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The Anthropocene as rupture

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Abstract

I argue that Earth System science – a recent paradigm shift in the earth and life sciences (Hamilton C and Grinevald J (2015) Was the Anthropocene anticipated? *The Anthropocene Review* 2(1): 59–72) – named the Anthropocene as the very recent rupture in Earth history arising from the impact of human activity on the Earth System as a whole. Many have mistakenly treated the new concept of the Earth System as if it were equivalent to 'the landscape', 'ecosystems' or 'the environment'. The new paradigm of Earth System science is erroneously understood as no more than a variation or development of established ecological sciences. Various attempts to invent new starting dates for the new epoch are based on these misconceptions, as are a number of arguments deployed to reject the Anthropocene altogether. In this context I consider the early Anthropocene hypothesis, three readings of the Anthropocene as instances of ecosystem change, and the notion of the 'good Anthropocene'. Using this frame I also assess the arguments of those who do not accept the idea of the new epoch. I defend the view that disciplines other than Earth System science distort the idea of the Anthropocene when they read it through their own lenses.

Keywords

Anthropocene, Earth System, ecosystems, paradigm shift

The debate over the Anthropocene – what it is, when it started and what it means – is blossoming, as befits an idea that is monumental in its importance. Yet it is bedevilled by misunderstandings that go to the heart of this very original scientific concept. Some of those who weigh in to the debate, including in prestigious journals, begin from a vital misconception. I will explain why this is so, but my essential point is that the Anthropocene concept cannot legitimately be separated from Earth System science and that Earth System science represents a recent paradigm shift in the earth and life sciences (Hamilton and Grinevald, 2015). It replaces our current scientific conception of the Earth as a whole and supersedes traditional geographical, geological and ecological thinking (and all compartmentalised scientific disciplines). I will argue that many ecologists,

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archaeologists, geographers, geologists, environmental historians and social scientists have yet to recognise that a 'scientific revolution' has occurred and, as a result, misinterpret the Anthropocene in a way that deprives it of its profound significance.

The making of Earth System science

Thomas Kuhn's language of 'paradigm shift' and 'scientific revolution' (Kuhn, 1962) has often been applied too freely, yet it seems to be justified in the case of Earth System science. If a paradigm is a distinct set of assumptions and patterns of thought then there can be no doubt that Earth System science represents a markedly new way of thinking about the Earth. More correctly, Earth System science is the name for systematic thinking about a perceived new object, the Earth System.

Ecological thinking, which emerged in the early 20th century and surged in the 1960s and 1970s, is the biological science of the relationship within communities of organisms and between them and their local environments, whereas Earth System thinking, which emerged in the 1990s, is the integrative meta-science of the whole planet as a unified, complex, evolving system beyond the sum of its parts. It is a transdisciplinary and holistic approach integrating earth sciences and life sciences, as well as the 'industrial metabolism' of humankind, all within a systems way of thinking, with special focus on the non-linear dynamics of a system.[1] While ecological thinking may or may not draw on systems concepts, Earth System science could not exist without systems thinking.[2] The gulf between the two remains even when the local environments of ecological thinking are aggregated up to the 'global environment'; the global environment thought this way is not the Earth System.

The idea of the Anthropocene was conceived by Earth System scientists to capture the *very recent rupture* in Earth history arising from the impact of human activity on the Earth System as a whole. The evidence shows that the rupture in Earth history may have occurred as recently as 1945 but certainly no earlier than the late 18th century. Its origins are explained briefly in a recent paper by Jacques Grinevald and myself in which we identify certain milestones in the development of the new paradigm of Earth System science (Hamilton and Grinevald, 2015). They included: the application in the 1970s of systems modelling to Earth's resources by the Club of Rome, following Jay Forrester's world system dynamics; James Lovelock's Gaia hypothesis first advanced (after three papers with Lynn Margulis) in 1979 with the publication of *Gaia: A New Look at Life on Earth* (Lovelock, 1979); early biophysical modelling of the Earth's biosphere in the 1980s (after Vernadsky's long-ignored work); the startling results of Antarctic ice-core drilling in the same decade; the formation of the International Geosphere-Biosphere Programme (IGBP) in 1983–1986; and, early work on global climate change leading to the 1985 Villach Conference and the formation in 1988 of the Intergovernmental Panel on Climate Change (IPCC).

