Proceedings of the Geologists' Association xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Proceedings of the Geologists' Association

journal homepage: www.elsevier.com/locate/pgeola

The stratigraphical signature of the Anthropocene in England and its wider context

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ARTICLE INFO

Article history:
Received 21 April 2017
Received in revised form 10 June 2017
Accepted 20 June 2017
Available online xxx

Keywords:
Anthropocene
Stratigraphy
Neobiota
Technofossils
Anthroturbation

ABSTRACT

The Anthropocene deposits of England, here regarded as those formed after ~1950 CE, are now extensive, take various forms, and may be characterized and recognized by a number of stratigraphic signals, such as artificial radionuclides, pesticide residues, microplastics, enhanced fly ash levels, concrete fragments and a novel variety of 'technofossils' and neobiotic species. They include the uppermost parts of both 'natural' deposits such as the sediment layers formed in lakes and estuaries, and more directly human-made or human-influenced ones such as landfill deposits and the 'artificial ground' beneath urban areas and around major constructions. 'Negative deposits' include the worked areas of quarries and regions such as the English Fenland, where thick peat deposits have ablated to leave a strongly modified underlying landscape, and extend beneath into the subterranean realm as mine workings, metro systems and boreholes. The production of these is still rapidly increasing and evolving in character, while the early signs of global change, such as warming, sea level rise, and modifications to biotic assemblages, are beginning to further modify the emerging geology of this new phase of Earth history.

1. Introduction

The Anthropocene is a term improvised by the atmospheric chemist Paul Crutzen and the limnologist Eugene Stoermer (Crutzen and Stoermer, 2000; also Crutzen, 2002) and introduced as a widely used term through Crutzen's deep involvement in the Earth System science community, where the term soon was widely adopted (e.g. Steffen et al., 2004). The geological community first took interest when the term, while still informal and having gone through none of the usual stratigraphical validation, appeared widely in publications as a geological time unit, usually without qualification as to its informal nature. Initial assessment by the Stratigraphy Commission of the Geological Society of London suggested that the term 'had merit' as a geological time unit (Zalasiewicz et al., 2008) and this led to invitation by the Subcommission on Quaternary Stratigraphy to constitute a Working Group on the 'Anthropocene', more commonly known as the Anthropocene Working Group (AWG). The group has been active since then in exploring the stratigraphic character and potential definition of the Anthropocene (e.g. Williams et al., 2011; Waters et al., 2014, 2016).

The Anthropocene, as emerging from these studies, does not primarily reflect local to regional human impact as regards changes to patterns of terrestrial biology, sedimentation, chemical character and so on (that is, it is not a synonym for 'significantly anthropogenic'), though of course such patterns are considered in its definition. It rather reflects substantial change to the Earth System in key parameters such as the carbon, phosphorus and nitrogen cycles, in overall rates of erosion and sedimentation, in biospheric changes and so on — as initially recognized by Paul Crutzen and his colleagues. These forms of change have a distinct stratigraphic expression via an array of patterns of proxy signals (summarized in Waters et al., 2016) that include:

- marked changes to CO_2 and methane atmospheric concentrations (preserved in polar ice layers);
- concomitant changes to patterns of carbon isotopes (specifically, a marked $\delta^{13}C$ anomaly via the Suess effect) and fly ash contents within sediments;
- changes to nitrogen isotope patterns from massive increase in fertilizer use;
- the dissemination of novel 'minerals' such as plastics and novel 'rocks' such as concrete within recent sediments;
- marked increase in heavy metals and other polluting substances (organic and inorganic, natural and artificial);

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http://dx.doi.org/10.1016/j.pgeola.2017.06.004
0016-7878/

- marked changes in the rate and character of sedimentation and erosion;
- marked changes to the 'neo-palaeontological' signal within recent sediments, from a combination of species introductions, assemblage modifications (especially through farming), extinctions and extirpations;
- incorporation of radionuclides scattered worldwide from atomic bomb tests.

Although some of these changes have been emerging over thousands of years, and spreading gradually and diachronously across the world, others are of much more recent origin, dating back to the Industrial Revolution or to the 'Great Acceleration' of human population growth, economic development and energy use in the mid-20th century (Steffen et al., 2007, 2015). While early studies suggested the beginning of the Industrial Revolution as marking the beginning of the Anthropocene (Crutzen, 2002; Zalasiewicz et al., 2008), subsequent analysis shows that a greater array of correlatable stratigraphic signals is associated with the mid-20th century event, and that that level would make a more effective chronostratigraphic boundary for general geological use (Waters et al., 2014; Zalasiewicz et al., 2015).

