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ANTHROPOCENE REVIEW

Is 'Anthropocene' a Suitable Chronostratigraphic Term?

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Abstract
Over the past two decades, the term 'Anthropocene' has ignited widespread academic and public interest. Since 2009, the term has been considered on stratigraphic grounds by the Anthropocene Working Group (AWG). The AWG has been championing a chronostratigraphic definition of the Anthropocene by advancing a proposal to formally recognize the unit as a post-Holocene epoch/series on the Geologic Time Scale and International Chronostratigraphic Chart. The proposal (i.e., the Anthropocene Hypothesis) has ignited debates among human, social, and natural scientists alike. One line of critique against the proposal concerns the chronostratigraphic suitability of the term 'Anthropocene.' This type of criticism holds that the term is inconsistent with the standard naming practices of the chronostratigraphic series; that it is inconsistent with other epochs of the Cenozoic era; that its etymology is faulty in several respects; and/or that its informal nature should be emphasized stylistically (e.g., with quotation marks or by writing the term with a lower case initial). The present contribution reviews this criticism and discusses it in the context of (chrono)stratigraphic classification and nomenclature to assess whether 'Anthropocene' is a suitable chronostratigraphic term. To do so, the analysis comments on and discusses guidelines, recommendations, and suggestions drafted by the International Stratigraphic Guide, which represents an international framework of reference for stratigraphic classification and nomenclature. Based on the underlying philosophy and recommendation of the Guide, there seem to be reasons to consider the 'Anthropocene' a suitable term in the context of chronostratigraphic nomenclature.

Keywords Anthropocene · Chronostratigraphy · Stratigraphic nomenclature · History and philosophy of science · Theoretical stratigraphy

1 Introduction

Research on the Anthropocene Hypothesis—namely, the scientific proposal of formally ratifying a post-Holocene Anthropocene Series/Epoch on the International Chronostratigraphic Chart and Geologic Time Scale (Zalasiewicz et al. 2019)—has been the center of gravity of recent debates on humans' geological agency and footprint on the Earth. The hypothesis is currently being championed by the Anthropocene Working Group (AWG), which was formed in 2009 under the recommendation of the Subcommission of Quaternary Stratigraphy (SQS). In just over a decade, the hypothesis has attracted widespread multidisciplinary interest, media coverage (Carrington 2016; Lewis 2009; Subramanian 2019; Vaughan 2022), and criticism alike (Finney 2014; Zalasiewicz et al. 2017c)—thereafter igniting an ongoing scientific debate.

Criticism against the Anthropocene Hypothesis unfolds in several ways, and across a wide spectrum of disciplines. To summarize it broadly, criticism could be distinguished between two kinds: criticism related to the *stratigraphic* nature of the proposed unit (e.g., difficulties in correlating Anthropocene geological sections globally, not sufficiently marked stratigraphic signals, the utility of a formal chronostratigraphic definition of Anthropocene, etc.), and criticism related to the *social*, *ethical*, and *political* significance of the hypothesis (e.g., the underlying undifferentiated '*Anthropos*' in 'Anthropocene,' the seemingly anthropocentric connotation of the term, its lack of historical explanatory power, etc.). Differentiating criticism is important, because, beyond the 'geological Anthropocene' (Zalasiewicz et al. 2021), the term has been adopted, reshaped, and repurposed within and outside the academic landscape for framing the extent of anthropogenic activities on the planet; the word

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"has been tossed into debate much more frequently than it has been explained or defined" (Davies 2018, p. 6), despite being "the most influential concept in environmental studies" (Moore 2016, p. 2).

A line of critique against the hypothesis converging natural, social, and human scientists concerns the terminological choice—namely, the use of the 'Anthropocene' term for the proposed epoch. At its core, this criticism holds that the term is unsuitable for its purpose, especially in the context of chronostratigraphy. This criticism addresses several aspects of the term, such as its capitalization, etymology, connotation, and more.

The present contribution briefly reviews the rationale and major points advanced by this type of criticism, asking whether the 'Anthropocene' represents a suitable chronostratigraphic term. To do so, the analysis critically draws on the guidelines of stratigraphic classification, nomenclature, and practices drafted by the International Stratigraphic Guide (Murphy and Salvador 2000; Salvador 1994) to determine if, in principle, the term 'Anthropocene' adheres to these guidelines, and therefore, if it is a suitable chronostratigraphic term.

Thus, the second section provides a brief history of the 'Anthropocene' as a concept within the natural sciences. Then, the third section outlines the major points of criticism against the term 'Anthropocene.' The fourth section addresses the 'Anthropocene' in the context of chronostratigraphic classification and nomenclature, emphasizing the nature, purpose, and importance of the International Stratigraphic Guide, the naming of chronostratigraphic units, and the preservation of traditional and well-established terms in geological classification and nomenclature. The fifth section assesses whether the 'Anthropocene' is a suitable chronostratigraphic term. Conclusions follow thereafter.

2 A Brief History of the 'Anthropocene' Concept

The history of the 'Anthropocene' concept is the history of a *scientific* term and idea. This is important to stress because, while the term lends itself to different meanings and applications, its origins are situated between Earth System science, geology, and—although less frequently discussed—water sciences (e.g., Codispoti et al. 2001; Ericson et al. 2006; Folke 2003; Meybeck 2001, 2002). Stressing its origins is also particularly important for legitimizing why stratigraphic literature is called upon to discuss the proposed term, and whether it can be considered 'well-established'—an aspect of considerable importance in determining its legitimacy in the context of chronostratigraphic classification, which is tackled in Sect. 4.3.

