

The ‘Anthropocene’: *alea iacta est*

The proposal of the ‘Anthropocene’ as a new geological epoch, characterized by the anthropization of the Earth system, has finally been submitted for formalization and there is no turning back

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Almost two and a half decades after its introduction, the ‘Anthropocene’ is still an informal term (this is why the quotation marks) whose precise definition and temporal extent remain undefined. However, this does not seem to be an obstacle for many scholars who inaccurately use this term as if it was already a well-defined formal epoch of the Geological Time Scale (GTS). Scientific rigor is as important in geology as in any other discipline, and the terms and concepts used are submitted to a process of standardization and formalization. The units of the GTS are represented in the International Chronostratigraphic Chart (ICC), and for a new unit (e.g., an era, a period or an epoch) to be incorporated, it should meet the requirements of the International Stratigraphic Guide (ISG) and must be approved by the International Commission on Stratigraphy (ICS) and ratified by the International Union of Geological Sciences (IUGS).

This process is similar to the addition of a new element to the Periodic Table of Elements (PTE), which is overseen by the International Union of Pure and Applied Physics/Chemistry (IUPAP/IUPAC). If the PTE is fundamental for understanding the intimate nature of matter, the ICC has the same importance for Earth science and evolutionary knowledge. Indeed, without the ICC, it would not be possible to understand the geological history of our planet and the origin and evolution of life on it. Such a fundamental framework requires high scientific accuracy.

The ‘Anthropocene’, as a prospect for a new geological epoch, has been evaluated by the Anthropocene Working Group (AWG), which has prepared a proposal that has recently been submitted to the ICS Subcommittee of Quaternary Stratigraphy (SQS) for approval, as a first step for formalization. In a former essay published in this journal six years ago, the author provided the main clues for a general understanding of the ‘Anthropocene’, which was still in a relatively embryonic state (Rull, 2017). During these six years, the issue underwent a significant progress leading to the completion of the current proposal. This essay aims to summarize the main developments that have precipitated such recent acceleration for a nonspecialist audience.

In a nutshell

The story began in 2000 when the Danish environmental chemist and Nobel recipient Paul Crutzen and the American ecologist Eugene Stoermer coined the term ‘Anthropocene’ to emphasize that the global consequences of human activities on the Earth system have already surpassed the range of variability of the Holocene – the epoch in which we live since the end of

the last glaciation – and the definition of a new geological epoch was needed (Crutzen & Stoermer, 2000). Actually, these authors proposed using an environmental concept to define a new unit of the GTS. It is worth noting that the term used to name this new unit implicitly suggested the rank of an epoch, as the suffix ‘-cene’ is reserved for the epochs of the Cenozoic era (Paleocene, Eocene, Oligocene, Miocene, Pliocene, Pleistocene and Holocene).

This proposal began to be analyzed in 2009 by the AWG, which was created specifically for this purpose and was led by the British geologists Jan Zalasiewicz until 2019 and Colin Waters from that date onward. Usually, the ICS grants four years to the working groups to complete a proposal, but in the case of the ‘Anthropocene’, the process has taken almost 15 years. Among the potential causes for this delay, there has been an intense debate between the AWG and influential members of the ICS and the IUGS on several aspects, such as the nature of the stratigraphic unit to be defined and its starting point, that is, the time when the Earth system, as a whole, became primarily anthropogenic.

The ‘Anthropocene’ critics – which include the ICS Secretary General, the British geologist Philip Gibbard, and the IUGS Secretary General, the American geologist Stanley Finney, who are directly involved in the approval/ratification of the AWG proposal – emphasize that this new epoch is currently defined as a historical phase based on environmental criteria, but a valid chronostratigraphic unit must be defined on the basis of distinct and characteristic rock bodies following the criteria of the ISG (e.g., Finney, 2015; Gibbard & Walker, 2014; Edwards, 2015; Finney & Edwards, 2015). According to these criteria, the first step is to locate the rock strata that characterize the new unit and the particular features (the stratigraphic markers) that differentiate it from the underlying unit. Then, the base of the new unit is dated using geological methods to provide the chronological framework.

