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Article

The Anthropocene: an Australasian perspective and survey

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Introduction

In 2000, Crutzen and Stoermer suggested that the Holocene (the geological period of time since 11,700 years ago: Walker et al., 2009) had finished and that humanity had now entered the "Anthropocene". As summarised by Steffen et al. (2011) and Wolfe et al. (2013), these scientists were referring to the Anthropocene as the interval of demonstrable human alteration of global biogeochemical cycles, beginning subtly in the late 18th Century following James Watt's invention of the coal-fired steam engine, and accelerating markedly in the mid-20th Century (called "The Great Acceleration").

The term "Anthropocene" is now regularly used in the geological/environmental literature, appearing in nearly 200 peer-reviewed articles in 2012, and three new journals were launched over the last few years specifically focussed on the topic (see also Waters et al., 2014). The problem is that the Anthropocene has not yet been formally defined and different disciplines have different viewpoints as to when the Anthropocene began, if at all (e.g. Brown et al., 2013; Gillings and Paulsen, 2014; Table 1). In addition, most perspectives on these issues are derived from the Northern Hemisphere (Bostock et al., 2015).

In 2016, members of the International Commission of Stratigraphy (ICS), as custodians of the formal Geologic Time Scale, will decide whether the Holocene epoch has given way to the Anthropocene and, if so, (*1*) where the boundary between the two should be placed, known as a "golden spike" or Global Stratotype Section and Point (GSSP), and (*2*) when the age or date of inception took place, known as a Global Standard Stratigraphic Age (GSSA). As well as the issues of defining a stratotype and age, the Anthropocene Working Group (AWG) of the Subcommission on Quaternary Stratigraphy, which advises ICS, is to recommend which hierarchical status the Anthropocene should attain if adopted. If it is to be a geological "epoch" (i.e. at the same hierarchical level as the Pleistocene and Holocene epochs) then it would lie within the Quaternary Period and follow the (terminated) Holocene Epoch. Alternatively, it could be considered at a lower hierarchical level such as "age", implying it is a subdivision of the ongoing Holocene Epoch (Monastersky, 2015).

At the same time the ICS will decide whether to formally adopt a proposal to subdivide the Holocene into three sub-epochs (Walker et al., 2012; see also Lowe, 2013). This parallel effort to subdivide the Holocene is relevant to the Anthropocene question because it clearly characterizes the Holocene as being based primarily on natural climatic/environmental events, thus leaving open the possibility of a subsequent epoch defined entirely by the global signature of significant human impact on the environment.

A key problem in attempting to define the Anthropocene is to distinguish between the *detection* of human impacts and their (patchy) distribution in time and space (which are known from archaeological and palaeoenvironmental records, e.g. see Ellis et al., 2013; Ruddiman et al., 2015), and the point at which the *magnitude* of human impacts on the Earth system (key biogeochemical cycles) exceeds the influence of the natural systems and which can be recognised in the context of geological time (Steffen et al., 2011; Wolfe et al., 2013). In a nutshell, the Holocene might be seen as wholly adequate to cover the former, and the Anthropocene could be used to cover the latter (Bostock et al., 2015).

Table 1. Ages or dates proposed in the literature for the start of the Anthropocene (after Bostock et al., 2015, adapted from Lewis and Maslin, 2015).

Option	Event	Age or date	Geographical extent
1	Use of fire	Early Pleistocene	Global but highly localised and diachronous
2	Megafaunal extinction	50,000-600 yrs BP	Global but diachronous
3	Origin of agriculture	~11,000 yrs BP to present	SW Asia then global
4	Intensification of agriculture	~8,000 yrs BP to present	Eurasian then global
5	New-Old World collision	AD 1492-1800	Eurasia- Americas
6	Industrial Revolution	AD 1760 to present	NW Europe then global
7	Tambora eruption (Indonesia)	AD 1815 (April)	Global: synchronous sulphate fallout at both poles
8	Great Acceleration	AD 1950	Many local events, global influence
9	Nuclear weapon detonation	AD 1945 to present (peak AD 1964)	Global

Australasian perspective

Bostock et al. (2015) have presented an Australasian perspective on defining the Anthropocene for the newsletter of the Australasian Quaternary Association (AQUA), and have invited feedback and comments (by 1 September 2015) that will be compiled and sent to AWG to help advise the ICS. If readers are interested in this topic and would like to see the full article of Bostock et al. (2015), then please contact David Lowe (email address given below). We do not suggest that Australasian evidence should necessarily be at the forefront of defining the onset or formal stratigraphic status of the Anthropocene, but that the evidence from our region should be compatible with, and should help inform, any globally applicable definitions.

