Anthropocene: New Epoch, New Paradigm, New Responsibilities	Eos, Transactions American Geophysical Union	90	49	473	//	//	Natural Sciences	Earth System science	1401	PL	EN	Journal Article
N. Mahowald; S. Albani; G. Winckler	2009	Model insights into paleodust proxies (Invited)	//	90	52	//	Eos Trans. AGU	//	Natural Sciences	Oceanography, Climatology	2398	CL	EN	Abstract
J. Sanderman; J. Baldock; R. Farquharson	2009	Can agricultural soils effectively remove legacy carbon from theatmosphere? Lessons from Australian long-term soil experiments. (Invited)	//	90	52	//	Eos Trans. AGU	//	Natural Sciences	Soil Science	2179	CL	EN	Abstract
J. C. Washburn	2009	Biosphere2 and Earthbuzz	//	90	52	//	Eos Trans. AGU	//	Social Sciences	Pedagogy	1645	PL	EN	Abstract
A. D. Ashton; E. Carruthers; A. Piliouras; H. Taylor	2009	Overwash controls coastal barrier response to sea-level rise	//	90	52	//	Eos Trans. AGU	//	Natural Sciences	Oceanography, Geology	1497	PL	EN	Abstract
K. Tanaka; B. C. O'Neill; D. Rokityanskiy; M. Obersteiner; R. S. J. Tol	2009	Evaluating Global Warming Potentials with historical temperature	Climatic Change	96	4	443-466	//	//	Natural Sciences	Climatology	100	PL	EN	Journal Article
T. S. Bianchi; M. A. Allison	2009	Large-river delta-front estuaries as natural ''recorders'' of global environmental change	Proceedings of the National Academy of Sciences,	106	20	8085-8092	//	//	Natural Sciences	Limnology	554	PL	EN	Journal Article
R. R. Twilley; V. Rivera-Monroy	2009	Sediment and Nutrient Tradeoffs in Restoring Mississippi River Delta: Restoration vs Eutrophication	Journal of Contemporary Water Research & Education	141	1	39-44	//	//	Natural Sciences	Limnology	256	PL	EN	Journal Article
J. Harrington	2009	Water for Agriculture: Global Change and Geographic Perspectives on Research Challenges for the Future	Journal of Contemporary Water Research & Education	142	1	36-41	//	//	Social Sciences, Natural Sciences	Hydrology, human geography	780	PL	EN	Journal Article
A. A. Kotov; S. Ishida; D. J. Taylor	2009	Revision of the genus Bosmina Baird, 1845 (Cladocera: Bosminidae), based on evidence from male morphological characters and molecular phylogenies	Zoological Journal of the Linnean Society	156	//	1-51	//	//	Natural Sciences	Biology	40	PL	EN	Journal Article
A. While	2009	Book review: A New Diplomacy for Sustainable Development: The Challenge of Global Change	Geographical Journal	175	4	322	//	//	Social Sciences	Political science, Sustainability studies	1244	PL	EN	Journal Article
J. Feichter; T. Leisner	2009	Climate engineering: A critical review of approaches to modify the global energy balance	The European Physical Journal Special Topics	176	1	81-92	//	//	Natural Sciences, Social Sciences	Geology	151	PL	EN	Journal Article
G. Vince	2009	Surviving in a warmer world	New Scientist	201	2697	28-33	//	//	Humanities	Ecocriticism	290	PL	EN	Journal Article
X. Li; J. Dodson; J. Zhou; X. Zhou	2009	Increases of population and expansion of rice agriculture in Asia, and anthropogenic methane emissions since 5000BP	Quaternary International	202	1-2	41-50	//	//	Natural Sciences	Geology, physical geography	263	PL	EN	Journal Article
NewScientist	2009	Optimistic, and for good reason	New Scientist	203	2725	3	//	//	Social Sciences	Environmental studies	962	PL	EN	Journal Article
B. Holmes	2009	Earth: the comeback	New Scientist	204	2728	32-35	//	//	Natural Sciences	Earth System science	3502	CL	EN	Journal Article
