Waiting for the Anthropocene

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Abstract

The idea that we are living in the Anthropocene, a new geological epoch defined by human activity, has gained substantial currency across the academy and with the broader public. Within the earth sciences, however, the question of the Anthropocene is hotly debated, and recognized as a question that gets at both the foundations of geological science, and at issues of broad philosophical importance. For example, official recognition of the Anthropocene requires us to find a way to use the methods of historical science to make predictions. It also involves determining the role that political motivations should play in establishing scientific kinds. I bring the perspective of philosophy of science to bear on these questions, ultimately arguing that formal recognition of the Anthropocene should be indefinitely deferred.

1 A New Epoch

My office window looks out on one of the world's largest open-pit mines, where mountains have been shredded into a rust-coloured stain. At the visitor's centre, the mining company proudly declares that their mine is visible from space. Such signs of humanity's status as a geological force are everywhere, and even the most evidence-resistant climate change sceptic can't deny human influence on the planet in the face of a mine visible from space. Humankind is indubitably reshaping the Earth.

Our status as geological agents has led some to propose that we live in a new geological epoch, one driven by human artifice as much as the tilt of the earth, biological evolution, and natural catastrophes. In 2000, atmospheric chemist Paul Crutzen (Crutzen and Stoermer [2000]) suggested a name for this new epoch, the 'Anthropocene', derived from roots meaning 'human' and 'new'. Despite not being proposed by geologists, not originally having a basis in stratigraphic data, and not being formally accepted by any scientific body, the name spread rapidly throughout academia, first in the Global Change community (Steffen *et al.* [2011]), but soon among researchers of all stripes. Many in the humanities and social sciences, while acknowledging that the Anthropocene is an open question, in practice assume its existence. 'A new geological epoch, the Anthropocene, has been declared' claim historians Robin and Steffen ([2007], p. 1694). Sociologist Nigel Clark examines the 'disastrous' political consequences of the Anthropocene ([2014]). Bruno Latour ([unpublished]) acknowledges that the Anthropocene is not yet formally adopted, but points to it as something that anthropologists must embrace to keep their discipline relevant. From economists (Sachs [2008]) to legal scholars (Purdy [2015]), academics across the university are examining what this new epoch means for their disciplines. Outside the academy there are publications dedicated solely to the Anthropocene,[1] and journalists report on the Anthropocene as if formalizing it as a geological epoch were merely, well, a formality.[2]

Recently, much of this certainty that official recognition of the Anthropocene is inevitable has been bolstered by the recommendation of the 'Anthropocene' Working Group (AWG) of the Subcommission on Quaternary Stratigraphy (SQS) of the International

[1] See <www.anthropocenemagazine.org/>.

[2] See <www.theguardian.com/environment/2016/aug/29/declare-anthropocene-epoch-experts-urge-geological-congress-human-impact-earth> and <www.nytimes.com/interactive/2016/01/11/science/anthropocene-epoch-definition.html>.

Commission on Stratigraphy (ICS), which is a constituent of the International Union of Geological Sciences (IUGS). After years of deliberations, in 2016 the working group voted thirty to three, with two abstentions, to recommend formal recognition of the Anthropocene. And although many outsiders have taken this to vindicate the concept of the Anthropocene, many of the members of the AWG among the most important scientific proponents of the new epoch, so the AWG may not comprise a representative sample of the broader geological community. The AWG vote is merely a first step towards formal designation of the Anthropocene, which would also require ratification by the SQS, the ICS, and the Executive Committee of the IUGS. This iterative bureaucratic procedure exemplifies the cautious and careful deliberation among earth scientists over whether to recognize the Anthropocene, which presents a nice contrast to the breathless enthusiasm for the Anthropocene found among activists, journalists, and many academics. In geology, it's hardly a foregone conclusion that all these bodies will ratify the Anthropocene, since according to some involved in the debate, 'The current view of the Earth-Science community is that it should remain informal' (Gibbard and Walker [2014], p. 29).

In what follows, I endorse the position that the Anthropocene should remain informal. The distance between the approach earth scientists take towards the Anthropocene and the approach of its proponents outside geology is grounded not merely in expertise and the constraints of formalized procedure, but in taking different perspectives on how to answer the question. For the geologist, it is primarily a question that should be answered the way we have answered other questions of geochronology: from a historical perspective. To broader audiences, however, it is often a contemporaneous, political question about the potentially disastrous effects we are having on our planet. I'll argue that from both perspectives we have reason to hold off on proclaiming the dawn of the Anthropocene.

1.1 Criteria for designating a new epoch

Asking whether the Anthropocene should be designated a new epoch is not the same as asking whether humans are significant geological agents. Humans are significant geological agents, as are all sorts of organisms, from algae to earthworms to trees. The Anthropocene question runs deeper, involving both the kind of impact humans are having on the geological record, and the degree of that impact.

