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Notes
The term ‘Anthropocene’ in the context of formal geological classification

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Abstract: In recent years, ‘Anthropocene’ has been proposed as an informal stratigraphic term to denote the current interval of anthropogenic global environmental change. A case has also been made to formalize it as a series/epoch, based on the recognition of a suitable marker event, such as the start of the Industrial Revolution in northern Europe. For the Anthropocene to merit formal definition, a global signature distinct from that of the Holocene is required that is marked by novel biotic, sedimentary and geochemical change. Although there is clear evidence of anthropogenic effects in geological sequences, it is uncertain whether these trends are sufficiently distinct, consistent and dated for the proposal for a Holocene/Anthropocene boundary to be substantiated. The current view of the Earth-Science community is that it should remain informal. For formal definition a Global Stratigraphic Section and Point (GSSP) is required. Adoption of the term ‘Anthropocene’ will ultimately depend on recognition of a global event horizon. Without this, there is no justification for decoupling the Anthropocene from the Holocene. If the Anthropocene is deemed to have utility, it should be as an informal historical designation rather than a formally defined stratigraphic unit (of whatever status) within the geological timescale.

The ‘Anthropocene’ (meaning anthrōpos ‘human being’ and kainos ‘new’) is a term that has become increasingly widely used since it was first proposed by Paul Crutzen & Eugene Stoermer (2000) to denote the present time interval, in which many geologically significant processes and conditions have been, and continue to be, profoundly altered by human activities. Processes include changes in erosion and sediment transport resulting from agriculture and urbanization, and variations in the chemical composition of the atmosphere, oceans and soils, with notable perturbations in element cycling, such as carbon, nitrogen, phosphorus and various metals. Changes in environmental conditions generated by these various processes include global warming, ocean acidification and coastal eutrophication and ensuing anoxia; habitat loss, species range shifts and extinctions; and globally significant physical and chemical changes, including cryospheric loss, ozone depletion and accelerating eustatic sea-level rise (e.g. Orr et al. 2005; Nicholls et al. 2007; Chen et al. 2011; Urban et al. 2012).

The increasing prominence of humans during the present (Holocene Series/Epoch) interglacial has been marked by a progressive increase in their effect on the natural environment and its processes, and this has long been recognized in palaeoenvironmental reconstructions. These anthropogenic effects, which have reached significant levels during the last few centuries, and particularly since the Industrial Revolution in northern Europe, have resulted in marked changes to the Earth’s surface. Indeed, almost every aspect of the contemporary global environment is now modified, or at least influenced, by human activity (Crossland 2005; Zalasiewicz et al. 2010; Steffen et al. 2011). There is a body of opinion within the geological community that this accelerated human impact may be reflected in the recent stratigraphic record, and that the anthropogenic effect can be distinguished from natural ‘background’ conditions (Zalasiewicz et al. 2008). Although the term Anthropocene was initially invoked informally to describe this period of expanding human influence on the global environment (Crutzen 2002), and was apparently suggested by chance (Steffen et al. 2004), it is increasingly being applied to the recent geological record, where the term is viewed, by some, as being equivalent to those used as series-status subdivisions of the Cenozoic Erathem (‘recent life’), notably the Pleistocene and Holocene.

An important consequence of the recognition of the increasing intensity of human impact on the natural environment, and its possible manifestation in the geological record, has been the initiation of...
Reliable numerical ages have been added gradually through the application of biostratigraphy. This is currently being considered by a Working Group of the Subcommission on Quaternary Stratigraphy (SQS). In the meantime, a separate Working Group of the SQS, jointly with INTIMATE (integration of ice-core, marine and terrestrial records), has been examining the case for a formal subdivision of the Holocene Series/Epoch (M. J. C. Walker et al. 2012). In the light of a possible conflict between the two groups, the Holocene working group has not considered the Anthropocene question. Nevertheless, they acknowledge that although there is a clear distinction between these two initiatives, the Holocene subdivision being based on natural climatic/environmental events and the concept of the Anthropocene focusing on the human impact on the environment, there may indeed be areas of overlap. We return to the subdivision of the Holocene below.

In this paper we consider the designation of the Anthropocene as a formal time-stratigraphic unit against the background of these ongoing discussions. We examine the term Anthropocene in the context of the formal definition of geological timescale units, particularly in relation to the requirement for relating such units to unequivocal Global Stratotype Section and Point (GSSP, ‘golden spike’) localities, and we also evaluate the potential value and utility of defining the episode of recent human activity as a new stratigraphic unit within the geological timescale (GTS).

