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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 refer to 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 as a new epoch following the Holocene was explored further by the Stratigraphy Commission of the Geological Society of London (Zalasiewicz et al., 2008) leading, 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 AWG is evaluating 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

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3 Europe. However, the AWG increasingly came to favour a later date in the mid-twentieth
4 century that coincides with what has been termed the 'Great Acceleration' (Steffen et al.,
5 2015) in human impacts on Earth systems (e.g. Zalasiewicz et al., 2015; Syvitski et al., 2020;
6 Figure 1). Since then, the AWG has been working towards a definition of the Anthropocene
7 as a new series/epoch beginning around CE 1950 (Zalasiewicz et al., 2017; 2019), and appears
8 to have reached an internal agreement that this is marked by the Great Acceleration (Head
9 et al., 2021a).

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12 Formally establishing the Anthropocene as a series/epoch¹ requires that certain protocols
13 must be followed. A proposal from the AWG is submitted to the SQS and, if approved is
14 transmitted to the ICS for further consideration. In order to be accepted a supermajority
15 (60%) of voting members is required. If accepted, the proposal is passed to the International
16 Union of Geological Sciences (IUGS) for ratification. Fundamental to any proposal is the
17 identification of a type or representative stratigraphical section that contains a unique basal
18 boundary or Global boundary Stratotype Section and Point (GSSP). This is a formally ratified
19 (by the IUGS) point in a rock, sediment or ice sequence that is characterised by physical,
20 chemical and biological changes in a continuous depositional succession (Remane et al.,
21 1996). The boundary represents the series base and delineates a horizon that is
22 representative of the same point worldwide. By definition, the boundary is time-parallel (i.e.
23 it is globally isochronous); it cannot be diachronous. The AWG has been exploring potential
24 GSSPs, based principally on radionuclide fall-out from atomic weapons testing in the 1940s
25 and 1950 that left a global, broadly isochronous signature in lake sediment and other
26 depositional successions (Waters et al. 2018), but no formal proposal has yet been made.
27 Until it is, then any definition of the Anthropocene must remain informal. However, the
28 question might arise as to whether the international geological community would welcome a
29 new series/epoch for which the lower boundary is based on the radiogenic by-products of
30 weapons of mass destruction. These are significant issues in Late Holocene stratigraphy that

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¹In 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).

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3 will eventually be debated within the SQS and ICS, but it is important that the wider
4 Quaternary community contribute to deliberations on any formally submitted proposal, as
5 has happened in the past (Finney and Edwards, 2016). However, a further practical problem
6 also remains. The stratigraphical record is unequivocal in showing that measurable human
7 impacts on Earth system functioning extend back several thousand years into the Holocene
8 in many parts of the world, and possibly earlier in some regions (Roberts et al., 2021).
9 Moreover, a range of proxy records reveals the markedly time-transgressive nature of human
10 impact when studied on historical or human timescales. Human-environment
11 transformations that affected global processes began in different places at different times
12 and demonstrably spread geographically at different rates (Figure 1). This is the case
13 irrespective of whether it is ecosystem change and mass extinction of large vertebrates at
14 the end of the last cold stage (Seersholm et al., 2020); the development of early farming
15 influencing atmospheric loading of trace gases (Ruddiman et al., 2016); long-term patterns of
16 tropical deforestation affecting precipitation, temperature, soil stability and the carbon cycle
17 (Roberts et al., 2021); land clearance in the Americas (Lewis and Maslin, 2015); extent and
18 impacts of major European biome changes (Fyfe et al., 2015); global-scale industrial
19 development with associated transformation of waterways (diversion, canalisation and
20 damming: Merritts et al., 2011); or extraction of fossil fuels for energy (Smith and Zeder,
21 2013; Lewis and Maslin, 2018). It is also true that in archaeological chronologies boundaries
22 between major archaeological periods (Mesolithic, Neolithic, Bronze Age, etc) are not time
23 parallel, for the same reasons. An isochronous and meaningful lower boundary for the
24 Anthropocene is similarly impractical, since it fails to reflect the evidence. While the
25 series/epoch status of the Anthropocene defined by the CE 1950 radiogenic spike in
26 sedimentary accumulations has the merit of being underpinned by a broadly isochronous and
27 global stratigraphical record (as required for a GSSP), the time-transgressive nature of human
28 impacts on Earth systems during the Holocene raises questions about the validity, and indeed
29 the applicability, of defining the Anthropocene as a new (and meaningful)
30 chronostratigraphical/geochronological unit in the GTS.
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54 55 56 **The Anthropocene as a geological stage/age**