Identification of all other formal units of the geological timescale occurred when geologists and palaeontologists had reason to group a continuous and distinctive set of strata. Reasons include dividing up the history of the earth after a major global change, or just the presence of a clear marker at a spot where a division would be useful for reference purposes. A typical marker used to distinguish adjacent strata is a change in the fossil record (Waters *et al*. 2014: 1), but in the current Quaternary period geologists have relied more on alternating stretches of glacial spread and retreat (Wolff [2014], p. 256). Procedures for identifying and formalizing these chronostratigraphic divisions are found in the *International Stratigraphic Guide*, and for divisions not in the very distant past, involve identification of a Global Boundary Stratotype Section and Point (GSSP). A GSSP is a concrete point on a well-preserved outcrop identifying the lower boundary of the division in question. That point is marked with a bronze disk called a 'golden spike' which signals that this point is both reliably radiometrically dated and that the stratum it marks contains primary and secondary markers such as fossil and chemical contents which allow it to be equated to strata of the same age globally. For example, the K–Pg boundary between the Cretaceous and the Palaeogene is marked by a golden spike in El Kef, Tunisia in rock dated 66 million years old at a point where iridium content, among other markers such as microscopic fossils, records the effects of the impact event which created the Chicxulub crater in the Yucatán Peninsula (Molina *et al*. [2006]).

Ideally, stratigraphers would apply similar methodology to identifying a possible Anthropocene, but since we're contemporaneous with the proposed epoch, we can't. Instead we must consider the question 'from the viewpoint of a geologist viewing sequences [of rock] thousands or millions of years in the future' (Wolff [2014], p. 255). Would that future geologist see justification for driving a golden spike into a rock layer that was formed around the twentieth century? Asking such a question is a radical shift for a historical science like geology, because it requires the historical science to become a science of prediction; to tell us not about what happened thousands or millions of years ago, but to tell us what the Earth will look like thousands or millions of years from now. Were the Anthropocene to be ratified, it would be the unique division in geological time to be based on 'projections into future millennia' rather than on evidence of the past (Finney [2014], p. 26; The Human Epoch [2011]). Call this standpoint on determining the status of the Anthropocene the future geologist's perspective.

Taking the future geologist's perspective doesn't necessarily commit us to waiting millennia before we decide on the Anthropocene question. If we are living in the Anthropocene, Anthropocene strata have been deposited and are currently being deposited, so we can make predictions about what these strata will look like to the future geologist. Arguments about the Anthropocene aren't based on speculation, but study of recent geological deposits and current human activity, which in combination with our best theories in the earth sciences allow us to predict what recent and near future strata will look like to the future geologist.

Many authors have noted that the type of prediction required to evaluate the future geologist's perspective may also lie partially outside the expertise of earth scientists. Given that the state of the earth in the distant future depends on contemporary human behaviour, it has been argued that making the correct prediction must involve social science (Ellis *et al*. [2016]) and that the boundaries between the earth sciences and the study of human history must be dissolved (Chakrabarty [2009]). Whether or not this is the case, understanding the future geologist's perspective on a possible Anthropocene certainly requires tools not traditionally found in the geologist's toolkit.

In contrast to the future geologist's perspective, many advocates of the Anthropocene evaluate its conceptual utility from the synchronic perspective. In this perspective, we see the possible existence of the Anthropocene as a question about our current relationship to our planet. Because 'the implications of formalizing the Anthropocene reach well beyond the geological community', we must consider the effect that formalizing it (or not) would have on public and academic understanding of humankind and the Earth (Waters *et a*l. [2016], p. 145). From the synchronic perspective, the question of ratifying the Anthropocene is political as well as scientific.

My argument is straightforward. From the future geologist's perspective, we should hold off on formal approval of the Anthropocene because extant geological changes don't reach the thresholds necessary to define a new epoch, and predictions about the future are impossible given human capability to slow and reverse anthropogenic effects. Regarding the synchronic perspective, we have little evidence that ratifying the Anthropocene will have the positive political effects its proponents suggest. Worse, doing so could backfire. Whichever perspective we adopt, we should hesitate to fully endorse the Anthropocene.

2 The Future Geologist's Perspective

Our hypothetical future geologist, while examining strata created in our day, will be asking herself whether the stratal markers for a potential Anthropocene are as significant as the markers at the boundaries of established geological epochs. An epoch is a chronostratigraphic division longer than an age and shorter than a period. The -cene suffix for the Anthropocene suggests its status as an epoch, but the Anthropocene could, in principle, be recognized as an age, period, or even era. For present purposes, we'll ask solely whether to designate an Anthropocene epoch. If the Anthropocene is an epoch, the geological changes represent by its markers must be on par with the changes demarcating other epochs (Waters [2014], p. 3). To ask whether the Anthropocene is a new period is to set a high bar and thus make rejecting it too easy, and to ask if it is an age is to diminish its significance to levels incompatible with the pro-Anthropocene hype. Earth scientists recognize that since the question is one of relative significance, which requires judgement about when quantitative difference becomes qualitative (Castree [2017]), it is a question of 'considerable philosophical importance' (Gibbard and Walker [2014], p. 32).

