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The Anthropocene as an Event, not an Epoch

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ABSTRACT: Over the course of the last decade the concept of the Anthropocene has become widely established within and beyond the geoscientific literature but its boundaries remain undefined. Formal definition of the Anthropocene as a chronostratigraphical series and geochronological epoch following the Holocene, at a fixed horizon and with a precise global start date, has been proposed, but fails to account for the diachronic nature of human impacts on global environmental systems during the late Quaternary. By contrast, defining the Anthropocene as an ongoing geological *event* more closely reflects the reality of both historical and ongoing human-environment interactions, encapsulating spatial and temporal heterogeneity, as well as diverse social and environmental processes that characterise anthropogenic global changes. Thus, an Anthropocene Event incorporates a substantially wider range of anthropogenic environmental and cultural effects, whilst at the same time applying more readily in different academic contexts than would be the case with a rigidly-defined Anthropocene Series/Epoch.

Introduction

On 14th September 2021, Bauer et al. (2021) published a preliminary correspondence in *Nature* which proposed that the Anthropocene should be defined as an 'event' rather than a geological 'epoch'. This was followed by a paper in *Episodes* (Gibbard et al., 2021) which described in greater detail the rationale behind the proposal. Defining the Anthropocene as an event is a significant departure from current thinking, but it offers a solution to the long-standing methodological problem of how to define the multi-faceted Anthropocene as a stratigraphical unit when the onset of transformative human activities, as reflected in the geological record, is markedly time-transgressive. However, we are aware that *Episodes* might not be widely read by Quaternary scientists. Consequently, we here take the opportunity to bring this redefinition of the Anthropocene to the attention of the wider Quaternary community. We explain further why defining the Anthropocene as a chronostratigraphical unit has proved to be so problematical (cf. Edgeworth et al., 2019), and reiterate our alternative approach of considering the Anthropocene not in chronostratigraphical or geochronological terms (series/epoch), but rather as an ongoing '*anthropogenic event*', analogous to biotically driven, events in deep geological time which have also had far reaching impacts on global environmental systems.

The Anthropocene as a geological epoch.

The term 'Anthropocene' is now firmly embedded in earth science literature, following its introduction by Paul Crutzen to define a new geological epoch/period characterised by the increasing human impact on Earth's geological, biological and climatic systems (Crutzen, 2002, 2009; Crutzen and Stoermer, 2000). The concept of the Anthropocene was explored further by the Stratigraphy Commission of the Geological Society of London, and specifically the idea that Crutzen was proposing a formal Anthropocene Epoch following the Holocene (Zalasiewicz et al., 2008). This led, in 2009, to the establishment of the Anthropocene Working Group (AWG) within the Subcommission on Quaternary Stratigraphy (SQS) of the International Commission on Stratigraphy (ICS). The aim of the AWG is to evaluate the Anthropocene as a potential unit of series/epoch status in the International Chronostratigraphic Chart upon which the Geological Timescale (GTS) is based (Waters et al., 2014). Crutzen's view was that an appropriate start date for the Anthropocene would be

during the mid-late eighteenth century, coinciding with the Industrial Revolution in western Europe. However, the AWG increasingly came to favour a later date in the mid-twentieth century that coincides with what has been termed the 'Great Acceleration' (Steffen et al., 2015) in human impacts on Earth systems (e.g. Zalasiewicz et al., 2015; Syvitski et al., 2020; Figure 1). Since then, the AWG has been working towards a definition of the Anthropocene as a new series/epoch beginning around CE 1950 (Zalasiewicz et al., 2017; 2019), and appears to have reached an internal agreement that this is marked by the Great Acceleration (Head et al., 2021a).

Formally establishing the Anthropocene as a series/epoch[1] requires that certain protocols must be followed. A proposal from the AWG is submitted to the SQS and, if approved is transmitted to the ICS for further consideration. In order to be accepted a supermajority (60%) of voting members is required. If accepted, the proposal is passed to the International Union of Geological Sciences (IUGS) for ratification. Fundamental to any proposal is the identification of a type or representative stratigraphical section that contains a unique basal boundary or Global boundary Stratotype Section and Point (GSSP). This is a formally ratified (by the IUGS) point in a rock, sediment or ice sequence that is characterised by physical, chemical and biological changes in a continuous depositional succession (Remane et al., 1996). The boundary represents the series base and delineates a horizon that is representative of the same point worldwide. By definition, the boundary is time-parallel (i.e. it is globally isochronous); it cannot be diachronous. The AWG has been exploring potential GSSPs, based principally on radionuclide fall-out from atomic weapons testing in the 1940s and 1950 that left a global, broadly isochronous signature in lake sediment and other depositional successions (Waters et al. 2018), but no formal proposal has yet been made. Until it is, then any definition of the Anthropocene must remain informal. However, the question might arise as to whether the international geological community would welcome a new series/epoch for which the lower boundary is based on the radiogenic by-products of weapons of mass destruction. These are significant issues in Late Holocene stratigraphy that