Altogether, this body of evidence is known as the Global Boundary Stratotype Section and Point (GSSP), or more popularly the “golden spike”, and should be recognizable globally. Without the GSSP, it is not possible to measure geological time; therefore, the definition of a new chronostratigraphic unit makes no sense. It is important to bear in mind that the only available evidence for measuring geological time is rock strata. Without rocks, time passes but it cannot be measured by geological methods. This situation is similar to that of a sandglass without sand, for which time cannot be measured.

In the case of the ‘Anthropocene’, the GSSP and its global expression remain undefined. In August 2016, in the 35th International Geological Congress held at Cape Town, South Africa, the AWG members voted that the starting point of the ‘Anthropocene’ should be placed at the mid-20th century – coinciding with the so-called Great Acceleration, when many indicators of Earth’s anthropization (e.g., population increase, industrialization, globalization) experienced an abrupt increase (Head et al., 2022) – and that the most suitable stratigraphic markers be radionuclides, mainly plutonium (^{239}Pu) and radiocarbon (^{14}C), generated by the atomic tests carried out in the early 1950s (Zalasiewicz et al., 2017). Therefore, a specific date and a set of stratigraphic markers based on environmental considerations were given before identifying the GSSP, which is contrary to the ISG rules and to the empirical nature of stratigraphic science, as emphasized by the opponents. However, this is how the AWG decided to proceed.

The AWG proposal has been the object of many critiques, not only because of the procedure but also because other previously proposed starting points were dismissed. Indeed, in the original proposal, Crutzen and Stoermer postulated that the ‘Anthropocene’ could encompass the last centuries or the last millennia, even the whole Holocene, which began 12.7 thousand years ago. Since then, numerous studies have proposed a wide range of dates within this

timeframe, and have emphasized the asynchronous nature of human impact across the globe (review in Lewis & Maslin, 2015).

In 2019, at the request of the ICS, the AWG reaffirmed its chronological definition, which confirmed that the proposal for the 'Anthropocene' epoch to be submitted to the ICS/IUGS will consider the mid-20th century as the starting date, and there is no turning back. Although opponents argue that, so defined, the available sedimentary record accumulated in barely 75 years is insufficient to characterize a geological epoch, the AWG concentrated on identifying of the GSSP representative of this time period, that is, a rock body that met the pre-established conditions.

Latest developments

In the last years, the AWG prospect has undergone a significant boost that has been decisive for the development of the final proposal. After a thorough review of the available evidence (Waters et al., 2018), this working group concluded that the most suitable candidates for the 'Anthropocene' GSSP were paleoarchives able to provide high-resolution (annual or seasonal) records from the 20th century, such as (i) annually laminated (varved) sediments from lakes, coastal marine environments and anoxic marine basins; (ii) annual growth rings from trees, corals, mollusks and speleothems; and (iii) annual/seasonal accumulation layers from glacial ice caps. These archives are able to provide the chronological reliability and resolution needed for a precise identification of the first appearances of the appropriate markers and hence of the beginning of the 'Anthropocene'.

The most suitable (primary) markers should meet the condition of being widespread and globally correlatable. This is the case for the previously mentioned radionuclides (²³⁹Pu and ¹⁴C) and the ¹³C stable isotope, which are found worldwide across most sedimentary environments. Other supporting markers identified were fly ash, Pb, biotic turnovers/anthropogenic introductions, and stable isotopes such as $\delta^{15}\text{N}$ or $\delta^{18}\text{O}$, among others (Table 1).

Combining the better suited archives and markers, a total of 12 localities around the world were selected for a more intensive study as GSSP candidates (Figure 1; Table 1). Using the rock archives from these localities and the abovementioned stratigraphic markers, the beginning of the 'Anthropocene' was tentatively placed between 1945 and 1968, with most dates situated in the 1950s. In agreement with former expectations, plutonium is the most common primary 'Anthropocene' marker in these sites (Waters et al., 2023). After a detailed site-by-site analysis published in a 2023 special number of the journal *Anthropocene Review*, the AWG voted that the best suited GSSP candidate was the Canadian Crawford Lake, whereas the other candidates could serve as supporting localities useful for global correlations. The announcement was intended for the 4th International Congress on Stratigraphy celebrated on July 2023 in Lille (France), but this was not allowed and was finally made in parallel in a press conference specially organized for this purpose by the AWG and the German Max Plank Society.