What sort of geological events are of epochal significance? This question covers not just the stratigraphic signals that divide chronostratigraphic series, but of the types of accompanying global change that justify designation of geochronological epochs. Not every potential marker demarcates a formal boundary, or we'd have a proliferation of divisions. Instead, we use markers for 'the simple reference convenience of dividing up long timespans' (Gibbard and Lewin [2016]) or to represent significant global change and transformational events. Let's get a feel for what characterized the most recent epochs. The Palaeocene epoch begins with the bolide impact which precipitated the mass extinction that ended the non-avian dinosaurs (though this is a period and era boundary as well, and so is a more significant transition than most epochs). The transition between the Palaeocene and the Eocene is marked by a carbon isotope signature suggesting a release of carbon to the oceans and atmosphere, which accompanied a number of other significant geological events including a peak in temperature (8 °C higher than today), a notable spike in atmospheric oxygen, and the emergence of large placental mammals in the fossil record (Falkowski *et al*. [2005]). The Eocene to Oligocene transition is marked by the extinction of planktonic fossils contemporaneous to an extinction event called the Grande Coupure, which saw turnover in mammal species, but did not rise to the level of the great mass extinctions. It also saw global cooling of 2.5–5 °C and the corresponding shift from a heavily forested world to the dominance of grasslands (Liu *et al*. [2009]). The Oligocene–Miocene and Miocene–Pliocene transitions are complex and don't necessarily represent transformational events of the same significance, but are useful in subdividing the Neogene Period.[3] The Pliocene to Pleistocene transition begins with first of eleven periods of major glaciation (the 'Ice Age'), and the Pleistocene transitions to the Holocene at the end of the last of these glacials. Related to the end of the glaciation, the Holocene is also marked by the emergence of agriculture and large human settlements, and roughly coincides with the extinction of many large mammals. These are the sorts of major changes which define recent epochs.

For three different reasons, we are not yet justified in claiming that current human geological activity will rise to epochal significance from the future geologist's perspective.

(1) Many of our geological impacts can be mitigated by future human behaviour. To the future geologist, this may make them relatively insignificant, brief anomalies.

(2) Some anthropogenic activities are best conceived as continuations of processes that originated in the Holocene, so the future geologist will not see them as marking a new

[3] Note that the time period being subdivided into two epochs here is over 20 million years, three orders of magnitude greater than the time period that would be subdivided in to the Holocene and Anthropocene. The reference utility of a new division won't justify designating the Anthropocene.

post-Holocene epoch. Social scientists have noted that many of the supposed markers of the Anthropocene predate industrialization by centuries or millennia (Ellis *et al.* [2016]). Thus, those markers go back into the Holocene.[4]

(3) Many clear examples of human impact will be seen by the future geologist as local catastrophes rather than geologic events of global reach and long-term impact. As we've seen, epochs are typically defined by long-term global change.

Of course, if there is a small set of significant markers to which none of these three issues applies, then a future geologist will still have grounds to ratify the Anthropocene. To address this, I have canvassed the literature searching for as many recently proposed markers of the Anthropocene as possible. In what follows, I argue that each is susceptible to at least one of (1)–(3). Given that fact, we should hold off on predicting that the Anthropocene will be a distinct epoch from the future geologist's perspective.

2.1 Climate change

Anthropogenic climate change is probably the first thing that comes to mind when most of us think about humanity reshaping the world. The effects of temperature change on the stratal record are indirect, however. For example, global temperature change leads to migrations, extinctions, and adaptations which leave a trace in the fossil record. Global warming is only one component of anthropogenic effect on the fossil record, however, so I'll treat fossils in a separate section. Here, I'll focus on the most geologically significant secondary effect of climate change—its effect on the cryosphere.

[4] Most proposals for the Anthropocene date its beginning somewhere between the beginning of the Industrial Revolution to the mid-twentieth century (Zalasiewicz *et al.* [2008]).

Due to climate change, ice melting and corresponding sea-level rise have been accelerating.[5] From 1990 to 2009 the oceans rose by approximately 3 mm each year (Church and White [2011]). By contrast, over the period of 1880 to 2009 the average rise was only about half that, approximately 1.5 mm per year (ibid). What will this accelerating sea-level rise add up to? Let's take the worst-case scenario. Recent re-evaluations of the contribution of melting Antarctic ice suggest that if we don't drastically cut back on carbon emissions, sea-level increase by the year 2100 will be around double previous estimates: up to 2 meters higher than present (DeConto and Pollard [2016]). According to the same models, Antarctica alone could contribute another 15 meters of sea-level by 2500, if greenhouse emissions follow current trends. Sea-level change of this magnitude, of course, will leave clear markers in the sedimentary record, as will vanishing glaciers. Even on more conservative estimates of sea-level change, the future geologist will see evidence of our effect on the oceans.

Nevertheless, we are not yet justified in predicting that the future geologist will see anthropogenic sea-level rise as epochal. For some perspective, consider the fluctuations of sea-level during the Pleistocene epoch. These are sea-level changes within an epoch, not ones which defined new epochs. The Pleistocene was characterized by repeated cycles of glaciation. Accordingly, during the Pleistocene, sea-level fluctuated in some places by more than 100 meters (Voris [2000]; Sathiamurthy and Voris [2006]). This far outstrips the amount of sea-level change we expect to result from anthropogenic climate change, even in the worst-case scenarios. For this reason, ice melt in the coming centuries would not be, in the words of one expert, 'so qualitatively different from previous events in the Pleistocene' that it would 'necessarily warrant the erection of a geological boundary' (Wolff [2014], p. 257).

[5] Sea-level change results from multiple factors, include hydrological engineering and plate tectonics, among others. But ice melt is presently the primary causal factor.

