Research Article

The Anthropocene Borderline Problems

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Understanding anthropogenic global change requires combining geo-ecological and socio-economic insights into borderline problems. The geological notion of an Anthropocene epoch is such a problem. The Anthropocene epoch proposal, made by Earth system scientists more than two decades ago, triggered debates in many scholarly disciplines, and since 2009 geological stratigraphers have sought to find consensus about Anthropocene as part of the Geological Time Scale. Recently the discussion has focussed on three geological concepts (events, epoch, episode) that constitute differently designed geo-societal borderline problems. Although these concepts have comparable scientific foundations, interpreting the underpinning findings and consequent insights raises differences. This essay outlines how specifying anthropogenic global change as a suite of geological events (or an episode) within the Holocene or as a novel epoch following the Holocene, respectively, applies different geo-philosophical perspectives and, therefore, has distinct societal ramifications. These concepts differ substantially in how to situate geosciences in culture and history. Renn's theory of evolution of knowledge provides a methodological framework to examine such differences, for example, in their potential for societal action. The concept of events of anthropogenic global change might favour cooperation among different disciplines. The concept of an epoch, the Anthropocene, seems helpful in causing transformative societal action. Both outcomes are beneficial. Having to choose between them is unfortunate. Therefore, it is explored how both concepts could be applied by distinguishing the geological past from the present, designing the geo-societal borderline problem such that a (geological) Anthropocene would also mark a philosophical paradigm shift consolidating the epistemic status of geological sciences.

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1. Introduction

In 2000 Crutzen and Stroemer (2000) wrote in the newsletter of the International Biosphere Geosphere Programme (IGBP), *"it seems to us more than appropriate to emphasise the central role of mankind in geology and ecology by proposing to use the term ‚anthropocene' for the current geological epoch."* [p.17] because human activities modified the dynamics of the Earth System (referred to in the following as the C/S-proposal). Several years later, Maslin and Lewis insisted, "*there must be room for the formally stratigraphically defined Anthropocene Epoch and the more fluid and broader use of the Anthropocene*" because the philosophical sense of the notion 'Anthropocene' is to stimulate "*debate and discussion within and beyond science about human impact of the Earth System*" (Maslin and Lewis 2015) [p.7]. Like others, these four scientists belong to influential user communities of geologists' concepts but do not themselves conceive these concepts. Like other users of geological terminology, they emphasise that geological time is more than merely a geological subject.

After a sluggish start, the novel notion of an 'Anthropocene' caused ample repercussions in a wide range of natural and social sciences (Brauch 2021) and the public sphere (Sklair 2021a). Likewise, reactions within Earth sciences could be passionate, e.g. (Steffen et al. 2007) (Finney and Edwards 2016). Currently – at the time of writing – the Anthropocene Working Group (AWG) is preparing to propose a global boundary stratotype section and point (GSSP) to specify the base of an Anthropocene (Waters and Turner 2022). The AWG is an *ad hoc* scientific body of the Subcommission on Quaternary Stratigraphy (SQS) of the International Commission on Stratigraphy (ICS), a constituent body of the International Union of Geological Sciences (IUGS). Hence, formally speaking the AWG is a low-level body within an International Non-governmental Organisation (INGO) of geologists. The AWG will make its proposal to the SQS. The final adjudication would be by the IUGS after the ICS approves it.

The large-scale disruptions of Earth's dynamics in the late Holocene are interpreted by some in a different way, for example, as a suite of geological events (Braje and Erlandson 2013) (Braje and Lauer 2020) (Bauer et al. 2021) (Gibbard et al. 2021) (Gibbard et al. 2022). This interpretation is distinct from interpreting the same scientific information as the ecological dawn of a geological epoch (Anthropocene) with a geological base set, for example, at the beginning of the Great Acceleration (Steffen et al. 2015) that has fundamentally shifted the Earth System dynamics (Head et al. 2022a) (Head et al. 2022b). In addition, it was recently proposed to use the concept of a geological episode (Waters et al. 2022). These authors developed the idea of an 'Anthropogenic Modification Episode' of

~50ka duration, including as its climax the 'Great Acceleration Events Array' centred around the mid-twentieth century that provides a base for a geological epoch, the Anthropocene.

Being fully aware of these developments, circumstances and contexts, well-known geological stratigraphers wrote, *"an Anthropocene Event incorporates a substantially wider range of anthropogenic environmental and cultural effects, while at the same time applying more readily in different academic contexts than would be the case with a rigidly defined Anthropocene Series/Epoch"* (Gibbard et al. 2022) [p. 395; my underlining]. These authors invoke specific societal contexts ("*cultural effects"*, *"different academic contexts"*), the relevance (for geological stratigraphy) of which some of them had previously rejected (Finney 2014). After a decade-long debate, this shift of line of reasoning[1] finally acknowledges that non-stratigraphic aspects (e.g., societal contexts) are relevant when analysing the C/S-proposal with methods of geological stratigraphy. This essay deepens this insight by discussing the implications of the alternative Anthropocene-Events-concept or Anthropocene-Epoch-concept[2].

The essence of the Anthropocene-Events-concept emphasises large-scale anthropogenic environmental change traceable in proto-historical and historical times. Instead, the Anthropocene-Epoch-concept highlights a shift in the dynamics of the Earth System. Both concepts lump the human socio-economic agents into the (debatable) notion of an *Anthropos* (implications are discussed, e.g., by Lewis and Maslin (2018)). However, both concepts differ regarding which collective *Anthropos* might be meant, the Anthropocene-Events-concept being more all-embracing than the Anthropocene-Epoch-concept. To illustrate the difference, the Anthropocene-Epoch-concept requires a specified base dated in global human history. A substantial fraction of the Anthropocene literature is devoted to debating this issue (e.g., (Zalasiewicz et al. 2019) [p. 242-286]). Therefore, the Anthropocene-Epoch-concept alludes to hegemonic human agents. For example, allusion would be made to the barons of the slave trade, sugar, and cotton industries (Mokyr 2016) when selecting the Orbis Spike (Lewis and Maslin 2015a) as the marker of the base of the epoch. When choosing the Great Acceleration in the mid-Twentieth Century, allusion would be made to affluent Western societies.

These recent debates, which involve stratigraphic methodologies and geological concepts, indicate that societal contexts are pertinent even for matters of geological stratigraphy. Phrasing like "*applying more readily in different academic contexts"* (Gibbard et al. 2022) [p. 395] convene philosophical perspectives, including values. Although the raw, primary scientific evidence of the basic features of the Earth System does not differ, the interpretation varies, and socio-cultural issues arise. However, the reasons to consider societal contexts when exploring the C/S-proposal are more evolved than

simply *"cultural effects"* or *"academic contexts"*. The most substantial differences between both geological concepts, this essay claims, regard the respective potentials for societal action (e.g., empowerment of citizens to ensure operating within planetary boundaries (Steffen et al. 2015) (Lade et al. 2020)). This feature is essential to distinguish the significance of the Anthropocene as a geological epoch from that implied by a suite of events.

The methodology applied in this essay stems from Renn's theory of the evolution of knowledge (Renn 2020). This theory, developed by scholars of the history of science, offers two abstract concepts, 'borderline problem' and 'economy of knowledge'[3], which serve as the primary analytical lenses in this essay. After discussing the Anthropocene as a geological epoch, as distinct from a suite of events, this essay also touches upon the notion of geological time to illustrate further options for interpretation.

Finally, two caveats are offered regarding matters which could not be developed further in the following. First, many geological concepts are more than mere scientific notions because they nurture societal and cultural views, and they are cultural artefacts as the emergence of geological sciences in human history witnesses (Seddon 1996) (Wilson 2010). The titles of some books publicising Earth System sciences, including geology, may serve as convenient examples: "*How to build a habitable planet"* (Langmuir and Broecker 2012) or *"Timefulness - How Thinking Like a Geologist can help to save the World"* (Bjornerud 2018). Second, conceptualising Anthropocenes relates to philosophical issues (Trischler 2016) (Lundershausen 2018b) (Wallenhorst 2019), such as epistemic authority (Finney 2014) (Castree 2017) or political implications (Angus 2016) (Dryzek 2016), and encroaches on such topics as law and governance (Vidas et al. 2015) (Dryzek and Pickering 2019).

