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Quaternary AUSTRALASIA



Defining the Anthropocene

Policy-making in focus

Making the most of INQUA 2015

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RECENT PUBLICATIONS

FRONT COVER PHOTO:

Coring at Warneet, Victoria, Australia. The core was taken as part of a 'blue carbon' stock assessment commissioned by the Port Phillip and Westernport Catchment Management Authority. At this particular site we sampled saltmarsh, mangrove, and freshwater drains. The site had some of the highest carbon stocks across the entire state of Victoria (see report by Paul Carnell *et al.* "The Distribution and Abundance of 'Blue Carbon' within Port Phillip and Westernport", available from Peter Macreadie: Peter.Macreadie@uts.edu.au). Photo: Peter Macreadie.

INSIDE FRONT COVER PHOTO:

Ground Swell by Matthew Harding, on display at Sydney Airport.

This work explores the geological history of the Botany region. The zoomorphic forms are made from 9000 year old Forest Red Gum and Angophora wood dredged during the construction of the parallel runway. These forms move across the ancient river systems that existed during the last ice age, which has since flooded to create Botany Bay. The presence of earth, air, fire and water speak of the essential forces that shape and sustain life. Photo: Patrick De Deckker.





MEET A MEMBER OF THE AQUA EXECUTIVE COMMITTEE

STEVEN PHIPPS: TREASURER, AQUA

Steven grew up in the wilds of the UK, before being lured to Gondwanaland by the ancient mountains and forests of New Zealand. After experimenting with a few different career options, and discovering a love of fine wine along the way, he eventually completed a PhD in climate modelling at the University of Tasmania in 2006. Subsequently, he came to realise that simulating past climates is only a worthwhile exercise if your model is constrained by real-world data. Thus he embarked on a weird and wonderful journey with all the weird and wonderful members of the Australasian Quaternary research community. In 2010, that journey took him to Stradbroke Island and his first AQUA Biennial Meeting. There was a vacancy for Treasurer and, as he has always embraced quantitative approaches, he thought that he should put his hand up. Thus began an equally weird and wonderful journey through AQUA's finances. However, after five years in the job, he is finding it increasingly hard to find the time to count all of AQUA's accumulated wealth. At the upcoming AGM, he will therefore be handing over his responsibilities to whomever is sufficiently gullible and enthusiastic to accept this critical role. He is looking forward to continuing to get his hands dirty with the proxy data, and notes that he is available for fieldwork.

The advent of the Anthropocene in Australasia

Helen C. Bostock[1], David J. Lowe[2], Richard Gillespie[3], Rebecca Priestley[4], Rewi M. Newnham[5], Scott D. Mooney[6]

1. *National Institute of Water and Atmospheric Research, Private Bag 14901, Wellington 6021, New Zealand*
2. *Earth Sciences, School of Science, Faculty of Science and Engineering, University of Waikato, Private Bag 3105, Hamilton 3240, New Zealand*
3. *Centre for Archaeological Science, School of Earth and Environmental Sciences, University of Wollongong, Northfields Avenue, Wollongong NSW 2522, Australia, and Department of Archaeology and Natural History, School of Culture, History and Language, Australian National University, Acton 2601, Australia*
4. *Science in Society group, Victoria University of Wellington, P.O. Box 600, Wellington 6140, New Zealand*
5. *School of Geography, Earth and Environmental Sciences, Victoria University of Wellington, P.O. Box 600, Wellington 6140, New Zealand*
6. *School of Biological and Earth and Environmental Sciences, UNSW, Kensington, Sydney, NSW 2052, Australia*

INTRODUCTION

As early as the late 19th Century, several scientists had suggested that humans were starting to influence the physical environment of planet Earth (e.g. Marsh, 1864; Stoppani, 1873; Arrhenius, 1896; Chamberlain, 1897). This idea was resurrected and expanded in 2000 by Paul Crutzen, a Nobel Prize-winning chemist, and the late Eugene Stoermer, a professor of biology specialising in diatoms, who suggested that we had left the Holocene and entered the "Anthropocene" (Crutzen and Stoermer, 2000). As summarised by Steffen et al. (2011) and Wolfe *et al.* (2013), these iconoclastic 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 (termed "The Great Acceleration"). Thus Crutzen and Stoermer (2000) argued that the Anthropocene should be an epoch, and for a starting date at the beginning of the Industrial Revolution (Monastersky, 2015).

