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Crafting Attributes of a Geological Now

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Taking an Earth Science framework as its point of departure, this paper delves into the sociocultural ramifications of two distinct geological interpretations—epoch and event—of the contested but widely acknowledged term "Anthropocene." While the term has gained considerable traction for encapsulating planetary-scale anthropogenic changes (PSAC), its meanings are varied, spanning scientific, philosophical, and cultural discourses. Earth scientists often examine PSAC through the lens of their discipline, yet the complex sociocultural implications attached to such geoscientific concepts call for an interdisciplinary perspective. Introduced by Crutzen and Stoermer in 2000, the term "Anthropocene" is designed to account for the transformative impact of modern societies on Earth System dynamics. Presently, two opposing viewpoints exist within geological discourse to describe PSAC: the "Anthropocene-as-an-event" concept, which underscores the accretion of human-induced changes, and the "Anthropocene-as-an-epoch" concept, focusing on a substantial alteration in Earth System dynamics. Utilising Renn's theory of "The Evolution of Knowledge," the paper posits these concepts as scientific borderline problems, catalysts for epistemic inquiries, linked to specific "economies of knowledge." The ensuing analysis accentuates the multidimensionality of articulating PSAC from an Earth Science viewpoint, asserting that it not only mandates understanding the geological dimensions but also calls for integrating sociocultural and philosophical contexts. The paper concludes that geological terminology should consider associated cultural contexts of Earth Science to establish leadership for vital epistemic concepts.

Keywords: anthropocene, the evolution of knowledge, borderline problems, stratigraphy, science and technology studies

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INTRODUCTION

Geology portrays Earth's deep history. Other Earth Science disciplines apply geologic concepts. In this intellectual lineage, Crutzen introduced the notion of "*anthropocene*" (Crutzen and Stoermer, 2000) to baptise the 'geological now'. Later, writing "*Anthropocene*," Paul Crutzen (2002) used the formal codification of a geological epoch. The concept of an Anthropocene swiftly accrued multiple interpretations (Zalasiewicz et al., 2021) [Table 1, p.11–12], often with little attention to the rigour of geological practices.

Within the Earth Science communities, a debate persists as to whether the "geological now," i.e., the "anthropocene," should be classified as an event (Gibbard et al., 2022), episode (Head et al., 2023), or epoch (Head et al., 2022b). These categorical choices yield disparate portrayals of "human-modified deposits and anthropogenic signals in the stratigraphic record" (Finney and Gibbard, 2023) [p.461]. Specifically, the term "epoch" is typically reserved for swift planetary isochronous alterations of the

Earth described in the Geological Time Scale (GTS) and encoded in the International Chronostratigraphic Chart (ICC). Conversely, the terms "event" and "episode" offer more flexible frameworks (Head et al., 2022b; Waters et al., 2022), capturing neither rapid nor globally synchronous Earth alterations.

Each of these notions—event, episode, or epoch—engages with the scientific evidence differently (Zalasiewicz et al., 2019) and invokes cultural and geo-philosophical connotations (Koster et al., 2023; Rosol et al., 2023). This paper aims to interrogate from an Earth Science viewpoint the process of naming the "geological now," using the event-epoch debate as a focal point.

To acknowledge the current informal geological status of the term Anthropocene, the expressions "Planetary-Scale Anthropogenic Change" (PSAC) or "Crutzen/Stroemer-proposal" (C/S-proposal) are employed as substitutes if suitable.

Ending the Holocene?

Crutzen and Stoermer (2000) [p.17] informed in the IGBP newsletter: "[I]t 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."

The assertion that human activities have significantly transformed the dynamics of the Earth System,[1] and therefore necessitating marking the Holocene's end, is the kernel of the C/S-proposal. If accepted, the proposal would alter the geological subdivision of the Quaternary (Gibbard and Lewin, 2016), currently consisting of two epochs (Pleistocene and Holocene). The C/S-proposal triggered vibrant responses in natural, social and human sciences (Brauch, 2021) and the public sphere (Sklair, 2021). However, from a geological sciences perspective, outsiders (scholars of Earth System Science, ESS) were trespassing into geological areas of expertise, i.e., naming geological time (Gradstein and Ogg, 2020). Some Earth Scientists reacted passionately (Steffen et al., 2007; Autin and Holbrook, 2012; Ellis and Trachtenberg, 2014; Finney and Edwards, 2016; De Wever and Finney, 2018).

From a geological sciences perspective, the timing of the C/S-proposal was inconvenient. It coincided with debates about the fate of the Quaternary (Gibbard et al., 2005; Gibbard and Cohen, 2008). It took several years before geological stratigraphers reacted (Zalasiewicz et al., 2008) to the C/S-proposal. In 2009, the "Working Group on the Anthropocene" (AWG) was established after geologists had agreed on the fate of the Quaternary[2] (Mascarelli, 2009). The Subcommission on Quaternary Stratigraphy (SQS) of the International Commission on Stratigraphy (ICS), a constituent body of the International Union of Geological Sciences (IUGS), instituted the AWG with a mandate to analyse the impact of PSAC in terms of geological stratigraphy. The AWG's efforts transpired amid stratigraphers agreeing on the specifics of the Quaternary, i.e., the stratigraphic base and subdivision of the Quaternary (Head and Gibbard, 2015), the Holocene's subdivision, and the use of physico-chemical methodologies (Walker et al., 2018). Since 2019, the AWG has presented its findings[3] after the IUGS ratified the Holocene subdivisions (Walker et al., 2018). Currently–at the time of writing–the AWG selected a candidate Global Boundary Stratotype Section and Point (GSSP) for the stratigraphic base of an Anthropocene (Waters and Turner, 2022; Witze, 2023). Next, the AWG possibly will make its official proposal to the SQS. The final adjudication of the modification of the GTS would be by the IUGS, acting as trustee for sound geological methodology (Witze, 2023).

