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# Global Boundary Stratotype Section and Point (GSSP) for the Anthropocene Series: Where and how to look for potential candidates

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## ABSTRACT

The Anthropocene as a potential new unit of the International Chronostratigraphic Chart (which serves as the basis of the Geological Time Scale) is assessed in terms of the stratigraphic markers and approximate boundary levels available to define the base of the unit. The task of assessing and selecting potential Global Boundary Stratotype Section and Point (GSSP) candidate sections, a required part of the process in seeking formalisation of the term, is now being actively pursued. Here, we review the suitability of different stratified palaeoenvironmental settings and facies as potential hosts for a candidate GSSP and auxiliary sections, and the relevant stratigraphical markers for correlation. Published examples are evaluated for their strengths and weaknesses in this respect. A marked upturn in abundance of radioisotopes of $^{239}$Pu or $^{14}$C, approximately in 1952 and 1954 CE respectively, broadly coincident with a downturn in $\delta^{13}$C values, is applicable across most environments. Principal palaeoenvironments examined include: settings associated with accumulations of anthropogenic material, marine anoxic basins, coral reefs, estuaries and deltas, lakes at various latitudes, peat bogs, snow/ice layers, speleothems and trees. Together, many of these geographically diverse palaeoenvironments offer annual/subannual laminae that can be counted and independently dated radiometrically (e.g. by $^{210}$Pb). Examples of possible sections offer the possibility of correlation with annual/seasonal resolution. From among such examples, a small number of potentially representative sites require the acquisition of more systematic and

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comprehensive datasets, with correlation established between sections, to allow selection of a candidate GSSP and auxiliary stratotypes. The assessments in this paper will help find the optimal locations for these sections.

## 1. Introduction

The Anthropocene Working Group (AWG), a working group of the Subcommission on Quaternary Stratigraphy (SQS) of the International Commission on Stratigraphy (ICS), is facilitating the process that will lead to the submission of formal proposals to define the Anthropocene as a chronostratigraphic unit. Such a unit comprises a body of strata formed during a specific interval of geological time. Units of the International Chronostratigraphic Chart (upon which the Geological Time Scale is based) are chronostratigraphic units, and each is defined by a synchronous base. The AWG is working towards a definition of the geological Anthropocene based on "the first appearance of a clear synchronous signal of the transformative influence of humans on key physical, chemical, and biological processes at the planetary scale. As such, it stands in contrast to various local or diachronous inscriptions of human influences on the Holocene stratigraphic record" (Zalasiewicz et al., 2017c). This working definition most closely aligns with the mid-20th century "Great Acceleration" in human population, resource consumption, global trade and technological evolution, proxy signals from which produce a distinctive stratigraphical boundary (Steffen et al., 2016). There are alternative interpretations of the definition of the Anthropocene, but these are generally grounded on a non-stratigraphical basis (e.g. the discussion on various geomorphological considerations of the start of the Anthropocene by Brown et al., 2017).

Within the Phanerozoic, the current internationally agreed method for defining chronostratigraphic boundaries is via selection of a Global Boundary Stratotype Section and Point (GSSP) as a physical reference level for a particular, and optimally correlatable, geological time boundary. The process of deciding on a GSSP, outlined by Remane et al. (1996) and Remane (1997, 2003) and summarised by Smith et al. (2014) is a complex process that normally requires: 1) an initial selection of a boundary level characterised by a marker event (the primary marker event) of optimal global correlation potential; 2) selection of a stratotype section from a number of potential sections, with the chosen stratotype section containing the best possible record of the primary marker event as well as other marker events that support global correlation; 3) ideally the selection of some auxiliary stratotypes in which the same level is represented by similar or other proxy signals in different parts of the world (Walker et al., 2009, in defining the Holocene Series, provided five auxiliary stratotypes as well as the GSSP); and, 4) definition of the precise point within stratified rock or sediment (or glacial ice in the case of the Holocene) that fixes the chronostratigraphic boundary with a precise moment of time. Formalisation of a GSSP is a careful procedure as, once ratified, it normally cannot be subsequently revised for at least ten years (Remane et al., 1996).