Z. Xue; A. Feng; P. Yin; D. Xia	2009	Coastal Erosion Induced by Human Activities: A Northwest Bohai Sea Case Study	Journal of Coastal Research	253	//	723-733	//	//	Natural Sciences	Oceanography	171	PL	EN	Journal Article

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G. Miehe; S. Miehe; K. Kaiser; C. Reudenbach; L. Behrendes; D. La; F. Schlütz	2009	How old is pastoralism in Tibet? An ecological approach to the making of a Tibetan landscape	Palaeogeography, Palaeoclimatology, Palaeoecology	276	1-4	130-147	//	//	Natural Sciences, Social Sciences	Human geography, climatology	123	PL	EN	Journal Article
J. Knight; S. Harrison	2009	Periglacial and paraglacial environments: a view from the past into the future	Geological Society, London, Special Publications	320	1	1-4	//	//	Natural Sciences	Physical geography, geology	757	PL	EN	Journal Article
J. Memmott	2009	Food webs: a ladder for picking strawberries or a practical tool for practical problems?	Philos Trans R Soc Lond B Biol Sci	364	1524	1693-9	//	//	Natural Sciences	Ecology	340	PL	EN	Journal Article
R. V. Short	2009	Population growth in retrospect and prospect	Philos Trans R Soc Lond B Biol Sci	364	1532	2971-4	//	//	Applied Sciences, Social Sciences	Medicine, environmental studies	1211	PL	EN	Journal Article
M. R. Allen; D. J. Frame; C. Huntingford; C. D. Jones; J. A. Lowe; M. Meinshausen; N. Meinshausen	2009	Warming caused by cumulative carbon emissions towards the trillionth tonne	Nature	458	7242	1163-6	//	//	Natural Sciences	Atmospheric science	225	PL	EN	Journal Article
J. Rockström; K. Noone; Å. Persson; S. Chapin; E. Lambin; T. Lenton; M. Scheffer; C. Folke; H. J. Schellnhuber; B. Nykvist; C. de Wit; T. Hughes; S. van der Leeuw; H. Rodhe; S. Sörlin; P. Snyder; R. Costanza; U. Svedin; M. Falkenmark; L. Karlberg; R. Corell; V. Fabry; J. Hansen; B. Walker; D. Liverman; K. Richardson; P. J. Crutzen; J. Foley	2009	A safe operating space for humanity	Nature	461	//	471-475	//	//	Natural Sciences	Earth System science	380	PL	EN	Journal Article
B. Riegl; A. Bruckner; S. L. Coles; P. Renaud; R. E. Dodge	2009	Coral reefs: threats and conservation in an era of global change	Ann N Y Acad Sci	1162	//	136-86	//	//	Natural Sciences	Ecology, biology	213	PL	EN	Journal Article
D. J. Reed	2009	Introduction	Journal of Coastal Research	10054	//	fmvii-fmxi	//	//	Natural Sciences, Social Sciences	Oceanography, environmental studies	617	PL	EN	Journal Article
D. Rose	2009	Introduction: Writing in the Anthropocene	Australian Humanities Review	//	47	87	//	//	Humanities	Ecocriticism	10870	CL	EN	Journal Article
M. Bastian	2009	Inventing Nature: Re-writing Time and Agency in a More-than-Human World	Australian Humanities Review	//	47	87	//	//	Humanities	Ecocriticism	118	PL	EN	Journal Article

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J. C. Ryan	2009	‘Plants That Perform For You’? From Floral Aesthetics to Floraesthesis in the Southwest of Western Australia	Australian Humanities Review	//	47	87	//	//	Humanities	Ecocriticism	99	PL	EN	Journal Article
A. P. Cracknell	2009	Sustainability-no hope!" or "Sustainability-no hope?""	Global Climatology and Ecodynamics: Anthropogenic Changes to Planet Earth	//	//	//	Springer-Verlag	Berlin Heidelberg	Social Sciences	Sustainability studies, sociology	117	PL	EN	Book Section