**Stratigraphic procedures and the geological timescale**

The stratigraphy of geological sequences is the foundation upon which the discipline of historical geology, and therefore the accurate reconstruction of Earth history, depends. It is concerned with all the elements of sedimentary successions, including their form, distribution, lithology, fossil content, depositional environment, vertical sequence and age. Stratigraphy is therefore a synthetic subject that examines the origin, and temporal and spatial distribution, of sediment strata and other rocks.

Chronostratigraphy (‘time-rock stratigraphy’) is the branch of stratigraphy that involves the application of time to rock successions, the goal of which is the establishment of a globally applicable standard timescale. The chronostratigraphical scale originated as a relative one that was calibrated primarily through the application of biostratigraphy. Reliable numerical ages have been added gradually to form a parallel, numerical timescale based on years. Chronostratigraphical divisions are ‘time/rock’ units, that is they refer to the sequence of rocks deposited during a particular interval of time. Geochronological divisions are the corresponding intervals of (continuous) geological time. Thus, it can be said that rocks of the Quaternary System were deposited during a time interval called the Quaternary Period.

In conventional stratigraphic practice, it is generally accepted that chronostratigraphical and geochronological boundaries should, as far as possible, be defined in continuous sedimentary sequences. Ideally, such sequences preserve multiple lines of evidence (multi-proxy records) and, in particular, continuous sedimentation spanning the boundary itself, that is, excluding time gaps. This continuity offers the opportunity for identifying, *inter alia*, palaeontological, isotopic, chemical and palaeomagnetic changes, and therefore enables the boundary to be identified as precisely as possible within the limits of the evidence contained within the sequence. Throughout the Phanerozoic, this approach provides not only a basis for accurately delimiting a boundary, but also a means by which that horizon can be extended beyond the stratotype locality for purposes of correlation.

The recommendations of the International Stratigraphic Guide (Hedberg 1976; Salvador 1994) require that all major chronostratigraphical subdivisions are defined with reference to boundary stratotype localities in sediment reference sequences. These are designated GSSPs, or ‘golden spikes’, and form the basis for the division of geological time in the internationally sanctioned GTS. This is the responsibility of the International Commission on Stratigraphy (ICS), which is a constituent group of the International Union of Geological Sciences (IUGS), the body that directs all aspects of global geoscience. The role of the ICS is to formulate the subdivision, classification and determination of geological time, that is, chronostratigraphy and geochronology. The ICS operates through subcommissions, each associated with a particular time period, the Subcommission for Quaternary Stratigraphy (SQS), for example, being responsible for the Quaternary (which includes the present day). Each of the subcommissions defines the time divisions for their respective periods, and the GSSPs that provide the basis for global correlation. Proposals are submitted to the IUGS, via the ICS, for formal ratification. Any changes that arise from the proposal are incorporated into the GTS (www.stratigraphy.org). Once a GSSP has been ratified by the IUGS, a 10-year moratorium on any change then applies. An alternative basis for defining a global stratotype is age and is referred to as a Global Standard Stratigraphic Age (GSSA).
This is a chronological reference point in the world’s rock record that is used to define a boundary, and has been employed most widely in the Precambrian where the lack of diagnostic fossils precludes the identification of recognizable GSSPs. As with a GSSP, boundaries defined in this way must also be ratified by the ICS to be internationally valid (Remane et al. 1996).

Subdividing the Quaternary record

Although stratigraphical procedures are of paramount importance to geologists working in all the time periods, from the Pre-Cambrian to the Cenozoic, applications of conventional stratigraphic practice are frequently far from straightforward in the Quaternary. This is because Quaternary geologists are attempting to subdivide what might appear to be very short periods of time across a range of different environments from the tops of mountains to the depths of the oceans. The extraordinarily limited time intervals that are recognized in the Quaternary require a critical understanding of the implications of stratigraphical analysis and procedures, and the essential distinctions between the various subdivisions of rock strata that allow for the effective division, correlation and reconstruction of history from rock sequences. In this sense, the fundamental need to identify and define reference sequences (GSSPs) that can be used to equate isochronous surfaces and events around the world becomes critical. This is a requirement not only for large-scale units, such as Stages or Series, but also for smaller-scales subdivisions.