[1]In stratigraphical nomenclature, 'series',' subseries' and 'stage' are *chronostratigraphical* or 'time-rock' terms that refer exclusively to all rocks/sediments formed during a specific interval of geological time, whereas 'epoch', 'subepoch' and 'age' are *geochronological* or time terms referring to the timespan of a stratigraphical unit (Salvador, 1994).

will eventually be debated within the SQS and ICS, but it is important that the wider Quaternary community contribute to deliberations on any formally submitted proposal, as has happened in the past (Finney and Edwards, 2016). However, a further practical problem also remains. The stratigraphical record is unequivocal in showing that measurable impacts on earth system functioning extend back several thousand years into the Holocene in many parts of the world, and possibly earlier in some regions (Roberts et al., 2021). Moreover, a range of proxy records reveals the markedly time-transgressive nature of human impact when studied on historical or human timescales. Human-environment transformations that affected global processes began in different places at different times and demonstrably spread geographically at different rates (Figure 1). This is the case irrespective of whether it is ecosystem change and mass extinction of large vertebrates at the end of the last cold stage (Seersholm et al., 2020); the development of early farming influencing atmospheric loading of trace gases (Ruddiman et al., 2016); long-term patterns of tropical deforestation affecting precipitation, temperature, soil stability and the carbon cycle (Roberts et al., 2021); land clearance in the Americas (Lewis and Maslin, 2015); extent and impacts of major European biome changes (Fyfe et al., 2015); global-scale industrial development with associated transformation of waterways (diversion, canalisation and damming: Merritts et al., 2011); or extraction of fossil fuels for energy (Smith and Zeder, 2013; Lewis and Maslin, 2018). It is also true that in archaeological chronologies boundaries between major archaeological periods (Mesolithic, Neolithic, Bronze Age, etc) are not time parallel, for the same reasons. An isochronous and meaningful lower boundary for the Anthropocene is similarly impractical, since it fails to reflect the evidence. While the series/epoch status of the Anthropocene defined by the CE 1950 radiogenic spike in sedimentary accumulations has the merit of being underpinned by a broadly isochronous and global stratigraphical record (as required for a GSSP), the time-transgressive nature of human impacts on Earth systems during the Holocene raises questions about the validity, and indeed the applicability, of defining the Anthropocene as a new (and meaningful) chronostratigraphical/ geochronological unit in the GTS.

The Anthropocene as a geological stage/age

If the Anthropocene is not to be a stratigraphical unit of series/epoch status, how then can it be defined? One possibility is to distinguish the Anthropocene as a *stage*/*age*, the lowest rank formal taxonomic unit in the stratigraphical hierarchy (Hedberg, 1976; Salvador, 1994). While

designated global stage names are required in the GTS, the conventional practice in Quaternary science has been to use regional rather than global stage divisions, especially in the European Pleistocene. Accordingly, their subseries ('Lower', 'Middle and 'Upper') or, more commonly, subepoch ('Early', 'Middle' and 'Late') equivalents have been favoured (Head et al., 2021b). In this classification, the Anthropocene would become the fourth (uppermost) stage/age (or subseries/subepoch) of the Holocene Series/Epoch following the Greenlandian, Northgrippian and Meghalayan (Walker et al., 2019). Two difficulties arise with this proposition, however. The designation of a stage/age requires a GSSP and this, as was discussed above, poses a problem for the time-transgressive evidence. Second, the name itself would have to change, for stages/ages are named after the type geographical locality (hence 'Greenlandian' to reflect the location of the Early Holocene GSSP on the Greenland ice sheet). As such the term 'Anthropocene' could no longer be employed.

The Anthropocene as a geological event

An alternative approach, and the one that we propose (Gibbard et al., 2021), is that the Anthropocene should not be designated as a formal chronostratigraphical/geochronological unit, but rather that it be defined as an ongoing *event*. In contrast with a series/epoch, the definition of a geological event has no formalisation procedures or GSSP requirements. While this means that the Anthropocene would not become a ratified unit within the international GTS, designation as an event in no way diminishes its significance in Earth's history. Indeed, it would define the Anthropocene in a similar way to globally significant transformations that have previously affected the Earth's biosphere. These include the Palaeoproterozoic Great Oxidation Event (GOE: *c*.2.4-2.0 Ga), the Great Ordovician Biodiversity Event (GOBE; 485-455 Ma), and the Middle-Late Devonian forestation of continents (DeFE: *c*. 390-360 Ma), all of which demonstrate that humans are not the first organisms to transform the global Earth system (Sagan, 2020). Prior to the GOE, Earth had a weakly reducing atmosphere in which oxidation was prevented. With the development of cyanobacteria and oxygen generation as a product of photosynthesis, atmospheric oxygen increased and radically changed the course of planetary development with the evolution of multicellular life (Schirrmeister et al*.,* 2013). During the GOBE, diversity of life and new communities increased exponentially, yet diachronously, through the marine realm (Servais and Harper, 2018). The evolution of forests and their spread across continents during the Devonian produced an even greater