2. Materials and Methods

This study compares two geological concepts of the Anthropocene, the Anthropocene-Events-concept (Gibbard et al. 2021) and the Anthropocene-Epoch-concept (Head et al. 2022b), regarding how they would shape societal action through knowledge about anthropogenic global change. A broad criterion for distinguishing these two concepts is the respective potential for (i) spreading knowledge across social communities, (ii) eventual societal action, and (iii) influencing governance, culture, and institutions.

Examining which concept of an Anthropocene has better potential to activate knowledge for societal action needs a theoretical framework. It is found in Renn's systemic theory of an 'evolution of knowledge' (Renn 2020) that will be applied, given (i) the specific features of the Geological Time Scale (GTS), (ii) the essence of the C/S proposal, and (iii) the geo-societal attributes of the contemporary World-Earth Nexus.

2.1. Evolution of Knowledge

Central to Renn's theory of the evolution of knowledge are the notions of 'borderline problems'[4] and 'economy of knowledge'[5]. These notions will serve as analytical lenses. Given that borderline problems drove the rise of modern earth sciences (geosciences) (Renn 2020) [p. 237-40], the application to geosciences is not novel.

Borderline problems are concepts (or objects) that possess features belonging to different sets of knowledge (Renn 2020) [p.81], which cause the integration and reorganisation of knowledge and drive the evolution of knowledge. The idea of an Anthropocene enshrines a set of borderline problems; for instance, *"[p] anetary boundaries is a concept characteristic of the borderline problems arising between studies of the Earth system and global human society in the Anthropocene"* (Renn 2020) [p. 364]. In this essay's context, the AWG's dealings combine a geological framework (the GTS) with understanding the current shift in the Earth System's dynamics. The outcome is a specific borderline problem, and the AWG's dealings showcase the subsequently triggered dynamics. Regarding the specific knowledge of the communities of geoscientists and Earth scientists, the concept of an Anthropocene develops into further borderline problems when shared with other communities. The enquiry presented in this study concerns which concept of anthropogenic global change (the Anthropocene) is an effective borderline problem and might evolve into transformation knowledge for the Anthropocene[6].

An economy of knowledge is the set of specific societal processes and material circumstances associated with a given knowledge that determine how knowledge mediates institutions, societal practices, and cultures. The knowledge is local (an 'epistemic island, (Renn 2020) [p 4.27]) when the external (material) representation and related societal processes concern only some people. Such knowledge has little societal impact. However, when local knowledge is shared among social groups, it might be transformed and subsequently trigger societal action. The Anthropocene Working Group (AWG) is a part of the material representation (in this instance, the institutionalised scientific-bureaucratic structures of the geological community that relates the AWG to the ICS/IUGS system). It

constitutes a particular local economy of knowledge. Hence, an enquiry of this essay is: which concept of anthropogenic global change (the Anthropocene), epoch or event, leads to an economy of knowledge that renders the idea of an Anthropocene as a shared knowledge of our societies having the potential to trigger societal action? In recent years, insights about anthropogenic global change got increasingly shared. In Renn's terminology, the knowledge became *"distributed within a society or group, constituting a common ground"* (Renn 2020) [p. 430] to be used for taking societal action (e.g., Conference of the Parties, Fridays for Future, Extinction Rebellions [7]).

Based on Renn's theoretical framework outlined above, the geological Anthropocene-Events-concept and Anthropocene-Epoch-concept are two specific borderline problems. They integrate and reorganise knowledge depending on their external (material) representation. For example, the differences in the narratives, practices, and bodies/institutions enshrined in both geological concepts distinguish them. Subsequently, (local) knowledge of anthropogenic global change might evolve (or not), perhaps towards transformation knowledge of groups such as geoscience/Earth-Science scientists, social science/humanities scholars, educational/cultural practitioners, concerned citizens, or public/political institutions. In other words, the framing of anthropogenic global change described as a suite of events or an epoch will determine the likely spread of knowledge about anthropogenic global change through society differently.

Political or cultural institutions both constitute and shape the general societal level that must evolve so that human societies thrive sustainably Biermann (2014), overcoming the *"pathological path dependency in institutions, practices, and ideas that developed under Holocene conditions"* (Dryzek and Pickering 2019) [p. 151]. Hence, both concepts of anthropogenic global change also might be gauged by how likely it is that they will affect the action potential of political or cultural institutions. In the words of an early (critical) reception of the notion of Anthropocene in geological literature: "*Science and society have much to gain from a clear understanding of how humans drive Earth-system processes… Let the Anthropocene retain its rightful place as a focal point in the culture wars over the recognition and interpretation of environmental process* " (Autin and Holbrook 2012) [p.71].

2.2. The C/S-proposal and the GTS

The C/S-proposal of an Anthropocene different from the Holocene emerged among Earth System scientists[8] (Steffen et al. 2020), an eminent scientific community distinct from the geological community that describes the Earth's geological history by the Geological Time Scale (GTS) and the

International Chronostratigraphic Chart (ICC)[9] (Gibbard and Cohen 2008) (Cohen et al. 2013) (Gradstein and Ogg 2020).

Developing the GTS is a long-enduring process undertaken by geological stratigraphers organised in the ICS, a constituent body of the IUGS, which regularly updates the GTS. It took almost a decade after the C/S-proposal for the geological communities to start to debate it formally (Zalasiewicz et al. 2008). The ICS's Subcommission on Quaternary Stratigraphy[10] (SQS) established the AWG[11] in 2009 *„to examine the term [Anthropocene] and its underlying stratigraphic basis in more detail and to consider, and subsequently make recommendations on, its possible formalisation."* A decade later, after an interim assessment result had been assessed in 2016[12], the AWG voted in 2019 with a substantial majority[13] that the Anthropocene should be treated as a standard chronostratigraphic unit having a base defined by one of the stratigraphic signals around the mid-twentieth century of the Common Era. This vote is the first step in further studies (Waters and Turner 2022) and a long decision process involving the ICS and, finally, the IUGS, which might (in future) lead to the Anthropocene being part of the GTS.

The GTS is a significant achievement of the ICS/IUGS system. The building blocks of the GTS are formally agreed upon by a hierarchy of committees installed within the ICS/IUGS system (Finney 2014). This process aims to provide a shared geological terminology supported by agreed protocols. Agreeing on the GTS complements informal intra-disciplinary consensus-building methods of geological disciplines. The most recent update of the online ICC [14] does not mention an Anthropocene, but the most recent compendium describing the GTS (Gradstein and Ogg 2020) introduces the concept (Zalasiewicz et al. 2020).

Irrespective of the specificities of ICS/IUGS protocols and the underpinning sciences, agreeing on the GTS is a societal process. Scientific peers agree about something they might consider 'scientific truth' or a 'suitable professional tool'; individuals, protocols and institutions interact. Using Renn's terminology, a material expression of an economy of knowledge is constituted of features like people, bodies/institutions and protocols/practices.

How geologists find consensus, and the typical epistemological features of such consensus-building processes, might be a fruitful matter for analysis elsewhere (Baker 1999) (Phillips 2012) (Frodeman 2014) (Bjornerud 2018). The study material available to describe this particular economy of knowledge is ample, such as that relating to the debate about the fate of the Quaternary[15] some time ago (Gibbard et al. 2005). For this essay, it is sufficient to consider that most subdivisions of the GTS are placed in

times when no human activity can be traced. Therefore, it should be sufficient to consider intra- and cross-disciplinary academic contexts when contemplating societal processes relevant to establishing these subdivisions. However, the most recent subdivisions of the GTS (Pleistocene, Holocene) overlap with the modern human species' existence; therefore, conceptually, human agency might play a role (Ellis and Ramankutty 2008) (Braje and Erlandson 2013) (Ruddiman et al. 2020). Only the most recent subdivision of the Holocene (GSSP for the Meghalayan at 4250 yr before the year 2000 of the Common Era) falls within human history (as distinct from humanity's prehistoric existence).

The Meghalayan GSSP marks a noticeable climate shift with likely repercussions on human societies (Walker et al. 2018). However, no claim is made that human activity caused this climatic change. The concept of an Anthropocene, and hence the C/S-proposal, fundamentally differs in this respect. The claim inherent to the C/S-proposal is about human agency causing the observed change. Therefore, any chosen specific description of the Anthropocene, whether as events, episode or epoch, and including different potential baselines of an epoch, points to specific societal contexts, just as the initial variant of the C/S-proposal referred to the onset of the industrial revolution in Europe. Therefore, considering merely intra- and cross-disciplinary academic contexts is insufficient when debating the beginning of the Anthropocene.