A. P. Cracknell; V. F. Krapivin; C. A. Varotsos	2009	Sustainable development problems in the context of global ecoinformatics	Global Climatology and Ecodynamics: Anthropogenic Changes to Planet Earth	//	//	//	Springer-Verlag	Berlin Heidelberg	Social Sciences	Sustainability studies	74	PL	EN	Book Section
M. Wagner; F.-W. Wellmer	2009	A Hierarchy of Natural Resources with Respect to Sustainable Development—A Basis for a Natural Resources Efficiency Indicator	Mining, Society, and a Sustainable World	//	//	91-121	Springer Verlag	Berlin, Heidelber	Applied Sciences, Social Sciences	Resource management, Sustainability studies	278	PL	EN	Book Section
F. von Geyer	2009	Forward	Mining, Society, and a Sustainable World	//	//	//	Springer Verlag	Berlin, Heidelberg	Social Sciences, Applied Sciences	Sustainability studies, engineering	266	PL	EN	Book Section
O. Slaymaker; T. Pencer; S. Dadson	2009	Landscape and landscape-scale processes as the unfilled niche in the global environmental change debate: an introduction	Geomorphology and Global Environmental Change	//	//	1-36	Cambridge University Press	Cambridge	Natural Sciences	Geology, Environmental science	84	PL	EN	Book Section
K. Kashiwaya; O. Slaymaker; M. Church; O. Slaymaker; T. Spencer; C. Embleton-Hamann	2009	Lakes and lake catchments	Geomorphology and Global Environmental Change	//	//	71-97	Cambridge University Press	Cambridge, UK	Natural Sciences	Limnology	54	PL	EN	Book Section
P. J. Crutzen; A. Mosier; K. Smith; W. Winiwarter	2009	Atmospheric N2O Releases from Biofuel Production Systems: A Major Factor Against “CO2 Emission Savings”: A Global View	Twenty Years of Ozone Decline: Proceedings of the Symposium for the 20th Anniversary of the Montreal Protocol	//	//	//	Springer	Dordrecht, The Netherlands	Natural Sciences	Atmospheric science	1407	PL	EN	Book Section
P. Crutzen	2009	Can We Survive the “Anthropocene” Period?	Project Syndicate	//	//	//	//	https://www.project-syndicate.org/commentary/can-we-survive-the--anthropocene--period (Accessed on July 29, 2021)	Natural Sciences	Geology, Earth System science	10601	CL	EN	Newspaper Article
D. Biello	2009	Grappling with the Anthropocene: Scientists Identify Safe Limits for Human Impacts on Planet	Scientific American	//	//	//	//	https://www.scientificamerican.com/article/scientists-identify-safe-limits-for-human-impacts/ (Accessed on July 29, 2021)	Natural Sciences	Biology, Earth System science	1197	PL	EN	Newspaper Article
S. Lewis	2009	A force of nature: our influential Anthropocene period	The Guardian	//	//	//	//	https://www.theguardian.com/commentisfree/cif-green/2009/jul/23/climate-change-humanity-change (Accessed on July 29, 2021)	Natural Sciences	Geology	5446	CL	EN	Newspaper Article

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J. Candau	2009	H2s = N2	La conscience dans tous ses états: Approches anthropologiques et psychiatriques: cultures et thérapies	//	//	//	Elsevier Masson	Issy-les-Moulineaux	Social Sciences, Applied Sciences	Anthropology, psychiatry	156	PL	FR	Book Section
S. Kapur; P. Zdruli; A. Faz; M. Pagliai; H. Eswaran	2009	The Anthropocene and the Anthroscape: point of view and activities of the WG-LD, IUSS	Advances in Studies on Desertification, 16-18 September	//	//	279-282	University of Madrid	Murcia (Spain)	Natural Sciences, Applied Sciences	Environmental science, resource management	7808	CL	EN	Conference Proceedings
S. Best	2009	Globalization and the Human Empire	Politics of Globalization	//	//	288-312	Sage Publications	New Delhi, India	Social Sciences	Sociology	48	PL	EN	Book Section