In summary, Bostock et al. (2015) suggested that the Anthropocene onset must be (largely) globally discernible, and hence the Australasian evidence precludes definitions 1-5 of Table 1, because, in the words of Ruddiman et al. (2015, p. 39), "the timing of these changes varied from region to region, leaving no single 'golden spike' to mark their onset". Our favoured options (definitions 6-9) are discussed briefly below.

Industrial Revolution and the 1815 Tambora eruption

The rise in the ice cores of CO_2 and other greenhouse gases is evident from the early 19th Century (definition 6), but it is difficult to define precisely. The initial change in concentrations is gradual, reflecting the variable spread in the use of coal, starting in northwest Europe and slowly spreading to North America and then globally. Hence there is no abrupt change in CO_2 or other products associated with the burning of fossil fuels (Lewis and Maslin, 2015).

In Australia, large-scale European colonisation did not occur until 1788 with the development of the penal colonies around Sydney and the satellite convict settlements on Norfolk Island (from 1789) and Hobart (1803). In New Zealand, Europeans set up small whaling and sealing stations around the country, and undertook other activities, from the early 19th Century (e.g. King, 2003), and large pakeha (primarily British) settlements developed thereafter. For the next ~100 years there is considerable evidence from historical records and palaeoenvironmental archives that the European settlers in both Australia and New Zealand had a considerable impact on the landscape, including draining wetlands and clearing forests, leading to changes in vegetation and increased charcoal in the archives, and large increases in sedimentation in lakes, estuaries, and near-shore environments (e.g. Wilmshurst, 1997; Haberle et al., 2006; Brooking and Pawson, 2011), with industrial-type activity being limited.

However, if the Industrial Revolution (i.e. dating from the late 18th Century or the early 19th Century) were to be chosen as the start of the Anthropocene, as originally suggested by Crutzen and Stoermer (2000), an option for defining a golden spike (GSSP) for this event is fallout from the Tambora volcanic eruption in Indonesia (definition 7), which occurred 200 years ago in April 1815, and resulted in global cooling and "the year without a summer" in the Northern Hemisphere (e.g. Oppenheimer, 2003; Smith, 2014). More importantly for generating a global marker, the eruption produced an instantaneous, synchronous, and recognisable aerosol-derived sulphate spike in the ice cores of both Greenland and Antarctica and in glacier ice in North and South America, a distinct signal in dendrochronological records (Briffa et al., 1998; Smith, 2014), and likely fine-grained ashfall over very wide regions potentially discernible as a cryptotephra deposit (a glass-shard concentration not visible as a layer in the field: Lowe, 2011; Davies, 2015). Probable fallout from Tambora in New Zealand was identified by Gehrels et al. (2008) from measurements of Pb isotopes in salt-marsh sediments at coastal south Otago. Thus the Tambora eruption deserves serious consideration as the GSSP for the start of the Anthropocene because it generated a demonstrably globally synchronous signal that ties in with associated evidence of increasing human impact, namely the atmospheric greenhouse gas rise from the early 1800s (Smith, 2014). Alternatively, this eruption event in 1815 could simply be seen as globally marking the start of an approximately 150-year *transition* from the Holocene to the Anthropocene.

Great Acceleration and Nuclear Age, AD 1950

Bostock et al. (2015) argued, however, that the definitions on balance that relate best to the evidence in the Australasian region are 8 and 9 (Table 1), respectively the "Great Acceleration" combined with the "Nuclear Age" at around AD 1950 (i.e. between AD 1945 and 1965).

The Great Acceleration was an important time globally, with a major expansion of human population after World War II, and the development of many new technologies and materials (plastic, artificial fertilizers, advent of new breeds of crops such as rice, etc.) (e.g. Wolfe et al., 2013; Steffen et al., 2015). Although large-scale environmental development (such as the "grasslands revolution" in New Zealand) occurred from the late 19th and early 20th centuries (e.g. Brooking and Pawson, 2011; Cushman, 2013; Brooking and Wood, 2013; Park, 2013), and accelerating soil erosion, flooding, sedimentation, and measurable human-derived geochemical influences are recorded in landscapes and in lacustrine and marine sediments from the 1920s onwards (e.g. Rawlence, 1984; Hume et al., 1989; Page et al., 2000; Augustinus et al., 2006; Gomez et al., 2007; Gehrels et al., 2012; Basher, 2013), the 1950s was an important decade for both New Zealand and Australia with markedly increased intensification of land use, including the advent of aerial topdressing from 1948-49 in New Zealand, leading eventually to widespread changes (degradation) in water quality (e.g. Pawson and Brooking, 2013).