The core of the C/S-proposal is the end of a period of climatic stability, the Holocene, because the Earth System's dynamics changed (Waters et al. 2016). Notwithstanding persisting geological processes like plate tectonics, volcanism or erosion, human activities influenced the contemporary planetary dynamics (Steffen et al. 2015) (Rosol et al. 2017) (Otto et al. 2020a) (Syvitski et al. 2020) (Steffen 2022), for example, of climate, erosion, hydrology and chemical cycles, leading to the *"exodus from the Holocene"* (Renn 2020) [p.355]. Therefore, observing the effect of human agency is forced on the agenda of geological stratigraphers when analysing the C/S-proposal or refuting it, with wide-ranging ramifications, including philosophical questions.

2.3. Observing geo-societal features (I)

Contemporary societies are social-ecological systems (see, for example, (Donges et al. 2017) (Biggs et al. 2021)) which bind the entire globe into a single entity, the World-Earth Nexus. The instruments of the processes of integration of the human World and Earth are global supply chains, an all-embracing division of labour, a planetary technosphere, and a shared knowledge system leading to a worldwide ergosphere[16] (Haff 2014) (Haff 2017) (Rosol et al. 2017) (Renn 2018) (Otto et al. 2020b). Cycles of

matter, energy, and information link the Earth's socio-economic (sub) systems to the planet's physical and biological (sub) systems. People purposefully design (engineer, build) the economic intersections with planet Earth (Herrmann-Pillath and Hederer 2022) to meet their needs (e.g. food, shelter, health) and preferences (e.g. lifestyle), applying a hegemonic (political) culture (Biermann 2014) (Dryzek and Pickering 2019). Within this broad geo-socio-historic context, Anthropocene science took shape, including place-making for geological thinking.

The particular scientific concept of an Anthropocene as a distinct part of the geological terminology has triggered studies of the implications for education (see, for example (Olvitt 2017) (Murga Menoyo 2021)). Likewise, it has led to studies on public literacy in Earth systems sciences (Wysession et al. 2012) (Marone and Bouzo 2021) or geoscientific culture (Phillips 2012) (Peppoloni and Di Capua 2016) (Bohle et al. 2017) (Nagy and Bohle 2021) (Peppoloni and Di Capua 2022). Quests like these about promoting the educational power or culture of Anthropocene science within contemporary societies are neither academic nor naïve because they raise issues with ethical connotations, such as choices about 'what is promoted', 'to whom' and 'by whom'; hence, asking *cui bono*?'.

The scientific notion of an Anthropocene, coined two decades ago, has since metamorphosed, diversified and gained substantial public visibility (Hamilton 2017), (Angus 2016), (Lewis and Maslin 2018) (Will 2021), (Brauch 2021). Some years ago, Leslie Sklair (2017) qualified the status quo of this development *"rarely has a scientific term moved so quickly into wide acceptance and general use –while not yet officially part of the scientific canon, it is in the first stages of institutionalisation" [p.776].* Since 2017, the number of scientific publications using the notion of an Anthropocene has increased further. Google Scholar lists for the keyword 'Anthropocene' ~60k and ~74k publications for 2000-2016 and 2017-2022, respectively.

When assessed in these societal contexts, the geological Anthropocene-Events-concept and the Anthropocene-Epoch-concept offer contemporary societies two distinct (cultural and political) messages to describe the Anthropocene. The message of the Anthropocene-Events-concept goes like this: "*business as usual since aeons along within a suite of cultural and historical events"*. The message of the Anthropocene-Epoch-concept goes like this: *"no business as usual any longer because a stage shift of the Earth System occurred"*.

The choice between both geological concepts of the Anthropocene also requires an understanding of the related socio-political implications for the societal status of geological sciences because *"[r] egardless of what the International Commission on Stratigraphy decides, the genie is out of the bottle"*

(Lorimer 2017) [p. 123]. One might speculate how the development of the Anthropocene concept shaped the views of the current president (2020-2024) of the IUGS (John Ludden), who closes his 2020 presidential address[17], "*we need to refine and redevelop the IUGS to respond to what the public and governments now expect of the largest global union of geological sciences - the International Union of Geological Sciences"*. 'If the geological community, having been made more visible to a wider audience by the genesis of the Anthropocene, is perceived as failing to rise to the challenge to humanity that the Anthropocene represents, then its public standing and its capacity to help humankind may be seriously impaired.'

2.4. Observing geo-societal features (II)

The AWG is part of a comprehensive scientific process engaged in pursuing a specific scientific question within the framework of state-of-the-art methods, namely applying (geological) stratigraphy to determine a novel aspect of the GTS. Among the diverse communities of scientists studying Earth, the subcommunity gathered as the AWG agreed[18] (with a large majority) in 2019 that the Anthropocene is a distinct epoch (Zalasiewicz et al. 2019). The Holocene, a unique epoch within the Quaternary, should end because human activity shifted the Earth system into a new gear (Waters et al. 2016) (Head et al. 2021) (Steffen 2022). The AWG took this position knowing about claims that human activity likely shaped the Holocene's early development (Ruddiman et al. 2015) (Bauer and Ellis 2018) (Braje 2018) (Ruddiman et al. 2020).

Opinions diverging from the position of the AWG have been presented during the last decades for various reasons, for example, because of specific methodological issues or conceptual considerations (Lewis and Maslin 2015a) (Ruddiman 2018) (Gibbard et al. 2021). The methodological debates were extensive, and the description of the science behind the Anthropocene concept is detailed, including alternatives to majority views (Lewis and Maslin 2018) (Ellis 2018) (Zalasiewicz et al. 2019). It can safely be assumed that methodological issues were tackled according to the state-of-the-art and appropriate rigour, and the AWG delivers scientific assessments of due quality.

The geoscience and Earth science communities do not form a homogeneous entity, as witnessed by the debates accompanying the work of the AWG (Autin and Holbrook 2012) (Finney and Edwards 2016) (Rull 2017) (De Wever and Finney 2018) (Zalasiewicz et al. 2021). To add further complexity, the scientific-bureaucratic process of which the AWG is a part was not designed to debate scientific issues that have repercussions far beyond the participating disciplines. Hence the 'AWG as an instrument',

including the scientific-bureaucratic processes in which it is embedded (i.e., the approval process of the bodies of the ICS/IUGS system), is equipped to assess adequately matters relating to a specific methodology (e.g., The Geological Timescale). This being the case, any deliberation of these bodies about broader issues (e.g., borderline problems) might be less pertinent. The AWG was well aware of such issues (Lundershausen 2018a) (Lundershausen 2018c) when sticking to the limitations of its mandate (Will 2021).

2.5. Observing geo-societal features (III)

There is a compelling need for human activities to be symbiotic with planet Earth (Barrière et al. 2019) to mitigate the impact of the Great Acceleration of anthropogenic global change since World War II, including rethinking *"the place of political economy in relation to the Earth System"* (Dryzek and Pickering 2019) [p. 5]. Triggering human activities that are symbiotic with planet Earth needs a compelling narrative and metaphor. Hence, associated metaphors may be used to compare the Anthropocene-Events-concept and the Anthropocene-Epoch-concept.

The climate stability of the Holocene epoch, following the highly variable climate of the Pleistocene, spurred distinctive cultural adaptations of our species (Gibbard and Head 2020). Climate stability came paired with profound cultural change. The domestication of animal and plant species contributed to the discovery of agriculture at various locations, prompting a rise of urban civilisations and a conversion of *biomes* into *anthromes* (Ellis et al. 2010) (Ellis 2011). This long-term anthropogenic regional change can be interpreted as proto-historical and historical processes which left distinctive marks in the fossil, archaeological and geological records. Accordingly, it is argued that the notion of the Anthropocene should guide a holistic understanding of a multistage human activity impacting planet Earth (Braje 2015) (Kunnas 2017), (Lewis and Maslin 2018). Conceptually, within such a perception of continuity, contemporary citizens could nonetheless be conceived of as having unprecedented power (Hamilton 2017), including the responsibilities this brings and the political institutions it requires (Dryzek and Pickering 2019).

