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ESEX Commentary

Marking time in Geomorphology: should we try to formalise an Anthropocene definition?

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ESPL
Earth Surface Processes and Landforms

ABSTRACT: The value of a formally defined Anthropocene for geomorphologists is discussed. Human impacts have been diachronistic, multifaceted and episodic, as demonstrated by the record of alluvial deposition in the UK. Rather than boxing time into discrete eras or periods, modern research uses calendar dates and multiple dating techniques to explore co-trajectories for a range of human impacts. Despite the value of 'The Anthropocene' as an informal concept and as a prompt to useful debate, arriving at a single, generally acceptable formal definition is impractical, and has some disadvantages. Copyright © 2013 John Wiley & Sons, Ltd.

KEYWORDS: Anthropocene; alluvium; human impacts

Introduction

Debating formal definitions for the Anthropocene has many intriguing echoes from the geohistory debates of the nineteenth century (Rudwick, 2007). The latter eventually established a hierarchical chronosystem with identified eons, eras, periods, epochs and ages. It was recognizing that sediment types (what would now be called facies) of particular ages could vary considerably according to their local sedimentary and climatic environments. What became preserved could nevertheless be correlated by characteristic markers, especially fossil content, whether initially assuming species immutability or otherwise. This might involve first appearance and presence/absence (for example with or without the remains of vascular plants or fish) or frequency and dominance (as in Lyell's adoption of percentages of modern species for each of his subdivisions of the Tertiary). The debates could be fierce, and in the nature of nineteenth century science, they involved many what might now be regarded as separate disciplines. All this essentially involved refinement and sought-after subdivision, as does the debate about carving out the Anthropocene today (Zalasiewicz *et al*., 2008).

Nineteenth century debates were heavily concept-laden. Was Earth history notably cyclical (following Hutton and Lyell) or progressive following the cooling of the Earth (Fourier and Scrope)? Had processes – 'actual causes' – essentially been as presently observed somewhere on Earth, or had Earth history been punctuated by one or more watery or other catastrophes? Opinions were often realigned in the light of contemporary stimuli, such as the eruption of Mount Etna or the emergence of the Baltic coast, and following field recognition and eventual understanding of phenomena such as erratics.

Anthropocene debates have similarly been triggered by catastrophic portents, as in the dire effects of global warming and pollution (Steffen *et al*., 2011). But one might also reasonably expect the debate to make full use of the prior and extensive record of anthropogenic impacts available from historical, archaeological, Quaternary and (not least) geomorphological research (Brown *et al*., 2013; Ellis *et al*., 2013). Formal designation of a simple, single 'Anthropocene Epoch/Age' is also potentially obfuscatory simply because this history has proved not only directional but also diachronistic, multifaceted and episodic. The challenge of deciding on a single global anthropogenic isochron is a difficult one, with problems reminiscent of the nineteenth century in dealing with the same facies of different ages, and what would today be described in formal stratigraphic nomenclature as homotaxial errors. Epochs will appear fuzzily defined when their boundaries are examined in detail, though this is proportionally insignificant when they last for millions or hundreds of thousands of years. For the geologically brief Holocene this becomes more intractable because potential definition criteria span timescales similar to the period itself. Intermittent and complex anthropogenic signals are also intertwined with non-anthropogenic environmental ones, notably arising from Holocene climatic and vegetation variability, the latter also affected by human activity.

Anthropogenic Alluvium

In the UK, anthropogenic land-surface transformations associated with the Enlightenment and industrial revolution were preceded as well as succeeded by other important events and episodes. Earlier periods have been systematically evidenced by analysis of a large database (Macklin *et al.*, 2012) of all published carbon-14 (^{14}C) dated Holocene fluvial deposits in the UK (Figure 1). Importantly this is based on objective discrimination between dated alluvial units using sedimentological, palynological and geochemical indicators for deforestation, cultivation and metal mining impact (Foulds *et al.*, 2013; Macklin *et al.*, submitted for publication) to identify what we term anthropogenic alluvium. Impact onsets unsurprisingly occurred at different times from the Bronze Age (*c.* 4400 cal. BP) onwards, with most units dating to the last 1000 years. There is an apparent time lag of *c.* 1500 years between the adoption of agriculture and impact on floodplain sedimentation, with an important peak in the medieval period. Records elsewhere for colluvial (Lang, 2003), alluvial (Houben *et al.*, 2012) and lake (Dearing and Jones, 2003) sediments show similar though not identical episodes and punctuated trajectories, some showing sensitivity down to particular crop cultivation level, with others responding to centennial changes. Not all impacts produce alluvial signals: early deforestation may have lead essentially to colluvial rather than alluvial storage, and impacts prior to intensive cultivation may have been hydrological rather than sedimentological. This is shown very clearly by phases of accelerated lake sedimentation prior to 4400 cal. BP that are recorded in small, primarily upland catchments at *c.* 6000 (coincident with the adoption of agriculture) and *c.* 5000 cal. BP (Edwards and Whittington, 2001) but are not found in the UK floodplain sedimentary archive. Even within the relatively short period following the Enlightenment, there were multiple overlapping impacts (from industry, urbanization, pollutant input, river regulation and channel engineering) that combined to produce distinct episodes such as the UK river 'contamination window' following industrialization but preceding improved quality legislation in the later nineteenth century (Lewin, 2013). This has recently been documented in the Swale catchment,