transformation. Many biogeomorphic phenomena that operate in modern terrestrial environments appeared for the first time (Davies et al., 2021), and the dramatic changes in levels of atmospheric oxygen and carbon dioxide became a driver of Late Devonian mass extinction and latterly of Late Devonian-Carboniferous glaciation (Le Hire et al., 2011; Dahl and Ahrens, 2020). However, despite their firm basis in the stratigraphical record, (Eriksson and Cheney, 1992; Buick, 2008), neither the GOE nor the GOBE, nor the Devonian continental forestation event, are employed to define time-unit boundaries within the GTS. They are, nonetheless, widely regarded as major transformative phases of the Earth system. Moreover, they are not particular points in time; they were significant events that varied spatially and temporally, as is the case with ongoing anthropogenic transformations. Indeed, Crutzen in proposing an Anthropocene was not principally attempting to define a new formal stratigraphical unit, but rather was drawing attention to increasing human influence on the planet. Accordingly, the Anthropocene should be defined as: 'the aggregated effects of human activities that have transformed, and continue to transform, the Earth system and influence biodiversity, thereby producing a substantial, characteristic and unique record in sedimentary strata and in human-modified ground' (cf . Gibbard et al., 2021).

Event stratigraphy was first proposed for the recognition, study and correlation of the effects of important physical or biological events in the broader stratigraphical record (Ager, 1973). Geological events can be time-transgressive, multi-temporal and spatially variable, ranging by orders of magnitude from minutes to millions of years, and from local to regional and, ultimately, global (Rawson et al., 2002). The event paradigm has been firmly embedded in Quaternary science from the mid-nineteenth century onwards, with the subdivision of Quaternary time being based on the recognition of successive climatic events, principally glacials and interglacials but also stadials and interstadials, their use in stratigraphical classification being generally referred to as 'climate-stratigraphy'. Highly-resolved stratigraphical successions, such as those from ice cores, provide evidence of millennial-scale climatic events that are superimposed on these broad glacial-interglacial cycles (Björck et al., 1998; Rasmussen et al., 2014), while other short-term episodes, such as Dansgaard-Oeschger events and Heinrich events are evident in ice-core sequences and deep-ocean sediment records respectively (Dansgaard et al, 1993; Hemming, 2004). The hallmark of all these events is that while time intervals are broadly consistent at a range of spatial scales, the litho- or

biostratigraphical boundaries that mark the onset and termination of the events in the stratigraphical record may be diachronous; hence time-transgression is inbuilt within the event-stratigraphy paradigm. This means that events cannot be considered as chronostratigraphical nor geochronological units, for understanding of Earth systems, but this does not diminish the value or applicability of the concept, as is evident in the widespread use of events in Quaternary science.

Conclusions

Recognising the Anthropocene as an important transformative chapter of recent Earth history has been a feature in publications across a wide range of disciplines, yet a formal definition of the Anthropocene has so far proved elusive. Recent attempts have focussed largely on formalising the Anthropocene as a rigidly constrained chronostratigraphical/ geochronological division in the international GTS. These efforts have been compromised, however, by difficulties in determining the onset of the Anthropocene in the global stratigraphical record, and by the fact that human impact has been a diachronous, heterogeneous and socially-differentiated process. A shift to an event framework for defining the Anthropocene, as proposed herein, is a practical solution that overcomes many of these problems. It frees the concept from the constraints of geological formalisation as well as from its alignment with established chronostratigraphical and geochronological units within the Holocene Series/Epoch. It also provides a universal term (a common language) that facilitates communication beyond the geoscience community with the social sciences and humanities (Gibbard et al., 2021). Above all, it acknowledges the Anthropocene as a major transformative episode in Earth history, in keeping with similar scale events in the earlier geological record.

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Authors' contributions.

The paper was written and edited by PG and MW, whilst all authors conceived of, reviewed and interpreted the information presented. The drafting of the article and its critical revision for important intellectual content is the result of equal co-operation between all the authors. All authors approved the final publication.

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Figure caption

Figure 1: Geological timeline (top) compared with historical timeline (bottom). A number of different starting dates have been proposed for the Anthropocene that correspond to different environmental and social changes that are evident as markers in the stratigraphical record. The 'AWG view' refers to the Anthropocene Working Group 'Great Acceleration' proposal for a start date in the mid-twentieth century. Colour densities broadly indicate the intensity of change; (a) indicates years. Modified after Ellis et al. (2016) and Gibbard et al. (2021).