It may still be, however, that we are in the early stages of a trajectory of warming and sea-level rise that will eventually exceed Pleistocene and Holocene patterns (Waters *et al*. [2016]). Even if we are on such a trajectory, it's not too late to leave it by drastically reducing greenhouse gas emissions or through technological responses such as carbon capture or solar radiation management. Even if we can't restore the climate to its pre-industrial Holocene trajectory, since we may have passed the point of no return on that (Clark *et al*. [2016]), we can still limit the long-term impact of climate change, so that it doesn't reach epochal significance. Models suggest that maintaining moderate to high carbon emissions levels could lead to maximum temperature anomaly of 4–6 °C, which probably would be significant enough to warrant a new epoch. But this is not inevitable. Even given realistic economic constraints, action today could still limit warming to 2 °C (Hubacek *et al*. [2017]), which would not be as significant. Viewed at coarse resolution (the resolution the future geologist will likely rely on), sea-level has been monotonically increasing throughout the Holocene (Lambeck *et al*. [2014]). Anthropogenic effects have accelerated the rise, but it is a continuation of a Holocene-long trend. If we hold warming to 2 °C the future geologist will likely see current sea-level rise not as a break with the past, but as merely a continuation of Holocene trends. It would thus be premature to predict that present climate change would impel the future geologist to declare the Anthropocene an epoch. Come 2500, if the sea level really is tens of meters higher than the present, we can revisit the question, but for now, let's treat that future as something within our power to prevent.

2.2 The fossil record, excluding humans

There are three major anthropogenic effects on the fossil record: increased rates of extinction, the introduction of new organisms, and human-mediated migration. I'll address each in turn.

In the history of life, there have been five major mass extinctions. Many scientists suggest that human activity is causing a sixth. Even on conservative estimates, vertebrate species are going extinct at rates dozens of times higher than the background rate (Ceballos *et al*. [2015]). The fossil record will provide evidence of this to the future geologist. Whether that geologist will see the current extinction event as epoch-defining depends on the success of our conservation efforts. Present extinction rates are high, but the number of species which have gone extinct is far short of the level of the great mass extinctions. The End-Permian Extinction, for instance saw the loss of up to 95% of all species (Benton and Twitchett [2003]), and we are nowhere near that grim tally. Recent estimates suggest that modern extinctions have wiped out around 7% of species (Régnier *et al*. [2015]), and if left unmitigated, climate change could lead to another 15–37% of extant species going extinct (Thomas *et al*. [2004]). This may not quite rise to the level of the great mass extinctions, but mass extinctions defined periods and even eras, not merely epochs. Even so, we have yet to reach the level of epoch-defining extinction events such as the Grande Coupure or Pleistocene/Holocene megafauna extinction yet either (Waters [2014], p. 4). Even those scientists who most loudly prophesy the sixth mass extinction do so not to proclaim the Anthropocene, but to call on us to prevent it: 'Averting a dramatic decay of biodiversity and the subsequent loss of ecosystem services is still possible through intensified conservation efforts, but that window of opportunity is rapidly closing' (Ceballos *et al*. [2015], p. 1; see also Thomas *et al*. [2004]). As long as that window of opportunity remains open, however, conservation efforts by the next few generations of humans could make extinction a poor marker of the Anthropocene (Barnosky [2014]). In other words, whether the future geologist will see present-day extinctions as marking a new epoch will depend on our choices in the coming decades.

In addition to extinctions, we also influence the palaeontological record by introducing new kinds of fossils through artificial selection.[6] Holsteins, Clydesdales, and Valais Blacknoses wouldn't be depositing bones in sediments if humans hadn't bred them. The deformed skulls of pugs are certainly an evolutionary novelty that couldn't exist without ongoing human intervention. But even leaving aside the question of whether domesticated organisms are distinct or widespread enough to mark an epochal change in fossil deposits, their emergence can't mark the Anthropocene because they emerged earlier in the Holocene. Since 'no new species are known to have originated during the past few hundred years' (Barnosky [2014], p. 152), the presence of novel taxa from human activity can't mark the Anthropocene. More promising is the presence of new lineages. Maize in particular is widespread, fossilizes well, and possesses varieties only bred or engineered recently. I see two reasons to be sceptical that the future geologist would use a modern maize variety to mark a new epoch, and these reasons would apply to most other domestic species as well. First, when looking at the fossil record of maize breeding, by far the strongest signals in the palaeontological record are unlikely to be a modern crop variety, but instead the emergence of maize as a food crop several thousand years ago, or the global spread of maize during the Columbian Exchange. Selecting a variety bred around 1950 would be arbitrary by comparison. Second, given current rates of genetic engineering, it is quite likely that the dominant strains of maize today won't be dominant a century or two from now. We are thus not justified in predicting that a currently widespread modern variety of maize (or any other domesticated organism) will be a stratigraphic signal of sufficient depth to be

[6] Genetic engineering, at least to the extent it has presently been done, is likely to be barely distinguishable from domestication from a palaeontological viewpoint, so the same arguments apply.

useful to the future geologist. So, the modifications to the fossil record caused by domestication will almost certainly not be seen by the future palaeontologist as marking a new epoch.