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58 If the Anthropocene is not to be a stratigraphical unit of series/epoch status, how then can it
59 be defined? One possibility is to distinguish the Anthropocene as a *stage/age*, the lowest rank
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3 formal taxonomic unit in the stratigraphical hierarchy (Hedberg, 1976; Salvador, 1994). While
4 designated global stage names are required in the GTS, the conventional practice in
5 Quaternary science has been to use regional rather than global stage divisions, especially in
6 the European Pleistocene. Accordingly, their subseries ('Lower', 'Middle and 'Upper') or,
7 more commonly, subepoch ('Early', 'Middle' and 'Late') equivalents have been favoured
8 (Head et al., 2021b). In this classification, the Anthropocene would become the fourth
9 (uppermost) stage/age (or subseries/subepoch) of the Holocene Series/Epoch following the
10 Greenlandian, Northgrippian and Meghalayan (Walker et al., 2019). Two difficulties arise with
11 this proposition, however. The designation of a stage/age requires a GSSP and this, as was
12 discussed above, poses a problem because of the time-transgressive nature of the evidence.
13 Second, the name itself would have to change, for stages/ages are named after the type
14 geographical locality (hence 'Greenlandian' to reflect the location of the Early Holocene GSSP
15 on the Greenland ice sheet). As such the term 'Anthropocene' could no longer be employed.

26 27 28 29 **The Anthropocene as a geological event**

30 An alternative approach, and the one that we propose (Gibbard et al., 2021), is that the
31 Anthropocene should not be designated as a formal chronostratigraphical/geochronological
32 unit, but rather that it be defined as an ongoing *event*. In contrast with a series/epoch, the
33 definition of a geological event has no formalisation procedures or GSSP requirements. While
34 this means that the Anthropocene would not become a ratified unit within the international
35 GTS, designation as an event in no way diminishes its significance in Earth's history. Indeed,
36 it would define the Anthropocene in a similar way to globally significant transformations that
37 have previously affected the Earth's biosphere. These include the Palaeoproterozoic Great
38 Oxidation Event (GOE: c.2.4-2.0 Ga), the Great Ordovician Biodiversity Event (GOBE; 485-455
39 Ma), and the Middle-Late Devonian forestation of continents (DeFE: c. 390-360 Ma), all of
40 which demonstrate that humans are not the first organisms to transform the global Earth
41 system (Sagan, 2020). Prior to the GOE, Earth had a weakly reducing atmosphere in which
42 oxidation was prevented. With the development of cyanobacteria and oxygen generation as
43 a product of photosynthesis, atmospheric oxygen increased and radically changed the course
44 of planetary development with the evolution of multicellular life (Schirmermeister et al., 2013).
45 During the GOBE, diversity of life and new communities increased exponentially, yet
46 diachronously, through the marine realm (Servais and Harper, 2018). The evolution of forests
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3 and their spread across continents during the Devonian produced an even greater
4 transformation. Many biogeomorphic phenomena that operate in modern terrestrial
5 environments appeared for the first time (Davies et al., 2021), and the dramatic changes in
6 levels of atmospheric oxygen and carbon dioxide became a driver of Late Devonian mass
7 extinction and latterly of Late Devonian-Carboniferous glaciation (Le Hir et al., 2011; Dahl and
8 Arens, 2020). However, despite their firm basis in the stratigraphical record, (Eriksson and
9 Cheney, 1992; Buick, 2008), neither the GOE nor the GOBE, nor the Devonian continental
10 forestation event, are employed to define time-unit boundaries within the GTS. They are,
11 nonetheless, widely regarded as major transformative phases of the Earth system. Moreover,
12 they are not particular points in time; they were significant events that varied spatially and
13 temporally, as is the case with ongoing anthropogenic transformations. Indeed, Crutzen in
14 proposing an Anthropocene was not principally attempting to define a new formal
15 stratigraphical unit, but rather was drawing attention to increasing human influence on the
16 planet. Accordingly, the Anthropocene should be defined as: 'the aggregated effects of
17 human activities that have transformed, and continue to transform, the Earth system and
18 influence biodiversity, thereby producing a substantial, characteristic and unique record in
19 sedimentary strata and in human-modified ground' (cf . Gibbard et al., 2021).