Most Earth Scientists concur with the evidence of substantial disturbances in Earth's late Holocene dynamics, or PSAC; some even view the Holocene as partially human-influenced (Ruddiman, 2003; Ruddiman et al., 2020). Some Earth Scientists perceive PSAC as an accumulative geological event (Braje and Erlandson, 2013; Gibbard and Walker, 2014; Kunnas, 2017; Braje and Lauer, 2020; Bauer et al., 2021; Gibbard et al., 2022; Walker et al., 2023). Conversely, others interpret the same scientific information as the precursor of the end of the actual geological epoch (the Holocene). For this latter group (Waters et al., 2016), the qualitative alterations spurred by the Great Acceleration (Steffen et al., 2015b) have fundamentally displaced the Earth System dynamics out of the typical Holocene conditions (Head et al., 2022c). The C/S-proposal did not directly address this specific issue, although it affirmed the inception of an additional geological epoch to name the "geological now."

The dichotomy between event and epoch interpretation recently became somewhat smoothed with the proposal of a geological episode concept (Waters et al., 2022), namely the idea of an "Anthropogenic Modification Episode" of ~50 ka duration, including as its climax, the "Great Acceleration Events Array" centred around the mid-twentieth century that provides a base for a new geological epoch, the Anthropocene.

What Is Framing Current Debates?

The kernel of the AWG's findings is combining Earth System Science (ESS) and geological stratigraphy (Steffen et al., 2016). The stratigraphic marker is set to label a stage shift of the Earth System dynamics. Most AWG members support ending the Holocene (Zalasiewicz et al., 2019). Nonetheless, this view remains challenged from various angles. For instance, halfway through AWG's work, Maslin and Lewis asserted: "[T]here must be room for the formally stratigraphically defined Anthropocene Epoch and the more fluid and broader use of the Anthropocene" (Maslin and Lewis, 2015) [p.7]. For them, like

[1]The spelling (majuscule and singular) shall carry the meaning of a single integrated system.

[2]Correspondence ICS-INQUA on definition and status of the Quaternary/Pleistocene. http://quaternary.stratigraphy.org/definitions/correspondence/ (accessed 22nd May 2023).

[3]Working Group on the "Anthropocene." http://quaternary.stratigraphy.org/working-groups/anthropocene/ (accessed 22nd May 2023).

others (Fressoz, 2012; Bonneuil and Fressoz, 2013), the notion of an Anthropocene extends beyond a geological subject and implies a philosophical and historical rationale, e.g., (Chakrabarty, 2021).[4]

Geological notions summarise long-standing professional practices and norms distinct from those in other science disciplines, e.g., mathematics or physics. For example, a worldwide and century-spanning coordination effort consolidated an enormous corpus of diverse geological knowledge in GTS (Gradstein and Ogg, 2020). In addition to being a professional instrument for many, geological notions serve as a powerful interdisciplinary narrative for Earth's history (Frodeman, 1995; Phillips, 2012). It has philosophical and cultural connotations as books by professional Earth scientists for public audiences witness, e.g., (Zalasiewicz, 2010; Langmuir and Broecker, 2012; Beerling, 2017; Meyer, 2022). For example, titles like "Timefulness - How Thinking Like a Geologist Can Help to Save the World" (Bjornerud, 2018) reveal the cultural dimensions woven into geology, others like "Making The Geological Now" (Ellsworth and Kruse, 2013) illustrate artists' perceptions of geological notions. Unsurprisingly, also the Earth scientists' professional prose has narrative power when debating PSAC, as two quotes show that situate the given debate:

"Earth's unprecedented transformation by human activities has been diachronous, heterogeneous, socially differentiated. Therefore, representing the profound, long-term impact on the Earth's system by a rigidly defined beginning basal boundary for a geological series/epoch of decades' duration, implying an immediate switch from a natural to a human-dominated world, fails to encompass the time-transgressive development that is implicit in the continuing Anthropocene Event" (Finney and Gibbard, 2023) [p. 461,462].

"We thus propose recognising a long, slow-unfolding Anthropocene Modification Episode (the AME), outside of formal chronostratigraphy, leading to and incorporating the Great Acceleration Event Array (the GAEA) that signals the onset of a chronostratigraphic Anthropocene epoch/series. This proposed terminology accurately reflects the various human-caused changes to the planet while acknowledging that many Earth System parameters have, in the past 70 years, escaped the envelope of variability of the Holocene Epoch" (Waters et al., 2022) [p. 23].

The "Anthropocene-is-an-event-concept" (AVC) underscores that PSAC is traceable in proto-historical, historical times and enfolds in contemporary times. Conversely, the "Anthropocene-is-an-epoch-concept" (APC) accentuates a recent shift in the dynamics of the Earth System. Both concepts refer to responsible socio-political-economic agents through the summary notion of an *Anthropos* ([implications are discussed, e.g., by Lewis and Maslin (2018)]. However, both concepts substantially differ regarding the collective *Anthropos* they imply. The AVC identifies a suite of human agents from prehistoric hunters (of megafauna) over neolithic agriculture to industrial societies. The APC necessitates a dated geological base of the epoch. Therefore, the APC hints at hegemonic human agents at a specific moment in human history. A considerable portion of the Anthropocene literature is devoted to debating this issue; for example (Zalasiewicz et al., 2019), [p. 242–286]. For instance, if the Orbis Spike (Lewis and Maslin, 2015a) were selected as the marker of the base of the epoch 'Anthropocene' allusion would be made to the barons of the slave trade, sugar, and cotton industries (Mokyr, 2016).