The term 'Anthropocene' has a prehistory dating at least to post-WWII Soviet geological literature, where it appeared sporadically (and more often as 'Anthropogene') as a synonym of Quaternary (Gerasimov 1979; Shanster 1973; Vinogradov et al. 1968; see also foreword to Angus 2016). Lake biologist and diatom expert Eugene Stoermer (1934–2012) used the term 'Anthropocene' as an informal yet intuitive category during his classes at the University of Michigan and the Iowa Lakeside Lab during the 1980s and'90 s. His usage of the term stressed the dramatic impact of humans on water bodies. As recalled by Stoermer's former student Sarah A. Spaulding (personal communication, June 7, 2020): "I recall Gene Stoermer using the term Anthropocene, but in such a way that it did not even seem new, or even novel. It was another way that he expressed what he had observed for decades." Notoriously, the term was given new impetus by Nobelist Paul Crutzen (1933–2021), who came up with the term independently during his intervention at the International Geosphere-Biosphere Programme Scientific Committee meeting in Cuernavaca, Mexico, in late February 2000. A series of seminal publications credited Crutzen as the originator of the modern version of the 'Anthropocene' concept, most notably his *IGBP Newsletter* article (Crutzen and Stoermer 2000), and his contribution to *Nature* entitled "Geology of Mankind" (Crutzen 2002). Crutzen's prestigious and influential position among the ranks of academia ensured that the term 'Anthropocene' survived and spread—perhaps at the expense of similar alternatives, such as Anthrozoic (Revkin 1992), Homogenocene (Samways 1999), or the German term Anthropozoikum (Markl 1986).

Over the years, the term 'Anthropocene' began to gradually spread, especially in disciplines neighboring the Earth System science and water science communities as well as the geosciences. These disciplinary areas played a pivotal role in the early survival and spread of the term across disciplinary domains, particularly in the natural sciences. By the end of the decade, the term also resonated among geologists and stratigraphers of the Geological Society of London who took Crutzen's informal proposal under rigorous stratigraphic consideration. To select a date, the 'stratigraphic turn' of the 'Anthropocene' could be located in May 2006 with a meeting of the Geological Society of London at Burlington House (Zalasiewicz et al. 2018). The meeting set the premises for discussions that later led to the publication of the seminal *GSA Today* paper "Are we now living in the Anthropocene?" (Zalasiewicz et al. 2008), to the establishment of an Anthropocene Working Group under the Subcommission of Quaternary Stratigraphy, and to the ongoing proposal of defining the 'Anthropocene' on stratigraphic grounds (Zalasiewicz et al. 2017a, 2018, 2021).

Environmentally oriented humanities, social sciences, and arts only began to systematically engage with the concept after 2009, following the formation of the AWG and the

seminal publication of "The Climate of History: Four Theses" by historian Dipesh Chakrabarty (2009). The 'Anthropocene' has established itself firmly and quickly among environmental discussions, becoming an idea that "can help us reconceptualize the humanities in new ways that make them compelling for the twenty-first century" (Merchant 2021, p. xi). As a vehicle for reconsidering the relationship between humans and the Earth, the 'Anthropocene' "does not just imply conflation of the natural and the social, but also a 'radical' change in perspective and action in terms of human awareness of and responsibility for a vulnerable earth" (Pálsson et al. 2013, p. 4).

During the past decade, the term has witnessed a steep surge in interest, paralleled by a diversified range of applications of the concepts across the humanities, social sciences, natural sciences, and applied sciences. One of the products of this multidisciplinary surge in interest was also the proliferation of terminological variants stemming from the environmental humanities and social sciences, such as Capitalocene (Moore 2016), Technocene (Hornborg 2015), Chthulucene (Haraway 2015), Thanatocene (Bonneuil and Fressoz 2016), and more. Each of these neologisms stresses one or more key aspects of the present world, complementing some apparent 'blind spots' that the 'stratigraphic Anthropocene,' as a technical (viz., chronostratigraphic) term, cannot fully encompass. Yet, as of the present, the term 'Anthropocene' is the only one that has been considered on formal stratigraphic grounds among the pool of existing terminological alternatives.

3 Mapping Criticism Against the Term 'Anthropocene'

The name chosen for the proposed epoch is perhaps the most discussed topic in Anthropocene literature—perhaps paralleled only by debates over the beginning of the proposed unit of time (Edgeworth et al. 2015; Lewis and Maslin 2015; Syvitski et al. 2020; Waters et al. 2018). The question of naming the epoch has involved feminist epistemology (Schneiderman 2016), postcolonial studies (Crist 2013; Yusoff 2019), ecocriticism (Crist 2013), and even Foucault (Davis 2011). This sudden interest in stratigraphic nomenclature is peculiar insofar as theories and practices of stratigraphic nomenclature have been largely unknown to this type of scholarship before the popularization of the Anthropocene. It is, however, less of a surprise once one acknowledges that the Anthropocene, as a "metaphor for a changing society" (Robin 2014, p. 19), encompasses themes and issues deeply intertwined with human affairs.