When taking the Anthropocene-Events-perspective, it gets plausible to concede that a steadily unfolding anthropogenic global change resulted from successive socio-political 'historical successes', for example, the 'Columbian exchange' (Boivin et al. 2012) (Braje and Erlandson 2013). Consequently, anthropogenic global change is tamed as a framework of shifting baselines (Soga and Gaston 2018), including framing the Great Acceleration as a phase within a much longer path-dependent

incremental change instead of a singular state-shift of Earth System dynamics (Waters et al. 2016) (Head et al. 2021). The qualitative disturbance of Earth's global carrying capabilities by the recent massive quantitative affluence of a part of the human population is eclipsed (Steffen 2022) (Lade et al. 2020) (Otto et al. 2020a). This view is a choice with political connotations, including denial.

The C/S-proposal, namely the end of the Holocene, marking a state-shift of Earth System dynamics, justifies the Anthropocene-Epoch-concept within the logic of the GTS. Likewise, it might indicate a necessity to alter human institutions because the *"[political] ideas that developed under Holocene conditions …, did not recognise the possibility that the Earth system could be anything other than benign (indeed, mostly did not recognise the Earth system at all)"* (Dryzek and Pickering 2019) [p. 151]. The Anthropocene-Events-concept is less explicit regarding specific human agency than the epoch concept, and instead, it includes a broad suite of diverse human practices contributing to Earth System processes (Bauer and Ellis 2018). Hence, the choice of an Anthropocene as a suite of geological events versus a geological epoch implies socio-political, cultural, and ethical views.

Despite these significant differences, the two concepts of an Anthropocene share the rationale of an inclusive and multidisciplinary scientific understanding of anthropogenic global change so that human societies may thrive sustainably. Notwithstanding, this rationale is coupled with inquiring about the specific human agent (s) responsible for modulating or ending the Holocene. Unfortunately, for both concepts, the sub-notion *Anthropos* fails explicitly to name them, obscures their identity and short-circuits debate about it (Baskin 2019). That said, the timing for the onset of an epoch or events would implicitly encode a particular primary human agent. Dating the beginning of an epoch indicates which hegemonic human agents were responsible. In this way, an epoch Anthropocene epoch based in the mid-twentieth century would highlight the role of affluence and prowess of a part of the human population. Alternatively, multistage Anthropocene Events/Episode concepts would brush over this socio-economic feature.

3. Discussion

Renn's theory provides a framework to situate the evolution of geoscientific knowledge in societal contexts (Renn 2020). For example, climate change is a borderline problem that interfaces Earth System sciences, culture, economy, and governance. Initially, climate science was a specific local knowledge of a small group of researchers, an epistemic island. Subsequently, within decades, climate science evolved into transformative knowledge used by a global community of citizens, decision

takers and institutions. This process happened because climate science was part of an effective economy of knowledge with an effective external material representation, for example, an inter-governmental advisory body called the Intergovernmental Panel on Climate Change (IPCC).

Compared to the borderline problem of climate change and the IPCC, the AWG has dealt on a more modest societal scale. However, anthropogenic global change is a broader subject than climate change, climate change being an essential constituent of global change. Therefore, the concept of a new geological epoch (established using proper stratigraphic methods and endorsed by the IUGS), the Anthropocene, could be a noticeable contribution to handling climate change issues.

Scholars of international politics, law and global (Earth System) governance argue that the political institutions of the Holocene are insufficient for the Anthropocene (Biermann 2014) (Vidas et al. 2015) (Dryzek and Pickering 2019). The AWG being aware of the broader context of its subject, acknowledges the specific economy of knowledge to which it belongs (Will 2021), including the particular constraints of the ICS/IUGS system. Therefore the AWG opted to tackle a limited borderline problem solely combining knowledge from Earth System science and geological stratigraphy, leaving aside other knowledge (Lundershausen 2018a), for example, insights from social/historical sciences (Dyer-Witheford 2018) (Castree 2021).

3.1. Geoscientific Borderline Problems

Two overlapping concepts have been formulated: the geological concepts of ‘anthropogenic global change as a suite of geological events’ and ‘anthropogenic global change as a geological Anthropocene epoch’. The respective borderline problems can be distinguished through Renn’s theory, using concepts like local knowledge, economies of knowledge, and external representations (e.g., publications, bodies, institutions, networks, and associations).

First, some researchers (Lewis and Maslin 2015b) (Bauer and Ellis 2018) (Kunnas 2021) (Bauer et al. 2021) argue that the Anthropocene-Events-concept would side-line interdisciplinary quarrels the Anthropocene-Epoch-concept evokes, such as finding a single marker in the geological record to define the Anthropocene's start. Likewise, Gibbard and coworkers (Gibbard et al. 2021) describe the Anthropocene-Events-concept as fruitful for developing the science of anthropogenic global change[19]. Hence, they sketch a borderline problem within sciences. For them, the Anthropocene-Epoch-concept comes with difficulties[20] or missed opportunities[21], which may hinder intra-disciplinary cooperation. For example, the Anthropocene-Events-concept could apply to all

disciplines of Quaternary research (Head and Gibbard 2015) (Gibbard and Head 2020) that is organised internationally by the International Union for Quaternary Research[22], a peer of the IUGS, both being members of the International Science Council[23].

Second, Head and coworkers (Head et al. 2021) advocate the Anthropocene-Epoch-concept based solely on the understanding that a system shift[24] of the dynamics of the Earth System is unfolding (Folke et al. 2021) (Otto et al. 2020b) that should be represented in the structure of the Geological Time Scale. The authors side-line other features of the history of anthropogenic global change. It is in that particular vein of thought that the AWG agreed on an Anthropocene as a geological epoch different from the Holocene.

The AWG, when opting for the Anthropocene-Epoch-concept, gather into the associated borderline problem (i) a discipline-specific approach (i.e., the Geological Time Scale), (ii) a systems perspective of how planet Earth functions (i.e., Earth System Sciences), (iii) a robust human component (i.e., the Great Acceleration), and (iv) challenging views on developments of the Earth System (i.e., system shift). The borderline problem thus formulated is complex but clear-cut, including a distinct choice regarding the socio-economic context by specifying the base of the Anthropocene in the mid-Twentieth Century[25].

3.2. Comparing Borderline Problems: Epoch v. Event,

The epoch and the event concepts of anthropogenic global change describe two specific epistemic islands and sets of local knowledge. Both concepts seem suitable for contemporary societies to acquire (some) system knowledge "*required to understand complex systems like the sphere of the Earth system and its human components*" (Renn 2020) [p. 430]. Nevertheless, the two concepts differ regarding the perimeters of the science thy aggregate, the related economies of knowledge, and likely the potential for societal action.

The Anthropocene-Events-concept considers it essential to identify a suite of cumulative incremental human interventions in the Earth System during the Holocene. These interventions are factual, and the event concept places them on comparable footing. The final stroke, the Great Acceleration, is not singled out, and this kind of normalisation adjusts the perceived magnitude of the current stage shift in the dynamics of the Earth System. Presenting the Anthropocene as a suite of events promotes a narrative of *"human business as usual"*. Some philosophical views might favour this consequence, e.g. (Asafu-Adjaye et al. 2015) (Braje 2018).

The reactions of diverse scholarly communities and parts of the general public (Robin et al. 2014) (Jagodzinski 2018) (Dryzek and Pickering 2019) (Sklair 2021b) (Brauch 2021). (Rosol 2021) to the Anthropocene-Epoch-concept corroborate that it is an efficient borderline problem. The Anthropocene-Epoch-concept, promoting the narrative *"no business as usual any longer because a stage-shift of the Earth System occurred"*, has triggered a noticeable evolution of knowledge, including showing potential for societal action. A related economy of knowledge is discernible, including diverse (scientific, cultural, and political) bodies (see, for example (Jagodzinski 2018) (Thomas 2022)).

Shaping societies' system knowledge requires processes and circumstances favourable to appropriate knowledge outside the sciences. Local (scientific) knowledge must evolve into transformation knowledge to shape societies' knowledge systems. It is challenging to establish *ex-post* the extent to which gain or loss of impetus to shape extra-science knowledge systems might have depended on how anthropogenic global change was conceptualised. However, it seems questionable that a hypothetical proposal of a suite of events within the Holocene, even if made by a Nobel Prize Laureate like Paul Jozef Crutzen, would have gained attention outside some scientific circles. Likewise, such a hypothetical proposal would not have caused the establishment of a distinct ICS/IUGS task group, the AWG, that emerged as an effective external representation of knowledge, including reaching out to cultural and public spheres (Sklair 2021b).