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 have been launched over the last few years specifically focussed on this topic, namely The *Anthropocene Review*, *Anthropocene*, and *Elementa: Science of the Anthropocene*. In 2014, the Geological Society, London, published A Stratigraphical Basis for the Anthropocene (Waters et al., 2014), a 321-page volume devoted to the subject. The problem is that the Anthropocene has not yet been formally defined and different disciplines (and even scientists within the same discipline) have different viewpoints as to when the Anthropocene began, if at all (Table 1). In addition, most perspectives on this issue are derived from the Northern Hemisphere, although Brown *et al.* (2013) and Ellis *et al.* (2013) and some others have taken a more global viewpoint.

Table 1: Dates or ages proposed in the literature for the start of the Anthropocene, arranged in chronological order. Adapted from Lewis & Maslin (2015)

	EVENT	AGE OR DATE	GEOGRAPHICAL EXTENT	REFERENCE
1	Use of fire	Early Pleistocene	Global but highly localised and diachronous	Roebroeks and Villa (2011); Glikson (2013)
2	Megafaunal extinction	50,000-600 yrs BP	Global but diachronous	Barnosky (2014)
3	Origin of agriculture	~11,000 yrs BP to present	SW Asia then global	Smith and Zeder (2013)
4	Intensification of agriculture	~8,000 yrs BP to present	Eurasia then global	Ruddiman (2013) (see also Monastersky, 2015)
5	New-Old World collision	AD 1492-1800	Eurasia – Americas	Lewis and Maslin (2015)
6	Industrial Revolution	AD 1760 to present	NW Europe then global	Crutzen and Stoermer (2000)
7	Tambora eruption (Indonesia)	AD 1815 (April)	Global: synchronous sulphate fallout at both poles	Smith (2014)
8	Great Acceleration	AD 1950	Many local events, global influence	Waters *et al.* (2014); Steffen *et al.* (2015)
9	Nuclear weapon detonation	AD 1945 to present (peak AD 1964)	Global	Steffen *et al.* (2007); Zalasiewicz *et al.* (2011; 2015); Wolfe *et al.* (2013)

HOW TO DEFINE THE ANTHROPOCENE AND WHEN IT SHOULD START

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, where the boundary between the two should be placed. As well as the issue of timing, the Anthropocene Working Group (AWG, chaired by Jan Zalasiewicz) 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; see also http://quaternary.stratigraphy.org/workinggroups/anthropocene/).

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; Gibbard, 2015). This parallel effort to subdivide the Holocene is relevant to the Anthropocene question because it clearly characterises the Holocene as being based 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.

The Holocene was formally ratified by the ICS in 2006. It is defined as the most recent epoch of the Quaternary Period, being broadly the time since the first signs of climatic warming at the end of the Younger Dryas/Greenland Stadial 1 cold phase (11,700 calendar years before the year AD 2000) through to the present day (Walker *et al.*, 2009). The official boundary of the Holocene is defined in the Greenland NGRIP ice core at 1492.45 m depth (marked by an abrupt shift in deuterium excess values), and selected auxiliary lacustrine and marine records, including sediments in Lake Maratoto in northern New Zealand representing the Australasian parastratotype. Holocene stratigraphic records, as well as providing evidence of climate and sea-level change, geomorphological and hydrological processes, vegetational changes, and faunal migrations, also contain archaeological data that attest to the development of society, and the evolving relationships between people and the environment (e.g. Walker *et al.*, 2012; Roberts, 2014). A key problem in attempting to define the

Anthropocene is to distinguish between the detection of human impacts and their distribution in time and space, 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 totally adequate to cover the former, and the Anthropocene should perhaps be used to cover the latter.