More promising is how human activity has redrawn the biogeographical map. Previous epochs have been in part defined by the way geological changes have allowed species to move to new places, which affects the fossil record. The composition of modern American fauna, for instance, is due to an Oligocene land bridge between Europe and North American, and to the Pliocene formation of the Isthmus of Panama linking the American continents. Modern humans have similarly created new corridors for species migration, and migrations may be occurring at an atypically high rate and across atypically long distances (Mack *et al.* [2000]). Lizards in the Caribbean, for instance, no longer need to drift on a natural raft to get from island to island; they can just hop on a boat. Consequently, Caribbean lizard migration maps nicely onto the flow of human economic activity (Helmus *et al.* [2014]). Such migrations will certainly be visible to the future geologist, but are they significant enough to justify a new epoch? Not yet, and maybe never. Compare, for instance, yesteryear's epochal joining of the Americas by a land bridge to the present-day human-assisted migrations of external species to Australia. In South America, placental mammals replaced most of the marsupials, including all the large marsupials, but in Australia the kangaroos are hopping along quite well.[7] Australian flora has seen a more drastic change, since 'introduced plant species now outnumber the native plant species' (Barnosky [2014], p. 156), but whether this results in the wholesale replacements of taxa will depend on whether we are able to prevent the extinction of large numbers of the native species. So, while human shipping has led to increased migrations, we aren't yet seeing the type of continental-level species replacements that mark other epochs in the fossil record. As with anthropogenic

[7] Too well; see (Howland [2014]).

extinctions and artificial selection, it's too soon to call the Anthropocene based on human-abetted migration.

2.3 The human fossil record

The mere global presence of human body fossils can't define the Anthropocene, since our global presence as a dominant species is typical of the Holocene (Gibbard [2014], p. 32). Our trace fossils,[8] however, are more promising indicators. Fossilized subway tunnels would be of a kind with fossilized worm burrows, and such trace fossils are geochronologically significant because they evince novel animal behaviours (Williams *et al.* [2014]). Roads, buildings, and landfills are among the most likely trace fossils that a future palaeontologist will attend to (Barnosky [2014]). The problem with each of these that they either predate the Anthropocene, aren't of global scale, or both. Subway tunnels, for instance, are not yet widely distributed enough to be epoch-making. This may be true even of buildings, since urban areas cover less than one percent of the unglaciated land area (Waters *et al*. [2014]). Likewise, roads, landfills, and buildings date back to the beginnings of human agriculture—that is, to the beginning of the Holocene—and thus can't mark the beginning of the Anthropocene. Many of these pre-Anthropocene constructions, such as Roman roads and Mesoamerican pyramids, have proved to be enduring, and thus we will have widespread human trace fossils deep into the Holocene. True, modern construction uses materials unknown the ancients, and so will be geologically distinguishable, but the history of innovation means that the future geologist will be able to use human trace fossils to distinguish strata at a fine grain all throughout the Holocene. Further justification is needed for arguing that any particular transition in trace fossil composition should mark a new epoch. And if a near-

[8] A remnant of activity rather than the preservation and replacement of corporeal material.

future revolution in construction ends up looking more significant to the future geologist than anything done to date, pegging the Anthropocene to an extant revolution in construction will have been premature. Finally, many of these trace fossils may not be lasting parts of the record. Increased recycling and wider use of biodegradable materials could prevent many of these human behaviours from leaving much trace. Our potential trace fossils thus do not yet look like the sort of thing that would lead a future palaeontologist to declare a new epochal boundary.

2.4 Direct anthropogenic deposits

Mine tailings, land reclamation, landscaping, backfilling, and so on could all create sedimentary layers on their own, and these are novel geologic processes, which might warrant the future geologist considering the Anthropocene a distinct epoch. By now, my response should be easily anticipated. First, these processes go back at least throughout the Holocene; archeologists have studied them for decades, and call the result artificial ground (Edgeworth [2014]). Moreover, they tend to be local, not global processes. Most artificial ground will not be preserved in the geological record (Ford *et al*. [2014]; Waters *et al.* [2014]), in part because anthropogenic deposits are thinner and less continuous than natural sedimentation. To account for direct anthropogenic deposits at all, stratigraphers would have to redefine stratigraphic methods and definitions (Ford *et al*. [2014]). In other words, the future geologist, if working according to present methods, would not treat mine tailings and so forth as reason to identify an Anthropocene.

2.5 Chemical markers

Some geochemists have proposed that 'The human induced mobilization of trace elements on a global scale' could be a significant long-term marker of the Anthropocene (Gałuszka *et al*. [2014], p. 233). Leading candidates include iron oxides and lead from fuel combustion (Gałuszka *et al*. [2014]; Snowball *et al.* [2014]), radioactivity from nuclear fallout (Hancock *et al*. [2014]; Zalasiewicz *et al*. [2014]; Lewis and Maslin [2015]; Waters *et al*. [2015]), and nitrogen from fertilizers. As trace elements, nitrogen and other nutrients don't leave as clear a signature as metals (Rauch [2012]), but metals will not necessarily be notable to the future geologist for two reasons. First, many are likely to be recycled, given their economic value (Rauch [2012]). Second, others, like the iron oxides and lead, might be inconsequential blips in the geological record. Anthropogenic lead dispersal has already sharply dropped off since the introduction of unleaded gasoline (Gałuszka *et al*. [2014], p. 233), and iron oxides will follow as we shift to alternative fuel sources altogether (Waters *et al*. [2014]). That leaves radioactive fallout.

More specifically, it leaves plutonium in the form of ^{239}Pu and ^{240}Pu, which unlike most components of fallout have long enough half-lives to be visible to the future geologist (Hancock [2014]). Nuclear detonations occurred between the years 1945 and 1980, and distributed plutonium globally, ensuring that it could be a global marker. 1945 would also mark a plausible start date for the Anthropocene, given the post-World War II acceleration in industrialization. Additionally, the use of plutonium as the mark of the Anthropocene resonates with a paradigmatic geological boundary as well: the iridium content used to mark the K–Pg boundary. For all these reasons, the use of plutonium fallout to demarcate the Anthropocene has become a common proposal (Hancock *et al*. [2014]; Zalasiewicz *et al*. [2014]; Lewis and Maslin [2015]; Waters *et al.* [2015]).