Critical scholarship on this topic shares several lines of critique, most commonly the seemingly blind notion of *Anthropos* in the '*Anthropo*-cene' (Crist 2013; di Chiro 2017; Malm and Hornborg 2014), but also the lack of historicity in the term (LeCain 2015; Moore 2016) and its underlying anthropocentric nature (Crist 2013; Jensen 2013; Suckling 2014). Besides criticism on a discursive and societal level, humanists and social scientists also have engaged with the technical nature of the term. For instance, historian Timothy J. LeCain (2015) observes that "none of the other officially recognized geological periods are named for a specific class or order of creatures, much less one species" (p. 19).[1] Similarly, historian Christophe Bonneuil (2015) notes that "the naming practice is an anomaly in the stratigraphic nomenclature: until now, geological divisions were named after their main flora and fauna composition, not after any causal agent" (p. 19). Philosopher of science Jay Foster (2018) also notices that "[i]f the nomenclature for the proposed new epoch were to stick with the tradition of mentioning only *effects*, then the anthropos should receive no explicit mention" (p. 24).

Scientists within and outside the stratigraphic community have paralleled this type of criticism. Finney and Edwards (2016) stress the non-geological origins of the term, noting that "[i]n contrast to all other units of the ICS chart, the concept of the Anthropocene did not derive from the stratigraphic record. It arose with Paul Crutzen […], a Nobel Laureate in Chemistry, who suggested that because of a greatly increased human impact on the Earth system" (p. 6). This criticism implies that the term has more significance in the context of Earth System science than chronostratigraphy, given also that Crutzen was not a stratigrapher himself. This seeming contrast with other units of the International Chronostratigraphic Chart is shared by physicist and meteorologist Guido Visconti (2014), who holds that the "etymology of the word is not consistent with the meaning of other geologic epochs" (p. 381). This is only true if considering the epochs of the Cenozoic Era (< 66 million years), whose names are broadly indicative of faunal succession (e.g., Holocene meaning 'wholly new,' Pleistocene meaning 'most new,' etc.). However, naming differs among epochs of other eras, as discussed later in Sect. 4.2.

Walker et al. (2015) also argue that the etymology of the term 'Anthropocene' (from ἄνθρωπος, 'anthropos,' meaning 'human'; and καινός, 'kainos,' meaning 'new') "makes no sense at all" (p. 205) once literally translated into 'human new,' in that humans have already existed during the Holocene (and appeared much earlier than that). The authors also argue that the selection of the '-cene' suffix implicitly attributes to the Anthropocene the status of epoch/series, so that "[n]o consideration is given to the possibility that the 'Anthropocene' might be designated a

[1] Presumably, LeCain is using the term 'period' informally, not in its geochronological sense.

unit of lesser rank, i.e., of stage, age, or even sub-stage/sub-age status" (ibid.). This argument is also advanced by current ICS Secretary-General Philip Gibbard and geologist Michael Walker (2014), who note that an epoch-level change "is not supported by the geological evidence" (p. 32). Because the epochs of the Cenozoic Era are all characterized by the '-cene' suffix, it seems that the 'Anthropocene' was attributed *ex ante* the unit level of epoch. Indeed, ever since the Anthropocene was taken into stratigraphic scrutiny, the unit level of series/epoch was considered the most suitable level to reflect "[t]he degree of environmental change wrought by humans" (Zalasiewicz et al. 2011, p. 1049; see also Zalasiewicz et al. 2008; Zalasiewicz et al. 2010). If a lower unit level were to be assigned to the proposed unit, for instance, as a stage/age, then the term "would need to carry the appropriate "-ian" ending" (Head and Gibbard 2015, p. 24) that characterizes the naming of stages/ages units.

To further stress the informal nature of the 'Anthropocene' term, paleoclimatologist William Ruddiman—popular for his 'early anthropogenic hypothesis' (Ruddiman 2003, 2007; Ruddiman et al. 2020)—has suggested not capitalizing 'anthropocene.' This way of stylizing the word "would allow for modifiers appropriate to the specific interval under discussion, such as early agricultural or industrial" (Ruddiman et al. 2015, p. 39; see also Ruddiman 2018) without restriction to a formal, chronostratigraphy-based definition. A similar alternative has been advanced by biologist and paleoecologist Valentí Rull (2017, 2018), who uses quotation marks to highlight the informal nature of the term—despite its being used "as if it was already formalized" (2018, p. 4).

The AWG (Zalasiewicz et al. 2017c) has responded to criticism against the etymology and usage of the term 'Anthropocene.' However, the principles and guidelines informing the naming of chronostratigraphic units have seen less theoretical engagement than would be expected in these debates from both sides. This aspect requires further consideration.

4 The 'Anthropocene' in the Context of Chronostratigraphic Nomenclature

Criticism against the suitability of the term 'Anthropocene' can be evaluated through the principles and guidelines of stratigraphic nomenclature to determine whether the term is a suitable chronostratigraphic term. These principles and guidelines can be extrapolated from the *International Stratigraphic Guide* (or simply *Guide*). Thus, a preliminary probe into the nature and purpose of the *Guide* is necessary. Then, the principles of stratigraphic nomenclature and classification, particularly in respect to naming chronostratigraphic units and the preservation of 'well-established' names, are discussed.

4.1 Meaning and Purpose of the Guide

The *Guide* is an international reference framework for stratigraphic classification, nomenclature, and procedures. Its fundamental purpose is "to promote international agreement on principles of stratigraphic classification and to develop an internationally acceptable stratigraphic terminology and rules of stratigraphic procedure" (Salvador 1994, p. 2).