Considering the work of the AWG, the balance of geoscientific arguments seems ready for a decision to be made. Maintaining the GTS in its present form looks less likely than not, given the findings of the AWG (e.g., (Zalasiewicz et al. 2017) (Zalasiewicz et al. 2019))[26]. However, one might still expect that, after the AWG agrees on an Anthropocene GSSP, it will be debated whether the Anthropocene should be a stage/age of the Holocene, the Anthropoyan.

3.3. Redesigning the Anthropocene Borderline Problem

Notwithstanding upcoming debates, the Anthropocene-Epoch-concept is a viable scientific option. Because it might hinder cross-disciplinary cooperation, well-known researchers challenge it. Although this potential downside seems to show an inward-looking (or even parochial) concern, it is worth tackling. Therefore, it is explored in the following whether the benefits of both concepts could be obtained by modifying the underlying borderline problem.

Peer consensus is essential in geological sciences when defining terminology, as, for example, the process of stratigraphers agreeing on the fate of the Quaternary[27] illustrates. Also, the suggestion

(Waters and Turner 2022) of an Anthropogenic Modification Episode climaxing in the Great Acceleration Events Array in the mid-twentieth century shows how consensus-seeking among stratigraphers happens. Conceivably, the Anthropocene Episode approach is a good compromise within geosciences. Considering broader societal messages, the Anthropocene-Episode-approach presents anthropogenic global change as a continuum, ending with a narrative like this: *"...and we broke it, finally"*. Hence, the episode narrative refers to the crucial shift in the dynamics of the Earth System, although embedded in the primary message of systemic continuity. The latter is an established Anthropocene discourse (Bonneuil and Fressoz 2013) (Dalby 2015).

The formulation of the episode-narrative, and indeed the events-narrative, has been driven by the mismatch between the essence of the Anthropocene notion and the constraints of achieving an intra-geological consensus among peers about proper geological terminology using established methods.' The essence of *"the Anthropocene concept [is]... about the human impact of the Earth System, which is the true paradigm shift in our thinking"* (Lewis and Maslin 2015b) [p.7]. Therefore, for the purpose of generating transformation knowledge, any geological meaning should come second to the philosophical meaning. However, the former should not be compromised, which might be achieved as illustrated now.

The (cultural) notion of geological time and the (scientific) methodology of a geological time scale are not synonymous. This feature can be used. The International Chronostratigraphic Chart (ICC) includes an unsuspicious parameter called 'present' that currently has no specific geological meaning (Bohle and Bilham 2019). The parameter relates geological and historical time, which *mutatis mutandis* is what any notion of an Anthropocene conveys. Recently the marker was moved from 1950 to 2000 CE for convenience (Gradstein and Ogg 2020) [p. 11], although other years could be selected.

It is an option to give the ICC parameter 'present' the meaning of separating the geological past from the present. At this 'point zero' in the ICC, set at a date in human history, the 'geological past' would end, and the 'geological present' would begin. The AWG's findings might specify the 'point zero' date in the ICC.

Understood as a borderline problem, the 'point zero' in the ICC would acknowledge the impact of the Great Acceleration and the state shift of the dynamics of the Earth System, implement the C/S-proposal, and recognise the beginning of a geological present clearly distinct from the past. Subsequently, the Holocene would be the last epoch of the geological past, including those Anthropocene events occurring before the selected date, and the geological present might be called the

Anthropocene (or stay nameless if ICS/IUGS prefers). The graphical adjustment of the ICC would be subtle, but the message would be strong and unmistakable. The Phanerozoic, Cenozoic, and Quaternary would cross the 'point zero' line (currently marked 'present') in the ICC. An Anthropocene could follow the Holocene (the 'most recent'), separated by the line 'present', which might be rebaptised as the Great Acceleration Event.

The thus redesigned borderline problem of the geological Anthropocene concept would keep the most vital philosophical insight, the state shift of the dynamics of the Earth System, while preserving the alternative geological concepts describing anthropogenic global change, including the respective expected benefits.

Some might perceive this (provocative) illustrative option for adjusting the GTS as suggesting breaking the central paradigm of the stasis of geological processes (Rudwick 1998). However, ending the geological past at a specific moment in human history would be a (geo-philosophical) convention to structure a time scale (the ICC) and would say nothing about geological processes and broader conceptions of geological time. A specific feature would be selected to specify a convenient 'point zero' for an established scale (the ICC), just as the melting point of water sets 'point zero' of the Celsius temperature scale.

The conventional alternative to the suggested option would be to settle either on the Anthropocene-Events-concept or the Anthropocene-Epoch-concept. Opting for the former has the taste of being parochial and the likely consequence that other scientific communities than geology will take the epistemological leadership in how to name the present (and future) stage of the Earth System. However, distinguishing explicitly between the geological past and present would be a powerful message from the geological community, taking epistemological leadership. Possibly, it would be a message more fundamental than adding the epoch Anthropocene to the current ICC.

4. Conclusion

This essay makes the case that characterising anthropogenic global change requires more than assessing geoscientific features, for example, through methods of geological stratigraphy. It is discussed that determining anthropogenic global change as a suite of geological events, a geological episode, or a geological epoch implies taking different views on human agency. The appraisals underpinning the notions of event, episode or epoch prioritise selected cultural, historical, socio-economic and geological features. Therefore, describing global anthropogenic change in terms of

geological concepts implies tackling geo-societal borderline problems, which are complex and involve both geoscientific and philosophical statements, for example.

Unsurprisingly, alternative geological terminologies have been proposed – epoch (Head et al. 2022a) (Head et al. 2022b), event (Gibbard et al. 2021) (Gibbard et al. 2022), episode (Waters et al. 2022). The first notion prioritises a scientifically sound concept of an Anthropocene Epoch marking the shift of the Earth System dynamics because it facilitates political and cultural change and addresses any scientific and public community without an intermediary. The second notion prioritises a scientifically sound concept of a suite of events of anthropogenic global change because it facilitates scientific cooperation. The third option of conceiving an episode was made after reviewing geological terminology, and it pictures a *crescendo* of events culminating in the Great Acceleration. The episode concept does not enlarge the options available to associate societal implications with the (geological) Anthropocene compared to the 'epoch-event' alternative. The episode notion might be seen as an intra-disciplinary compromise downsizing the emphasis of epochal change.

The choice, epoch v. events/episode, seems unfortunate - taking sides, either facilitating political and cultural change or scientific cooperation. Therefore, this essay illustrates how this unfortunate choice between alternatives could be avoided by distinguishing geological past and present. Namely, the AWG findings might specify the end of the Holocene, the final epoch of the geological past. The concept of geological events of anthropogenic global change would apply within the Holocene (termed, if one likes, as "Anthropogenic Modification Events" (Waters et al. 2022)) to illustrate how human activity incrementally influenced planet Earth. Correspondingly, as suggested by Maslin and Lewis (2015), the geological present, the Anthropocene, would mark the shifts caused by the Great Acceleration regarding human impact on planet Earth, altered Earth System dynamics, and philosophical paradigms.

Footnotes

[1] In hindsight, some earlier publications seem to favour choices other than an Anthropocene Epoch because of academic acceptance of „*many Holocene geoscientists and archaeologists who do not accept that the Holocene has ended*" (Gibbard and Walker 2014) [p.35].

[2] In the following, 'Anthropocene-Events-concept' and 'Anthropocene-Epoch-concept' will be used as shorthands; it is acknowledged that the suffix 'cene' as a dedicated meaning in geological

stratigraphy that the shorthands circumvent.

[3] Renn's notion 'economy of knowledge' should not be confounded with the habitual term 'knowledge economy' as a shorthand for particular economic system.

[4] Borderline problems are (Renn 2020) [p427]: "Challenging objects or problems that belong to multiple distinct systems of knowledge. Borderline problems put these systems into contact (and sometimes into direct conflict) with each other, potentially triggering their integration and reorganisation."