AUSTRALASIAN PERSPECTIVE

In this article we present an Australasian perspective, and invite your feedback and comments, which will be compiled and sent to AWG to help advise the ICS. 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 inform, any globally applicable definitions. Because Australia (and Papua New Guinea) and New Zealand (and other Pacific islands of Polynesia) have very different Quaternary histories, they are treated separately in the brief overviews below.

AUSTRALIA AND PAPUA NEW GUINEA

Based on the dating of occupation and burial sites, humans arrived in Australia and Papua New Guinea around 45,000—50,000 years ago (e.g. Roberts and Jones, 2000; Turney *et al.*, 2001a; Bowler *et al.*, 2003; Allen and O'Connell 2014). Around this time there is also considerable evidence for significant changes in fluvial hydrology and lake levels (Magee *et al.*, 2004; Cohen *et al.*, 2015), evidence for charcoal and biological turnover (Turney *et al.*, 2001b; Mooney *et al.*, 2011), and for the extinction of the megafauna (Roberts *et al.*, 2001; Gillespie, 2008). There is still considerable debate in Australia, partly due to the sparse distribution and often poor quality dating of megafaunal sites, whether human hunting and associated practices, including use of fire, or climate change, or some combination of both, caused the demise of the megafauna (e.g. Miller *et al.*, 2005; Gillespie *et al.*, 2006; Brook *et al.*, 2007, 2013; Prideaux *et al.*, 2010; Rule *et al.*, 2012; Murphy *et al.*, 2012; Price, 2012; Wroe *et al.*, 2013; Cohen *et al.*, 2015). During the early to mid-Holocene period there is evidence for plant domestication in the highlands of Papua New Guinea (Denham *et al.*, 2003; Haberle, 2007), but Aboriginals on mainland Australia primarily remained hunter-gatherers.

The first Europeans landed on Australia in the 17th Century, but 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) (e.g. King, 2003). For the next ~100 years there is considerable evidence from historical and palaeoenvironmental archives that the European settlers had a considerable impact on the landscape, with massive deforestation of the east coast forests especially, leading to changes in the vegetation, increased charcoal in the archives, and large increases in sedimentation in lakes, estuaries, and near-shore environments (Haberle *et al.*, 2006). A significant acceleration of the impact of these and other land-use activities occurred in the 1950s (e.g. Douglas *et al.*, 2010; Gehrels *et al.*, 2012; Macreadie *et al.*, 2012).

PACIFIC ISLANDS AND NEW ZEALAND

In comparison with the early arrival of humans in Australia, many of the Pacific islands were only discovered and populated by seafaring Polynesians in the Late Holocene, with colonisation of West Polynesia from around 200 BC, central East Polynesia from around AD 900-1100, and Hawaii, Easter Island (Rapanui), and South Polynesia, from around AD 1200-1300 (Anderson, 2015a). The earliest arrival in New Zealand (part of South Polynesia) was not until the 13th Century, possibly around AD 1280 (Lowe and Pittari, 2014). Why New Zealand was settled so late in prehistory is debated, but, as well as being a remote archipelago, its discovery has been linked to the requirement of sophisticated sea craft and navigation and was possibly associated with a peak in El Nino frequencies (e.g. Anderson *et al.*, 2006; Anderson, 2015a, 2015b), or just general changes in the wind systems during this period (Goodwin *et al.*, 2014). The early Polynesians (who culturally became Maori in New Zealand) brought with them domesticated plants and animals (dogs and rats), although some of the tropical plants were not suitable for the New Zealand climate. Evidence from peat, lake, and marine-derived pollen records, lacustrine sedimentation records, and bones of the commensal Pacific rat Rattus exulans, rat-nibbled seed cases and snail-shells, fire records, ancient DNA, and archaeological studies show that Polynesians had a substantial impact on the landscape from around 700 years ago (e.g. Higham and Hogg, 1997; Wilmshurst, 1997; Ogden *et al.*, 1998; Schmidt and Higham, 1998; Higham *et al.*, 1999; McGlone and Wilmshurst, 1999; Brook, 2000; Anderson, 2002, 2005, 2013; Wilmshurst *et al.*, 2008, 2011, 2014; Lowe, 2011; Perry *et al.*, 2012; Jacomb *et al.*, 2014; Anderson, 2015c). There is also considerable evidence that hunting of the local wildlife in New Zealand lead to the extinction of a species of sea lion and many birds (~ 40 species) (Collins *et al.*, 2014), including several megafauna: all nine species of moa (extinct from AD 1440 ± 20; Perry *et al.*, 2014) and Haast's Eagle (extinct around AD 1400; Tennyson and Martinson, 2006).