The Crawford Lake sediments are formed by clearly visible annual laminations consisting of dark (organic)/light (calcite) seasonal couplets, which provide a continuous and detailed chronology for the 20th century. In these sediments, the bomb test signal (notably ²³⁹Pu) is clearly visible at approximately 15.6 cm depth, which corresponds to 1950. This boundary is marked by an unusually thin calcite layer, as a result of enhanced terrigenous supply from the basin due to the rapid industrialization of the area during the Great Acceleration, along with an abrupt decline in elm pollen due to a documented widespread disease of this tree. Other

stratigraphic markers of the GSSP horizon included a ^{137}Cs peak; increases in fly ash and elements such as Fe, K, Ti, Cu and Pb; and declines in $\delta^{15}\text{N}$ and Ca (McCarthy et al. 2023).

Some critics, especially the American geologist and former ICS member Lucy Edwards, argue that barely a few centimeter of unconsolidated lake sediments can easily be mixed or removed – even the whole lake could dry out in a matter of centuries or millennia – which would irreversibly eradicate the ‘Anthropocene’ GSSP. The same would be true for other candidates if we also consider sea-level shifts an erosion by aerial exposure, among other disturbing factors (Perkins, 2023). However, the AWG decision was made and the final proposal, yet still unpublished, could be summarized as follows:

The ‘Anthropocene’ as a new geological epoch following the Holocene commenced in 1950 and its GSSP lies in the sediments of Crawford Lake, at a depth of 15.6 cm. The primary stratigraphic marker is the radionuclide fallout (^{239}Pu), which resulted from mid-20th century bomb tests. Other localities widespread worldwide may serve as auxiliary sections (especially Beppu, Shailongwang and Śnieżka), and other proxies signaling the global influence of human activities (notably ^{14}C , fly ash, heavy metals and stable N/O isotopes) could be used as auxiliary stratigraphic markers.

Further complications

In the last couple of years, while the AWG was finalizing the analysis and selection of GSSP candidates, a new challenging possibility has emerged that may challenge the progress made by this working group during the last decade. Indeed, all the work developed to date by the AWG has been based on the idea of the ‘Anthropocene’ as a prospective geological epoch, as initially proposed by Crutzen and Stoermer. But now, a group of stratigraphers consider that the ‘Anthropocene’ could be better defined as an event (Gibbard et al., 2022). This could affect the ‘Anthropocene’ formalization process, as this group includes the most influential ICS/IUGS critics quoted above.

A geological event is a time-transgressive concept that is not included in the GTS/ICC; therefore, it does not need to be homologated using a fixed point in time, such as a GSSP, and is able to accommodate the spatiotemporal heterogeneity characteristic of human impact on Earth. An event is not a minor geological feature, by no means, as it can imply fundamental worldwide transformations, such as those attributed to human activities and even greater. For example, a well-known geological event is the Great Oxidation Event (GOE), which radically changed the course of evolution, including the development of multicellular life and the colonization of land. The GOE was not a point in time but rather a gradual process lasting approximately 300 million years (2400-2100 Ma).

According to Gibbard et al. (2023), an ‘Anthropocene Event’ could incorporate a far broader range of transformative anthropogenic practices, both in time and space, than an ‘Anthropocene Epoch’. The AWG replied that the ‘Anthropocene Event’ concept includes all kinds of human activities with local to global impacts that developed over the last 50 millennia, thus obscuring the recent abrupt planetary change involving the entire Earth system, which is what the ‘Anthropocene Epoch’ wants to emphasize. In addition, they recall that the suffix ‘-cene’ characterizes Cenozoic epochs and is therefore inappropriate for naming an event (Head et al., 2023).

What's next?