[5] An economy of knowledge refers to (Renn 2020) [p. 151-153], "all societal processes pertaining to the production, preservation, accumulation, circulation, and appropriation of knowledge mediated by its external representation" [p.429], and external (material) representation to: "any aspect of the material culture or environment of a society that may serve as an encoding of knowledge", [p. 224]

[6] „Knowledge concerned with the collective and individual actions to ensure a sustainable life in the Anthropocene" (Renn 2020) [p. 430].

[7] UN Conference of the Parties (COP) | UNFCCC; https://fridaysforfuture.org/; https://rebellion.global/

[8] "*The Anthropocene as proposed in 2000 had two meanings. In a geological context, Crutzen proposed the Anthropocene as a new epoch to follow the Holocene in the Geological Time Scale (GTS)140. In an Earth System context, the Anthropocene was proposed as a very rapid trajectory away from the 11,700-year, relatively stable conditions of the Holocene60. The two definitions, although not identical, have much in common"* [Box 2, p.60]

[9] https://stratigraphy.org/timescale/

[10] https://stratigraphy.org/files/ICS_SubcommReport2009.pdf [p.5]

[11] https://stratigraphy.org/files/ICS_AnnReport2009.pdf [p.14]

[12] *„a proposal for formal definition could be ready in c. 2-3 years time, the preceding period being an establishment of the narrative concerning this possible division"* https://stratigraphy.org/files/ICS-Business-IGC35.pdf

[13] http://quaternary.stratigraphy.org/working-groups/anthropocene/

[14] https://stratigraphy.org/news/143

[15] http://quaternary.stratigraphy.org/definitions/correspondence/

[16] *"With their rapidly evolving culture, humans have introduced an "ergosphere" (a sphere of work, as well as of technological and energetic transformations) as a new global component of the Earth system, in addition to the lithosphere, the hydrosphere, the atmosphere, and the biosphere, thus changing the overall dynamics of the system.*" (Renn 2018) [p. 7],

[17] https://www.iugs.org/__files/ugd/f1fc07_ca038c357c7a41e7914ab9ff35e90118.pdf [p.8]

[18] http://quaternary.stratigraphy.org/working-groups/anthropocene/

[19] "A shift to a geological event framework is a solution that... offers a way forward through conceptual and disciplinary barriers by freeing the concept from the constraints of geological formalisation..., an events framework will also be more congruent with social science and humanities research.... Acknowledging the Anthropocene as an event combines geological, ecological, and archaeological approaches and their respective scales of analysis, encouraging interdisciplinary collaboration... in a field of research where scholars across the sciences can more productively work together using a common language" (Gibbard et al. 2021) [p.6,7]

[20] „disciplinary and conceptual confusion and conflict over the designation" (Gibbard et al. 2021)[p.6]

[21] "an events designation will provide a more comprehensive, flexible, and broadly helpful paradigm for formal definition of human impacts on Earth that fits both geological systematics and the sciences in general, while allowing for better resolution on the various social and cultural practices that influence Earth" (Gibbard et al. 2021) [p.6]

[22] https://www.inqua.org

[23] Homepage - International Science Council

[24] "Earth System depicts a planetary trajectory that departed from the envelope of Holocene variability in the mid-20th century and argues for an Anthropocene at the rank of series/epoch... represent[ing] a complex planetary response to human impact involving lags, abrupt shifts and feedback loops. Nevertheless, ...around the mid-20th century, many important Earth System parameters began strong trajectories away from Holocene norms.... Human impacts have a long and attenuated history that can be traced into the Late Pleistocene, but they did not become an overwhelming global environmental force until the mid-20th century" (Head et al. 2021) [p.14].

[25] Alternative ‘dates of onset’ of variants of the Anthropocene-Epoch-concept indicate different socio-economic contexts. Each describes a specific borderline problem, namely a different combination of historical/cultural incidents, cultural, and societal matters, and geoscientific features.

[26] Conceptually, the options exist because the ICS/IUGS might conclude that stratigraphic methods cannot establish the Anthropocene as epoch, rejecting the findings of the AWG. Subsequently, the established geological nomenclature would persist.

[27] http://quaternary.stratigraphy.org/definitions/correspondence/

References

- Angus I (2016) Facing the Anthropocene - Fossil Capitalism and the Crisis of the Earth System. Monthly Review Press, New York
- Asafu-Adjaye J, Blomqvist L, Brand S, et al (2015) An Ecomodernist Manifesto. Oakl Breakthr Inst 31
- Autin WJ, Holbrook JM (2012) Is the Anthropocene an issue of stratigraphy or pop culture? GSA Today 22:60–61. https://doi.org/10.1130/G153GW.1
- Baker VR (1999) Geosemiosis. Geol Soc Am Bull 111:633–645. https://doi.org/10.1130/0016-7606(1999)111<0633:G>2.3.CO;2
- Barrière O, Behnassi M, David G, et al (2019) Coviability of Social and Ecological Systems: Reconnecting Mankind to the Biosphere in an Era of Global Change. Springer International Publishing, Cham
- Baskin J (2019) Global Justice and the Anthropocene: Reproducing a Development Story. In: Biermann F, Lövbrand E (eds) Anthropocene Encounters: New Directions in Green Political Thinking. Cambridge University Press, pp 150–168
- Bauer AM, Edgeworth M, Edwards LE, et al (2021) Anthropocene: event or epoch? Nature 597:332–332. https://doi.org/10.1038/d41586-021-02448-z
- Bauer AM, Ellis EC (2018) The Anthropocene Divide: Obscuring Understanding of Social-Environmental Change. Curr Anthropol 59:209–227. https://doi.org/10.1086/697198
- Biermann F (2014) Earth System Governance World Politics in the Anthropocene. The MIT Press, London

- Biggs R, Vos A de, Preiser R, et al (2021) The Routledge Handbook of Research Methods for Social-Ecological Systems. Routledge, London
- Bjornerud M (2018) Timefulness - How Thinking like a Geologist can help to save the World. Princeton University Press, Princeton
- Bohle M, Bilham N (2019) The 'Anthropocene Proposal': A Possible Quandary and A Work-Around. Quaternary 2:19. https://doi.org/10.3390/quat2020019
- Bohle M, Sibilla A, Casals I Graells R (2017) A Concept of Society-Earth-Centric Narratives. Ann Geophys 60:. https://doi.org/10.4401/ag-7358
- Boivin N, Fuller DQ, Crowther A (2012) Old World globalization and the Columbian exchange: Comparison and contrast. World Archaeol 44:452–469. https://doi.org/10.1080/00438243.2012.729404
- Bonneuil C, Fressoz J-B (2013) L'événement Anthropocène - La terre, l'histoire et nous. Le Seuil
- Braje TJ (2018) The Anthropocene as Process: Why We Should View the State of the World through a Deep Historical Lens. Rev Estud e Pesqui Avançadas do Terc Set 1:04. https://doi.org/10.31501/repats.v1i1.9927
- Braje TJ (2015) Earth Systems, Human Agency, and the Anthropocene: Planet Earth in the Human Age. J Archaeol Res 23:369–396. https://doi.org/10.1007/s10814-015-9087-y
- Braje TJ, Erlandson JM (2013) Looking forward, looking back: Humans, anthropogenic change, and the Anthropocene. Anthropocene 4:116–121. https://doi.org/10.1016/j.ancene.2014.05.002
- Braje TJ, Lauer M (2020) A Meaningful Anthropocene?: Golden Spikes, Transitions, Boundary Objects, and Anthropogenic Seascapes. Sustainability 12:6459. https://doi.org/10.3390/su12166459
- Brauch HG (2021) The Anthropocene Concept in the Natural and Social Sciences, the Humanities and Law – A Bibliometric Analysis and a Qualitative Interpretation (2000–2020). In: Paul Crutzen and the Anthropocene; A new Epoch in Earth's History. Springer International Publishing, Cham (CH), pp 289–438
- Castree N (2017) Speaking for the 'people disciplines': Global change science and its human dimensions. Anthr Rev 4:160–182. https://doi.org/10.1177/2053019617734249
- Castree N (2021) Framing, deframing and reframing the Anthropocene. Ambio. https://doi.org/10.1007/s13280-020-01437-2
- Cohen KM, Finney SC, Gibbard PL, Fan J-X (2013) The ICS International Chronostratigraphic Chart. Episodes 36:199–204. https://doi.org/10.18814/epiiugs/2013/v36i3/002
- Crutzen PJ, Stroemer EF (2000) The 'Anthropocene'. Glob Chang Newsl 41:17–18