As the literature record shows, Earth scientists also debate the societal contexts of their disciplines when comparing APC and AVC. For example, sociocultural arguments are made in favour of the AVC, i.e., "applying more readily in different academic contexts" (Gibbard et al., 2022) [p. 395]. Such arguments are essential because geological concepts might differ in the potential for societal action, such as empowering citizens to ensure that human operations stay within planetary boundaries (Steffen et al., 2015b; Lade et al., 2020; Rockström et al., 2023). Whilst assessing a potential for societal action is challenging, the portrayal of the PSAC through either the APC or the AVC indicates differently configured bundles of geological concepts and societal perspectives. These different perspectives are explored in this paper.

MATERIALS AND CONCEPTS

This section describes the materials and analytical concepts used in this paper.

The Crutzen/Stroemer-Proposal

The C/S-proposal is about the end of a period of relative climatic stability, the Holocene because the stage of the Earth System's dynamics changed (Steffen et al., 2015a; Waters et al., 2016). It is argued (Steffen et al., 2015b; Rosol et al., 2017; Otto et al., 2020a; Syvitski et al., 2020; Steffen, 2022) that human activities caused planetary dynamics to take a trajectory away from Holocene conditions despite geological processes like plate tectonics, volcanism or erosion persist.

The C/S-proposal of a geological epoch, Anthropocene, different from the geological epoch Holocene, emerged among Earth System scientists (Steffen et al., 2020).[5] The

[4]"However, so long as we think of the name and the concept of the Anthropocene as a measure—and a critique—of the impact humans have had on the geobiology of the planet, we cannot escape the moral pull of world history, for questions of empires, colonies, institutions, classes, nations, special-interest lobbies—in a word, the world system created by European empires and capitalism—are then never far from our concerns. . . the Anthropocene, so long as it is seen as a measure of human impact on the planet, can have only plural beginnings and must remain an informal rather than a formal category of geology, capable of bearing multiple stories about human institutions and morality. The issue cannot be separated from political and moral concerns." [p. 167–168].

[5]"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). 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 Holocene. The two definitions, although not identical, have much in common" [Box 2, p.60].

scientific communities of ESS and Geology are distinct. Habitually, only the latter describes the Earth's geological history (Gibbard and Cohen, 2008; Cohen et al., 2013; Gradstein and Ogg, 2020). The geological sciences exercise leadership for the geological terminology of the GTS and the ICC. The development of ESS as a scientific endeavour happened jointly with the rise of the notion of an "Anthropocene." The ESS is a relatively novel discipline (Steffen et al., 2020), evolving with the International Geosphere-Biosphere Program (IGBP), anchored in physical and biological sciences and using heavily mathematical techniques.

When the C/S proposal emerged from the ESS community,[6] the geological community discussed the fate of the Quaternary, the geological period to which an Anthropocene would belong. It had been proposed to substitute the term Quaternary by extending the Neogene Period to the present. Also, geological subdivisions of the Quaternary (e.g., Holocene) were unclear. The IUGS coordinated the decade-long debates, including maintaining inter-organisational cooperation. The issues about the Quaternary were settled in 2008 (Mascarelli, 2009), and the issues about the Holocene in 2018 (Gibbard and Head, 2020).

It took the geological communities almost a decade to formally debate the C/S-proposal (Zalasiewicz et al., 2008). In 2009, the ICS's Subcommission on Quaternary Stratigraphy[7] (SQS) established the AWG[8] "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 result had been presented in 2016,[9] the AWG voted in 2019 with a substantial majority[10] that the Anthropocene should be treated as a standard chronostratigraphic unit and that the stratigraphic signals around the mid-twentieth century of the Common Era (CE) specify its base. This vote was a step towards further studies to identify candidate sites for a GSSP to mark the baseline of the Anthropocene (Waters and Turner, 2022; Witze, 2023). A subsequent decision process involving the ICS and, finally, the IUGS might lead to including the Anthropocene in the GTS.

Agreeing on features of the GTS, including a GSSP, is more than following the ICS/IUGS protocols and practices. It is a societal process, i.e., scientific peers using previously established protocols agree on what they perceive as "scientific truth" or a "practical professional tool."

The Geological Time Scale

GTS is a significant achievement of the ICS/IUGS community. Developing the GTS is a long-enduring process. The elements of the GTS are formally agreed upon (Finney, 2014) to provide geological terminology supported by established protocols. Given that the Anthropocene is not officially confirmed as a geological epoch, the most recent update of the ICC[11] does not mention it. However, the most recent compendium of the GTS (Gradstein and Ogg, 2020) introduces the concept (Zalasiewicz et al., 2020).

Most subdivisions of the GTS are placed at times of no human activity. The study object (Earth's geology) and the observer (human geologist) are disjunct. Therefore, only internal practices of scientific disciplines determine societal processes associated with establishing formal geological terminology.[12] Nonetheless, the most recent subdivisions of the GTS (Pleistocene, Holocene) overlap with the modern human species' existence; therefore, conceptually, human agency might play a role in determining their features (Ellis and Ramankutty, 2008; Braje and Erlandson, 2013; Ruddiman et al., 2020). Hence, the study object and the observer might be disjunct to a lesser degree than for older subdivisions of the GTS. One might speculate that contemporary humans might find their assessment of a geological fact influenced by appreciating their ancestors' deeds, e.g., the impact of the use of fire (Shuman et al., 2022). Only the most recent subdivision of the Holocene, the Meghalayan, falls within human history. The Meghalayan GSSP (4,250 years before the year 2000 CE) marks a noticeable planetary climate change with likely repercussions on regional human societies (Walker et al., 2018). No claim is made that human activity caused this climatic change. The C/S-proposal of a geological epoch Anthropocene fundamentally differs in this aspect because it involves claiming that human activity caused PSAC.