I grant that plutonium will be an excellent candidate marker for the future geologist. The deposition of trace plutonium, however, does not in itself warrant designating a new epoch so soon after the beginning of the last epoch. Nuclear activity hasn't yet caused radical global change, and hopefully never does. Trace plutonium is at best then a convenient marker which the future geologist could correlate with more significant events, such as mass extinction or climate change. Consequently, the support it provides for ratifying the Anthropocene depends on other human activities, and if my arguments in the surrounding subsections are sound, those don't yet warrant ratification either.[9]

2.6 Hydrology

We began our examination of potential geological markers of the Anthropocene with a discussion of ice, and we'll end with water, specifically the effect humans have had on the water cycle independent of climate change. The hydrologic cycle is one of the most important biogeochemical cycles, geologically speaking, given its involvement in erosion, sedimentation, and chemical weathering. According to many scholars, however, the old hydrologic cycle is outdated. We now participate in the 'hydrosocial cycle' (Linton [2008]), where the movement of water is part of a feedback loop with the physical and political movement of people. We dam rivers, drain groundwater, and chop down the trees which stabilize river catchments. All this will affect the rock formations that the future geologist will study.

[9] Similar to these sorts of chemical markers, there has been an increase in the number of mineral species in recent years, even using the International Mineralogical Association's strict definition of mineral (Nickel and Grice [1998]). This increase is an indirect effect of human activity, and may resemble prior transitions in mineral evolution (Hazen *et al.* [2008]). So far there are ninety-one recognized new mineral species of this sort (Hazen *et al*. [2017]), but they are typically evanescent and not widely distributed (Cross [2017]) and so do not represent a epochally significant geological event. Both as markers and as indicators of significant global change, the chemical markers discussed in the preceding section are better candidates than these interesting, but relatively insignificant, new minerals.

This is one of the toughest cases for my argument. Unlike with climate change or mass extinction, it is utterly unlikely that we will mitigate or reverse the changes we've made to the water cycle. Yes, sometimes we put the winding curves back into rivers that our grandparents straightened (for example, Follstad Shah *et al*. [2007]; Wohl *et al*. [2015]), and our dams are often removed—or fail—after enough time. But canals, reservoirs, dykes, and so forth are going to be part of the water cycle for the foreseeable future. Nor can I convincingly argue that the hydrosocial cycle isn't of global reach.

What I can argue is that global anthropogenic influence on the water cycle predates the proposed Anthropocene. It clearly does. Large-scale irrigation in China, Mesopotamia, Egypt, Persia, South Asia, and Mesoamerica go back at least two millennia, and up to eight millennia. The history of tapping groundwater goes back around as long, and dams had been built in most of these areas by the first century BCE. Beginning in the eleventh century CE, rulers in central and southern India constructed tens of thousands of artificial reservoirs (Oppen and Subba Rao [1987]). At the same time, monks in the Netherlands built dykes that would claim more and more land from the sea. I could adduce more examples, but the point is clear. The hydrosocial cycle predates the Industrial Revolution. It predates the Scientific Revolution. It has a history going back more than halfway through the Holocene. The future geologist will look back on the human impact on the water cycle and see it as geologically significant. But they will see it as part of the Holocene, not the Anthropocene.

2.7 Summing up

At this point in history, we can't confidently predict that a future geologist would look back on humanity's geological influence and see anything that would justify differentiating an

Anthropocene epoch from the Holocene. Some of our activity lacks the impact of other epoch-defining processes. Other activity is more significant, but continues trends of the Holocene rather than breaking with them. The potentially most significant human geological effects, however, aren't inevitable. Mass extinction, nuclear winter, and geologically unprecedented global warming are all real possibilities, but it is still within our power to prevent them. From the future geologist's perspective, therefore, we are not yet justified in ratifying the Anthropocene.

Each of the three kinds of arguments I make against potential markers of the Anthropocene is open to an obvious objection. Here are my responses:

(1) I have argued that many of our impacts on the planet could be mitigated by better environmental stewardship. The future geologist, however, might still be able to see the industrial era as an inflection point in the earth's history, one where geological processes such as sea-level rise and species extinctions occurred at accelerating rates, even if those rates later declined due to conservation. I grant this, but even so, the future geologist won't see such inflection points as marking a new epoch unless their impact is long term. All sorts of events cause temporary inflection points in geologic processes—a major volcanic eruption can cause temporary global cooling, for instance—but only an enduring effect warrants a new stratigraphic division.

(2) Given how much of human influence on geology dates back thousands of years, why not, instead of proposing a new epoch, just rename the Holocene the 'Anthropocene'? Two reasons. First, doing so would obscure the fact that the major geological shift at the Pleistocene–Holocene boundary was non-anthropogenic climate change. Second, humanity's potentially most significant geological effects don't emerge during the early Holocene. Said threats include mass extinction, massive global warming, and

nuclear apocalypse, all of which only really become possibilities close to the present day, and won't be realized, if at all, until the future.