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36 Event stratigraphy was first proposed for the recognition, study and correlation of the effects
37 of important physical or biological events in the broader stratigraphical record (Ager, 1973).
38 Geological events can be time-transgressive, multi-temporal and spatially variable, ranging by
39 orders of magnitude from minutes to millions of years, and from local to regional and,
40 ultimately, global (Rawson et al., 2002). The event paradigm has been firmly embedded in
41 Quaternary science from the mid-nineteenth century onwards, with the subdivision of
42 Quaternary time being based on the recognition of successive climatic events, principally
43 glacials and interglacials but also stadials and interstadials, their use in stratigraphical
44 classification being generally referred to as 'climate-stratigraphy'. Highly-resolved
45 stratigraphical successions, such as those from ice cores, provide evidence of millennial-scale
46 climatic events that are superimposed on these broad glacial-interglacial cycles (Björck et al.,
47 1998; Rasmussen et al., 2014), while other short-term episodes, such as Dansgaard-Oeschger
48 events and Heinrich events are evident in ice-core sequences and deep-ocean sediment
49 records respectively (Dansgaard et al, 1993; Hemming, 2004). The hallmark of all these events
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3 is that while time intervals are broadly consistent at a range of spatial scales, the litho- or
4 biostratigraphical boundaries that mark the onset and termination of the events in the
5 stratigraphical record may be diachronous; hence time-transgression is inbuilt within the
6 event-stratigraphy paradigm. This means that events cannot be considered as
7 chronostratigraphical nor geochronological units, for understanding of Earth systems, but this
8 does not diminish the value or applicability of the concept, as is evident in the widespread
9 use of events in Quaternary science.
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18 **Conclusions**

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20 Recognising the Anthropocene as an important transformative chapter of recent Earth history
21 has been a feature in publications across a wide range of disciplines, yet a formal definition
22 of the Anthropocene has so far proved elusive. Recent attempts have focussed largely on
23 formalising the Anthropocene as a rigidly constrained chronostratigraphical/
24 geochronological division in the international GTS. These efforts have been compromised,
25 however, by difficulties in determining the onset of the Anthropocene in the global
26 stratigraphical record, and by the fact that human impact has been a diachronous,
27 heterogeneous and socially-differentiated process. A shift to an event framework for defining
28 the Anthropocene, as reiterated herein, is a practical solution that overcomes many of these
29 problems. It frees the concept from the constraints of geological formalisation as well as from
30 its alignment with established chronostratigraphical and geochronological units within the
31 Holocene Series/Epoch. It also provides a universal term (a common language) that facilitates
32 communication beyond the geoscience community with the social sciences and humanities
33 (Gibbard et al., 2021). Above all, it acknowledges the Anthropocene as a major transformative
34 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.