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

The *Guide*, by definition, was intended "to be a guide and not a code" (p. xi), meaning that its recommendations and values do not sharply delimit stratigraphy from non-stratigraphy, least science from pseudo-science. On the contrary, "the *Guide* favors a broad and unrestrictive approach in defining principles, proposing rules, and recommending procedures" (p. 4). In the case of conflicting views on matters of stratigraphic classification, terminology, and practices, the *Guide* "favors the less prohibitive one—the one that allows the greater freedom for both points of view" (ibid.). It also acknowledges that "hard and fast rules" cannot be applied equally to every stratigraphic matter of debate, and thus "common sense may best indicate what [solution] will most effectively promote clarity, understanding, and progress" (ibid.). These are important points in framing the philosophy underlying the classification and naming of stratigraphic units as conflict emerged in the very naming of the 'Anthropocene.'

4.2 Stratigraphic Nomenclature and the Naming of Chronostratigraphic Units at Series Level

The *Guide* defines stratigraphy as the "descriptive science of rock strata" and "rock bodies forming the Earth's crust and their organization into distinctive, useful, mappable units based on their inherent properties or attributes" (Salvador 1994, p. 13). These properties and attributes form categories or types of *stratigraphic units*, such as lithostratigraphic units (based on lithological properties of rock bodies),

biostratigraphic units (based on fossil record), magnetostratigraphic units (based on magnetic properties), and more. Each unit expresses a set of specific properties of rock bodies that, when correlated with one another, aim at delivering a better picture and understanding of the past and present stratigraphy and history of the Earth.

Chronostratigraphic units are one among these types of stratigraphic units. They are the only time-dependent material categories among stratigraphic units, and they "are defined as encompassing all rocks formed during a certain time span of Earth history regardless of their compositions or properties" (pp. 101–102). Chronostratigraphic units are particularly valuable because they are based on a universal property: time. As such, chronostratigraphic classification (i.e., the organization of rocks based on their age or time of formation) offers "the best promise of being recognized, accepted, and used worldwide and of being, therefore, the basis for international communication and understanding" (p. 90). Chronostratigraphic units form the International Chronostratigraphic Chart, which in turn forms the basis for the Geologic Time Scale. The concept of Global Boundary Stratotype Section and Point or GSSP, which has resonated vividly in Anthropocene debates, is first and foremost a chronostratigraphic concept and method; it is used to determine how and where to fix the (lower) boundaries of chronostratigraphic units in geological sections (Lucas 2018, 2020; Smith et al. 2015; Walsh et al. 2004).

Stratigraphic units are the basic working entities for stratigraphic classification. In turn, classification requires guidelines for the definition, naming, and usage of stratigraphic unit terms: a stratigraphic nomenclature. A useful preliminary distinction adopted by the *Guide* discerns between *formal* and *informal* unit terms (sections 3.A.5.a/b), stressing that the "initial letter of an informal unit term is printed in lowercase" (p. 14). This observation relates to the *type* (e.g., biostratigraphy, lithostratigraphy, chronostratigraphy, etc.) and *rank* (e.g., group, formation, epoch, period, etc.) of stratigraphic terms, namely, the second term of the binomial designation (e.g., Quaternary *Period*) rather than the first, which is always capitalized (e.g., *Jurassic* System, *Chonta* Formation). In a footnote, the *Guide* also specifies that capitalization of terms is "made with reference to the English language," so that this "may not be applicable for use in languages with different rules of orthography" (ibid.). These remarks seem relevant as the Anthropocene has not yet seen official ratification by the ICS and IUGS—the entities ultimately in charge of ratifying geological time units. Indeed, some critics of the Anthropocene hypothesis advocate for keeping the 'anthropocene' lowercased (Ruddiman 2018; Ruddiman et al. 2015), or to use quotation marks (Rull 2018) to emphasize its informal status. Yet, the *Guide* does not seem to discourage the formal use of informal stratigraphic terms, but rather the opposite ("the informal use of formal stratigraphic terms (formation, member, biozone, series, etc.) in published documents is *strongly discouraged*," Salvador 1994, p. 14), prior to informal terms being duly defined and described. Whether or not an Anthropocene unit should see formal ratification, it seems to be the case that the AWG has at least attempted to define and describe the proposed unit throughout its activities (Zalasiewicz et al. 2019). This, along with the fact that both formal and informal geochronological time units (e.g., Precambrian) are always capitalized, seems to legitimize capitalizing the 'Anthropocene.'

Additional guidelines concerning the naming of stratigraphic units are given in section 3.B.3 of the *Guide*. For most types of stratigraphic units, the geographic location of the unit provides the unit's name, followed by its type and/or rank. Specific details on the geographic source of a name are given in section 3.B.3.a.i: "Geographic names should be derived from permanent natural or artificial features at or near which the stratigraphic unit is present," and "[a]ppropriate names may be selected from those shown on state, provincial, county, forest service, topographic, hydrographic, or comparable maps" (Salvador 1994, p. 20). For instance, 'La Luna Formation' identifies a geological section in a specific region (La Luna, a small town close to the Maracaibo Basin in northwest Venezuela), and the type and rank ('Formation,' a lithostratigraphic unit term) of the section. Biostratigraphic units differ, because they use the name of the appropriate fossils and their respective type/rank rather than geographic location. For instance, '*Cynognathus* Assemblage Zone' identifies a geological section where the fossil of a genus (*Cynognathus*, a tetrapod of the Middle-Late Triassic) appears, and the type of biostratigraphic unit or 'biozone' indicative of how this fossil record appears in the geological section ('Assemblage Zone').