(3) Many of our impacts are too local to be epoch-defining, but could it be the case that the sum of all these small impacts adds up to one epochal event? No, so long as the concept 'epoch' continues to belong to chronostratigraphy. The requirement that a marker have global reach plays the ineliminable stratigraphic role of correlating the strata that belong to the same unit worldwide. Local stratigraphic events can merit naming a local formation, but these local formations do not have corresponding divisions in geochronology.

3 The Synchronic Perspective

What if the future geologist's perspective is a luxury we can't afford? Perhaps ratifying the Anthropocene could play an important role as a signal from scientific authorities that our world is undergoing a crisis of our own making. Such a signal could help motivate the kind of political action necessary to ensure that there are future geologists to study the Earth, and an Earth for them to study. As an editorial in *Nature* argues, 'Official recognition of the concept' Anthropocene 'would encourage a mindset that will be important not only to fully understand the transformation now occurring but to take action to control it' (The Human Epoch [2011]). Given these pressing concerns, perhaps the real questions surrounding the Anthropocene are first, whether the world is in that state of anthropogenic crisis, and second, if formal designation of the Anthropocene can help us face the crisis.[10] To the first question, I agree with my interlocutors

[10] I'm not imputing political motives to every proponent of the Anthropocene, many of whom explicitly deny anything more than stratigraphic motives (Zalasiewicz *et al*. [2017]). The synchronic perspective is worth considering, however, if at least some proponents have political motivations (some do) and if the political argument is compelling (it can be).

that the answer is clearly, 'Yes, we face an environmental crisis of our own making'. I depart from my interlocutors by denying that scientific recognition of the Anthropocene would help.

Let's clear some brush. You might think that there are two kinds of reasons for formal adoption of the Anthropocene: scientific and political reasons. You might then worry that if the scientific reasons (the future geologist's perspective) don't support ratification, but we do it for political reasons anyway, that we've done something scientifically improper. Many scientists have expressed just this sort of worry, in papers titled things such as 'The "Anthropocene" Epoch: Scientific Decision or Political Statement?' (Finney and Edwards [2016]), and 'Is the Anthropocene an Issue of Stratigraphy or Pop Culture?' (Autin and Holbrook [2012]). 'When we explain the fundamental difference of the Anthropocene from the chronostratigraphic units established by the International Commission on Stratigraphy to proponents for its recognition', Finney and Edwards complain, 'they often reply that the human impact on the Earth system must be officially recognized, if for no other reason than to make the public and governmental agencies aware of that impact' ([2016], p. 9). This suggests that both sides of the Anthropocene debate understand that the motivation for designating the new epoch can be as much about politics as it is about geology. If this is the case, however, then perhaps 'formalizing the Anthropocene is a misguided attempt to "scientize" a particular set of value judgements' (Castree [2017]).

Thinking that scientizing value judgements is wrong requires us to accept a premise distinguishing the epistemic and the political. But a strong version of any such distinction is untenable. Even a mere statement of fact can be highly political ('Vaccines don't cause autism', for example). Among other ways in which values can carry epistemic weight, philosophers of science have argued that: we have political reason to avoid pursuing certain scientific questions

(Kitcher [2003], Chapter 8); that values are just a kind of fact, and thus carry epistemic weight (Clough [2015]); that scientists should consider the political implications of their research (Roberts [2009]); and that non-epistemic values are essential to scientific reasoning when the scientific outcome will have broad impact (Douglas [2000]). These philosophers' convincing arguments suggest that we are sometimes justified in including political motivations among our reasons to adopt a scientific position. Since the environmental crisis is the most significant political situation humanity has ever faced, we can't tackle relevant scientific questions without considering the political dimensions.

With that brush-clearing out of the way, let's consider the political dimensions of the Anthropocene. The purported political benefit of the Anthropocene is that its designation will convince the public and policy-makers that humans are having significant effect on the environment. I deny this.

Suppose that the SQS, ICS, and IUGS all vote in favour of defining the present epoch as the Anthropocene. Should we expect a shift in public opinion about our relationship to the environment? No. I opened this paper by observing that the scale of human geological agency is largely undeniable. Who, then, are the holdouts that we aim to convince by ratifying the Anthropocene? There are the young Earth creationists, but they can't be our target, since they already reject everything that geologists tell them. The real targets, of course, are the climate sceptics. Climate sceptics generally don't deny all human geological agency. They know as well as the rest of us that humans literally move mountains. Their scepticism is focused on anthropogenic climate change specifically. Fortunately, we have a growing body of science explaining what makes people climate change sceptics. Unfortunately, a look at that literature casts serious doubts on the claim that we would change their minds by ratifying the Anthropocene.

For one thing, we know that climate sceptics are immune to presentations of scientific consensus. Studies produce a consistent figure of 97% support for the thesis of anthropogenic climate change among experts (Cook *et al*. [2016]), and climate advocates are not quiet about this fact. Nevertheless, 51% of Americans either deny climate change, or deny that it is the result of human activity (Funk and Kennedy [unpublished]). In other words, the most relevant set of scientists—climate scientists—exhibit a strong, widely publicized consensus that we're causing global warming, but the sceptics are unmoved. Why would we think that a less relevant set of scientists—stratigraphers—with a less strong consensus would fare any better if they publicly declared that humans are affecting the climate (among other things)?