The concept of the Earth System encompassed and transcended previous objects of study such as 'the landscape', 'ecosystems' and 'the environment'; it is the Earth taken as a whole in a constant state of movement driven by interconnected cycles and forces, from the planet's core to the atmosphere and out to the moon, and powered by the flow of energy from the Sun. It is a single, dynamic, integrated system, and not a collection of ecosystems. As I will argue, the elision of the Earth System with these earlier objects of study is at the centre of most of the confusion over the Anthropocene.

James Lovelock's notion of the Earth functioning like a living organism, with its own atmospheric circulation and homoeostatic physiological systems (Lovelock, 2006: 19), has met with a variety of criticisms, but the underlying conception of the Earth as a dynamic, unified, functioning totality has been accepted by the Earth System science community, although the idea of a 'self-healing' Gaia deploying negative feedbacks to correct disturbances has been heavily criticised, not

least by Paul Crutzen (2004). Tyrrell (2013) shows that since Lovelock put his idea into the world some 30 years ago our understanding of the Earth System has changed dramatically. As Earth scientists have found means of taking a more fine-grained view of Earth history, especially through the analysis of ice-cores, the geological trajectory of the Earth appears much more wild and unpredictable. There is no built-in stabiliser; life does not bring the planet back into equilibrium (Tyrrell, 2013: 168–169). And the idea that the Earth self-regulates is contrary to the observed fact that the Anthropocene represents a rupture in the evolution of the Earth System.

The distinctiveness of Earth System science as a paradigm-shifting meta-science is becoming apparent only now with the debate over the Anthropocene. In particular, various attempts to invent new starting dates for the new epoch are showing up the gulf between Earth System science and traditional geographical, geological and ecological thinking, which is shown to be inadequate when applied to the Earth System as a whole.

Grasping the idea of the Earth System – emphasising the coevolution of the geosphere and the biosphere, and now the techno-anthroposphere – requires a kind of *gestalt* shift, one big 'Aha' moment or usually several smaller ones. Without it the Earth is understood as the aggregation of ecosystems more or less modified by humans. In the absence of such a *gestalt* shift it is possible to read the idea of the Anthropocene into older forms of disciplinary thinking in the geological, archaeological, palaeo-anthropological, palaeo-ecological or human geographical traditions.

And so, soon after the concept was proposed in the year 2000, a number of scientists and social scientists began to put forward interpretations of the Anthropocene that, mostly unwittingly, *deflate* the significance of the new epoch and the threat it poses to humankind and the Earth. Most of the deflationary moves have appeared in the scientific literature and popular science magazines as proposals for differing starting dates for the new epoch. As I will argue, these are based on misreadings of the concept, although one move has been an explicit attempt to reframe it in a positive light. Let me now outline these moves and why they are misreadings of the Anthropocene concept as developed by Earth System scientists.

The 'early Anthropocene' hypothesis

Soon after Paul Crutzen's first short commentaries on the new epoch (Crutzen, 2002; Crutzen and Stoermer, 2000), palaeoclimatologist William Ruddiman published a paper arguing that the Holocene–Anthropocene shift occurred not at the end of the 18th century with the Industrial Revolution but 5000–8000 years ago with the onset of forest clearing and farming, which led to enhanced levels of CO_2 and CH_4 in the atmosphere (Ruddiman, 2003). Ruddiman understood that he needed to show a change in the state of the climate system, which in hindsight was to his considerable credit, as others have misunderstood this fundamental point about the new epoch.

However, Ruddiman's interpretation of the data turns out to be unpersuasive (Ruddiman, 2003). Crutzen and Steffen (2003) immediately defended the claim that the Anthropocene properly began in the late 18th century by showing that human impact on the Earth System 5000 to 8000 years ago is not discernible, and certainly was not large enough to upset permanently the stability of the Holocene Earth. The data do show an unambiguous shift occurred in the late 18th century, the beginning of the Industrial Revolution. And the charts also show an incontrovertible leap after the Second World War.

> The mid-twentieth century was a pivotal point of change in the relationship between humans and their life support system… The period of the Anthropocene since 1950 stands out as the one in which human activities rapidly changed from merely *influencing* the global environment *in some ways* to *dominating it in many ways*. (Crutzen and Steffen, 2003: 253)

A number of other analyses have rejected the evidence for Ruddiman's early Anthropocene hypothesis, leading the IPCC to conclude in its Fifth Assessment Report that it is not clear that the small and very slow changes in CO_2 and CH_4 from around 8000 years ago were due to human activity, let alone were sufficient to change the course of the Earth System (Ciais et al., 2013: 483–485, figure 6.6).