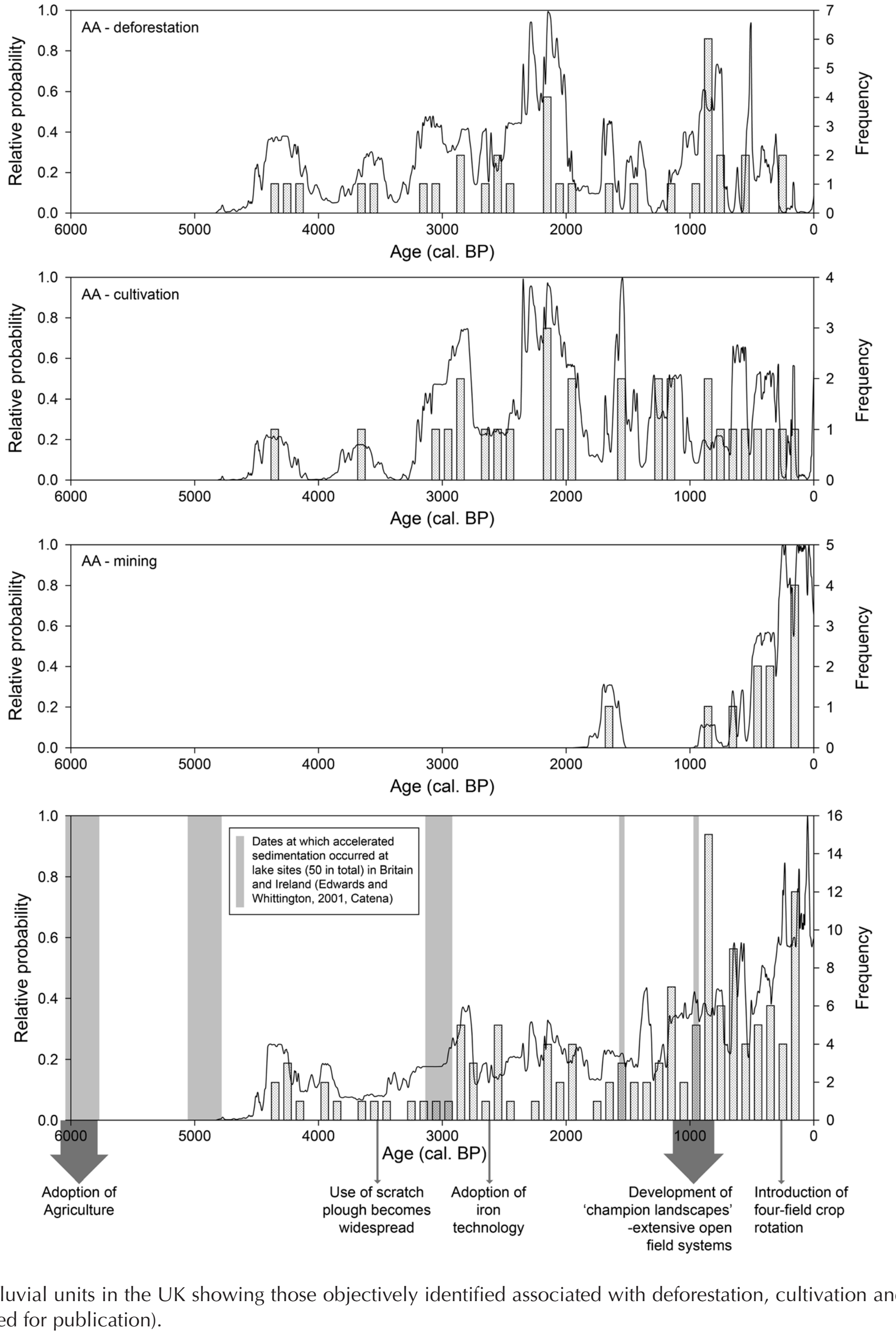

Figure 1. Holocene fluvial units in the UK showing those objectively identified associated with deforestation, cultivation and metal mining (from Macklin *et al.*, submitted for publication).