References

- Ager DV. 1973. *The Nature of the Stratigraphic Record*. Wiley, New York.
- Bauer M, Edgeworth M, Edwards LE et al. 2021. Anthropocene: event or epoch? *Nature* **597**: 332.
- Björck S, Walker MJC, Cwynar L et al. 1998. An event stratigraphy for the Last Termination in the North Atlantic region based on the Greenland Ice Core record: a proposal by the INTIMATE group. *Journal of Quaternary Science* **13**: 283-29.
- Buick R. 2008. When did oxygenic photosynthesis evolve? *Philosophical Transactions of the Royal Society, London* **363**: 2731-2743.
- Crutzen PJ. 2002. Geology of Mankind. *Nature* **415**: 23.
- Crutzen P. 2009. Can we survive the 'Anthropocene period'? *Project Syndicate* 5.
- Crutzen PJ, Stoermer EF. 2000. The 'Anthropocene' *IGBP Global Change Newsletter*, **41**: 17-18.
- Dahl TW, Arens SKM. 2020. The impacts of land plant evolution on Earth's climate and oxygenation state – an interdisciplinary review. *Chemical Geology* **547**: doi.org/10.1016/j.chemgeo.2020.119665.
- Dansgaard W, Johnsen SJ, Clausen H et al. 1993. Evidence for general instability of palaeoclimate from a 250-kyr ice core record. *Nature* **364**: 218-220.
- Davies NS, Berry CM, Marshall JEA et al. 2021. Devonian Landscape Factory: plant-sediment interactions in the Old Red Sandstone of Svalbard and the rise of vegetation as a biogeomorphic agent. *Journal of the Geological Society of London* **178**: 2020-225.

- 1
2
3 Edgeworth M, Ellis, EC, Gibbard PL et al. 2019. The chronostratigraphic method is unsuitable
4 for determining the start of the Anthropocene. *Progress in Physical Geography* **43**: 334-
5 344.
6
7
8 Ellis E, Maslin M, Boivin N et al. 2016. Involve social scientists in defining the Anthropocene.
9 *Nature* **540**: 192-193.
10
11 Eriksson PG, Cheney RS. 1992. Evidence for the transition to an oxygen-rich atmosphere
12 during the evolution of red beds in the lower Proterozoic sequences of southern Africa.
13 *Precambrian Research* **54**: 257-269.
14
15
16 Finney SC, Edwards LE. 2016. The “Anthropocene” epoch: Scientific decision or political
17 statement. *GSA Today*: **26**, 4-10.
18
19
20 Fyfe, RM, Woodbridge J, Roberts N. 2015. From forest to farmland: pollen-inferred land cover
21 change across Europe using the pseudobiomization approach. *Global Change Biology* **21**:
22 1197-1212.
23
24
25 Gibbard P, Bauer AM, Edgeworth M et al. 2021. A Practical Solution: The Anthropocene is an
26 Event, not a formal Epoch. *Episodes* **44**: doi.org/10.18814/epiugs/2021/021029.
27
28
29 Head MJ, Steffen W, Fagerlind D. 2021a. The Great Acceleration is real and provides a
30 quantitative basis for the proposed Anthropocene Series/Epoch. *Episodes* **44**:
31 doi.org/10.18814/epiugs/2021/021031.
32
33
34 Head MJ, Pillans B, Zalasiewicz J et al. 2021b. Formal ratification of subseries for the
35 Pleistocene Series of the Quaternary System. *Episodes*: **44**, 241-247.
36
37
38 Hedberg HD. 1976. *International Stratigraphic Guide*. Wiley: New York.
39
40 Hemming S. 2004. Heinrich events: massive late Pleistocene detritus layers of the North
41 Atlantic and their global climate imprint. *Reviews of Geophysics* **42**:
42 doi:10.1029/2003RG000128.
43
44
45 Le Hir G, Donnadieu Y, Godd ris Y et al. 2011. The climate change caused by the land plant
46 invasion in the Devonian. *Earth and Planetary Science Letters* **310**: 203-212.
47
48
49 Lewis SL, Maslin MA. 2015. Defining the Anthropocene. *Nature* **519**: 171-180.
50
51
52 Lewis SL, Maslin MA. 2018. *The Human Planet. How we created the Anthropocene*. Penguin
53 Random House, UK.
54
55 Merritts D, Walter R, Rahnis M et al. 2011. Anthropogenic streams and base-level controls
56 from historic dams in the unglaciated mid-Atlantic region, USA. *Philosophical*
57 *Transactions of the Royal Society*, London **369**: 1-34.
58
59
60