Abel Tasman was the first known European to reach New Zealand in AD 1642 with evidence of possible contact by further Dutch explorers after AD 1705 ± 5 (Palmer *et al.*, 2013). Following the arrival of Cook in 1769, there is ample evidence for explorers, missionaries, whalers, sailors and traders, with small whaling and sealing stations around the country from the early 19th Century (e.g. King, 2003). The Treaty of Waitangi was signed in 1840 and large pakeha (primarily British) settlements continued to develop during the 19th Century. Further dramatic changes in the vegetation occurred during this European era, as observed from historical as well as geological and palaeoenvironmental archives. Pollen records in particular indicate resurgence in forest clearances by early pakeha settlers and accompanying introduction of a wide range of exotic plants. The large-scale development of grasslands occurred in the late 19th and early 20th centuries with the so-called "grasslands revolution", which lead to forest clearance on lowlands through to steeplands, and the widespread and efficacious drainage of wetlands (e.g. King, 2003; Brooking and Pawson, 2011; Cushman, 2013; Brooking and Wood, 2013; Park, 2013). Accelerating soil erosion and measurable environmental geochemical influences are recorded in landscapes and in lake and marine sediments from the 1920s onwards (e.g. Rawlence, 1984; Hume *et al.*, 1989; Page *et al.*, 2004; Augustinus *et al.*, 2006; Gomez *et al.*, 2007; Gehrels *et al.*, 2012; Basher, 2013), with a markedly increased intensification of land use from the 1950s, including the advent of aerial topdressing (from 1948-49), leading eventually to widespread changes (degradation) in water quality (e.g. Pawson and Brooking, 2013).

THE GREAT ACCELERATION

It is clear that the 1950s was an important decade for both New Zealand and Australia, and it is also an important time globally, with a major expansion of human population after World War II, intensification of land use, and the development of many new technologies and materials (plastic, artificial fertilizers, advent of new breeds of crops such as rice, etc.). This period, as noted earlier, has been called the "Great Acceleration" (e.g. Wolfe *et al.*, 2013; Monastersky, 2015; Steffen *et al.*, 2015). These changes have had a major impact on our atmosphere and climate with atmospheric CO_2 and methane rapidly increasing after the 1950s. It is now estimated that nearly half of the nitrogen in our bodies was produced in a factory using the Haber-Bosch process. In addition, ever-enduring 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 (Vince, 2014; Kidwell, 2015; Young, 2015). Steffen *et al.* (2015) emphasise that only beyond the mid-20th Century acceleration is there unequivocal evidence for fundamental shifts in the state and functioning of the Earth system that exceed the range of variability of the Holocene, and which are driven by human activities. Thus these authors consider that the beginning of the Great Acceleration is "by far the most convincing for a start date for the Anthropocene".