- Dalby S (2015) Framing the Anthropocene: The good, the bad and the ugly. Anthr Rev 3:1–19. https://doi.org/10.1177/2053019615618681
- De Wever P, Finney S (2018) The anthropocene: A geological or societal subject? Biodivers Evol 251–264. https://doi.org/10.1016/B978-1-78548-277-9.50014-0
- Donges JF, Winkelmann R, Lucht W, et al (2017) Closing the loop: Reconnecting human dynamics to Earth System science. Anthr Rev 4:151–157. https://doi.org/10.1177/2053019617725537
- Dryzek JS (2016) Earth System Governance: World Politics in the Anthropocene. By Frank Biermann. Cambridge, MA: MIT Press, 2014. 260p. Perspect Polit 14:176–178. https://doi.org/10.1017/S153759271500345X
- Dryzek JS, Pickering J (2019) The politics of the Anthropocene. Oxford University Press, Oxford
- Dyer-Witheford N (2018) Struggles in the Planet Factory: Class Composition and Global Warming. In: Interrogating the Anthropocene. Springer International Publishing, Cham, pp 75–103
- Ellis EC (2018) Anthropocene: a very short introduction. Oxford University Press, Oxford, UK
- Ellis EC (2011) Anthropogenic transformation of the terrestrial biosphere. Philos Trans R Soc A Math Phys Eng Sci 369:1010–1035. https://doi.org/10.1098/rsta.2010.0331
- Ellis EC, Goldewijk KK, Siebert S, et al (2010) Anthropogenic transformation of the biomes, 1700 to 2000. Glob Ecol Biogeogr 19:589–606. https://doi.org/10.1111/j.1466-8238.2010.00540.x
- Ellis EC, Ramankutty N (2008) Putting people in the map: anthropogenic biomes of the world. Front Ecol Environ 6:439–447. https://doi.org/10.1890/070062
- Finney SC (2014) The 'Anthropocene' as a ratified unit in the ICS International Chronostratigraphic Chart: fundamental issues that must be addressed by the Task Group. Geol Soc London, Spec Publ 395:23–28. https://doi.org/10.1144/SP395.9
- Finney SC, Edwards LE (2016) The "Anthropocene" epoch: Scientific decision or political statement? GSA Today 26:4–10. https://doi.org/10.1130/GSATG270A.1
- Folke C, Polasky S, Rockström J, et al (2021) Our future in the Anthropocene biosphere. Ambio 50:834–869. https://doi.org/10.1007/s13280-021-01544-8
- Frodeman R (2014) Hermeneutics in the Field: The Philosophy of Geology. In: Babich B, Ginev D (eds) The Multidimensionality of Hermeneutic Phenomenology. Contributions to Phenomenology. Springer, Cham, pp 69–79
- Gibbard P, Cohen KM (2008) Global chronostratigraphical correlation table for the last 2.7 million years. Episodes 31:243–247. https://doi.org/10.18814/epiiugs/2008/v31i2/011

- Gibbard P, Walker M, Bauer A, et al (2022) The Anthropocene as an Event, not an Epoch. J Quat Sci 37:395–399. https://doi.org/10.1002/jqs.3416
- Gibbard PL, Bauer AM, Edgeworth M, et al (2021) A practical solution: the Anthropocene is a geological event, not a formal epoch. Episodes 1964:1–9. https://doi.org/10.18814/epiiugs/2021/021029
- Gibbard PL, Head MJ (2020) The Quaternary Period. In: Geologic Time Scale 2020. Elsevier, pp 1217–1255
- Gibbard PL, Smith AG, Zalasiewicz JA, et al (2005) What status for the Quaternary? Boreas 34:1–6. https://doi.org/10.1080/03009480510012854
- Gibbard PL, Walker MJC (2014) The term 'Anthropocene' in the context of formal geological classification. In: Geological Society, London, Special Publications. pp 29–37
- Gradstein FM, Ogg JG (2020) The Chronostratigraphic Scale. In: Geologic Time Scale 2020. Elsevier, pp 21–32
- Haff PK (2014) Humans and technology in the Anthropocene: Six rules. Anthr Rev 1:126–136. https://doi.org/10.1177/2053019614530575
- Haff PK (2017) Being human in the Anthropocene. Anthr Rev 4:103–109. https://doi.org/10.1177/2053019617700875
- Hamilton C (2017) Defiant Earth - The Fate of Humans in the Anthropocene. Wiley, Polity Press, Cambridge
- Head MJ, Gibbard PL (2015) Formal subdivision of the Quaternary System/Period: Past, present, and future. Quat Int 383:4–35. https://doi.org/10.1016/j.quaint.2015.06.039
- Head MJ, Steffen W, Fagerlind D, et al (2021) The Great Acceleration is real and provides a quantitative basis for the proposed Anthropocene Series/Epoch. Episodes 1–18. https://doi.org/10.18814/epiiugs/2021/021031
- Head MJ, Zalasiewicz JA, Waters CN, et al (2022a) The proposed Anthropocene Epoch/Series is underpinned by an extensive array of mid-20th century stratigraphic event signals. J Quat Sci 1–7. https://doi.org/10.1002/jqs.3467
- Head MJ, Zalasiewicz JA, Waters CN, et al (2022b) The Anthropocene is a prospective epoch/series, not a geological event. Episodes. https://doi.org/10.18814/epiiugs/2022/022025
- Herrmann-Pillath C, Hederer C (2022) A New Principles of Economics. Routledge, London
- Jagodzinski J (ed.. (2018) Interrogating the Anthropocene. Springer International Publishing, Cham

- Kunnas J (2017) Storytelling: From the early Anthropocene to the good or the bad Anthropocene. Anthr Rev 4:136–150. https://doi.org/10.1177/2053019617725538
- Kunnas J (2021) Anthropocene event idea is empowering. Nature 598:257–257. https://doi.org/10.1038/d41586-021-02753-7
- Lade SJ, Steffen W, de Vries W, et al (2020) Human impacts on planetary boundaries amplified by Earth system interactions. Nat Sustain 3:119–128. https://doi.org/10.1038/s41893-019-0454-4
- Langmuir C, Broecker W (2012) How to build a habitable planet? Princeton University Press, Princeton
- Lewis SL, Maslin MA (2018) The Human Planet - How We Created the Anthropocene. Penguin Random House, London
- Lewis SL, Maslin MA (2015a) A transparent framework for defining the Anthropocene Epoch. Anthr Rev 2:128–146. https://doi.org/10.1177/2053019615588792
- Lewis SL, Maslin MA (2015b) Defining the Anthropocene. Nature 519:171–180. https://doi.org/10.1038/nature14258
- Lorimer J (2017) The Anthropo-scene: A guide for the perplexed. Soc Stud Sci 47:117–142. https://doi.org/10.1177/0306312716671039
- Lundershausen J-G (2018a) Marking the boundaries of stratigraphy: Is stratigraphy able and willing to define, describe and explain the Anthropocene? Geo Geogr Environ 5:e00055. https://doi.org/10.1002/geo2.55
- Lundershausen J (2018b) Engaging Anthropocene Science : Perspectives on the role of geoscientific practices on Anthropocene debates. Tübingen
- Lundershausen J (2018c) The Anthropocene Working Group and its (inter-) disciplinarity. Sustain Sci Pract Policy 14:31–45. https://doi.org/10.1080/15487733.2018.1541682
- Marone E, Bouzo M (2021) Humanistic Geosciences: A Cultural and Educational Construction. In: Geo-societal Narratives. Springer International Publishing, Cham, pp 201–212
- Maslin MA, Lewis SL (2015) Anthropocene: Earth System, geological, philosophical and political paradigm shifts. Anthr Rev 2:108–116. https://doi.org/10.1177/2053019615588791
- Mokyr J (2016) Institutions and the Origins of the Great Enrichment. Atl Econ J 44:243–259. https://doi.org/10.1007/s11293-016-9496-4
- Murga Menoyo MÁ (2021) La educación en el Antropoceno. Posibilismo versus utopía. Teoría la Educ Rev Interuniv 33:107–128. https://doi.org/10.14201/teri.25375