Any description of the onset of a geological epoch, Anthropocene associates a specific societal context, just as the initial C/S-proposal referred to the industrial revolution in Europe. Hence, the study object (Earth's geology) and the observer (human geologist) are not disjunct. Consequently,

[6]As the story is told, the notion of an Anthropocene emerged as a spontaneous proposal at the meeting of the IGBP in Cuernavaca (México). The IGBP newsletter reports about the suggestion. Crutzen and Stoermer use minuscule spelling (anthropocene) but emphasise an "epoch" concept. The lead article in the newsletter written by the IGBP chair spells "Anthropocene" ("...the environmental significance of human activities is now so profound that the current geological era can be called the 'Anthropocene' epoch...").

[7]Compiled ICS Subcommission Annual Reports (2009). https://stratigraphy.org/files/ICS_SubcommReport2009.pdf [p.5] (accessed 22nd May 2023).

[8]International Commission on Stratigraphy (2010), Annual Report 2009. https://stratigraphy.org/files/ICS_AnnReport2009.pdf [p.14] (accessed 22nd May 2023).

[9]International Commission on Stratigraphy, Minutes of the ICS Business Meeting, IGC, Cape Town, 31 August 2016. https://stratigraphy.org/files/ICS-Business-IGC35.pdf (accessed 22nd May 2023).

[10]Working Group on the "Anthropocene." http://quaternary.stratigraphy.org/working-groups/anthropocene/ (accessed 22nd May 2023; accessed 22nd May 2023).

[11]International Stratigraphic Chart, International Commission on Stratigraphy (2022). https://stratigraphy.org/news/143 (accessed 22nd May 2023).

[12]Example: Definition and Rank of Quaternary, International Commission on Stratigraphy (2005). https://stratigraphy.org/files/Q1.pdf (accessed 11th October 2023).

societal contexts, cultural aspects, and philosophical connotations are brought to the table, likely affecting the scientific assessment process, as the diversity of the Anthropocene concepts (Zalasiewicz et al., 2021) [Table 1, p.11,12] indicates. The C/S-proposal forces on the agenda of geological stratigraphers the quest to describe the effects of human agency within the GTS because, metaphorically speaking, the human-driven alteration of climate, erosion, hydrology, nutrient cycles, etc., seems to have led to the *"exodus* from the Holocene" (Renn, 2020) [p.355].

The Notion Anthropocene

At the beginning of the 21st century, the notion of "Anthropocene" came timely, only loosely attached to a specific geological meaning, and went "viral" (Sklair, 2017).[13] Since 2017, the number of scientific publications using the notion of an Anthropocene has increased further (Brauch, 2021). Google Scholar lists for the keyword "Anthropocene" ~50 k and ~71 k publications for 2000–2016 and 2017–2022, respectively.

The word "Anthropocene" went viral because it suited as a marker to which many interpretations could be attached referring to science, philosophy, culture, history or power (Angus, 2016; Hamilton, 2017; Lewis and Maslin, 2018; Brauch, 2021; Chakrabarty, 2021; Sklair, 2021; Will, 2021). The term served to label the PSAC as driven by complex-adaptive social-ecological systems of a planetary extent that portray modern societies (Donges et al., 2017; Donges et al., 2020; Biggs et al., 2021). These systems are characterised by matter, energy, and information cycles, which firmly tie socio-economic, physical, and biological subsystems. System attributes are global supply chains, an all-embracing division of labour, a planetary technosphere, and a worldwide knowledge system (Haff, 2014; Haff, 2017; Rosol et al., 2017; Otto et al., 2020b). These attributes shape a worldwide ergosphere[14] (Renn, 2018) so that people can construct the socio-economic intersections of the World and Earth (Herrmann-Pillath and Hederer, 2022) to meet their needs (e.g., food, shelter, health) and preferences (e.g., lifestyle, power relations), applying a hegemonic culture (Biermann, 2014; Dryzek and Pickering, 2018).

In these multifaceted circumstances, the notion of an Anthropocene was handy. Re-codifying it as "Anthropo-scene" (Lorimer, 2017) to indicate a multidimensional concept had little impact. The notion of an Anthropocene as part of an informal geological terminology has triggered studies regarding the implications for education (Olvitt, 2017; Murga Menoyo, 2021). Likewise, it has led to reflections on public literacy in ESS (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).

Summarising, the notion of an Anthropocene, coined two decades ago as a scientific term in ESS, has metamorphosed, diversified, and gained visibility. The multiple meanings of the notion specify contexts for any geological interpretation that, whenever ready, may come late but will be necessary.

The Anthropocene Working Group

Despite its ambitious-sounding name, "Working Group on the Anthropocene," the AWG is only mandated to pursue a specific geological question using state-of-the-art methods. The AWG was established to apply geological stratigraphy for establishing a possible novel aspect of the GTS. Compared to customary working groups of the ICS/IUGS system, the AWG was of diverse scholarly composition. The AWG agreed[15] with a significant majority in 2019 that the Anthropocene is a distinct epoch (Zalasiewicz et al., 2019; Waters and Turner, 2022). The Holocene should end because human activity associated with the "Great Acceleration" after WWII 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, for example, because of conceptual considerations (Lewis and Maslin, 2015a; Ruddiman, 2018; Gibbard et al., 2021). Also, methodological debates were extensive, and the description of the science behind the Anthropocene concept is detailed, including discussing alternatives to the majority view (Ellis, 2018; Lewis and Maslin, 2018; Zalasiewicz et al., 2019). Likely, the AWG tackled the methodological issues according to the state-of-the-art and with rigour.