THE ATOM BOMB EFFECT

The mid-20th Century was also the start of the nuclear age. The first nuclear bomb was detonated by the United States of America (USA) on 16 July 1945. In the subsequent nuclear arms race, first the USA and Soviet Union, and then the United Kingdom, France, and China, began developing and testing nuclear weapons of ever-increasing size. The first thermonuclear bomb (or hydrogen bomb) was detonated by the USA in 1952, this new type of bomb, which the Soviet Union first tested in 1953, produced much larger yields of fission products and blasted radioactive isotopes high into the stratosphere where they spread around the world and were deposited as nuclear (radioactive) fallout.

It was a New Zealand scientist, Athol Rafter, who first observed that nuclear weapon detonations – particularly the hydrogen bomb tests – were significantly increasing levels of radiocarbon in the atmosphere. In a 1957 paper he coined the phrase "the atom bomb effect" (Rafter and Fergusson, 1957) and outlined how nuclear weapons tests had doubled atmospheric radiocarbon in the Northern Hemisphere and increased Southern Hemisphere levels by 60%. These increases produced a sudden spike of "bomb carbon" in the 1960s (Figure 1).

During 1961-62, many high-yield weapons were tested by the USA and Soviet Union, after which both countries signed the 1963 Limited Test Ban Treaty (tests by France, and then China, continued). In both northern and southern hemispheres, peak strontium-90 (^{90}Sr) and caesium-137 (^{137}Cs) levels were reached in 1964. The two-year delay between peak testing and peak deposition was due to the long residence time of fallout in the stratosphere. In the Southern Hemisphere, peak ^{90}Sr and ^{137}Cs deposition averaged 40% of Northern Hemisphere levels, with higher levels of deposition in areas with higher rainfall (Matthews, 1993).

GOLDEN SPIKE (GLOBAL STRATOTYPE SECTION AND POINT: GSSP) OR GLOBAL AGE (GLOBAL STANDARD STRATIGRAPHIC AGE: GSSA), OR BOTH, FOR THE ANTHROPOCENE?

For the Anthropocene to become a formal geological unit it needs to be recorded in the geological, sediment, or ice records (preferably all of these archives) as a stratigraphically significant single global event (or at least covering a significant proportion of the globe), and

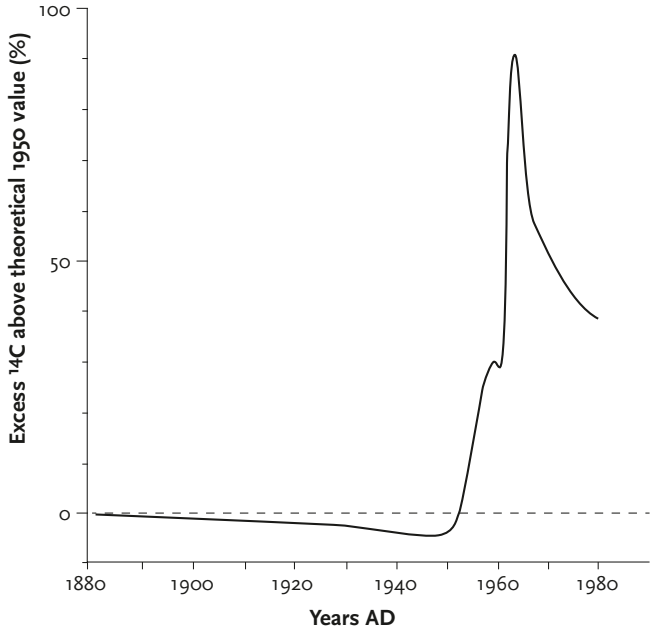


Figure 1: Atmospheric radiocarbon abundance, showing the fossil fuel effect and nuclear bomb effect (Gillespie, 1984).

