https://doi.org/10.1038/s43017-026-00823-w

Time matters in the case against the Anthropocene epoch

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Defining the Anthropocene as a formal epoch with a fixed stratigraphic marker and global start date remains contentious. This Comment summarizes the arguments for a time transgressive extended Anthropocene event that encompasses cumulative diachronous human impacts over millennia, viewing it as an open-ended and transformative episode in Earth history.

Defining units of time (such as eons, eras, periods, and epochs) within the Geological Timescale (GTS) is not trivial. The International Commission on Stratigraphy (ICS) carefully studies the spotty physical record of geologic time preserved in rocks, sediments, and glacial ice, identifying professionally agreed-upon boundaries at globally identifiable times that mark the start and end of each time unit in the International Chronostratigraphic Chart. Each unit is paired with a unique geologic marker (Global Boundary Stratotype Section and Point, GSSP) based on stratigraphic principles, resulting in a standardized, internationally agreed geologic timescale.

The Holocene epoch is the current formalized geologic time unit which began 11,700 years ago, when postglacial warming and megafauna extinction – the latter possibly due to humans – left a geologic record now used to mark the end of the previous Pleistocene epoch. The impacts of extensive anthropogenic climate change, extinctions, and geochemical changes to Earth's atmosphere, oceans, land, and ice can be seen as warranting an end to the Holocene and the rise of a new epoch, the Anthropocene. Nevertheless, we argue that defining an Anthropocene series (a chronostratigraphic unit) at a fixed stratigraphic horizon with a precise global start date is problematic.

In this Comment, we discuss the issues with trying to pinpoint a chronostratigraphic horizon for an Anthropocene epoch and outline the arguments for a time-transgressive extended Anthropocene event that incorporates cumulative human impacts.

Proposed Anthropocene epoch is too short

An Anthropocene Working Group (AWG) was established by ICS's Subcommission on Quaternary Stratigraphy (SQS) in 2009 to examine the possibility of a formal division of the GTS for the Anthropocene. Fifteen years later, the ICS rejected the AWG's proposal for an Anthropocene epoch starting in 1952, defined primarily by a global record of 'bomb spike' radionuclides in soils and sediments. If it had been accepted, the proposed Anthropocene epoch would have spanned, at present, less than a human lifetime. By contrast, the next shortest (and youngest) geological time unit, the Holocene epoch, started at 11,700 yrs BP and is ongoing.

The formal Global Boundary Stratotype Section and Point (GSSP, or 'golden spike') for the base of the Holocene Series[1] is 1,492.45 m deep in an ice core from a borehole in the central Greenland ice sheet, located at 75.10° N latitude and 42.32° W longitude. It is defined by an abrupt change in deuterium excess that signals a rapid ~3-yr shift in climate and ocean water temperature. By contrast, the Anthropocene might not yet be of long enough duration to pinpoint a GSSP with certainty. For example, the best age estimate for the Holocene stratotype is well constrained at 11,700 ± 99 yr b2k (before the year 2000) based on stratigraphic principles involving the counting of diagnostic annual layers in Greenland ice cores[1]. However, high-precision ^{14}C dating of the base of the Holocene at five global auxiliary stratotypes yields dates that span from 12,049 to 11,305 cal. yr BP (2σ calibrated ages at 99.6% probability)[1]. This equates to an error of 372 years on an arithmetic mean age of 11,667 yr, or roughly 3%.

If in 10,000 years, an Anthropocene GSSP were to be defined in sediments from the present, a radiometric dating error of 3% would be 300 years. In that case, the diachronous nature of many anthropogenic events, such as the Great Acceleration of the mid-20th century, the Industrial Revolution of the 19th century, and the colonization of the Americas in the 18th century, would seem isochronous.

The mid-20th century global record of bomb pulse radionuclides in soils and sediments is as widespread and stratigraphically fixed as any temporal marker can be in the geologic record. Nevertheless, a seemingly perfect marker horizon is not sufficient to define a new chronostratigraphic unit, nor are accelerations in long-developing human-driven environmental trends that began over centuries to millennia. We do not suggest that current evidence for a mid-20th century anthropogenic disturbance signal is invalid. Rather, the timing is so geologically recent that stratigraphic signals that currently appear diachronous (spanning hundreds or possibly thousands of years) will, at some point in the future, likely appear as an isochronous geological horizon (temporally equivalent). Undoubtedly, additional future anthropogenic-driven phenomena will also be added to this ongoing geological event, and the debate will continue.