The AWG proposal was submitted to the ICS on October 31, 2023 and is now under discussion. The exact content of the proposal has not been released, but the main points are those summarized above. Within the ICS, the first instance is the SQS – which is led by two relevant AWG members, Zalasiewicz (Chair) and the Canadian geologist Martin Head (Vice-Chair) – and the second instance is the ICS Executive, where the opponent Gibbard is the Secretary General. In both cases, a minimum of 60% majority is needed for approval. This will not necessarily be a quick step, as the SQS should analyze in detail the proposal, and there is no a specific schedule for this. If the proposal is approved by the ICS, then it will be submitted for ratification to the IUGS where Finney, one of the most active critics of the AWG proposal, is the Secretary General. Again, a detailed re-evaluation may be needed.

According to Waters (pers. comm.), the current AWG Chair, none of these steps are guaranteed to pass and there is no any preliminary feedback from the ICS, as the Executive of this organism prevented the AWG members to discuss the issue with the SQS members. Waters also told the author that the SQS is not favorable to publish the submitted proposal for the moment, but this possibility may not be ruled out in the future, and the AWG would possibly be authorized to disclose the document on its website.

Expectations

The risk of the 'Anthropocene' proposal not being formalized, in its current status, is real, and the AWG is aware of this. The fact that a number of relevant ICS/IUGS members, who should vote for final approval/ratification, have repeatedly questioned AWG decisions strongly suggests this possibility. Noteworthy, the AWG always reaffirmed its position and answered the critiques without reconsidering the questioned points, which did not contribute to changing the opponent's perspective.

This situation fostered the interest of the author in potential alternatives to the eventual rejection of the current 'Anthropocene' prospect and approached a number of AWG, ICS and IUGS members to ask for their input on this matter. The IUGS members who were contacted declined to comment on the issue arguing that, as members of the organization responsible for the final decision, they preferred not to express their personal opinion on the subject.

The AWG members, including Zalasiewicz and Head, were reluctant to modify the current proposal to downgrade the 'Anthropocene' to one more Holocene stage/age, as suggested by Philip Gibbard and other critics (Gibbard et al., 2022). These AWG members emphasized that changes associated with the 'Anthropocene' are of greater magnitude than those associated with current subdivisions of the Holocene. When asked for an eventual plan B, Zalasiewicz responded that there is no such thing and that the AWG will remain attached to the 'Anthropocene' concept, as originally defined by Crutzen (who is also a member of the AWG) and Stoermer. ICS members, such as Gibbard and Edwards, commented on the survival of 'Anthropocene' term regardless of the final out come, in a cultural sense to emphasize the human influence on global environmental issues, a topic that is beyond the competence of geological organisms.

The whole discussion can be read at Rull (2018), but the general impression is that both proponents and opponents of the current 'Anthropocene' proposal remain attached to their own positions and are reluctant to change their mind. The AWG has already crossed its Rubicon, and now we should wait for the result of the SQS deliberations in the first instance. This Subcommittee can endorse or reject the proposal but can also request modifications.

According to Waters (pers. comm.), some SQS members have published strongly in favor of the AWG proposal and others strongly against, and the result is uncertain, especially if we consider that a 60% majority is required. *Alea iacta est*.

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Links to the involved organizations

Anthropocene Working Group (AWG) - <http://quaternary.stratigraphy.org/working-groups/anthropocene/>

International Commission on Stratigraphy (ICS) - <https://stratigraphy.org/>

International Union of Geological Sciences (IUGS) - <https://www.iugs.org/>

Subcommission of Quaternary Stratigraphy (SQS) - <http://quaternary.stratigraphy.org/>

Table 1. The localities of Fig. 1, with indication of the type of archive, the date suggested for the beginning of the 'Anthropocene' in each site (A-onset), the thickness of the 'Anthropocene' sediments (A-thick) in cm, and the stratigraphic markers used. AAs, anthropogenic artifacts; BTIs, biotic turnovers/anthropogenic introductions; HD, historical documentation; LT, lithology; SCPs, spheroidal carbonaceous particles (fly ash). Raw data from Waters et al. (2023).