The conventional approach to the subdivision of the Quaternary stratigraphic record is to employ evidence for contrasting climatic conditions to characterize individual stratigraphic units (geologic–climatic units). This follows recommendations by the American Commission on Stratigraphic Nomenclature (1961, 1970), which recognized a geologic–climatic unit as indicating ‘an inferred widespread climatic episode defined from a subdivision of Quaternary rocks’ (ACSN 1970, p. 31). Although climatostratigraphy does not always find favour with geologists working in older parts of the record, in the Quaternary, where climatic change is the hallmark of the past two million years, it is difficult to envisage a scheme of stratigraphic subdivision that does not specifically acknowledge this fact (Lowe & Walker 1997). Indeed, it is now apparent that the principal driver of recent global climatic fluctuations, namely variations in Earth’s orbit and axis (Milankovitch forcing), is reflected not only in key stratigraphic horizons within the Quaternary record, but can also be detected in pre-Quaternary sequences at least as far back as the late Paleocene (Lourens et al. 2005). ‘Astronomical pacing’ provides both an index of the major climatic shifts and a basis for estimating the age of these events. As a consequence, major intervals of geological time within the Neogene and the Quaternary, which are evident in the climatic record, can be further defined as chronostratigraphic units within the GTS (Zalasiewicz et al. 2004).

The GTS is based on a hierarchical system of classification in which time-rock sequences (chronostratigraphy) and their corresponding intervals of time (geochronology) are represented by units of progressively lower rank. The Quaternary has the rank of system (a chronostratigraphical unit of high rank) and period (the equivalent geochronological unit) within the Cenozoic Era (Remane et al. 1996a, b). The Pleistocene is traditionally placed within the Quaternary at the next-lower rank of series (chronostratigraphy) or epoch (geochronology). The lower boundary of the Quaternary Series/Pleistocene Epoch is located at the GSSP at the base of the Gelasian Stage/Age in the Monte San Nicola section, Sicily, and dated at 2.58 Ma. Both the lower boundary of the Quaternary, and its status as a unit of series/stage rank, were ratified by the IUGS in 2010 (Gibbard et al. 2010).

The position of the Holocene

As currently defined, Holocene (meaning ‘wholly modern’) is the name for the most recent interval of Earth history and includes the present day. It is the second series or epoch of the Quaternary System/Period, and the boundary stratotype (GSSP) is located in the Greenland NGRIP ice core and dated to 11.7 ka (Walker et al. 2009).

The origin of the term Holocene is inextricably linked to the development of the nomenclature of ice-age time divisions. Two terms arose independently in the early to mid-nineteenth century to encompass near-surface, often unconsolidated, deposits: the Quaternary (Desnoyers 1829; Reboul 1833; von Morlot 1854) and the Pleistocene (Lyell 1839), although the former considerably predates this usage, having been proposed by Giovanni Arduino in 1759 for the fourth stage or ‘order’, which he recognized as the alluvial sediments of the Po plain, in northern Italy (Schmeer 1969; Rodolico 1970). Both Quaternary and Pleistocene were originally established for marine deposits, in the Paris basin and in eastern England, respectively. However, with the recognition that the extensive ‘Drift’ or ‘Diluvial’ deposits represented greatly extended glaciation in recent Earth history, both soon became synonymous with the Ice Age, and latterly with the rise of humans. The Quaternary differed in encompassing Lyell’s (1837) ‘Recent’
or Forbes’ (1846) ‘Postglacial’, a period termed the Holocene by Gervais (1867–69), with the latter formally adopted by the 1885 International Geological Congress (IGC).

The terms ‘Recent’, or less formally ‘Postglacial’, as alternatives to the Holocene, although still commonly used by geologists, are invalid (cf. Gibbard & van Kolfschoten 2005). A further term, ‘Flandrian’, derived from marine transgression sediments on the Flanders coast of Belgium (Heinzelin & Tavernier 1957), has often been used as a synonym for Holocene (e.g. Nilsson 1983, p. 23). It has been adopted by authors who consider that the last 10 ka should have the same stage status as previous interglacial events and thus be included in the Pleistocene. In this case, the latter would thus extend to the present day (cf. West 1968, 1977, 1979; Woldstedt 1969; Hyvärinen 1978). However, this usage has been continually criticized (e.g. Morrison 1969) and has been losing ground over the last three decades (Flint 1971, p. 324; Lowe & Walker 1997, p. 16). Accordingly, the term Holocene Series/Epoch is now more widely adopted, partly in recognition of the modern usage but also, more importantly, because of the importance in the present interglacial of the evolution of the human environment. Indeed, it is this anthropogenic signature that is the hallmark of the Holocene, setting it apart from previous interglacials, and taken as a fundamental justification for its status as a time-stratigraphic unit of Series/Epoch rank as it is currently defined (Walker et al. 2009).