The proposed Anthropocene unit is meant to be ratified as a *chronostratigraphic* unit (at the series level), and thus as a parallel *geochronological* unit of time (at the epoch level). The main difference between chronostratigraphic units and geochronological units is that the latter are abstract, non-material categories reflecting time periods, and thus are not stratigraphic units per se. To illustrate the difference between chronostratigraphic and geochronological units: an observer can see and touch a Jurassic System (chronostratigraphic unit), but cannot see and touch the Jurassic Period (geochronological unit), because the latter only represents a time interval and not a material entity. The purpose and utility of dividing between chronostratigraphic and geochronological time units, and thus between an International Chronostratigraphic Chart and a parallel Geologic Time Scale, has been an object of debate (see Zalasiewicz 2004; Zalasiewicz et al. 2013; Zalasiewicz et al. 2004).

The *Guide* dedicates section 9.J to the "Naming of Chronostratigraphic Units" (Salvador 1994, p. 97), but

only a few remarks related to the proper use of capitalization and binomial designation are advanced before sending the reader back to sections 3.B.3 and 3.B.4—both dealing with general principles of stratigraphic nomenclature. More detailed guidelines for the naming of chronostratigraphic units at the series level (the level currently being considered by the AWG) are provided in section 9.C.4.d. As for other stratigraphic units, "[a] new series name should preferably be derived from a geographic feature in the vicinity of its stratotype or type area" (p. 81). However, "the names of currently recognized series which are of other origins should not be changed" (ibid.). Chronostratigraphic units have been given names on different grounds throughout history, showing that the naming practice is far from consistent. For instance, names for the currently seven series of the Cenozoic Erathem (66 Ma–present) are characterized by the suffix '-cene,' and are indicative of different faunal compositions rather than geographic locations. The Permian System (298.9–251.9 Ma) is divided into Cisuralian, Guadalupian, and Lopingian, which are terms of geographic origin and use the '-ian' suffix characteristic of stages rather than series. The four series of the Silurian System (443.8–419.2 Ma), namely, Přídolí, Ludlow, Wenlock, and Llandovery, are named after locations and take neither the '-cene' nor the '-ian' suffix. Similarly to the Permian System, the series of the Cambrian System (541.0–485.4 Ma), namely, Terreneuvian, Miaolingian, and Furongian, use the '-ian' suffix and are named geographically—with the exception of Series 2 (following the Terreneuvian Series and preceding the Miaolingian Series), whose lower boundary has not yet been ratified (via GSSP) as of January 2022. Most of the remaining series on the International Chronostratigraphic Chart are derived from their position (Lower, Middle, Upper) within their respective systems rather than from geography and consequently use neither the '-ian' nor the '-cene' suffixes.

Similar inconsistencies are found in the naming of system units, which are named after chronologic positions, lithological properties, geography, and even ancient Welsh tribes (i.e., Silurian and Ordovician) and are not distinguished by the use of any particular suffix. This hints that practical value and preservation of historical names are given priority over the desire for uttermost terminological consistency. Notably, these represent inconsistencies only insofar as one looks at the naming of *all* chronostratigraphic units. One could evaluate naming consistency based on the chronostratigraphic series within individual eonothems, erathems, or systems, and notice no inconsistencies. This is the case, for instance, in the naming of the chronostratigraphic series within the Cenozoic Erathem. Indeed, the naming of these series seems to be the primary argument behind accusations of etymological inconsistency, because the term 'Anthropocene,' unlike the names for previous series of the Cenozoic, would not equally express novelty in the faunal succession in sedimentary records—according to critics (Walker et al. 2015).

4.3 Traditional and 'Well-Established' Stratigraphic Units and the Principle of Tolerance and Flexibility

The previous section concluded by mentioning that preservation of historical names may outweigh the necessity of complete naming consistency. Indeed, section 3.B.3.g of the *Guide* includes an insightful remark on the preservation of "traditional and well-established names" (p. 22). This passage is particularly valuable, because it provides grounds for legitimizing the use of the term 'Anthropocene' in the context of chronostratigraphic nomenclature. The section observes:

> Although it is strongly urged that all new stratigraphic units be named according to the recommendations of this *Guide*, it is realized that there are many well-established and traditionally used stratigraphic units, particularly lithostratigraphic units, of long historical standing for which exception should be made. […] Such units should not be abandoned merely because they lack geographic names. Tolerance and flexibility are advised. It is suggested that national stratigraphic bodies make recommendations concerning the conservation of such units under their original names, but it is also recommended that detailed definitions, characterizations, and descriptions be published, and specific stratotypes be designated, as in the case of newly defined units. (pp. 22–23)

The *Guide* gives examples of lithostratigraphic units (e.g., the Millstone Grit Group, a lithological unit of the Carboniferous System deriving its name from millstones used for grinding grain into flour rather than from a locality), but the principle of "tolerance and flexibility" equally applies to all stratigraphic units with a longstanding history or that are well established, including chronostratigraphic units regardless of the diverse origins of their names. Consequently, this principle should also apply to the term 'Anthropocene' insofar as it is recognized as 'traditional' or 'well-established.'

From a conservative standpoint, it is difficult to recognize the 'Anthropocene' term as 'traditional,' if 'traditional' means long established. Many traditional chronostratigraphic units that are currently used have names whose history spans for more than a 100 years, dating as far back as the early 19th century. This is a much longer history than the two-decade history of the 'Anthropocene' concept. From a less conservative approach, one could extend the history of the term to include its occurrences in Soviet geological literature during the second half of the 20th century (although the Anthropocene in Soviet literature was substantially

different from the 'modern' Anthropocene). Even then, the term would still be hardly recognizable as traditional, not least because of the restricted and heavily politicized research community where the term was being applied.