For another thing, some research indicates that beliefs on politicized scientific issues like climate change reflect social identity and not scientific knowledge. In experiments by Kahan ([2015]), conservatives with more education and better scientific literacy were less likely to accept anthropogenic climate change than less-educated conservatives. The depressing implication of this research is that we are already polarized according to our political affiliations, religions, and other markers of social identity, and that the presentation of scientific information only increases that polarization.[11] To the extent that this is the case, we shouldn't expect the designation of the Anthropocene to change sceptics' minds, and it may just polarize their beliefs further. This is especially likely given the lack of a stratigraphic justification for the Anthropocene. Designation of the Anthropocene without publicly acceptable stratigraphic

[11] While surprising at first glance, Kahan's results cohere with decades of evidence from social psychology that people are subject to belief polarization: when two people who disagree are presented with the same piece of evidence, each strengthens their existing belief (Lord *et al*. [1979]; Baron [2008]).

support could feed into climate denialists' paranoia that the science they disagree with is driven by a liberal political agenda, and thus lead them to reject the science of global change even more vigorously.

Some research on the communication of climate change facts is more optimistic. Ranney and Clark ([2016]) found that instruction on the mechanisms of climate change did change the attitudes of subjects across the political spectrum. The attitude change was modest, but on something as important as climate change, even a modest improvement is worth celebrating. Although Ranney and Clark's results give us some reason to hope that educating the public might have a positive political effect, the type of education that they found successful involved much more than merely slapping a label on something, which is what designating the Anthropocene would be. Their explanation of their success in changing minds is that '*Mechanistic* knowledge [...] is critical' because it can 'break ties' for subjects sitting on the fence ([2016], p. 51). To change minds, they needed to present detailed, mechanistic facts of climate change, facts that according to preliminary experiment, zero percent of subjects fully understood, even subjects who already accepted climate change ([2016], p. 54). Note how different this type of science communication is from merely declaring the Anthropocene. Telling the public that we are in the Anthropocene conveys no detailed, mechanistic facts about how humans affect the planet. Furthermore, we can communicate those mechanistic facts whether we ratify the Anthropocene or not. In short, even the research that suggests that science can change minds tells us that actions like formalizing the Anthropocene are not the way to do it.

We thus have sufficient reason to think that adopting the Anthropocene as a political tactic is unlikely to change perspectives on the environmental crisis,[12] and may even make things worse. It might have a more subtly detrimental political outcome as well. Whether or not it is an epoch, the 'Anthropocene' is certainly a buzzword, and buzzwords play into the politics of science by influencing who gets research funding. 'Perhaps one of the more relevant issues we in the scientific community have with terms like Anthropocene is a tendency to market catch phrases that produce questionable labels', worry Autin and Holbrook, since 'scientists face pressure to develop and sustain a credibility' that may force them adopt those labels to receive funding and venues for publication ([2012], p. 61). The Anthropocene, due to its broad appeal beyond the earth sciences, risks becoming a black hole that sucks in and distorts research, and official recognition of the epoch would only make this worse. One harmful possibility is that it would tilt the balance of support away from Holocene studies towards Anthropocene studies. Since most kinds of drastic human–environment interaction have their roots deep in the Holocene, understanding our relationship to nature requires substantial support for Holocene studies. Work on the Anthropocene already has the advantages of novelty and buzzword status over Holocene studies. Official recognition of the Anthropocene would only exacerbate the imbalance, and thus, in an ironic inversion of Anthropocene proponents' goals, could undermine our ability to use the methods of earth science to better understand our relationship to nature.

[12] A reviewer points out that my arguments don't address a distinct political aim of officially recognizing the Anthropocene: shoring up the beliefs of those who aren't sceptical of human impact on the environment. I'm not sure what the effect of official designation would be on those already in the non-sceptical camp, but shoring up their beliefs is a less pressing concern, and could be done by alternative means which don't run the risk of further polarizing the doubters. The political resistance to addressing the environmental crisis depends more on doubters than wavering non-sceptics, hence my focus on the sceptics.

4 The Anthropocene Is Not Yet Set in Stone

In a literal sense, the Anthropocene is not yet set in stone. What the strata that future geologists will study to understand our day will look like depends on how seriously we take our role as environmental stewards in the coming years.

In a figurative sense, the Anthropocene is not yet set in stone. It has not yet been officially recognized by the relevant scientific bodies, and such recognition wouldn't carry the rhetorical weight we might wish it would. In fact, treating the Anthropocene as if it were figuratively set in stone makes it appear inevitable, and thus not worth the effort to try to prevent. But if we wait against the Anthropocene, and treat it as a yet-to-be-realized possibility, we retain the motivation to fight climate change, mass extinction, and other possible markers of an Anthropocene.

Environmental scholars outside the sciences may be suspicious of my thesis, given its opposition to an emerging orthodoxy within the environmental humanities. I ask these readers to examine the extent to which the push for the Anthropocene concept is rooted in factors antithetical to their commitments. We're hardly the first set of organisms to be globally significant geological agents on such a massive level, but many of our fellow living geological forces haven't merited their own epoch. In this context the push for the Anthropocene is revealed as anthropocentric hubris (Finney [2014]; Finney and Edwards [2016]). Moreover, agitation for designating the Anthropocene is centreed in the industrialized world, and the cause does not resonate so well with the concerns of the Global South (Gibbard and Walker [2014]; Giannuzzi [2016]; Henry [unpublished]). Perhaps recognizing the anthropo- and Western-centricity of the Anthropocene makes it a concept that we should not only hold off on formally adopting, but also be wary of employing informally.

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