These changes, globally and locally, have had a major impact on our atmosphere and climate with atmospheric CO_2 and methane rapidly increasing after the 1950s. It is estimated that nearly half of the nitrogen in our bodies today was produced in a factory using the Haber-Bosch process. In addition, plastic can now be found in all parts of the Earth – the current estimates suggest the ratio of plastic to marine life in the world's major marine gyres is 6 to 1 by weight (e.g. Vince, 2014; Kidwell, 2015; Young, 2015).

Others have argued that the date of around AD 1950 postdates the upward inflection of atmospheric CO_2 and CH_4 from fossil fuel and agricultural emissions at the start of the Industrial Revolution by more than a century, as noted earlier. Similarly, Ruddiman et al. (2015, p. 39) pointed out that "following the introduction of mechanized agriculture, most prairie and steppe grasslands had been plowed and planted with crops by 1900", and they implied that it does not make sense "to define the start of a human-dominated era millennia after most forests in arable regions had been cut for agriculture, most rice paddies had been irrigated, and CO_2 and CH_4 concentrations had been rising because of agricultural and industrial emissions". However, Steffen et al. (2015, p. 81) demonstrated that "only beyond the mid-20th Century acceleration is there clear evidence for fundamental shifts in the state and functioning of the Earth System that are beyond the range of variability of the Holocene and driven by human activities". Climatologically, this is the first interval where there is evidence that anthropogenic greenhouse gas forcings dominated over natural climate forcings (Hansen et al., 2008). Thus the ~AD 1950 date crucially fits with the definition of the advent of the Anthropocene as being the point at which the magnitude of human impacts on Earth system (key biogeochemical cycles) exceeds the influence of the natural systems (Wolfe et al., 2013).

In a similar way that the Tambora eruption provides a geochronological marker for the start of the Industrial Revolution, the global fallout of bomb-test radioisotopes has the potential to create a truly global isochronous marker horizon for the start of the Anthropocene after AD 1950 (Zalasiewicz et al., 2011, 2015). The nuclear weapon detonations introduced a range of human-induced (not naturally occurring) radioactive isotopes that can be traced in soil, sediment, ice, tree-ring, and coral archives. Caesium-137 and strontium-90 were first detected in soils in 1952, and there is evidence that bomb radiocarbon in geological/environmental archives peaked in 1965 in the Southern Hemisphere, slightly offset by a couple of years from the Northern Hemisphere peak in 1963 and that of the tropics in 1964 (Zalasiewicz et al., 2015).

There is no need for the Anthropocene (yet)

Other scientists completely disagree with all these proposals and believe that we are still in the Holocene and that the "anthropocene" should remain an informal unit (e.g. Smith and Zeder, 2013; Gibbard and Walker, 2014; Ruddiman et al., 2015). In this case, the name would continue to be used in the same way as such archaeological terms as Neolithic and Bronze Age (Monastersky, 2015).

Finally, another view is that we are in the transition towards the Anthropocene and need a much longer perspective to assess "the character of the fully developed Anthropocene" and it should be left to future generations to decide (with hindsight) when the Anthropocene began (Wolff, 2014). For example, Ruddiman et al. (2105) suggested that future changes − such as species extinctions and ocean acidification − may be much larger than those already seen. Similarly, Gillings and Paulsen (2014), who suggested that the 'Great Acceleration' be assigned a formal starting date of 1953, the year the structure of DNA was first published, noted that although "microbial evolution is currently keeping pace with the environmental changes wrought by humanity, it remains to be seen whether organisms with longer generation times, smaller populations, and larger sizes can do the same in the future".

Conclusion

Please have your say. Specific questions to address include:

(1) Should the Anthropocene be formalised as part of the Geological Time Scale?
(2) If adopted, when should it start?
(3) If adopted, what status should a formally defined Anthropocene have in the hierarchy of the Geological Time Scale: epoch, age, or something else?

Send your answers and comments on these issues to Helen Bostock (Helen.Bostock@niwa.co.nz) ***by 1 September 2015.*** Contact David Lowe (d.lowe@waikato.ac.nz) if you would like a copy of the full *Quaternary Australasia* article by Bostock et al. (2015).

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