What status for the Anthropocene?

As noted above, the status of the Anthropocene is currently being examined by a Working Group of the SQS. Both within that group and outside, there is an increasing body of opinion in support of the view that the informal nature of the term ‘Anthropocene’ should be replaced by a formal definition (e.g. Williams et al. 2011). If so, the Anthropocene would become the most recent time-stratigraphic subdivision of the GTS, and would constitute a formal unit of the Quaternary System/Period. Whether such a formalization is justified (and, if so, at what rank within the geochronological/chronostratigraphical hierarchy) is now considered.

The status of a potential formal Anthropocene division is one of considerable philosophical importance. This is because the higher the term’s rank, the greater the difference between conditions preserved and represented within the stratigraphic unit, and those of the immediately previous division. In the case of the term ‘Anthropocene’, the name selected implies, either intentionally or otherwise, that it should be seen as equivalent to Pleistocene and Holocene; that is, the term would have Series or Epoch status. If this was accepted, the corollary is that the Holocene has ended and we have entered a new geological interval, and such a transition would be equivalent to the changes between the Eocene and the Oligocene, or the Miocene and the Pliocene. In our view, a change of this magnitude is not supported by the geological evidence, the Anthropocene episode being too limited in duration when viewed from the perspective of the present, and with too variable a global stratigraphic signature to justify its elevation to a time-stratigraphic unit of Series or Epoch rank within the internationally agreed geological timescale.

The current position is that we are living in the Holocene Series/Epoch, and one of the key justifications for defining a Holocene Series, as a separate entity from the Pleistocene, is that humans (Homo sapiens) reached critical numbers and began influencing natural systems from the beginning of this time period onwards. As noted above, without this unique record of human impact there would be no justification for the Holocene being anything other than an interglacial, in common with all others in the Pleistocene. If the human dimension is accepted as a reasonable basis for a separate Holocene Series, as distinct from the Pleistocene, the activities of humans cannot then be used again in support of a discrete Anthropocene division. Given the extensive archaeological record of human/environment interaction throughout the Holocene (and even in earlier times), many workers find it difficult to accept the fact that ‘the Holocene interglacial has ended’. Indeed, when seen in the context of the long-term climatic and environmental changes that have occurred during the Quaternary, there would seem to be little justification for this view.

We referred above to the Working Group that is considering a subdivision of the Holocene. The proposals of that Working Group are for a tripartite subdivision of the Holocene Series/Epoch (Early, Middle and Late Holocene Sub-Series/Sub-Epochs), with boundaries at 8.2 and 4.2 ka respectively. The GSSP for the Early–Middle Holocene boundary is found in a stable isotope record from the archived Greenland NGRIP ice core, and the GSSP for the Middle–Late Holocene boundary is also in a stable isotope record, this time from an archived stalagmite from Mawlmuh Cave, NE India (M. J. C. Walker et al. 2012). These boundaries are based on significant natural events that register globally: the 8.2 ka event was an abrupt cooling episode triggered by catastrophic meltwater release into the North Atlantic from ice-dammed lakes at the northern margins of the Laurentide ice sheet, the signal of which can be found in both hemispheres, while at c. 4.2 ka there was a worldwide
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An aridification episode that was most pronounced in low- and mid-latitude regions, but which is also recorded in various proxy records from high-latitude regions. The point here is that these events are reflected in stratigraphic records from different parts of the world as broadly time-parallel marker horizons, so the GSSPs are of global significance. As such, the proposal for a subdivision of the Holocene is fully in line with the stratigraphic principles and practices described above. If a Holocene/Anthropocene boundary is to have the same credibility, then it must be underpinned by anthropogenic events that are as globally significant as the natural events that form the basis for the proposed Holocene GSSPs. In other words, the definition of the base of the Anthropocene must conform to the same stratigraphic principles.

Three questions follow from these discussions. (1) Is there a globally significant, human-induced and broadly time-parallel event that could form a basis for a stratigraphic boundary between the Holocene and Anthropocene? (2) Are we now living in a geological period that is significantly different from the preceding Holocene? (In other words, can the Holocene be considered to have ended?) (3) Would the recognition of the Anthropocene as a new geological period be of value to the wider Earth Science community?