Ruddiman's interests were scientific but the dispute has wider implications. One is that if humans have been a planetary force since civilisation emerged then industrialism and the extensive burning of fossil fuels did not represent anything fundamentally new in the human project.[3] If humans have been transforming the Earth for many thousands of years then it is in our nature to do so. The Anthropocene is therefore a natural event rather than the result of certain forms of social organisation and techno-industrial hubris. It does not reflect human failure, despite its dire consequences.

The Anthropocene as ecosystem change

A number of analysts have interpreted the Anthropocene as no more than the continuation of human impacts on the landscape or ecosystems, and so not as a rupture in the functioning of the Earth System. This has been taken to its furthest point by Ellis who claims that humans

> have been reshaping the terrestrial biosphere, and perhaps even the global climate, for millennia. The entire past 11,000 years of the Holocene might simply be renamed the Anthropocene. (Ellis, 2013: 32)

So nothing new has occurred. There is no Anthropocene; it is just another name for the Holocene. How is such a conclusion possible? The words to notice in the quoted passage are 'the terrestrial biosphere', human changes to which are enough, in Ellis's view, to define a new geological epoch.

In the first instance we should note that the exclusion of the oceans means Ellis cannot be thinking of the Earth System. Confusingly, Ellis also appeals to Ruddiman's (2003) arguments about land-use change and greenhouse gas emissions, claiming that early farming and forest clearing play 'the central role' in bringing about the Anthropocene (Ellis, 2013: 32). He makes this argument to defend his view that humans are not a destructive force but have always been 'sustained and permanent stewards of the biosphere'.

Such a misinterpretation of the Anthropocene arises from a misunderstanding of Earth System science. For Ellis, Earth System science equals traditional ecological science with the addition of what he calls the science of 'human systems' (Ellis, 2009). He believes he can take earlier work on biomes and anthromes – where anthromes are global ecological patterns influenced by human activity – and scale them up to get to the Earth System. In a more recent paper he ignores Ruddiman's argument that humans began to change Earth's climate 7000–8000 years ago and defines an Anthropocene without any appeal to climate change (Ellis, 2015b). Elsewhere, Ellis makes a list of human impacts – covering domestication of animals, genetic modifications, combustion of fossil carbon, changes to the nitrogen cycle, artificial lighting, soil tillage, nuclear power, earthworks and transport of materials – all of which 'taken together' are 'shifting the planet into a new epoch of geologic time; the Anthropocene' (Ellis, 2015b). As we will see, the identification of the Anthropocene with evidence of human impact on landforms is the basic misunderstanding that has dogged the debate.

More recently, Ellis has teamed up with Ruddiman and two others to complain that the recent choice by members of the Anthropocene Working Group of 1945 as an unambiguous starting date for the Anthropocene (Zalasiewicz et al., 2015a) ignores landscape changes going back

thousands of years (Ruddiman et al., 2015).[4] They ask: 'Does it really make sense to define the start of a human-dominated era millennia after most forests in arable regions had been cut for agriculture …?' The answer is 'yes', if those human activities did not change the functioning of the Earth System.

Any fair reading of the papers by Paul Crutzen and Will Steffen (e.g. Crutzen, 2002; Crutzen and Steffen, 2003; Steffen et al., 2007, 2015b) shows Ellis's approach to the Anthroposphere to be entirely misplaced. Crutzen, Steffen and others have always written of the new epoch *in contrast to* the Holocene as a geological epoch, never in terms of landscapes or ecosystems modified in the Holocene. None of the leading exponents of Earth System science believes that changes in the terrestrial biosphere alone can bring about a new epoch, and even less so if we are thinking of vegetation and landscape ecology. For example, after considering differing conceptions of the biosphere, Lenton and Williams (2013: 382) conclude that 'the terrestrial biosphere, in isolation, is not the right place to be looking for a planetary-scale tipping point; one must consider the coupled dynamics of the Earth system as a whole, including evolution'.[5] This brings home the unique importance, and difficulty, of the task set for the Anthropocene Working Group (AWG). The vast majority of chronostratigraphical units are defined using biostratigraphical change in a Global Boundary Stratotype Section and Point (GSSP) defined in marine successions (as in Zalasiewicz et al., 2015a) so that changes in the terrestrial biosphere would appear an unsuitable proxy in that context. Moreover, it could be argued that selection of GSSPs using biostratigraphical change has in many cases fixated on fairly insignificant evolutionary changes at the cost of the bigger picture of where the fundamental changes in the succession occur. The AWG is attempting first to identify where these major multi-spheric changes occur and only then attempting to select a single marker to define the GSSP.[6]