Human impacts are time-transgressive

The geological record of transformative human activities is markedly time-transgressive[2]. For example, prehistoric deforestation and the spread of agriculture have been cited as the causes of anomalous rises in atmospheric carbon dioxide and methane concentrations since 7,000 and 5,000 years ago, respectively[3]. These upward trends followed a downward trend in both atmospheric gases during the early Holocene that was similar to those of previous interglaciations. A synthesis of data from the global archaeological community concludes that most of the global terrestrial biosphere was substantially transformed by human activities that included hunting and gathering; deforestation;

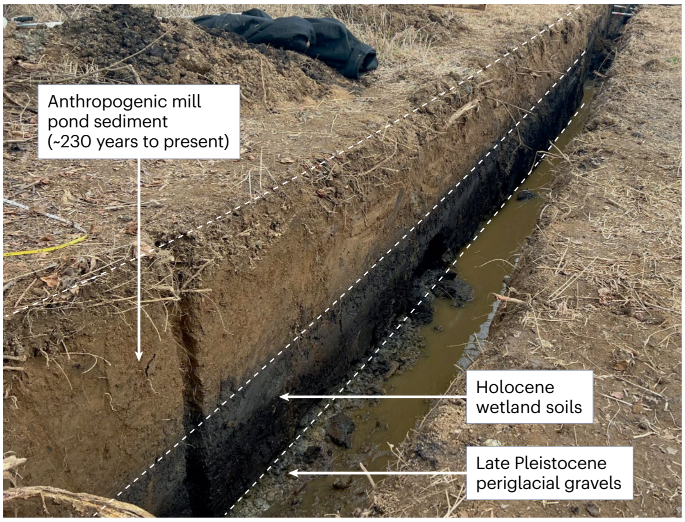

Fig. 1 | An example of anthropogenic sediment accumulation with clear stratigraphic boundaries. A stratigraphic section in Lancaster County, Pennsylvania, USA, exposes late Pleistocene-age periglacial gravels at the base (light gray), overlain by Holocene-age wetland soils (black and dark grey), which in turn are overlain by anthropogenic mill pond legacy sediments less than 350 years old (light brown). The entire 200+ cm column of sediments spans the last ~13,000 years, but the top ~85 cm was deposited since ~230 yr BP, marking the rapid increase in anthropogenic sedimentation rates[5,6]. This is a common stratigraphic sequence throughout the unglaciated mid-Atlantic region of the USA, demonstrating how anthropogenic acceleration of upland soil erosion and valley-bottom sediment accumulation were widespread and transformed valley landscapes.

burning; species introductions, domestication, and extinctions; and soil erosion by 3,000 years ago[4].

In the mid-Atlantic region of the eastern USA, there is extensive geologic evidence of time-transgressive human impacts that occurred between about 1630 and 1800, partly overlapping with the Industrial Revolution but occurring well before modern urbanization and widespread use of fossil fuels. For example, possibly hundreds of millions of beavers, a remarkable ecosystem engineer, existed in North America before the colonial era. Over millennia, they created carbon-rich wetlands that spanned valley bottoms. By the early 1700s, most beavers were gone; only 10–15 million remain at present.

Nearly simultaneously, the Holocene organic-rich sediments stored in beaver meadows and ponds were buried by mineral-rich sediments from upland soil erosion caused by wide-ranging anthropogenic deforestation and land clearing. Ubiquitous damming of rivers for water power that began in eastern North America during the early 1600s caused local rises in water (base) level that trapped immense amounts of this eroded sediment in mill ponds along valley bottoms, causing ecosystem and geomorphic changes across whole watersheds and landscapes (Fig. 1). Backwater effects from milldams extended as much as several kilometres upstream[5,6]. For example, approximately 180,000 m^3 of sediment would have been stored in a 2-km upstream section of a single 3-m-high milldam in a 60-m-wide valley[6]. More than 65,000 water-powered mills existed in the eastern USA by 1840[5]. Likewise, tens of thousands of water-powered mills existed throughout Europe by the 18th century, and it is possible that these streams have been responding to anthropogenic base-level rise and fall for up to a millennium[5,6].