In relation to the first of these questions, it has been suggested that the onset of the Anthropocene could be defined by the rapid industrialization and urbanization of western Europe and eastern North America in the late eighteenth century (Crutzen & Stoermer 2000), and numerous references have been made to the fact that evidence of these anthropogenic activities is preserved within the recent geological record (Steffen et al. 2001; Stoermer 2000), and numerous references have been made to the fact that evidence of these anthropogenic activities is preserved within the recent geological record (Steffen et al. 2007; Zalasiewicz et al. 2008; Williams et al. 2011). For example, the development of urban societies over the past two centuries has created ‘urban strata’ (e.g. the ‘artificial strata’ of Rosenbaum et al. 2003), while expanded town and city sites have influenced a range of geomorphological (e.g. fluvial) and pedological processes, and will have left their mark in stratigraphic sequences. Indeed, it has been suggested that human-affected soils (‘anthropic soils’) are potential ‘golden spikes’ for the Anthropocene (Certini & Scalenghe 2011). However, these markers, together with their geomorphological counterparts, are essentially local or, at best, regional in character, and are invariably time-transgressive (Gale & Hoare 2012). Moreover, with respect to the growth of urban centres, this is not a new phenomenon. Throughout the Middle and Late Holocene, city states from the Punjab (the Harappan civilization), through the Fertile Crescent (the Akkadian civilization) and Egypt, to the Mayan, Aztec and Inca cultures of Central and South America, have expanded, flourished and collapsed (Diamond 2005). Each has left an imprint in the archaeological and geological record, and any of these could have been designated a marker for increased human influence, yet the limited spatial impact of these cultures makes it unlikely that their stratigraphic signal could be used to define the onset of a period of global human dominance. The rapid industrialization of Western Europe and eastern North America during the eighteenth and nineteenth centuries was, by contrast, an event of much wider significance, but both industrialization and urban development was spatially variable and diachronous. It has therefore been suggested that an independent marker horizon, such as the increase in CO2 in polar ice cores (Crutzen 2002), could be used to designate the boundary between the Holocene and Anthropocene. A rise in CO2 levels from around AD 1750 is evident in both Arctic and Antarctic records (Barnola et al. 1995; Etheridge et al. 1996), is accompanied by the beginnings of an upward trend in the curve for CH4 and N2O (MacFarling Meure et al. 2006; Sowers 2010), and reflects increased levels of atmospheric trace-gas loading. As Zalasiewicz et al. (2011b) have pointed out, however, although seemingly abrupt on centennial timescales, these changes tend to be too gradual to provide useful stratigraphic markers at an annual or even decadal level, and this chronological imprecision is further exacerbated by the delay in sealing of the air bubbles during snow accumulation on the ice-sheet surface, which results in a temporal offset between the annual ice-core timescale and the atmospheric CO2 record (Bender et al. 1997). Stratigraphic resolution to the annual level, which is the aim of a GSSP for the Anthropocene (Zalasiewicz et al. 2011b), is therefore unlikely to be obtained from the ice-core record.

An additional difficulty with using the history of trace gases in ice cores to define the onset of the Anthropocene is that, although this is perhaps the clearest and most unequivocal indicator of human impact on the global atmospheric environment in the recent geological past, unfortunately it has little relevance to the vast areas of the planet that were not experiencing industrialization at that time. In other words, it does not coincide with a critical growth of human influence globally. Indeed, parts of the world with some of the largest concentrations of humanity, such as India and China, did not undergo their own industrial revolutions until the mid-twentieth century, some 200 years after the AD 1750 trace-gas event in the ice cores. This raises further doubts about the validity of the polar ice-core record as a potential GSSP for the base of the Anthropocene for, as we have already seen, any GSSP boundary should be a global one and, if
it is to be ratified by the IUGS, it must have worldwide applicability.