Table 1 provides a formal and comprehensive listing of the reasonable requirements for establishment of a GSSP, most of which will pertain also to a formal basis for the Anthropocene. It includes the requirement for stratigraphical completeness across the GSSP level, with adequate thickness of strata both above and below the boundary in order to demonstrate the transition. Therefore, the presence of an unconformity, marking a discontinuous succession, at or near the proposed boundary, would render it unsuitable. The selected section should also be accessible for subsequent investigations, ideally with provision for conservation and protection of the site.

The rank currently preferred by the AWG for the Anthropocene is that of series/epoch (Zalasiewicz et al., 2017c). The procedure leading to official acceptance of a GSSP for the Anthropocene Series/Epoch and its corresponding Age/Stage would require: 1) the selection by the AWG of a single GSSP candidate from one or more potential candidates, based on proposals submitted to it; 2) the recommendation of that proposal by the SQS; 3) its approval by the voting membership of the ICS; and 4) ratification by the Executive Committee of the International Union of Geological Sciences (IUGS). All voting within the ICS, and its constituent subcommissions and their working groups, requires a supermajority of 60% or more for a proposal to be approved.

Here we offer a preliminary assessment of palaeoenvironments and their depositional facies where potential GSSP candidate sections for defining the lower boundary of the Anthropocene may be located, based on the published literature. Few of these example sections were chosen with the specific purpose of defining the Anthropocene as a chronostratigraphic unit. Rather they show a range of proxy signals, analysed in published studies for varied (non-ICS) purposes. The palaeoenvironmental research illustrated in this review demonstrates the timing and processes through which these signals have been imprinted in strata, and the extent to which they allow stratigraphic correlation worldwide. Even with this considerable caveat, the possibilities of correlation are clearly demonstrated, and help constrain the range of potential targets for Anthropocene-specific ICS studies.

## 2. Key stratigraphic markers

The aim – not always achieved – is for GSSPs to have many guiding criteria to support the primary marker (Remane et al., 1996; Smith et al., 2014) to permit both regional and global correlation. This has been the early focus of the AWG, with the description of potentially suitable markers summarised by Waters et al. (2016), whose recommendations this study follows, and as reported by Zalasiewicz et al. (2017c), concludes that the primary marker for the

**Table 1**
Requirements for establishing a Global Boundary Stratotype Section and Point (GSSP). Table modified from Gradstein et al. (2012, Table 2.1, p. 36), revised from Remane et al. (1996) according to current procedures and recommendations of the ICS.

1. Name and stratigraphic rank of the boundary
   Including concise statement of GSSP definition
2. GSSP geographic and physical geology
   - Geographic location, including map coordinates
   - Geological setting (lithostratigraphy, sedimentology, palaeobathymetry, post-depositional tectonics, etc.)
   - Precise location and stratigraphic position of GSSP level and specific point
   - Stratigraphic completeness across the GSSP level
   - Adequate thickness and stratigraphic extent of section above and below
   - Accessibility, including logistics, national politics and property rights
   - Provisions for conservation and protection
3. Primary and secondary markers
   - Primary correlation marker (event) at GSSP level
   - Secondary markers – biostratigraphy, magnetostratigraphy, chemical stratigraphy, sequence stratigraphy, cycle stratigraphy, other event stratigraphy, marine–land correlation potential
   - Potential age dating from volcanic ash and/or orbital tuning
   - Demonstration of regional and global correlation
4. Summary of selection process
   - Relation of the GSSP to historical usage
   - References to historical background and adjacent (stage) units
   - Selected publications
   - Other candidates and reasons for rejection
   - Summary of votes and received comments
   - Other useful reference sections
5. Official publication
   - Summary for official documentation in IUGS journal *Episodes*
   - Digital stratigraphy (litho-, palaeo-, magneto-, and chemo-stratigraphic) images and graphic files submitted to ICS for public archive
   - Full publication in an appropriate journal