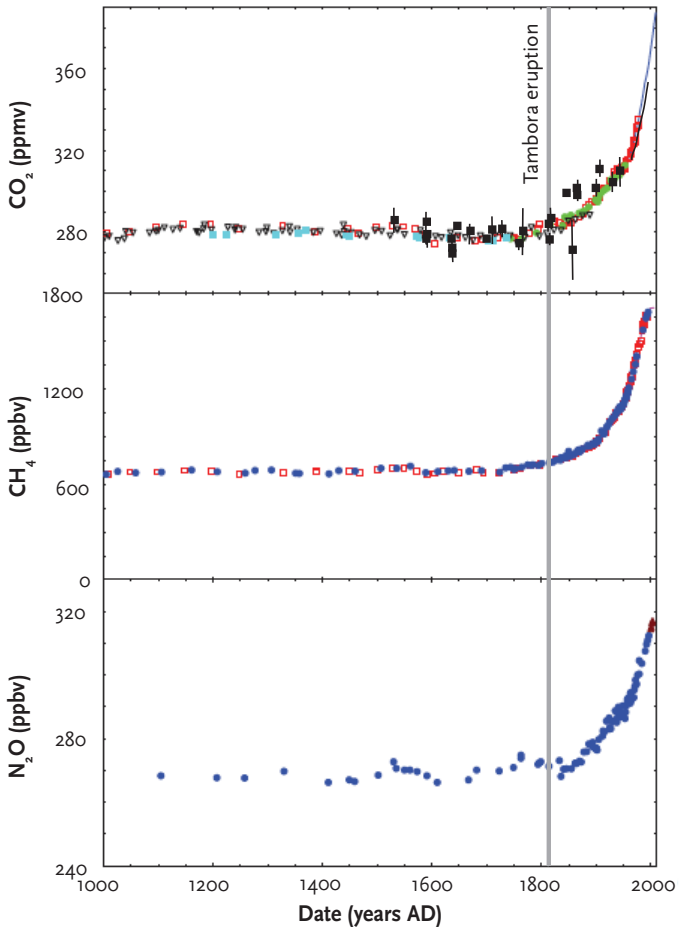


Figure 2: Changes in greenhouse gases recorded in ice cores in the last 1000 years with the date of the Tambora eruption (1815) indicated (vertical line). Coloured symbols represent data from Antarctic ice cores: red boxes = Law Dome, green circles = Siple, purple triangles = EPICA DML, blue boxes = South Pole; black boxes are data from GISP2, Greenland. Atmospheric CO2 measurements from Mauna Loa are also plotted (solid blue line) for the last ~50 years. Figure from Smith (2014), after Wolff (2011). Reproduced with acknowledgement and thanks to The Geological Society, London, and to Victoria C. Smith. (Please see the electronic issue for a colour version of this figure. Electronic issues are available on the AQUA website and through our ePublisher, Informit).

preferably not time-transgressive (i.e. not diachronous). If we accept that the Anthropocene onset must be (largely) globally discernible, the Australasian evidence outlined above precludes definitions 1-5 (Table 1). If we take definition 6 then the rise in CO_2 in the ice cores is clear, but it is difficult to define precisely. The initial change in concentrations is gradual, reflecting the sluggish and variable spread in the use of coal, starting in northwest Europe and slowly spreading to North America and then globally. So there is no abrupt change in CO_2 or other products associated with the burning of fossil fuels (Lewis and Maslin, 2015), but the marked rise in greenhouse gases nevertheless is evident from the early 1800s (Figure 2). One other suggestion for a golden spike (GSSP) for the early 19th Century (definition 7), relating chronostratigraphically to this greenhouse rise, has been fallout from the Tambora volcanic eruption (Indonesia), which occurred in April 1815, and resulted in a global cooling and "the year without a summer" in the Northern Hemisphere (e.g. Fischer *et al.*, 2007; 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, and a distinct signal in dendrochronological records (Briffa *et al.*, 1998; Oppenheimer, 2003; Smith, 2014). Probable fallout from Tambora in New Zealand was identified by Gehrels *et al.* (2008) from measurements of lead (Pb) concentrations and isotope values in salt-marsh sediments in southeast South Island. It is likely, on the basis of recent discoveries of cryptotephra deposits (sparse glass-shard concentrations not visible as layers: Lowe, 2011; Davies, 2015) at distances >7000 km from the eruption source (e.g. Lane *et al.*, 2013; Jensen *et al.*, 2014), that glass shards from the Tambora eruption are identifiable as cryptotephras in terrestrial and marine sediments over wide areas of the Earth's surface, hence potentially providing a definitive isochron or marker 'bed' on a hemispheric scale. Thus it could be argued that the Tambora eruption deserves serious consideration as the golden spike because it is 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 (Figure 2) (Smith, 2014). Another idea is that this eruption event could simply be seen as a global marker for the start of the ~150 year transition from the Holocene to Anthropocene.