As regards the scale of the Anthropocene, and hence its potential position within the hierarchy of geological time, the assessment of Waters et al. (2016) suggested that the scale of change overall was at least as great as that associated with the Pleistocene–Holocene transition, and significantly greater than the changes linked with the proposed subdivision of the Holocene into ages/stages (Walker et al., 2012). Hence – and giving effective geological validation of Crutzen's de facto hypothesis (2002) that conditions of the Holocene have terminated – the Anthropocene is currently being investigated as a potential new epoch (or, chronostratigraphically, a series) of the Quaternary. If such a proposal (currently being formulated) is eventually accepted by the International Commission on Stratigraphy and ratified, that would mean that the Holocene would have terminated, and that a new epoch (still within the Quaternary Period, and the Cenozoic Era) would have begun.

Until then, we continue to live, formally, within the Holocene Epoch, and the Anthropocene remains an informal unit. However, one of the long-term tests of the Anthropocene will be to examine how well it functions in practice as a unit of the International Chronostratigraphic Chart (that is, the Geological Time Scale of general use). The diverse geological construction of England, and the broader history of the UK in terms of history of human occupation, landscape modification, instigator of the Industrial Revolution and early inception of geological study, provides a good opportunity for such practical examination. This paper provides an initial sketch of how the Anthropocene might be recognized in England and compared with elsewhere in the UK.

2. How may one define Anthropocene deposits in England?

The question of distinguishing Anthropocene geological strata from Anthropocene geology-related phenomena arises here. For instance, much of England's housing stock, its roads, railways and airports (and the cars, trains and airplanes that use them), its farm soils – and, indeed, its natural soils – are made largely from geological materials, which have been put together within Anthropocene time, as that time is interpreted here, commencing in ~1950 CE (see Waters et al., 2016).

These materials and objects are not normally interpreted as geological strata or elements within them, even though they are largely derived from rocks and will ultimately (probably within decades or centuries) go back to become components of future strata. Hence, one might consider that they are already within a human-modified sedimentary cycle of the Anthropocene, and also part of the technosphere (*sensu* Haff, 2014), which has a material bulk that may now be considered on a global scale (Zalasiewicz et al., 2016a). However, they do not fall within the currently accepted norms of geology, and so we will not consider them further in this account, except as elements within, or affecting, more typically understood 'strata'.

What kinds of Anthropocene strata are there? One might firstly consider those strata forming by more or less natural processes, within lake, river and coastal systems, distinguished by

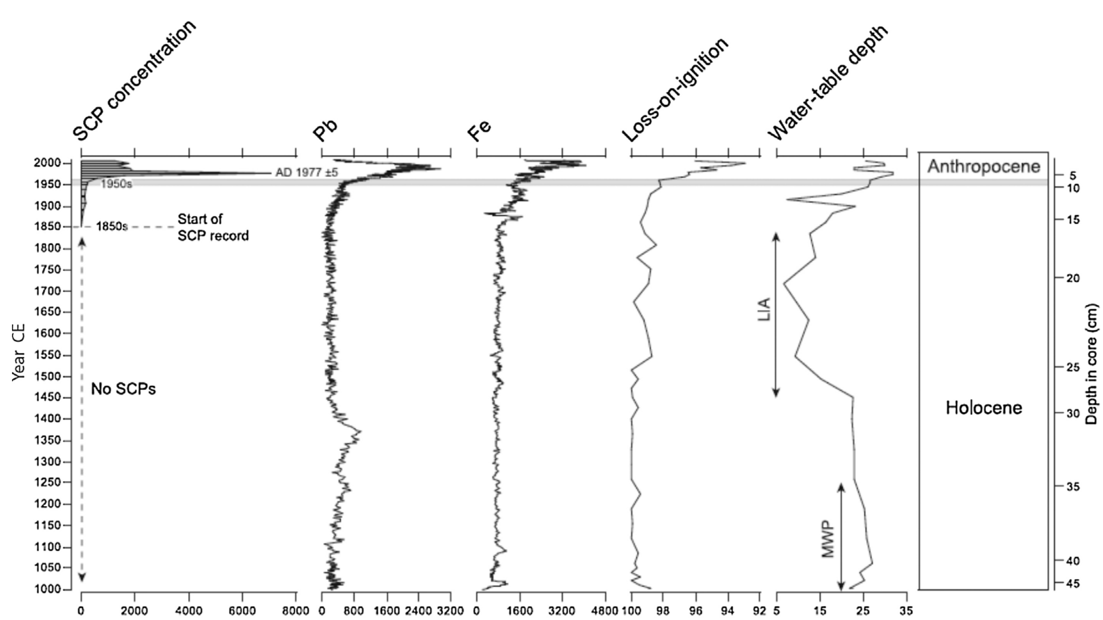

Fig. 1. Anthropocene strata of Malham Tarn Moss, Yorkshire, can be distinguished from underlying Holocene deposits on the basis of concentrations of spherical carbonaceous (fly ash) particles (SCPs), lead and iron. The first occurrence of SCPs in the section is in the 1850s, but there is a marked increase in abundance in the 1950s, with a peak in the 1970s. Atmospheric lead pollution from industrial activity and additives in petrol and increased soil erosion (reflected in the Fe and loss-on-ignition data) and change in water table show comparable upturns in the mid-20th century. Figure from Swindles et al. (2015).