- 1
2
3 Rasmussen SO, Bigler M, Blockley SPE et al. 2014. A stratigraphic framework for abrupt
4 climatic changes during the last glacial period based on three synchronised Greenland
5 ice-core records: refining and extending the INTIMATE event stratigraphy. *Quaternary*
6 *Science Reviews* **106**: 14-28.
7
8
9 Rawson P, Brenchley PJ, Allen PM et al. 2002. *Stratigraphical Procedure*. Geological Society of
10 London, London, 57 pp.
11
12
13 Remane J, Bassett MG, Cowie JW et al. 1996. Revised guidelines for the establishment of
14 global chronostratigraphic standards by the International Commission on Stratigraphy
15 (ICS). *Episodes* **19**: 77-81.
16
17
18 Roberts P, Hamilton R, Piperno DR. 2021. Tropical forests as key sites of the “Anthropocene”:
19 Past and present perspectives. *Proceedings of the National Academy of Sciences of the*
20 *USA* **118**: doi.org/10.1073/pnas2109243118.
21
22
23 Ruddiman WF, Fuller DQ, Kutzbach JE et al. 2016. Late Holocene climate: natural or
24 anthropogenic. *Reviews of Geophysics* **54**: 93-118.
25
26
27 Sagan D. 2020. Gaia versus the Anthropocene: untimely thoughts on the current
28 ecocatastrophe. *Ecocene: Cappadocia Journal of Environmental Humanities* **1**: 137-146.
29
30
31 Salvador A. 1994. International stratigraphic guide: A guide to stratigraphical classification,
32 terminology and procedure. *International Commission on Stratigraphy*. Geological
33 Society of America: Boulder.
34
35
36 Schirrmeister BE, de Vos JM, Antonelli A et al. 2013. Evolution of multicellularity coincided
37 with increased diversification of cyanobacteria and the Great Oxidation Event.
38 *Proceedings of the National Academy of Sciences of the USA* **110**: 1791-1796.
39
40
41 Seersholm FV, Werndly DJ, Greal A et al. 2020. Rapid range shifts and megafaunal extinctions
42 associated with late Pleistocene climate changes. *Nature Communications* **11**:
43 doi.org/10.1038.
44
45
46 Servais T, Harper DAT. 2018. The Great Ordovician Biodiversification Event (GOBE): definition,
47 concept, duration. *Lethaia* **51**: 151-164.
48
49
50 Smith BD, Zeder MA. 2013. The onset of the Anthropocene. *Anthropocene* **4**: 8-13.
51
52
53 Steffen W, Broadgate W, Deutsch L et al. 2015. The trajectory of the Anthropocene: The Great
54 Acceleration. *The Anthropocene Review* **2**: 81-98.
55
56
57 Syvitski J, Waters CN, Day J et al. 2020. *Communications Earth and Environment*.
58 doi.org/10.1038/s43247-020-00029-y
59
60

1
2
3 Walker M, Head MJ, Lowe J et al. 2019. Subdividing the Holocene Series/Epoch: formalisation
4 of Stages/Ages and Subseries/Subepochs, and designation of GSSPs and Auxiliary
5 Stratotypes. *Journal of Quaternary Science* **34**: 173-186.

6
7
8 Waters CN, Zalasiewicz J, Williams M, et al. (eds) 2014. A Stratigraphical basis for the
9 Anthropocene? *Geological Society of London Special Publication*, London.

10
11
12 Waters CN, Zalasiewicz J, Summerhayes C et al. 2018. Global Boundary Stratotype Section and
13 Point (GSSP) for the Anthropocene Series: Where and how to look for potential
14 candidates. *Earth Science Reviews* **178**: 379-429.

15
16
17 Zalasiewicz J, Williams M. Smith A et al. 2008. Are we now living in the Anthropocene? *GSA*
18 *Today* **18**: 4-8.

19
20
21 Zalasiewicz J, Waters CN, Williams M et al. 2015. When did the Anthropocene begin? A mid-
22 twentieth century boundary level is stratigraphically optimal. *Quaternary International*
23 **383**: 196-203.