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northern England (Foulds *et al.*, 2013) where high-resolution analyses of floodplain geochemical and mining production records, underpinned by radiometric analyses, have enabled the identification of a distinct, anthropogenically associated fluvial unit (Figure 2). This is termed by Foulds *et al.* (2013) as 'agro-industrial alluvium' and provides a regional event marker for the Anthropocene. Prehistoric and historical farming, as well as mining, have all accelerated or modified sedimentation, but this and the global record are diachronous and strongly differentiated according to societal development stage (Hoffmann *et al.*, 2010; Brown *et al.*, 2013).

Putting Time into Bins and Silos

Current research, as illustrated by the identification and dating of anthropogenic alluvium in the UK, has two incomparable advantages over the nineteenth century: available dating techniques now cover the appropriate time spectrum, and there are quasi-continuous records of environmental change, including that produced by human activity, from ice cores and ocean, lake and fluvial sediments. It is now possible to refine the timing of many episodes and impacts to centennial level resolution within the 11 700 years of the Holocene, and to annual level or less for some recorded data. Many onsets and impacts have quite legitimately been identified and dated: Pleistocene megafaunal demise, early Holocene carbon dioxide (CO_2) enhancement, deforestation, metal mining, accelerated soil erosion and anthrosols, the biological 'American Exchange' after 1492, the Industrial Revolution (sometimes parochially dated to 1750 or 1800 CE), fossil fuel exploitation, ocean acidification, the atmospheric impact of nuclear explosions, and what Steffen *et al.* (2011) call the 'Great Acceleration' of human activity and impacts in Organization for Economic Cooperation and Development (OECD) countries after the mid-twentieth century. Markers include bottle tops and beer cans. The prime need is to explore, and to some extent to manage, the complexities and co-trajectories of these impacts. For this a fuzzily identified Anthropocene performs a useful public and policy focus, but it is a side issue for the fine-tuned research efforts of present day sciences. For a formal unit recognized by the International Commission on Stratigraphy, could there possibly be a single 'golden spike' within a Global Stratotype Section that would be generally acceptable and globally applicable? Historians manage well enough with informal periodization (the middle ages, the early modern period, Georgian England, and even 'the long nineteenth century') – but then they also use calendar dates, as now can geomorphologists.

Academic pitfalls may be involved once an epochal definition gets tightened. If one defining date is identified, say 1800, this excludes many legitimate anthropogenic impacts from residing within the Anthropocene. A very early date downplays the striking acceleration and globalization of recent years. What may suit an atmospheric chemist may not be useful to an archaeologist and *vice versa* (Paul Ratzen, the distinguished atmospheric chemist who proposed the term, now appears to favour nuclear testing as the real start of the Anthropocene). Atmospheric, river, ocean and sediment systems adjust on different timescales. Geomorphologists work across an enormous range involving both recent and ancient impacts, from long-term continental evolution, through Holocene sedimentation and river development, to sub-decadal adjustment of river channel dimensions to flood frequency and magnitude change.

Once time is boxed into silos, such periods may also be viewed as assuming a kind of uniformity. Non-stationarity in time series of environmental change may be overlooked. Attention instead becomes focused on boundaries (as transitions, and tipping or turning points) that are at least in part a procedural artefact. To an extent this initially happened with the division of the Pleistocene into glacials and inter-glacials. But these have been shown to have considerable internal variability (with the later Pleistocene being dominated by cold conditions but not necessarily ones of glacial advance). At one temporal level cold marine isotope stages (MIS) (2, 6, 8, etc.) have proven usefulness, but at another (as within the last cold stage, MIS 2–5d, and for sub-Holocene anthropogenic impacts) boxing may conceal more than reveal. Pleistocene cold or warm stages (Gibbard and Lewin, 2002; Lewin and Gibbard, 2010), and alluvial responses over a range of Late Quaternary timescales