The Earth Science communities hold diverging views on how to describe PSAC, 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). Also, the scientific-bureaucratic process of the ICS/IUGS community, of which the AWG is a part, was not designed to assess scientific issues that have repercussions far beyond the participating disciplines. However, the AWG gathered some expertise to debate and consider these issues. The "AWG as an instrument," including its scientific-bureaucratic embedding (i.e., the approval process of the bodies of the ICS/IUGS system), is primarily equipped to assess matters relating to a specific methodology (e.g., the GTS). This being the case, any deliberation about broader issues might be less pertinent. The AWG was well aware of these circumstances when sticking to

[13]". . .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].

[14]"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].

[15]Working Group on the "Anthropocene." http://quaternary.stratigraphy.org/working-groups/anthropocene/ (accessed 22nd May 2023).

its mandate (Will, 2021) despite critics (Lundershausen, 2018a; Lundershausen, 2018b).

Two Geological Concepts

The debate about the geological meaning of the notion of Anthropocene mainly aggregates around two geological concepts. The first concept, "Anthropocene-is-an-event-concept" (AVC), emphasises the time-transgressive and spatiotemporal diachronous attributes of PSAC (Gibbard et al., 2021; Walker et al., 2023). The second geological concept, the "Anthropocene-is-an-epoch-concept" (APC), emphasises planetarily isochronous characteristics of PSAC (Head et al., 2022b).

Following the epistemological praxis of geological sciences (Phillips, 2012; Frodeman, 2014), whether a geological phenomenon is spatiotemporal diachronous (event) or planetarily isochronous (epoch) is decided by peer consensus on detailed descriptions and comparable practices, for example, see the description of epoch, events and episodes of Waters and coworkers (Waters et al., 2022).

Hence, settling the categorical choice between a "geological event" or "geological epoch" is not determined by a specific experiment. The settlement is the outcome of a social process among peers finding consensus.

The Evolution of Knowledge

Renn's theory of "The Evolution of Knowledge" (Renn, 2020), which examines the role of knowledge in global transformation, will be used in the following. Specifically, the notions of "economy of knowledge," "external representation" and "borderline problem" will be applied.

These notions are defined as:

- Economy of knowledge: "all societal processes pertaining to the production, preservation, accumulation, circulation, and appropriation of knowledge mediated by its external representation" [p.429], and
- External representation: "any aspect of the material culture or environment of a society that may serve as an encoding of knowledge" [p. 224].
- Borderline problem: "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" [p. 427].

Renn's framework leads to the following insights:

- In the given case, the economy of knowledge englobes the societal processes of how scientific and other communities deal with the given borderline problems of PSAC.
- The AWG and other structures, which are organising scientific and other communities for discussing PSAC, are part of the external representation of the knowledge economy dealing with PSAC.
- The notions of AVC or APC combine specific knowledge systems such as geological stratigraphy, archaeological stratigraphy, or ESS. The combinations result in borderline problems, i.e., a description of PSAC, including associated sociocultural connotations.

At first sight, a theory of the evolution of knowledge seems distant from Earth Science. Still, borderline problems such as plate tectonics drove the rise of modern Earth Science (Renn, 2020) [p. 237–40] and "[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].

Climate change is a well-known example of a borderline problem. The related societal processes to establish and use knowledge occur in an economy of knowledge, including the Intergovernmental Panel on Climate Change (IPCC) as part of the external representation. The experiences with climate change science illustrate that to be effective (i.e., having transformative power to influence societal change), an external representation of an economy of knowledge must include cultural and political institutions.

The AWG's cooperation with the *Haus der Kulturen der Welt Berlin* (HKW) offers a striking example of an external representation of an economy of knowledge involving cultural and political institutions. The AWK-HKW cooperation led 2019 to an international scientific programme to localise stratigraphic markers of APC (Waters et al., 2023), for which the German Federal Parliament (Bundestag) allotted funding (Rosol et al., 2023).[16]

The appropriateness of this kind of cooperation to build an effective economy of knowledge seems foreshadowed in an early (at that time unfavourable) reception in the geological literature of the idea of an epoch Anthropocene; the geologists Autin and Holbrook wrote[17] (Autin and Holbrook, 2012) [p.71] Scholars in political sciences corroborate this insight (Biermann, 2014), going so far saying that political or cultural institutions must overcome "pathological path dependency in institutions, practices, and ideas that developed under Holocene conditions" (Dryzek and Pickering, 2018) [p. 151].

[16]"The interlacing of cultural reflection and scientific assessment of the Anthropocene was then brought to an entirely new level when in 2019 HKW's director Bernd Scherer acquired financial support for a systematic assessment by the AWG of potential candidates for the Anthropocene's Global boundary Stratotype Section and Point (GSSP, often referred to as the "golden spike") by means of a special appropriation from the Bundestag, the German federal parliament," [p.2].

[17]"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."

DISCUSSION

In 2019, the AWG reached a consensus on designating a new geological epoch, termed the Anthropocene, to characterise a novel aspect of Earth System dynamics. The associated GSSP (Witze, 2023), which identifies mid-20th-century nuclear fallout as an isochronous marker, is a professional choice applying protocols of geological stratigraphy. If formally proposed, the ICS and IUGS governing bodies will evaluate the AWG's findings for its alignment with established geological practices. Societal implications of the AWG's findings are anticipated to be a subject of ongoing discussions.