Nevertheless, there seem to be arguments for considering the term 'Anthropocene' as 'well-established'—depending on the interpretation of 'well-established.'

One interpretation considers 'well-established' as a function of *popularity*. Inspiring artists and musicians, and featuring in art exhibitions, museums, documentaries, and the news, the 'Anthropocene' term and concept has become an object of press coverage (Zottola and de Majo 2022) and a vehicle for environmental communication (Davis and Turpin 2015; Möllers et al. 2015), aiding and connecting pre-existing narratives that stress the dramatic impact of humans on the Earth while encompassing and extending central predicaments such as global warming or climate change (Thomas 2019; Thomas et al. 2020). Within the academic research landscape, the term has been a central discursive hub in environmentally oriented humanities and social sciences (Bostic and Howey 2017; Ellis 2016; Emmett and Lekan 2016; McNeill and Engelke 2014; Merchant 2021; Robin and Steffen 2007). Across the natural sciences, the term has been particularly successful in Earth System science (Crutzen and Steffen 2003; Steffen et al. 2004; Syvitski et al. 2020), but also in water sciences (Codispoti et al. 2001; Meybeck 2001, 2002), biological sciences (Bennett et al. 2018; Wilkinson et al. 2014; Williams et al. 2015), and more. The world's largest linked research information dataset, *Dimensions*, counts more than 100,000 publications, 282 datasets, 756 grants, 16 patents, and 680 policy documents using the term 'Anthropocene' since 2000.[2] If well established is interpreted in terms of popularity, then the term 'Anthropocene' can very easily be considered well established.

The second interpretation of well established adopts a *linguistic* and *institutional* perspective. The term 'Anthropocene' has entered several English (and non-English) vocabularies, appearing in the Merriam-Webster and Oxford dictionaries. It has been translated into many languages, including German (Anthropozän), French (Anthropocène), Italian (Antropocene), Spanish (Antropoceno), Icelandic (Mannöld), Dutch (Antropoceen), Russian (Антропоцен), Chinese (人类世), and Japanese (人新世). In 2018, Elsevier published a five-volume *Encyclopedia of the Anthropocene*, and the term was included in the 2012 and 2020 editions of *The Geologic Time Scale* (Zalasiewicz et al. 2012, 2020). Several journals dedicated to multiple aspects of the Anthropocene have launched in recent years, including *Anthropocene Review*, *Anthropocene*, *Elementa: Science of the Anthropocene*, and most recently *Anthropocene Science*. The term has also been used in policy documents by both national and international institutions, most notably in the pivotal IPCC Assessment Reports, but also by the Food and Agriculture Organization, the International Union for Conservation of Nature, and by the United Nations Development Programme, to name a few. These aspects corroborate the fact that, both linguistically and institutionally, the 'Anthropocene' is a well-established term—either as an informal or (possibly) formal chronostratigraphic term.

One last interpretation of 'well-established' concerns the *application* of the term in science, especially in stratigraphic research. As mentioned, the term 'Anthropocene' has seen widespread application across the natural sciences, primarily in Earth System science, water sciences, and geosciences. The term is applied to define a state shift—either in the functioning of the Earth System (Syvitski et al. 2020), of oceans (Codispoti et al. 2001), of riverine fluxes (Meybeck 2001, 2002; Vörösmarty and Meybeck 2004), of sediment fluxes (Syvitski and Kettner 2011), or in the composition of existing biota (Dirzo and Raven 2003; Worm and Paine 2016). Whether informally or not, this literature has implemented the 'Anthropocene' concept *epistemically*, namely, to determine and characterize a new paradigm under which new conditions operate, and for which new knowledge forms are requested. This corroborates the functional and seemingly successful application of the term 'Anthropocene' among the natural sciences.

However, because the Anthropocene Hypothesis is *stratigraphic* in nature, its application in extant geological research—particularly Holocene and Quaternary research—has significant weight in assessing whether the term 'Anthropocene' is 'well-established' (as in, widely applied) in stratigraphic research. This question remains open. While most of the AWG members agree on a chronostratigraphy-based definition of the Anthropocene (Zalasiewicz et al. 2017b), some prefer a diachronous (Edgeworth et al. 2015) or a more inclusive definition of the concept (Ellis 2016). Reportedly, some ICS and SQS members "have not been persuaded by the arguments raised so far" (Monastersky 2015, p. 147) or by the utility of formalizing the proposed unit (Gibbard and Walker 2014; Klein 2015)—although a formal proposal is yet to be submitted by the AWG. The question of whether the 'Anthropocene' term is well established (viz., applied) in stratigraphic research depends primarily on the reliability and weight of stratigraphic evidence submitted by the AWG as well as the utility of the proposed unit. These aspects go

[2] Results retrieved from https://app.dimensions.ai/discover/publication by keywording 'anthropocene' (case-insensitive) on 7 Jan 2022. Naturally, results are coarse-grained and may not perfectly represent the actual number of publications (and other formats) where the term 'Anthropocene' appears.

beyond the naming procedures recommended by the *Guide*, and thus the scope of the present research.[3]

5 Discussion

The theoretical discussion of the principles of (chrono)stratigraphic classification and nomenclature so far undertaken can help determine the suitability of the 'Anthropocene' as a chronostratigraphic term.