K. Lawrence	2009	Toward a Democratic and Collectively Rational Global Commonwealth: Semi-Peripheral Transformation in a Post-Peak World-System	Globalization and the 'New' Semi-Peripheries	//	//	198-212	Palgrave Macmillan	New York	Social Sciences	Political science, sociology	169	PL	EN	Book Section
M. Bolling; O. Bubenzer	2009	Preface	African Landscapes: Interdisciplinary Approaches	//	//	//	Springer	New York	Social Sciences, Applied Sciences	Environmental studies, resource management	1122	PL	EN	Book Section
Ú. O. Spring	2009	Sustainable Development	Handbook on Building Cultures of Peace	//	//	//	Springer	New York	Social Sciences	Sustainability studies	267	PL	EN	Book Section
T. N. Sherratt; D. M. Wilkinson	2009	Big Questions in Ecology and Evolution	//	//	//	//	Oxford University Press,	New York, USA	Natural Sciences	Ecology, biology	101	PL	EN	Book
B. L. Turner II	2009	Land Change (Systems) Science	A Companion to Environmental Geography	//	//	168-180	Blackwell Publishing	Oxford	Natural Sciences	Environmental science	279	PL	EN	Book Section
H. F. Cook; S. A. F. Bonnett; L. J. Pons	2009	Wetland and Floodplain Soils: Their Characteristics, Management and Future	The Wetlands Handbook	//	//	382-416	Blackwell Publishing	Oxford	Natural Sciences, Applied Sciences	Ecology, hydrology	193	PL	EN	Book Section
W. B. Bull	2009	Tectonically Active Landscapes	//	//	//	//	Wiley-Blackwell	Oxford	Natural Sciences	Geology	18	PL	EN	Book
M. Dudley-Flores; T. Gangale	2009	Manufactured on the Moon, Made on Mars - Sustainment for the Earth Beyond the Earth	AIAA SPACE 2009 Conference & Exposition	//	//	//	American Institute of Aeronautics and Astronautics	Pasadena	Social Sciences	Economics, Sustainability studies	185	PL	EN	Conference Paper
E. C. Ellis; K. K. Goldewijk; S. Siebert; D. Lightman; N. Ramankutty	2009	Human Transformation of the Terrestrial Biosphere: Form, Extent, Duration, and Intensity	AGU Fall Meeting	//	//	//	//	San Francisco, USA	Social Sciences, Natural Sciences	Sociology, ecology	2322	CL	EN	Conference Paper
J. P. Obbard	2009	Climate Change - Living in the Anthropocene	Critical Issues in Climate Change and the Kyoto Protocol: Asia and the World	//	//	//	World Scientific Publishing	Singapore	Natural Sciences	Environmental science	1837	PL	EN	Book Section

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M. T. Boykoff	2009	Media representational practices in the Anthropocene Era	Uncertainties in Environmental Modelling and Consequences for Policy Making NATO Science for Peace and Security Series C: Environmental Security	//	//	//	Springer	The Netherlands	Social Sciences	Environmental studies	1143	PL	EN	Book Section
F. Wang; J. Chen	2009	Asia – Eastern Asia	Encyclopedia of Inland Waters	//	//	2250	Elsevier	//	Natural Sciences	Limnology, physical geography	137	PL	EN	Encyclopedia
J. Zalasiewicz; M. Williams	2009	A Geological History of Climate Change	Climate Change: Observed Impacts on Planet Earth	//	//	127-142	Elsevier	//	Natural Sciences	Geology, climatology	684	PL	EN	Book Section
C. Gibson; G. Waitt	2009	Cultural Geography	International Encyclopedia of Human Geography	//	//	99-110	Elsevier	//	Social Sciences	Human geography	90	PL	EN	Encyclopedia
H. Wanner	2009	Vom Holozän zum Anthropozän: Fakten und Fragen zu 10'000 Jahren Klima- und Menschheitsgeschichte	//	//	//	//	Humboldt-Universität zu Berlin, Philosophische Fakultät II	//	Natural Sciences	Climatology	182	PL	DE	Journal Article