Holocene Scenes

There is a compelling need for human activities to be symbiotic with planet Earth (Barrière et al., 2019) to mitigate the PSAC driven by the socio-economic activities since World War II called "the Great Acceleration." Triggering human activities that are symbiotic with planet Earth needs compelling narratives, and geological terminology describing the history of the Earth System can contribute to them.

Following the highly variable climate of the Pleistocene (Gibbard and Head, 2020), the relative climate stability of the Holocene epoch spurred distinctive cultural adaptations of humans. 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, the geological interpretation of these records could guide a holistic understanding of a multistage human activity impacting planet Earth (Braje, 2015; Kunnas, 2017; Lewis and Maslin, 2018; Gibbard et al., 2022). 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, 2018).

When taking the AVC perspective, it is conceded that the PSAC resulted from successive socio-political "historical events," such as the "Columbian exchange" (Boivin et al., 2012; Braje and Erlandson, 2013). Consequently, PSAC is a suite of shifting baselines (Soga and Gaston, 2018) tracing the impact of human activities. The qualitative disturbance of Earth's global carrying capabilities by the recent massive quantitative affluence of a part of the human population, the Great Acceleration (Otto et al., 2020a; Lade et al., 2020; Steffen, 2022), is identified as a phase within a more extended sequence of incremental changes. The AVC perspective is inclusive regarding human agency along the path of history. It includes a broad suite of diverse human practices contributing to altering Earth System processes (Bauer and Ellis, 2018).

In the suite of the C/S-proposal, namely the end of the Holocene, the AWG proposed the APC. The AWG considered that human activities associated with the Great Acceleration drive a state shift[18] in Earth System dynamics (Waters et al., 2016; Waters et al., 2023). Qualifying a change in the Earth System dynamics as a "state shift," "phase shift" or "tipping point" has political connotations (Otto et al., 2020a; Dietz et al., 2021). Changes that natural sciences would call "a state shift" are those that social scientists would call "a revolution"; mutatis mutandis, the historical moment of a state shift, implies identifying a hegemonic human agent.

Anthropo-Scenes

As outlined above, geological notions often can be associated with narratives. For example, the AVC and APC narrative might be formulated as follows:

- AVC: Human activity had environmental impacts for aeons, accompanying cultural developments and historical events.
- APC: Human activity caused a stage shift in Earth System dynamics; subsequently, human practices 'as usual' seem no longer possible.

Taking a strictly disciplinary perspective, assessing whether Earth System dynamics is experiencing a stage shift and what implications are for human societies is outside the scope of geological sciences. Hence, the AWG's findings present a borderline problem.

Climate change science can serve as an example illustrating the AWG's dealings. Climate change is a borderline problem combining ESS, culture, economy, and governance. Initially, climate science knowledge was limited to a small science community. Subsequently, it spread into a global community of citizens, decision-makers, and institutions and even became a political process at the United Nations level. This evolution happened when climate science became part of an effective economy of knowledge associated with an efficient external representation, including, for example, an inter-governmental advisory body, the IPCC.

Compared to the IPCC, and although PSAC is englobing climate change, the AWG operates at a much more moderate scale. The concerned science community is limited. However, its upscaling would be impressive if the IUGS would endorse the AWG's findings. Therefore, the attitude of the Earth Science communities is essential.

The AWG's cooperation network, for example, with the HKW, gives the potential to initiate outreach beyond science. It is recalled that because of the cultural implications of the geological concept of the Anthropocene, the AWG could begin an international scientific project to identify candidate

[18]As a simple example, if water evaporates, the physical system shifts from liquid to gaseous. Likewise, if water freezes, it alters its phase, and the dynamics go through a stage shift. Hence, phase shifts or stage shifts (or metaphorically speaking 'tipping points') are qualitative changes.

GSSP of the Anthropocene using public funds acquired by the HKW from the German federal parliament (Rosol et al., 2023). The IUGS, which habitually was silent about the work of the AWG, reported this achievement in its annual report 2021 [p.14],[19] indicating how extraordinary the achievement was.

Scholars of international politics, law and global (Earth System) governance argue that the actual political institutions (i.e., established under Holocene conditions) are insufficient for the Anthropocene (Biermann, 2014; Vidas et al., 2015; Dryzek and Pickering, 2018). This kind of insight could have motivated the AWG to broaden the borderline problem it tackles. However, the AWG acknowledged its mandate (Will, 2021), including the constraints of the ICS/IUGS system, and opted to combine only scientific knowledge from ESS and geological stratigraphy. Hence, the AWG left aside more general borderline problems (Lundershausen, 2018a; Dyer-Witheford, 2018; Castree, 2021) and stuck to a specific geoscientific borderline problem, namely, of describing the impact of the Great Acceleration on PSAC in geological notions.

Geoscientific Borderline Problems

Three geological descriptions of the impact of PSAC have been formulated: APC, AVC and the concept of an "Anthropogenic Modification Episode" (AEC). These descriptions combine geological and other concepts of PSAC in various ways. Hence, they are borderline problems in the sense of Renn's theory of Evolution of Knowledge (Renn, 2020). The selection of knowledge that is combined, the related economies of knowledge (e.g., communities, institutions), and different external representations (e.g., publication channels, social networks, public media) differentiate these geoscientific borderline problems.