In fact, if we look at how the global models have evolved both in their structure and their results, it seems that changes in the landscape and biota play a quite minor role in anthropogenic climate change. Since 1850, carbon fluxes in terrestrial ecosystems have been dwarfed by carbon fluxes in the atmosphere (Hamilton, 2013: table 1, 23). Moreover, the oceans store vastly more carbon than both the atmosphere and all biomass on the land, and they store much more heat than the atmosphere.

But even if we set these facts aside, Ellis's reading of Earth System science into landscape ecology, and his reading of shifts in the functioning of the Earth System into changes in the landscape, are seriously misleading. When he writes: 'The first step in embracing the Anthropocene is to grasp that there is nothing new about human alteration of Earth's ecology' (Ellis, 2015a), this is inconsistent with the essential novelty of Earth System science.

Ellis's 'drastically restricted vision', to borrow an apposite phrase from Thomas Kuhn (1962: 24), is shared by other sciences. A view from archaeology on the starting date controversy also begins with a pre-Earth System science understanding. In a paper titled 'The onset of the Anthropocene', published in the journal *Anthropocene*, the abstract begins:

> A number of different starting dates for the Anthropocene epoch have been proposed, reflecting different disciplinary perspectives and criteria regarding when human societies first began to play a significant role in shaping the earth's ecosystems. (Smith and Zeder, 2013: 8)

One need not read past this sentence to know that the authors have misconstrued the new epoch, and that their conclusions about the onset of the new epoch must be mistaken. It is the very last letter, the 's' in ecosystems, that gives it away. The Anthropocene does not begin when humans first play 'a significant role in shaping the earth's ecosystems'; it begins when humans first play

a significant role in shaping the *Earth*, that is, the Earth that evolves as a totality, as a unified, complex system comprised of the tightly linked atmosphere, hydrosphere, biosphere and geosphere. It is not about changes to ecosystems except insofar as ecosystems are affected by changes in the functioning of the Earth System.

The archaeological view is expressed as follows: 'the beginning of the Anthropocene can be usefully defined in terms of when evidence of significant human capacity for ecosystem engineering or niche construction behaviors first appear in the archaeological record on a global scale' (Smith and Zeder, 2013). These behaviours are traced to the domestication of plants and animals beginning 10,000 years ago. Using the same archaeological lens, Braje and Erlandson (2013) see the Anthropocene as no more than a part of a 'single complex continuum' over 50,000 years due to 'human geographic expansion'.

If through an archaeological lens some see an Anthropocene in domestication of plants and animals, and through a landscape ecology lens some see an Anthropocene in evidence of landscape change, both diminish the significance *and changed nature* of the human impact on the Earth System that the Anthropocene concept captures. These visions are inclined to lull the reader into the belief that the Anthropocene is no more than an interesting new way of expressing the traditional understanding of the human relationship to the natural environment. Yet, as Jacques Grinevald and I have shown, the Anthropocene concept would not have been possible without the emergence of Earth System science in the 1980s and 1990s as a way of understanding the novel role of humankind in the Earth System as distinct from the understanding embedded in environmental science (Hamilton and Grinevald, 2015).

It is also possible to misread the nature and significance of the Anthropocene by viewing it through the lens of geography. Reprising the 'pre-Columbian Anthropocene hypothesis' of Dull et al. (2010), one view locates the start of the new epoch in 1610 based on a complex narrative covering the colonisation of South America, introduced diseases, depopulation, forest regrowth, trans-continental trade, species exchange and pollen counts, all of which are said to be associated with a small dip in the atmospheric concentration of CO_2 in that year (Lewis and Maslin, 2015). However, the analysis failed to show numerically that the dip in CO_2 changed the functioning of the Earth System or was caused by human activity (Hamilton, 2015), and a number of Earth System scientists pointed out that in the pre-industrial Holocene there were many comparable dips in atmospheric CO_2 concentration and that a change of 10 ppm is well within the range of natural variability in the Holocene (Zalasiewicz et al., 2015b).