We would argue, however, that the definition(s) that relate best overall to the evidence in the Australasian region are definitions 8 and 9, respectively the "Great Acceleration" combined with the "Nuclear Age" at around AD 1950 (i.e. between AD 1945 and 1965). It is clear that globally there have been many changes in land use and technology and other developments from the mid-20th Century that have led to fundamental shifts in the functioning of the Earth system to a point where many biophysical indicators now exceed limits of Holocene variability. There is now an unprecedented "emergent, planet-scale coupling, via globalisation, between the socio-economic system and the biophysical Earth System", according to Steffen *et al.* (2015). The global fallout of bomb-test radioisotopes has the potential to create a truly global marker horizon for the Anthropocene (Zalasiewicz *et al.*, 2011; 2015). The nuclear weapon detonations introduced a range of 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, while there is evidence that bomb radiocarbon in geological 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 (Hua *et al.*, 2013; Zalasiewicz *et al.*, 2015). Unfortunately, not all of these bomb isotopes will be useful for the tracing of this event in the geological future because ^{90}Sr and ^{137}Cs have very short half-lives (28 years and 30 years, respectively), while radiocarbon is slightly longer with a half-life of 5,730 years. However, several other isotopes, such as plutonium-239 and iodine-129, have longer half-lives of 24,110 years and 15.7 million years, respectively, and hence the latter should therefore be evident in the geological record effectively indefinitely (Hancock *et al.*, 2014).

Others have argued that the date of around AD 1950 postdates the upward inflection of atmospheric CO_2 from fossil fuel combustion in ice cores by more than a century (Fig. 2). However, it is clear from the records that there is also an acceleration in the increase of atmospheric CO_2 at this time (Steffen *et al.*, 2015), with evidence that this is the first interval when anthropogenic greenhouse gas forcings dominated over natural climate forcings (Hansen *et al.*, 2008). Thus this ~AD 1950 date fits with the postulated 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). Taking a rather different, namely microbiological, viewpoint, Gillings and Paulsen (2014) suggested that the 'Great Acceleration' be assigned a formal starting date of 1953 (when the structure of DNA was first published) on the grounds that human manipulation of the biological information flows from DNA, to RNA, to protein, and thence to phenotype (a process known as the 'Central Dogma' of cell biology), is a major development in the course of evolutionary history. Because such manipulation "has the potential to expand the power of gene technology to whole-Earth scales", Gillings and Paulsen (2014) concluded that "DNA technology will be a powerful force in our future, and for dealing with the Anthropocene."

Finally, some have proposed that a GSSA alone may be more appropriate at this time to define the start of the Anthropocene because the community is still fleshing out the full range of physical, chemical, and biological phenomena associated with the postulated Holocene-Anthropocene transition (Zalasiewicz *et al.*, 2011; 2015; Wolfe *et al.*, 2013), and hence a GSSP can wait. However, 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. Autin and Holbrook, 2012; Gale and Hoare, 2012; 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). 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 (e.g. Drake *et al.*, 2014) – are projected to be much larger than those already seen but are difficult to predict.

Please send your thoughts and feedback to Helen Bostock (Helen.Bostock@niwa.co.nz) by **1 September 2015**.

Issues 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?

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