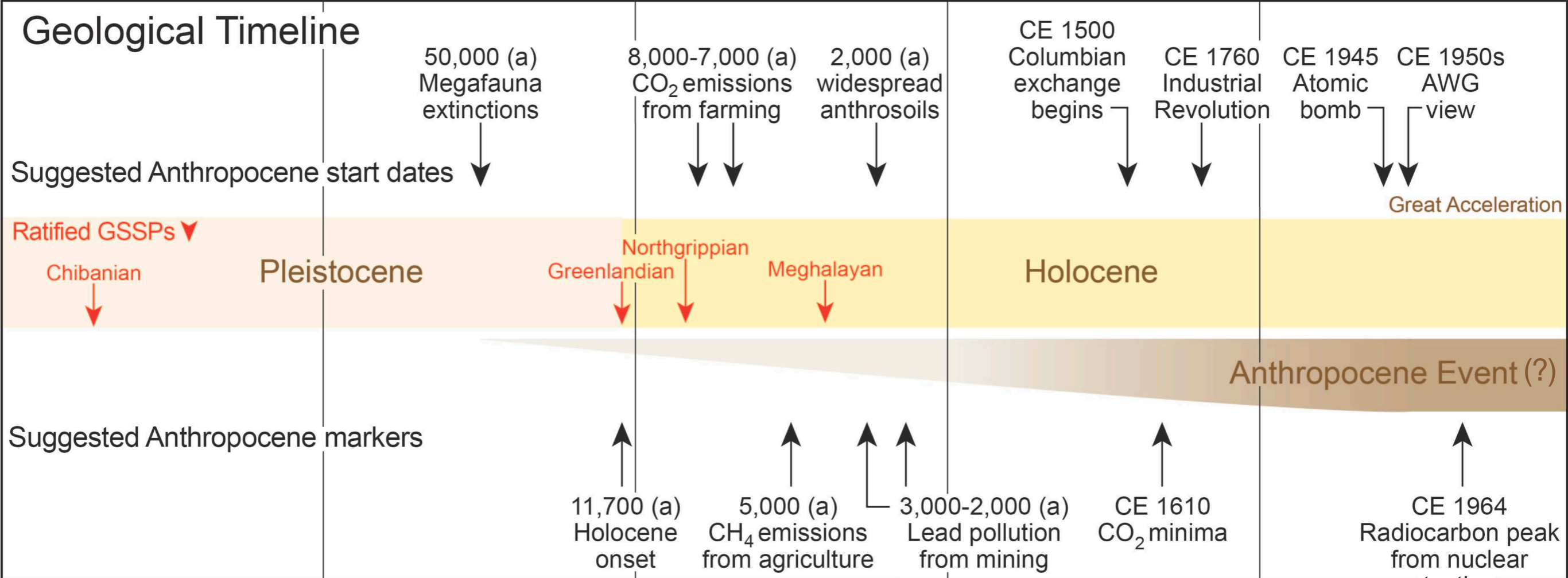
24
25
26 Zalasiewicz J, Waters CN, Summerhayes CP et al. 2017. The Working Group on the
27 'Anthropocene': summary of evidence and recommendations. *Anthropocene* **19**: 55-60.

28
29
30 Zalasiewicz J, Waters CN, Williams M et al. (eds) 2019. *The Anthropocene as a Geological Time*
31 *Unit: A Guide to the Scientific Evidence and Current Debate*. Cambridge university Press,
32 Cambridge.

33 34 **Figure caption**

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36 **Figure 1:** Geological timeline (top) compared with historical timeline (bottom). A number of
37 different starting dates have been proposed for the Anthropocene that correspond to
38 different environmental and social changes that are evident as markers in the stratigraphical
39 record. The 'AWG view' refers to the Anthropocene Working Group 'Great Acceleration'
40 proposal for a start date in the mid-twentieth century. Colour densities broadly indicate the
41 intensity of change; (a) indicates years. Modified after Ellis et al. (2016) and Gibbard et al.
42 (2021).
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Geological Timeline



Historical Timeline