In many parts of the world, a golden spike could be driven into the boundary separating sediments that accumulated slowly for millennia before human disturbance from those that buried them in a few decades to centuries since major human land transformations. However, these spikes would occur in different parts of the world at different times, and would also not account for the diachronic nature of the various different human impacts on global environmental systems[2]. For example, since the late 1800s, water-powered milldams have been replaced by larger hydroelectric dams, and millions of other dams have been built worldwide for irrigation, flood control, and other purposes[7]. In sum, the reservoirs from these dams increase Earth's terrestrial water surface area by hundreds of thousands of km and alter the flow of water in nearly half of the world's large rivers[7]. The amount of sediment trapped in global reservoirs is now estimated to be billions of metric tons each year, more than half of basin-scale sediment fluxes[8].

In other words, human impacts on multiple Earth systems are not only profound but also time-transgressive, which counters arguments for the designation of a new chronostratigraphic and geochronological unit in the GTS with a precise GSSP[4].

Event over epoch

A simple alternative to designating a new epoch has been proposed. The Anthropocene can instead be defined as an ongoing event, resulting from cumulative human activities that have transformed the Earth system and biodiversity over a few hundred to a few thousand years, creating a unique and lasting record in sediments and altered landscapes[2,9,10]. Such an event would be analogous to other biologically driven events that had far-reaching impacts on global environmental systems over geologic time. For example, past globally significant transformative events 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).

The benefits of an Anthropocene event are many. Time transgression is inbuilt within the 'event' term; geological formalization on the GTS is not required; the conceptual power of the Anthropocene for communicating across disciplines is retained; and the Anthropocene is acknowledged as an ongoing major transformative episode in Earth history, similar to earlier events in the geologic record.

There is little question that the Anthropocene is real, as seen by widespread human alterations of the geosphere, biosphere, hydrosphere, and atmosphere over the last few thousand years. Framing the Anthropocene as an open-ended transformative episode in Earth history emphasizes that the Anthropocene event is ongoing, and will unfold in ways that depend on how we act next.

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Published online: 8 September 2026

References

1. Walker, M. et al. Formal definition and dating of the GSSP (Global Stratotype Section and Point) for the base of the Holocene using the Greenland NGRIP ice core, and selected auxiliary records. *J. Quat. Sci.* **24**, 3–17 (2009).
2. Gibbard, P. et al. The Anthropocene as an event, not an epoch. *J. Quat. Sci.* **37**, 395–399 (2022).
3. Ruddiman, W. F. et al. Late Holocene climate: natural or anthropogenic? *Rev. Geophys.* **54**, 93–118 (2016).
4. Stephens, L. et al. Archaeological assessment reveals Earth's early transformation through land use. *Science* **365**, 897–902 (2019).
5. Walter, R. C. & Merritts, D. J. Natural streams and the legacy of water-powered mills. *Science* **319**, 299–304 (2008).
6. Merritts, D. J. et al. Anthropocene streams and base-level controls from historic dams in the unglaciated mid-Atlantic region, USA. *Phil. Trans. R. Soc. A* **369**, 976–1009 (2011).
7. Lehner, B. et al. High-resolution mapping of the world's reservoirs and dams for sustainable river-flow management. *Front. Ecol. Environ.* **9**, 494–502 (2011).
8. Vörösmarty, C. J. et al. Anthropogenic sediment retention: major global impact from registered river impoundments. *Glob. Planet. Change* **39**, 169–190 (2003).
9. Bauer, A. M. et al. Anthropocene: event or epoch? *Nature* **597**, 332–332 (2021).
10. Edgeworth, M. et al. The Anthropocene is more than a time interval. *Earth's Future* **12**, e2024EF004831 (2024).

Acknowledgements
The authors thank the Richard King Mellon Foundation, the Steinman Foundation, Franklin and Marshall College, the Chesapeake Watershed Initiative, the Pennsylvania Department of Environmental Protection, the Pennsylvania Department of Conservation and Natural Resources, and LandStudies Inc. for support.

Competing interests
The authors declare no competing interests.

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