Finally, pedologists have entered the debate arguing that evidence of anthropogenic modification of soils going back 2000 years defines the start of the Anthropocene (Certini and Scalenghe, 2011). Yet this argument too is based in a total misconception of the definition of the proposed new epoch: 'The Anthropocene is, by definition, the period when human activity acts as a major driving factor, if not the dominant process, in modifying the landscape and the environment' (Certini and Scalenghe, 2011: 1272). The soils argument has been taken apart by Gale and Hoare (2012); yet they reproduce its essential flaw when they interpret the Anthropocene as the initiation of 'significant human environmental impact … on the Earth's surface' and allow in data sources such as 'tree rings, landscape art and documentary records' as means of identifying its starting date.

That so many published scientists can misconstrue the basic definition of the Anthropocene as no more than the 'human footprint' on the landscape is a sign of how far Earth System science has to go in changing the way scientists think about the Earth.

A common feature of these misreadings of the Anthropocene through lenses other than that of Earth System science is that, by treating the new epoch as a continuation of landscape or ecosystem change going back centuries or millennia, they divorce it from modern industrialisation and the

burning of fossil fuels. In this way they deny that the Anthropocene represents a rupture in Earth history, and deprive it of its dangerous quality.

An interesting attempt to bridge the gap between Earth System science and other disciplines has been put forward in the form of the concept of the 'Palaeoanthropocene', 'the period from the beginning of human effects on the environment to the beginning of the Anthropocene' from around 1780 (Foley et al., 2013). The beginning of the Palaeoanthropocene would then be diffuse (including all of the Holocene and much of the Pleistocene), associated with local rather than global events and not be linked to geological boundaries or changes in the functioning of the Earth System. All of the erroneous concepts of the Anthropocene discussed above would fall into this pre-Anthropocene zone, with the Anthropocene reserved for describing the era of disruption in Earth System processes. It is an appealing compromise, although it does leave us wondering why the language of stratigraphy ('-cene') is used to name a period that has no geological underpinning.

The 'good Anthropocene'

Perhaps the most perverse reading of Crutzen's conceptual innovation is by those who reframe it as an epoch to welcome and look forward to. This assertively optimistic view has most recently been laid out in a document penned by the idea's leading advocates and titled *An Ecomodernist Manifesto*: 'A good Anthropocene demands that humans use their growing social, economic, and technological powers to make life better for people, stabilize the climate, and protect the natural world' (Breakthrough Institute, 2015). It goes so far as to foresee 'a great Anthropocene' unfolding this century.

The 'ecomodernists' welcome the new epoch as a sign of man's ability to transform and control.[7] They see it not as evidence of techno-industrialism's essential disregard for environmental impacts, nor of humankind's short-sightedness or greed; instead, it is an opportunity for modern humans to prove their ingenuity. The phrase 'good Anthropocene' was coined by Ellis in 2011. He urged us to see the 'age of humans' not as a crisis but as 'the beginning of a new geological epoch ripe with human-directed opportunity' (Ellis, 2011). Ecomoderns do not accept that there are natural planetary boundaries limiting human expansion: 'humans appear fully capable of continuing to support a burgeoning population by engineering and transforming the planet' (Ellis, 2011).

To those who claim that there are planetary boundaries that limit continued growth in human populations and economic advance (Steffen et al., 2015a) the ecomodernists respond that 'human systems' can adapt and indeed prosper in a hotter world because history and our technical ingenuity prove our flexibility. Critics of technological solutions stand in the way of the realisation of the vision – a 'planetary garden' where 'nearly all of us will be prosperous enough to live healthy, free, and creative lives' (Shellenberger and Nordhaus, 2011). The opposition between humans and nature is reconcilable, and climate change is a trial to be met and won with technology.

The 'good Anthropocene' is appealing to those who believe human ingenuity can conquer all, but it is contradicted by the evidence of likely impacts on humans and ecosystems of global warming, especially if it exceeds the 2°C guardrail, which seems very likely.[8] Yet there is another way of seeing why the 'good Anthropocene' is built on bad science if we turn our attention to the question of nature's resilience, the scientific concept on which the thesis relies (e.g. Kareiva et al., 2011).[9]

Throughout the late 18th and 19th centuries geology was dominated by uniformitarianism, the idea that the Earth is shaped by slow-moving forces that gradually transform it over very long time periods (Rudwick, 2005). Determined to distance the new science from Biblical accounts of divine Creation, the emerging profession was reluctant to accept any theory of catastrophism in which a transition from one period in Earth history to the next may be due to some natural paroxysm

(Knight and Harrison, 2014). In the end, the evidence for catastrophic changes (a result, for example, of asteroid strikes) could no longer be resisted and geologists accepted that gradual change can at times be interrupted by cataclysms. Today the GTS includes several transitions from one era or epoch or period to the next caused by catastrophic events. They are 'catastrophic' because change is so rapid that most existing life forms cannot adapt and die out.