Remarks concerning the usage of formal and informal unit terms suggest that the term 'Anthropocene' can be used without any stylistic emphasis. Indeed, lowercasing does not seem a commonly shared practice, and it is unlikely to become a habit in scientific literature. Many chronostratigraphic stages are informal (i.e., not defined via GSSP) but still capitalized (e.g., Aptian, Norian, Kungurian, Kasimovian, etc.). Similarly, using quotations marks might be more confusing than elucidating—especially in written reported speech or oral communication. Perhaps, this solution would be more useful to distinguish the 'Anthropocene' as a broader multidisciplinary concept or boundary object from the Anthropocene as a geological entity; or to distinguish the *abstract* term, concept, or idea of 'Anthropocene' from the *material* Anthropocene as a historical and/or geological entity (i.e., we live in the Anthropocene epoch, but we do not live in the 'Anthropocene' concept)—as shown by the stylization in the present analysis. Yet, both solutions seem more relevant to a conceptual, linguistic, or philosophical analysis than to stratigraphic language and practices.

Naming chronostratigraphic units after a geographic location in proximity to the unit's stratotype or type area is a recommended practice, but not mandatory, according to the *Guide*. Indeed, many of these units are not named on a geographic basis. Several series-level units do not follow the '-cene' suffix (which only characterizes the series of the Cenozoic), using instead the '-ian' suffix commonly attributed to stage-level units (but also used for some system-level units), or neither of these suffixes—following instead their position within a system or drawing from lithostratigraphy units (as with the series of the Silurian). The faunal composition loosely characterizing the names of series of the Cenozoic (whose names are primarily traditional and well established) is more the exception than the rule, seen from the entirety of the International Chronostratigraphic Chart. Assuming the Anthropocene to be etymologically inconsistent with these units, this would not seem sufficient to reject the term on purely nominalist grounds—especially considering its widespread application and success across disciplines and fields of knowledge within and outside the geosciences (not to mention outside the academic landscape).

Bonneuil's (2015) observation that the term 'Anthropocene' is an anomaly, because "geological divisions were named after their main flora and fauna composition, not after any causal agent" (p. 19) seems to confuse *defining* and *characterizing* geological units with *naming* them—three distinct practices in stratigraphic classification and nomenclature (see Murphy and Salvador 2000, p. 235). The same confusion seems to inform Foster (2018; see Sect. 3). Most chronostratigraphic units are *defined* and *characterized* based on (preferably) marine fossiliferous records that reflect a certain composition of flora and fauna at a given time, but they are not technically *named* after that composition (e.g., the terms 'Jurassic,' 'Quaternary,' or 'Devonian' are not chosen based on species composition). The confusion may arise from the fact that Bonneuil is implicitly considering the epochs of the Cenozoic (i.e., Paleocene, Eocene, Oligocene, Miocene, Pliocene, Pleistocene, and Holocene), which are *defined* and *characterized* by climatic, magnetic, *and also* biotic markers, and whose *names* reflect the relative faunal abundance and diversification (of molluscan taxa) in stratigraphic sequences. Yet, the *International Stratigraphic Guide* does not suggest naming chronostratigraphic units at the series level (or any other level) based on the fauna and flora composition of a given fossiliferous stratigraphic sequence; instead, it recommends naming a series after "a geographic feature in the vicinity of its stratotype or type area" (Salvador 1994, p. 81). While Bonneuil is correct in noticing that no geological unit is named after a causal agent, the 'Anthropocene' is as much as an anomaly as the series of the Cenozoic are in respect to other series of the International Chronostratigraphic Chart.

What these observations imply is that terminological consistency is not prioritized over practicality, preservation of traditional and well-established names, and overall flexibility and tolerance in the organization of the International Chronostratigraphic Chart. Terminological consistency is an epistemic virtue and *desideratum* in science and the ultimate purpose and goal of nomenclatures. However, its absence does not immediately translate into the absence of science, because other epistemic virtues than consistency may be sought after across organizational schemes and paradigms in scientific disciplines. If the overall epistemic gains of the Anthropocene Hypothesis outweigh the seemingly

[3] A preliminary keyword search in different geology journals shows (as of January 11, 2022) 103 results for *The Holocene*, 60 results for *Quaternary International*, 19 results for *Quaternary Research*, 17 results for *Journal of Quaternary Science*, six results for *Quaternary Geochronology*, and five results for *Episodes* (four of which are critical of the proposal). An in-depth analysis of this pool of publications should be conducted to assess whether the 'Anthropocene' concept/term could be considered well established in geologic and stratigraphic (especially Holocene and Quaternary) literature. The assimilation, application, and overall impact of the 'Anthropocene' concept in non-English speaking contexts also remains an open question that needs to be addressed.

Table 1 List of alternative names for the 'Anthropocene' based on geographic location and suffixes