In acknowledging these difficulties in the selection of an appropriate GSSP for the Anthropocene, Zalasiewicz et al. (2011b) have suggested that an alternative strategy might be to define the base of the Anthropocene numerically with a GSSA (Global Standard Stratigraphic Age). At the level of resolution sought (annual), and at this temporal distance, one possibility might be to select a numerical age, such as the beginning of 1800 in the Christian Gregorian calendar. This would allow simple and unambiguous correlation of the stratigraphical and historical records, as well as providing consistent utility and meaning to the currently used informal term. Should this proposal be deemed to be of value to the Geoscience community, the date could be proposed as a GSSA to the ICS and could then be ratified and given formal status by the IUGS. However, this compromise, although avoiding confusion regarding the onset of the Anthropocene interval, would suffer the same basic drawback as a GSSP, in that the basis for the selection of age is a perceived acceleration of human impact on the natural environment, which, as we have already seen, is globally diachronous. In other words, selecting an age such as 1800 is essentially a western perspective on world events, and the GSSA would have little meaning (or relevance) to those regions of Africa or Asia where an increase in the pace of economic development did not occur until at least a century later.

In terms of the second question posed above, the palaeoenvironmental evidence suggests that humans have been shaping the global environment to various degrees more or less throughout the course of the Holocene and, to some extent, even before (e.g. Miller et al. 2005; Archibald et al. 2012). This is clearly of considerable concern for the archaeological community, who see a continuum of human/landscape interactions at a range of temporal and spatial scales extending through the Holocene to the present day. Indeed, it has been suggested that ‘by defining the Anthropocene as a geological epoch beginning only 200 years ago, Crutzen and Stoermer truncate thousands of years of human interaction with the global environment’ (Periman 2006, p. 558). Clearly, even younger events that have been suggested as baselines for the Anthropocene suffer from the same difficulty. These include the ‘Great Acceleration’ of the second half of the twentieth century during which many human activities reached take-off points in terms of their environmental impacts (Steffen et al. 2011; Wolfe et al. 2012), and the short-lived episode of nuclear bomb testing of the mid-mid twentieth century, which is reflected in a radiogenic nuclide peak (in $^{14}$C and $^{137}$Cs) at around AD 1963 in sedimentary records (e.g. Goodsite et al. 2001; Kemp et al. 2009). Both events have been proposed as potential global markers for defining the onset of the Anthropocene (e.g. Zalasiewicz et al. 2008). However, although these are undoubtedly clear manifestations of human impact on the terrestrial and climatic environment, they simply mark one of many stages in human technological development. They certainly do not coincide with the onset of environmental changes resulting from human activity, and therefore have little value in defining the initiation of human impact (Gale & Hoare 2012). In passing, it is also worth noting that radiogenic nuclide fallout was significantly lower in the Southern Hemisphere than in the Northern Hemisphere, so the distinctive weapons’ fallout peak is often difficult to discern in sediment records from the Southern Hemisphere (e.g. Collins et al. 2001; Humphries et al. 2010).

Furthermore, anthropogenic effects have not only been manifest in the terrestrial sphere throughout the Holocene, but may also have impacted on the atmospheric environment. For example, the polar ice-core records show the first increase in CO$_2$ concentrations c. 8000 years ago, while CH$_4$ concentrations began a similar rise c. 5000 years ago. The former has been related to forest clearance by human groups in China, India and Europe, while the latter has been associated with expansion of rice farming and increasing livestock numbers (Ruddiman 2003, 2005; Ruddiman et al. 2011). A further rise in CH$_4$ concentrations in ice cores from the historical period have been equated with long-term increases in agricultural emissions and biomass burning during the period of the Roman empire, the Han dynasty and the Medieval Climatic Anomaly, all of these records indicating that human activity contributed to variations in both CO$_2$ and CH$_4$ emissions to the atmosphere in pre-industrial times (Sapart et al. 2012). Indeed, the ice cores also contain evidence of atmospheric heavy metal pollution (As, Pb, Bi, Cu and Zn), reflecting smelting of lead and copper ores extending back to the Greek–Phoenician period (Krachler et al. 2009). Similar records of atmospheric Pb pollution, reflecting late prehistoric mining and smelting, have been obtained from peat sequences (Shotyk et al. 1998; Le Roux et al. 2004). These different lines of evidence are manifestations of a process of increasing human influence on the natural environment throughout the Holocene. Although no one disputes the fact that there was a substantial amplification of human impact with the onset of the European Industrial Revolution, it is difficult to isolate a single horizon within the geological record that marks the global ‘tipping point’ where natural processes have been overtaken by human-induced environmental changes.
The third question concerns the utility of defining a separate geological time unit, the Anthropocene. When considering a possible subdivision of the Holocene, the SQS/INTIMATE Working Group were concerned with putting forward a scheme that the geological community would find useful and with which they would be comfortable to operate. An extensive literature review showed quite clearly that the terms ‘Early’, ‘Middle (or Mid-)’ and ‘Late’ Holocene were widely employed in Holocene research, so by formalizing these terms, the Working Group was effectively legitimizing what was already custom and practice. There is no doubt that the term ‘Anthropocene’ has caught the popular imagination, as witnessed by the number of publications that have appeared in recent years that incorporate the term; indeed, a new journal entitled *Anthropocene* is to be launched by Elsevier in 2013. However, the question remains as to whether or not the utility of the term will be as an informal designation for the period of recent enhanced human activity, or whether it can be defined in a geological sense as a formal time-stratigraphic unit of the GTS. At present, despite the implicit geological connotation of the suffix ‘-cene’ implying a rank of Series/Epoch status, the usage of the term has been predominantly historical rather than geological in its application and definition. Because the criteria initially used to justify a Holocene Series still obtain, and while fully accepting the profound and increasing influence of humanity on the natural environment over recent centuries, we remain firmly of the view that the designation of the Anthropocene as a time unit equivalent to Series or Epoch divisions cannot yet be justified on stratigraphical grounds. At best, the Anthropocene might become another name for the later Holocene (with a usage similar, perhaps, to ‘Dark Ages’ or ‘Middle Ages’), but in a geological context the term would remain informal. Indeed, this view has now been reinforced by the Geological Society of America, who have rejected the term from their 2012 Geological Time Scale because it has no ‘internationally sanctioned standing’ (J. D. Walker et al. 2012, p. 7). In many ways, our concerns are admirably expressed in a recent paper by Autin & Holbrook (2012), in which they write:

> Before we amend our stratigraphy and end the Holocene, it would be best to settle the question of where in the stratigraphic record to drive the golden spike that defines when humanity became one of the preeminent forces of nature. Even so, will finding this layer lead to a globally relevant correlation? As stratigraphers, we require criteria to map the Anthropocene with relevant and consistent meaning. Presently, we are left to map a unit conceptually rather than conceptualizing a mappable stratigraphic unit. (Autin & Holbrook 2012, p. 61)

**Conclusions**

In order for the Anthropocene to be defined as a formal stratigraphical unit, a global event, distinct from that of the Holocene or of previous interglacial phases of the Pleistocene, must be identified on the basis of novel biotic (i.e. biostratigraphical), sedimentary and geochemical change(s). Although there is unequivocal evidence in recent geological records of rapidly increasing anthropogenic impacts on natural environments and systems, it is uncertain whether the geological signature of these trends is sufficiently distinct, and adequately dated at the global scale, for a Holocene/Anthropocene boundary to be substantiated on stratigraphic grounds. That being the case, if the term is to be retained for the purposes of geological time division, it must remain informal.

As currently defined, we are living in the Holocene Series or Epoch, the last 11.7 ka of Earth history. Although, on strict geological grounds, this period can be considered to be the latest of a sequence of interglacials that have characterized the Quaternary, and hence could be regarded as a unit of the Pleistocene Series/Epoch, the rise of humans (*Homo sapiens*) to critical numbers and the increasing influence they have exerted on natural systems provides the critical justification for defining this period as a separate unit of Series/Epoch status within the GTS. As such, the activities of humans cannot then be used again to justify the definition of a discrete Anthropocene division. This is the view of many Holocene geoscientists and archaeologists who do not accept that the Holocene has ended.

Although there is a substantial popular movement towards the recognition of a new period that acknowledges, and may indeed be characterized by, the overwhelming influence of humans on much of the natural environment, we continue to live within the same climatically and biologically defined time interval for which the term ‘Holocene’ was proposed and formally ratified by the IUGS. In the absence of a globally identifiable anthropogenic marker event that can be clearly recognized in a range of depositional contexts, that can be mapped in a conventional geological sense, and that can provide a consistent stratigraphic basis for detaching the Anthropocene from the preceding Holocene, there is, in our view, no justification for formally defining the Anthropocene as a new stratigraphic unit (of whatever status) within the established geological timescale.

We are grateful to Prof. J. Lewin and Dr A. Smith for their helpful and insightful comments on an earlier version of the manuscript, and to one anonymous referee for a constructive critical review. We also thank the...
editors of this volume for their invitation to us to present this paper on behalf of the Subcommission of Quaternary Stratigraphy, and for their encouragement and assistance in preparing the final draft for publication.

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