Site	Map	Archive	A-onset	A-thick	Stratigraphic markers
East Gotland, Baltic Sea	EG	Anoxic marine basin	1956±4	26.5	LT, ²³⁹ Pu, ²⁴¹ Am
San Francisco, USA	SF	Estuary	Mid-20 th	230 (?)	Unclear
Searsville, USA	Sv	Lake	1948	366	²³⁹ Pu, SCPs, Pb, BTIs
Crawford, Canada	Cf	Lake	1950	15.6	²³⁹ Pu, SCPs, δ ¹⁵ N, BTIs
Sihailongwang, China	Sl	Lake	1953	8.8	LT, ²³⁹ Pu, ¹²⁹ I, ¹⁴ C, SCPs, PAHs, δ ¹³ C
Flinders, Australia	Fl	Coral reef	1958	36.9	²³⁹ Pu, ¹⁴ C, Sr/Ca, δ ¹⁸ O, δ ¹⁵ N
West Flower Garden, USA	WF	Coral reef	1957	28.4	¹⁴ C, ²³⁹ Pu
Palmer, Antarctica	Pm	Ice sheet	1952	3490	²³⁹ Pu, SCPs
Ernesto, Italia	Er	Cave speleothem	1960±3	0.4	¹⁴ C, S
Śnieżka, Poland	Sk	Peatland	1950-1955	39.5-44.5	²³⁹ Pu, ¹⁴ C, BTIs
Beppu, Japan	Bp	Bay	1953	64.6	LT, ²³⁹ Pu, ²¹⁰ Pb, δ ¹⁵ N
Vienna, Austria	Vn	Urban anthropogenic deposits	1945-1959	30	²³⁹ Pu, AAs, HD

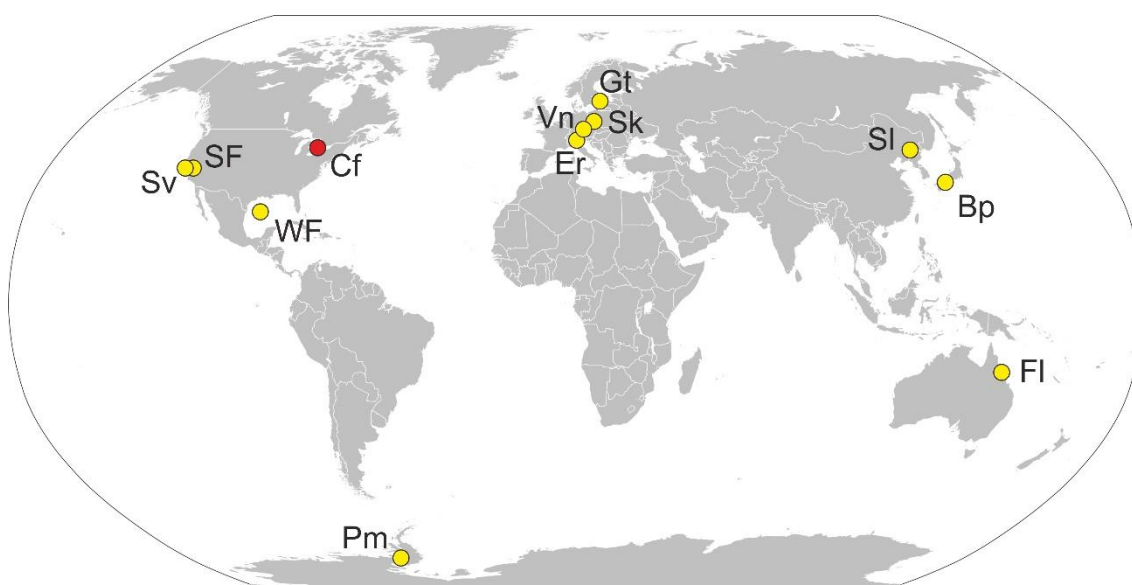


Figure 1. The 12 localities selected by the AWG to determine the most suitable GSSP for the 'Anthropocene'. The locality selected by the AWG as the best GSSP candidate (Crawford Lake; Cf) is highlighted in red. Redrawn from Waters et al. (2023).