GSSP location	Possible series/epoch-level names	Possible stage/age-level names
Searsville Reservoir, California, USA	Searsvillecene, Jaspercene	Searsvillian, Jasperian
Śnieżka Peatland, Sudetes Mountains, Poland	Sudetecene, Śnieżkacene	Sudetian, Śnieżkian
Sihai Longwan Maar Lake, Jingyu County, Jilin Province, China	Sihaicene, Jingyucene, Jilincene	Sihaian, Jingyan, Jilinian
San Francisco Bay, California, USA	Franciscocene, Alamedacene, Redwoodcene	Franciscian, Alamedian, Redwoodian
Crawford Lake, Milton, Ontario, Canada	Crawfordcene, Miltoncene, Nassagaweyacene	Crawfordian, Miltonian, Nassagaweyan
Flinders Reef, Queensland Plateau, Australia	Flindercene, Queenslandcene	Flinderian, Queenslandian
West Flower Garden Bank Reef, Gulf of Mexico, USA	Flowercene, Galvestoncene	Flowerian, Galvestonian
Eastern Gotland Basin, Baltic Sea	Gotlandcene, Balticene, Ventspilcene	Gotlandian, Baltician, Ventispilian
Palmer Ice Core, Antarctic Peninsula	Palmercene, Antarcticene	Palmerian, Antarctian
Ernesto Cave, Trentino, northern Italy	Ernestocene, Trentinocene, Tezzecene	Ernestian, Trentinian, Tezzian
City of Vienna, Austria	Viennacene, Karlcene, Resselcene	Viennian, Karlian, Resselian
Beppu Bay, Japan	Beppucene, Kyushucene	Beppunian, Kyushian

Some of the names are derived from towns, natural reserves, parks, or other permanent features next to the location. One of the possible stage/age-level names listed may also be assigned to the stage/age that would lie within an Anthropocene Series/Epoch. Stages and series need not have the same geographical root if either of the ones is chosen

inconsistent nature of the chosen term (for instance, because the hypothesis has explanatory power, is intelligible, is useful, is elegant, is simple, or has certain benefits for geological research and scientific knowledge overall), then the terminological choice becomes more of a nominalist conundrum than a philosophical or scientific question.

Nevertheless, if the 'geography clause' in naming chronostratigraphic units is enforced, and if consistency with suffixes is sought after, then a plausible compromise might be renaming the proposed unit based on the location of the GSSP selected to designate its lower boundary. The AWG is currently considering a pool of several GSSP candidates (AWG 2020), meaning that, theoretically, the 'Anthropocene' could be renamed after geographical features in the proximity of the selected GSSP. Some of these possible terminological alternatives are listed in Table 1.

If consistency with previous Cenozoic epochs in representing faunal succession rather than geographic location is sought after, perhaps a suitable name would be Homogenocene. This term was originally coined by entomologist Michael J. Samways (1999) to stress the homogenization "of the world's fauna and flora" (p. 65). The term would then represent the decreasing rates of biodiversity around the globe (Barnosky et al. 2011; Ceballos et al. 2015, 2017), as well as the translocations of alien species by humans leading toward a homogenous biota differing substantially from the Holocene biota.

In line with its overarching spirit, the *Guide* promotes tolerance and flexibility in naming stratigraphic units. This principle is especially useful for preserving traditional and well-established names. While the 'Anthropocene' can hardly be considered 'traditional' in the way several other chronostratigraphic unit terms are, it is 'well-established' in terms of *popularity* (within and outside academic research), *linguistic* and *institutional* recognition, and *application* among the natural sciences. This further corroborates the suitability of the 'Anthropocene' as a chronostratigraphic term. However, to what degree the 'Anthropocene' concept is 'well-established' (viz., applied) in the international stratigraphic community (i.e., whether stratigraphers and geoscientists are actively using the informal unit for research purposes) remains an open and decisive question.

Whether the 'Anthropocene' is an appropriate term in chronostratigraphic classification is ultimately a *nominalistic* question. Changing the term 'Anthropocene' does not change what it represents *stratigraphically*, namely, the set of properties that make the unit "functionally and stratigraphically distinct from the Holocene" (Waters et al. 2016, p. 137). Any of the possible names listed in Table 1 or others could be advanced to rename the proposed epoch, but the name per se would not change its stratigraphic definition and characteristics (although it would affect the broader perception of the 'Anthropocene' concept). Whether or not the stratigraphic record characterizing and defining the proposed Anthropocene unit is considered sufficient and/or convincing, the name only serves the practical function of delimiting a new stratigraphic boundary that is readily observable in the geological record. Its perseverance in chronostratigraphy is primarily a consequence of Crutzen's original (and informal) suggestion, and the emphasis placed on humans as the leading cause behind the emergence of this new stratigraphic record. Neither reason seems strong enough to reject the term as an invalid chronostratigraphic designation—especially in light of the principle of flexibility so much encouraged by the *Guide*.

6 Conclusions

The contribution provides a critical review of extant criticism against the chronostratigraphic suitability of the term 'Anthropocene' based on the naming principles and guidelines laid out by the *International Stratigraphic Guide*. The analysis suggests that the term 'Anthropocene' is indeed suitable in the context of chronostratigraphic classification, in that it does not conflict with the naming guidelines, recommendations, and philosophy set by the *Guide*. Additionally, the term is well established in the broader scientific, institutional, political, and popular arenas—a factor indicative of general applicability that may push toward maintaining the term in the context of chronostratigraphy. Nevertheless, if strict adherence to the naming guidelines advanced by the *Guide* is pursued, critics may request the term 'Anthropocene' be changed to accommodate for a geographic designation, or a term consistent with the naming of the series of the Cenozoic. Much of this criticism depends on the weight attributed to terminological consistency.

To say that the term 'Anthropocene' is suitable in the context of chronostratigraphic nomenclature says nothing concerning the overall *stratigraphic* validity of the proposed Anthropocene unit. Sound and convincing stratigraphic evidence ultimately has priority over issues of a nominal nature, which are only considered *after* such evidence has been discussed. This is a question related to the weight of the scientific evidence supporting the Anthropocene Hypothesis, evidence that is currently being discussed and evaluated by geologists and stratigraphers involved in the proposal.

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