- Nagy GM, Bohle M (2021) Geo-scientific Culture and Geoethics. In: Geo-societal Narratives. Springer International Publishing, Cham, pp 191–199
- Olvitt LL (2017) Education in the Anthropocene: Ethico-moral dimensions and critical realist openings. J Moral Educ 46:396–409. https://doi.org/10.1080/03057240.2017.1342613
- Otto IM, Donges JF, Cremades R, et al (2020a) Social tipping dynamics for stabilizing Earth's climate by 2050. Proc Natl Acad Sci 201900577. https://doi.org/10.1073/pnas.1900577117
- Otto IM, Wiedermann M, Cremades R, et al (2020b) Human agency in the Anthropocene. Ecol Econ 167:106463. https://doi.org/10.1016/j.ecolecon.2019.106463
- Peppoloni S, Di Capua G (2016) Geoethics: Ethical, social, and cultural values in geosciences research, practice, and education. In: Wessel; GR, Greenberg JK (eds) Geoscience for the Public Good and Global Development: Toward a Sustainable Future. Geological Society of America Special Papers, pp 17–21
- Peppoloni S, Di Capua G (2022) Geoethics: Manifesto for an Ethics of Responsibility Towards the Earth. Springer International Publishing, Cham
- Phillips J (2012) Storytelling in Earth sciences: The eight basic plots. Earth-Science Rev 115:153–162. https://doi.org/10.1016/j.earscirev.2012.09.005
- Renn J (2020) The Evolution of Knowledge - Rethinking Science for the Anthropocene. Princeton University Press, Oxford, UK
- Renn J (2018) The Evolution of Knowledge: Rethinking Science in the Anthropocene. HoST - J Hist Sci Technol 12:1–22. https://doi.org/10.2478/host-2018-0001
- Robin L, Avango D, Keogh L, et al (2014) Three galleries of the Anthropocene. Anthr Rev 1:207–224. https://doi.org/10.1177/2053019614550533
- Rosol C (2021) Finding common ground: The global Anthropocene Curriculum experiment. Anthr Rev 8:221–229. https://doi.org/10.1177/2053019621105343 7
- Rosol C, Nelson S, Renn J (2017) Introduction: In the machine room of the Anthropocene. Anthr Rev 4:2–8. https://doi.org/10.1177/2053019617701165
- Ruddiman WF (2018) Three flaws in defining a formal 'Anthropocene'. Prog Phys Geogr Earth Environ 42:451–461. https://doi.org/10.1177/0309133318783142
- Ruddiman WF, Ellis EC, Kaplan JO, Fuller DQ (2015) Defining the epoch we live in. Science (80-) 348:38–39. https://doi.org/10.1126/science.aaa7297
- Ruddiman WFF, He F, Vavrus SJJ, Kutzbach JEE (2020) The early anthropogenic hypothesis: A review. Quat Sci Rev 240:106386. https://doi.org/10.1016/j.quascirev.2020.106386

- Rudwick MJS (1998) Lyell and the Principles of Geology. In: Blundell DJ, Scott AC (eds) Lyell: the past is the key to the Presence. Geological Society of London, London, pp 3–15
- Rull V (2017) The "Anthropocene": neglects, misconceptions, and possible futures. EMBO Rep 18:1056–1060. https://doi.org/10.15252/embr.201744231
- Seddon G (1996) Thinking like a geologist: the culture of geology. Aust J Earth Sci 43:
- Sklair L (2021a) Geoethics: A Reality Check from Media Coverage of the Anthropocene. In: Geo-societal Narratives. Springer International Publishing, Cham, pp 127–134
- Sklair L (2017) Sleepwalking through the Anthropocene. Br J Sociol 68:775–784. https://doi.org/10.1111/1468-4446.12304
- Sklair L (2021b) The Anthropocene in Global Media. Routledge, Abingdon, Oxon
- Soga M, Gaston KJ (2018) Shifting baseline syndrome: causes, consequences, and implications. Front Ecol Environ 16:222–230. https://doi.org/10.1002/fee.1794
- Steffen W (2022) The Earth System, the Great Acceleration and the Anthropocene. In: Sustainability and the New Economics. Springer International Publishing, Cham, pp 15–32
- Steffen W, Crutzen PJ, Mcneill J (2007) The Anthropocene: Are Humans Now Overwhelming the Great Forces of Nature The Anthropocene: Are Humans Now Overwhelming the Great Forces of Nature? Will Steffen; Paul J Crutzen; John R McNeill. Ambio 36:614–621. https://doi.org/10.1579/0044-7447(2007)36
- Steffen W, Richardson K, Rockström J, et al (2015) Planetary boundaries: Guiding human development on a changing planet. Science (80-) 347:1259855–1259855. https://doi.org/10.1126/science.1259855
- Steffen W, Richardson K, Rockström J, et al (2020) The emergence and evolution of Earth System Science. Nat Rev Earth Environ 1:54–63. https://doi.org/10.1038/s43017-019-0005-6
- Syvitski J, Waters CN, Day J, et al (2020) Extraordinary human energy consumption and resultant geological impacts beginning around 1950 CE initiated the proposed Anthropocene Epoch. Commun Earth Environ 1:32. https://doi.org/10.1038/s43247-020-00029-y
- Thomas JA (ed) (2022) Altered Earth. Cambridge University Press, Cambridge, UK
- Trischler H (2016) The Anthropocene. NTM Zeitschrift für Geschichte der Wissenschaften, Tech und Medizin 24:309–335. https://doi.org/10.1007/s00048-016-0146-3
- Vidas D, Fauchald OK, Jensen Ø, Tvedt MW (2015) International law for the Anthropocene? Shifting perspectives in regulation of the oceans, environment and genetic resources. Anthropocene 9:1–13. https://doi.org/10.1016/j.ancene.2015.06.003

- Walker M, Head MJ, Berkelhammer M, et al (2018) Formal ratification of the subdivision of the Holocene Series/Epoch (Quaternary System/Period): two new Global Boundary Stratotype Sections and Points (GSSPs) and three new stages/subseries. Episodes 41:213–223. https://doi.org/10.18814/epiiugs/2018/018016
- Wallenhorst N (2019) L'Anthropocène décodé pour les humains. Le Pommier, Paris
- Waters CN, Turner SD (2022) Defining the onset of the Anthropocene. Science (80-) 378:706–708. https://doi.org/10.1126/science.ade2310
- Waters CN, Williams M, Zalasiewicz J, et al (2022) Epochs, events and episodes: Marking the geological impact of humans. Earth-Science Rev 104171. https://doi.org/10.1016/j.earscirev.2022.104171
- Waters CN, Zalasiewicz J, Summerhayes C, et al (2016) The Anthropocene is functionally and stratigraphically distinct from the Holocene. Science (80-) 351:aad2622–aad2622. https://doi.org/10.1126/science.aad2622
- Will F (2021) Evidenz für das Anthropozän -Wissensbildung und Aushandlungsprozesse an der Schnittstelle von Natur-, Geistes- und Sozialwissenschaften, Umwelt und. Vandenhoeck & Ruprecht, Göttingen
- Wilson L (2010) Religious assumptions in Lord Kelvin's estimates of the Earth's age. Earth Sci Hist 29:187–212. https://doi.org/10.17704/eshi.29.2.46678x0701k62j0j
- Wysession ME, LaDue N, Budd DA, et al (2012) Developing and Applying a Set of Earth Science Literacy Principles. J Geosci Educ 60:95–99. https://doi.org/10.5408/11-248.1
- Zalasiewicz J, Waters C, Williams M (2020) The Anthropocene. In: Gradstein F, Ogg JG, Schmitz MD, Ogg GM (eds) Geologic Time Scale 2020. Elsevier, Amsterdam, pp 1257–1280
- Zalasiewicz J, Waters CN, Ellis EC, et al (2021) The Anthropocene: comparing its meaning in geology (chronostratigraphy) with conceptual approaches arising in other disciplines. Earth's Futur 9:. https://doi.org/10.1029/2020EF001896
- Zalasiewicz J, Waters CN, Williams M, Summerhayes C (2019) The Anthropocene as a Geological Time Unit. Cambridge University Press
- Zalasiewicz J, Waters CN, Wolfe A, et al (2017) Making the case for a formal Anthropocene Epoch: an analysis of ongoing critiques. Newsletters Stratigr 50:205–226. https://doi.org/10.1127/nos/2017/0385

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