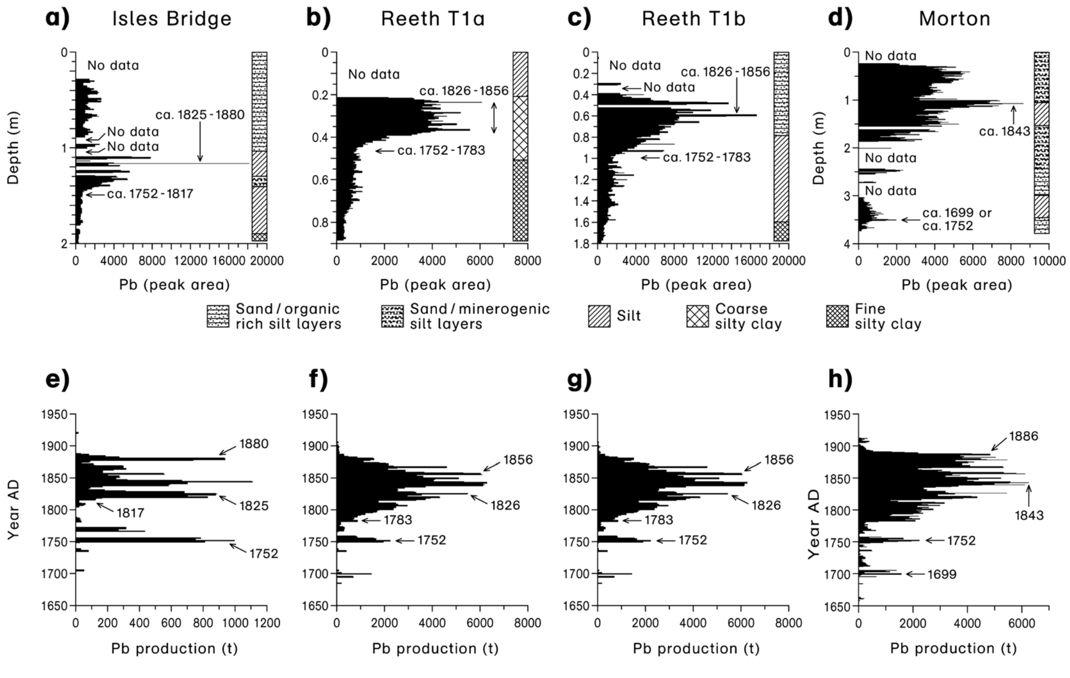

Figure 2. Anthropogenic alluvium; X-ray fluorescence (XRF) core scans for lead (Pb) concentrations, and Pb mining production in the Swale catchment, northern England (from Foulds *et al.*, 2013).

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relating to both climatic and anthropogenic signals (Macklin and Lewin, 2008) demonstrate episodic response to forcing episodes below perceived epoch/age thresholds. An 'Anthropocene' subdivision of the Holocene will necessarily and immediately be dissected into boundary-crossing and overlapping trajectories for research purposes, and data available for the Holocene allow many trajectories to be traced. Recommendations for the formal subdivision of the Holocene Series/Epoch into 'Early', Middle' and 'Late' defined by stratigraphical 'event' markers at 8.2 ka BP and 4.2 ka BP (Walker *et al*., 2012) have already been made. However, differences between the internal characteristics of these sub-epochs one with another were not defined.

Finally, and granting the public perception advantages of the Anthropocene concept, there are also tactical matters to consider. Anthropogenic effects are not all unidirectional and permanently established once some defined date or threshold has been crossed: is it desirable to reinforce the idea that they might be? To assume that would be the equivalent of taking a Whiggish view of history in which things got better (or in this case, worse) all the time. Episodes of soil erosion and associated accelerated floodplain sedimentation again came with population increase in the UK, but declined after the Black Death. River pollution levels rose, declined, and can rise again resulting from the remobilization of sediment-associated contaminants by major floods, which were first released by large-scale industrial and mining activities in the nineteenth century (Macklin *et al*., 2006). Geomorphologists are well placed to know about long-lasting inheritance or legacy effects, but environmental management may reduce some human impacts to 'pre-Anthropocene' states. Would a rigid and uncritical acceptance of the Anthropocene help or hinder such efforts, and would it aid research on major events? We are less sanguine than Zalasiewicz *et al*. (2010) that formal delimitation of the Anthropocene would not constrain approaches to curiosity-driven research, environmental policy and management. For example, a late-start definition may reinforce (and guide funding towards) the short timescale programmes that already characterize much of the climate change agenda.

Do Geomorphologists need a Formal Anthropocene?

We recognize that the Anthropocene is a useful popular and introductory device to stimulate political and public awareness of past and present human impacts on global geosystems and earth surface processes. The debate about how it might be defined has itself had positive achievements, including encouraging the geoscience community to consider more rigorously anthropogenic signals within, for example, the fluvial sedimentary archive. But, like the 'post-modern' period in the arts, its formal definition is problematic. There are so many equally legitimate alternatives, and we fear that this is likely to produce fruitless interdisciplinary wrangling. Modern science now primarily uses calendar dating and continuously variable data to reveal complex temporal interactions resulting from multiple, diachronic and overlapping anthropogenic impacts – not isochronic time boxes. Many impact complexities have in fact been appreciated for well over a century (Marsh, 1864); although with far more urgency and numerically-based sophistication in recent decades as human impacts have intensified. Political connotations are also drawn in now that there is a belief that human activity has come to 'dominate' natural systems and human security and prosperity are involved. Geomorphologists and others have been concerned with these for some considerable time, though over a timescale of centuries and millennia rather than the recent decades associated with the impacts of globalization and anthropogenic climate change. 'Marking time' through dating has been essential to these efforts, but at an academic level formal attempts to single-bin the Anthropocene may be seen as marking time in another sense: distraction from the real business of forward progress.

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