Since 2016 (Waters et al., 2016), researchers from the AWG have proposed the APC (Zalasiewicz et al., 2019; Head et al., 2021; Waters and Turner, 2022; Head et al., 2023). The vast majority of the AWG members argue[20] (Head et al., 2021) that a stage shift in the dynamics of the Earth System is unfolding (Otto et al., 2020b; Folke et al., 2021). Other historical and regional features of PSAC are sidelined. The essence of the APC is to mark a stage shift in Earth System dynamics using methods of geological stratigraphy. The AWG combined a discipline-specific approach (the GTS, modern stratigraphic methodology of physico-chemical markers, isochronous nuclear fallout), a systems perspective of how planet Earth functions (ESS, a stage shift of Earth System dynamics in the mid-20th Century), and a robust human component (the Great Acceleration). This borderline problem is simple, including a significant global socio-economic context related to the selected time window for the base of the Anthropocene in the mid-20th Century.

Recurrently, other researchers (including some members of the AWG) argue that the APC would cause interdisciplinary quarrels, such as finding a single marker in the geological record to define the base of the epoch (Lewis and Maslin, 2015b; Bauer and Ellis, 2018; Braje, 2018; Bauer et al., 2021; Gibbard et al., 2022). Instead, the AVC could be associated with multiple impacts of human activity traceable in many regional contexts and researched by various disciplines (Walker et al., 2023).[21] Likewise, Gibbard and coworkers describe the AVC as fruitful for developing science[22] (Gibbard et al., 2021). For these researchers, the AVC would appeal to the disciplines of Quaternary research (Head and Gibbard, 2015; Gibbard and Head, 2020; Koster, 2020), which are represented by the International Union for Quaternary Research (INQUA),[23] a peer of the IUGS, both being members of the International Science Council.[24] Subsequently, a possibility of a Renaissance-like evolution of the sciences of PSAC is evoked (Finney and Gibbard, 2023; Koster et al., 2023).

The AEC was proposed by proponents of the APC reacting to the AVC. The AEC seems constructed as a compromise. The authors (Waters et al., 2022), applying the geological notion of "episode," suggest an "Anthropogenic Modification Episode" climaxing in the "Great Acceleration Events Array" in the mid-twentieth century as the base of an Anthropocene Epoch. The AEC narrative refers to the shift in the dynamics of the Earth System embedded in a story of systemic continuity. The latter is an established Anthropocene discourse [e.g. (Bonneuil and Fressoz, 2013; Dalby, 2015; Cuomo, 2017; Kunnas, 2017)]. Some proponents of the AVC coldly received the AEC (Merritts et al., 2023). Considering the publication record, the AEC does not offer a noticeable alternative to the APC and AVC.

[19]International Union of Geological Sciences, Annual Report 2021. https://www.iugs.org/_files/ugd/f1fc07_a0de622776754cdfbf7bc40c5ca8ee6d.pdf (accessed 22nd May 2023).

[20]"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" [p.14].

[21]"As such an Anthropocene Event incorporates a far broader range of transformative human cultural practices and is more readily applicable across a range of academic fields than a rigidly defined Anthropocene series/epoch" [p.2].

[22]"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" [p.6,7].

[23]International Union for Quaternary Research. https://www.inqua.org (accessed 22nd May 2023).

[24]International Science Council. https://council.science (accessed 22nd May 2023).

All three concepts, APC, AEC and AVC, offer perspectives on PSAC that seem suitable for contemporary societies to "understand complex systems like the sphere of the Earth System and its human components" (Renn, 2020) [p. 430]. APC and AVC represent differently configured borderline problems. The question arises whether the differences between APC and AVC matter, including the potential, for example, of empowering citizens to take societal action[25] (Spencer, 2022). Shaping the knowledge systems of societies requires appropriate processes and circumstances, i.e., the economy of knowledge using Renn's terminology.

It is challenging to establish *ex-post* how insights into PSAC would have spread depending on whether it was promoted as an APC or AVC. However, it seems questionable that a hypothetical proposal of an event (within the Holocene) would have gained attention outside some scientific circles, even if made by a Nobel Prize Laureate like Paul Crutzen. Likewise, it seems questionable that the ICS/IUGS would establish a dedicated working group, which could evolve into an effective external representation of knowledge. The reactions of diverse scholarly communities and the general public to the APC corroborate that the APC efficiently promotes outreach, i.e., activates a vast economy of knowledge (Robin et al., 2014; Dryzek and Pickering, 2018; Jagodzinski, 2018; Brauch, 2021; Rosol, 2021; Sklair, 2021; Thomas, 2022).

Considering the studies of the AWG, the balance of geoscientific arguments seems ready for decision. 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)]. Conceptually, the option exists that ICS/IUGS reject the findings of the AWG because a qualified majority of geological stratigraphers consider that the agreed stratigraphic methods cannot determine a GSSP in the mid-20th Century. Subsequently, the established geological nomenclature would persist, or one might speculate whether then to introduce a stage/age in the Holocene, the *Anthropoyan*. In this context, it is perplexing that the feature "stage shift" of the Earth System dynamics is not scrutinised by those who disapprove of the APC, although it is the pivot of the C/S-proposal and the AWG's findings. At the time of writing, such debate did happen only occasionally (Head et al., 2022a; Nielsen, 2022) and is not taken up when arguing the AVC.

An Alternative Framing

Methodological concerns about the APC persist, namely, that "upper 10–15 cm of unconsolidated lake sediment" (Finney and Gibbard, 2023) [p. 462] might mark the lower boundary of an epoch when many more stratigraphic deposits give evidence of human activity.