K. J. Gregory; I. G. Simmons; A. J. Brazel; J. W. Day; E. A. Keller; A. G. Sylvester; A. Yáñez-Arancibia	2009	Environmental sciences: A Student's Companion	//	//	//	//	Sage	//	Natural Sciences	Environmental science	6	PL	EN	Book
T. M. Powers	2009	Environmental Holism and Nanotechnology	Nanotechnology & Society	//	//	109-123	Springer	//	Social Sciences	Science and Technology studies	264	PL	EN	Book Section
O. R. Young; W. Steffen	2009	The Earth System: Sustaining Planetary Life-Support Systems	Principles of Ecosystem Stewardship: Resilience-Based Natural Resource Management in a Changing World	//	//	295-315	Springer	//	Natural Sciences	Earth System science	322	PL	EN	Book Section
G. P. Kofinas; F. S. Chapin III	2009	Sustaining Livelihoods and Human Well-Being during Social–Ecological Change	Principles of Ecosystem Stewardship: Resilience-Based Natural Resource Management in a Changing World	//	//	295-315	Springer	//	Social Sciences, Applied Sciences	Sociology, Resource managements	86	PL	EN	Book Section
M. Drenthen; J. Keulartz; J. Proctor	2009	Nature in Motion	New Visions of Nature: Complexity and Authenticity	//	//	3-18	Springer	//	Humanities	Philosophy	61	PL	EN	Book Section
M. Beech	2009	Terraforming: The Creating of Habitable Worlds	Astronomers' Universe	//	//	//	Springer	//	Natural Sciences	Earth System science	44	PL	EN	Book
S. Dalby	2009	Peacebuilding and environmental security in the Anthropocene'	Environmental Peacebuilding: Managing Natural Resource Conflicts in a Changing World	//	//	//	Swisspeace	//	Social Sciences	Political science, international studies	1726	PL	EN	Book Section
S. B. Olsen	2009	A Practitioner's Perspective on Coastal Ecosystem Governance	Integrated Coastal Zone Management	//	//	251-265	Wiley-Blackwell	//	Natural Sciences, Social Sciences	Oceanography, ecology	807	PL	EN	Book Section

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J. J. Harrington; B. Yarnal; D. Liverman; B. L. Turner II; B. Yarnal; C. Polsky; J. Obrien	2009	Comparative assessment of human–environment landscape change	Sustainable Communities on a Sustainable Planet	//	//	107-136	//	//	Social Sciences	Environmental studies	80	PL	EN	Book Section
F. O. Sarmiento	2009	Geomorphology of Natural Hazards and Human-induced Disasters in Ecuador	Natural Hazards and Human-Exacerbated Disasters in Latin America	//	//	149-163	//	//	Natural Sciences	Geology	186	PL	EN	Book Section
C. R. Warren	2009	Wilderness: Origins and Evolution of the Concept	International Encyclopedia of Human Geography	//	//	254-259	//	//	Natural Sciences	Ecology	231	PL	EN	Journal Article
M. Quante	2009	The Changing Climate: Past, Present, Future	Relict Species: Phylogeography and Conservation Biology	//	//	9-56	//	//	Natural Sciences	Climatology, Environmental science	440	PL	EN	Book Section
AWG	2009	Newsletter Vol. 1	Anthropocene Working Group of the Subcommission on Quaternary Stratigraphy (International Commission on Stratigraphy)	//	//	//	//	//	Natural Sciences	Geology	9607	CL	EN	Journal Article
R. G. Rayfuse	2009	The Anthropocene, Autopoiesis and the Disingenuousness of the Genuine Link: Addressing Enforcement Gaps in the Legal Regime for Areas Beyond National Jurisdiction	UNSW Law Research Paper	//	2009-2	//	//	//	Humanities	Law	263	PL	EN	Journal Article
B. Yuill; D. Lavoie; D. J. Reed	2009	Understanding Subsidence Processes in Coastal Louisiana	Journal of Coastal Research	SI	54	23-36	//	//	Natural Sciences	Oceanography	96	PL	EN	Journal Article