Also, the AWG members' majority views do not settle the broader issue of the societal meaning of the APC. Emphasizing this concern, Lewis and Maslin wrote several years ago, "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]. Although the APC calls for a paradigm shift, Mark Maslin favours the AVC (Gibbard et al., 2022; Koster et al., 2023). Furthermore, the concern to be open to humanities and social sciences contributions is essential for favouring AVC (Edgeworth et al., 2015; Bauer et al., 2021; Walker et al., 2023). However, its validity is contested (Head et al., 2023), and it looks disapproved by the bibliographic record (Brauch, 2021).

Given that inter-disciplinary cooperation among scientists and scholars is a highly valued public good beneficial for society, it seems worth overcoming the dichotomy of AVC versus APC, which, surprisingly, the AEC does not deliver (yet). The following illustrates an option that can be designed by altering the borderline problem that frames the geological description of PSAC.

Four considerations are used in the following illustrative idea: First, Crutzen's wording, "[i]t seems appropriate to assign the term 'Anthropocene' to the present, in many ways human-dominated, geological epoch, supplementing the Holocene—the warm period of the past 10–12 millennia." (Crutzen, 2002) my underlining refers to a geological "now." Second, the AWG situates the end of the Holocene in the mid-20th Century. Third, the cultural notion of geological time and the scientific methodology specifying the GTS are not synonymous. Fourth, the ICC includes a parameter called "present," which was recently moved from 1950 CE to 2000 CE for the convenience of counting ages (Gradstein and Ogg, 2020) [p. 11].

The ICC parameter "present" has no specific geological meaning. It is suggested here that it could gain the definition of "point zero" in the ICC marking when the "geological past" ends and the "geological present" begins, and geological methodologies are adjusted accordingly. The "point zero" could acknowledge the state shift of the dynamics of the Earth System, implementing the kernel of C/S-proposal (ending the Holocene), and recognising the paradigm shift, i.e., the beginning of a "geological present" distinct from the "geological past." Subsequently, the Holocene would be the last epoch of the geological past. The associated borderline problem would emphasise the most vital philosophical insight, namely the state shift of the dynamics of the Earth System because of human activities. However, a central geological paradigm would be maintained: the stasis of geological processes in the "geological past" (Rudwick, 1998), adding a new geological force (i.e., human activity) only for the "geological present."

The adjustment to the GTS would be subtle, but the associated narrative would be unique. Also, the established practices of identifying a GSSP for subdivisions of the "geological past" would not be amended. Determining the

[25]"Designation of an Anthropocene time period as beginning with atmospheric tests of thermonuclear weapons might help focus human minds on possibilities for reducing the threat of a major nuclear war. This is a reason to support the proposal of the Anthropocene Working Group for such a designation, although a reason not directly related to strictly geologic criteria." (Spencer, 2022) [p.8].

marker of the onset of the "geological present" could follow a specific protocol. The AWG's findings might be used to this end. Ending the "geological past" at a particular moment in human history would be a convention to structure a time scale. It says 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.

CONCLUSION

Discussing concepts of a "geological now," this paper recalls that the observer (human agent, e.g., the geologist, the Earth scientist) and the observed object (Earth) are entangled when describing planetary-scale anthropogenic change (PSAC). Renn's theory of the "Evolution of Knowledge" (Renn, 2020) explains this entanglement and illustrates how different descriptions of a "geological now" are designed as specific borderline problems, each associated with a specific economy of knowledge and external representation.

The main variants of a "geological now" are epoch "Anthropocene" or an event. More variants may exist, as illustrated in this paper. These variants show how geological concepts and societal and cultural narratives relate. The AWG's description of PSAC, a new geological epoch "Anthropocene," is designed to mark a critical phase shift in Earth System dynamics. Therefore, the APC implies a narrative that might advocate altering societal practices. The alternative event concept of PSAC emphasises the continuousness of human interventions in the Earth System dynamics. The episode concept of the Anthropocene might be considered merely a compromise proposal seeking conciliation among dissenting peers.

The AWG designed the APC on a more diverse foundation than only geological sciences. The AWG combined geological stratigraphy (epoch, GSSP, stratigraphic methodology) and insights from Earth System Sciences (a stage shift of Earth System dynamics in the mid-20th Century, the Great Acceleration) into a specific (minimal) borderline problem. The AWG abstained from broadening this borderline problem, as evoked, for instance, by scholars of social sciences or humanities; for example, see (Thomas et al., 2020). Instead of using additional societal or cultural concepts to design the APC, the AWG respected the constraints of its disciplinary mandate. Despite this confinement, the AWG's findings imply a narrative of human practices that have led to an *"exodus* from the Holocene" (Renn, 2020) [p.355]. Those who challenge the APC could question its methodological foundation, namely, the stage shift of the Earth System dynamics or using physico-chemical markers located in unconsolidated sediments. The reader might witness such debates evoking dissent or methodological traditionalism in the coming years.

The opposition "Anthropocene epoch" versus an "Anthropocene event" is unproductive if reduced to a geological debate or a prioritisation of cultural transformation over scientific collaboration or *vice versa*. In the context of PSAC affecting both the World and Earth, formulating scientific concepts of Earth's "geological now" necessitates epistemic leadership that integrates science, societal concerns, and philosophical underpinnings. At the very least, such an integration should elucidate that in today's context, the subject of study (Earth) and the observer (humanity) are no longer mutually exclusive. Therefore, distinguishing between realms of a "geological past" and a "geological present," as illustrated in this paper, might be an alternative if an epoch Anthropocene seems geologically inappropriate.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

MB conceived the study, executed it and drafted the manuscript.

CONFLICT OF INTEREST

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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