Ecomodernists seem to have regressed to 19th-century uniformitarianism. Their central scientific claim is expressed by Kareiva and colleagues: 'Nature is so resilient that it can recover rapidly from even the most powerful human disturbances' (Kareiva et al., 2011). This belief is carried over to their interpretation of the Anthropocene. Ellis puts it plainly: 'Humans have dramatically altered natural systems … and yet the Earth has become more productive and more capable of supporting the human population. … *there is little evidence to date that this dynamic has been fundamentally altered*' (Ellis, 2011, emphasis added). These statements reflect a radical misreading of the scientific basis of the Anthropocene. The foundational point made by the Earth System scientists who proposed the Anthropocene is that the dynamic between humankind and the Earth *has* been fundamentally altered.

So the essential point of the Anthropocene concept is the opposite of the ecomodernist understanding. The Anthropocene is put forward not as a description of the further spread of human impacts on ecosystems but as *a new epoch in the Geological Time Scale*, a phase shift in the functioning of the Earth System (Zalasiewicz et al., 2011). It is not a continuation of the past but a step change in the biogeological history of the Earth. The previous step change, out of the Pleistocene and into the Holocene, saw a 5°C change in global average temperature and a 120-m change in sea levels. Geologically speaking, the Anthropocene event, occurring over an extremely short period, has been a very abrupt regime shift, closer to an instance of catastrophism than uniformitarianism.

In this light, Ellis's disquisitions on the adaptability of agricultural systems and the way ecosystems 'bounce back' after human disturbance, which he takes as proof of nature's resilience, are anachronisms in the precise sense of the term. To the extent that the evidence for the resilience of disturbed ecosystems is convincing (and some of it is), it is within-Holocene evidence that is used to defend the idea of the 'good Anthropocene'. But the environments that gave rise to that evidence are being relegated to the past. Whatever their validity in the Holocene, arguments about nature's fragility *versus* resilience are of little relevance for discussions of the unfolding Anthropocene.

The point of proposing a new geological epoch is that we are witnessing not continuous change but rupture – a rapid transition to a new geological epoch, or perhaps an era, that is *permanent*. While certain key signatures, such as fallout signals and black carbon levels, have declined in response to environmental measures, the dominant anthropogenic forces shifting the Earth System – including warming, acidification, nitrate concentrations and species extinctions – continue on an upward curve.[10] Human activities are pushing the Earth System out of the late Quaternary pattern into a 'no analogue state' (Crutzen and Steffen, 2003: 253). The Earth has now crossed a point of no return; its great cycles have changed, the chemical compositions of air and ocean have been altered in ways that cannot be undone except on a millennial timescale. In short, the Earth System is now operating in a different mode and nothing humans can do now, even ending the burning of fossil fuels in short order, can turn the geological clock back to the Holocene.

No Anthropocene

So far I have considered approaches that distort the meaning and significance of the Anthropocene by looking at it from perspectives other than Earth System science. A number of scientists reject the idea of the new epoch altogether, and their arguments are worthy of consideration.

First, in a peculiar argument, Smil (2015) accepts that human impacts are 'unprecedented' and imperil humankind but he opposes adding the Anthropocene to the GTS. The Anthropocene, he writes, is 'a new epoch characterized by the human control of the biosphere' but we in fact do not control the planet's fate and there is 'no rush to elevate ourselves into the creators of a new geological era' or 'congratulate ourselves by naming the era shaped by our actions'. Visconti (2014), too, seems to have read popular interpreters rather than Earth System scientists, claiming that 'fans of the Anthropocene have the conviction that *Homo sapiens* can subdue the Earth and shape it according to his needs'. Of course, none of the Earth System scientists arguing in favour of the Anthropocene as a geological epoch have ever suggested any of this and it is hard to know where Smil and Visconti may have gained these impressions. For the record, the Anthropocene concept captures the profound impact of human activity on the functioning of the Earth System (and not merely the biosphere) but says nothing about the ability of humans to control the system and certainly does not congratulate humans for creating the epoch. Although irrelevant to the proposal to formalise the new epoch, it is probably true that most Earth System scientists who publish on the topic believe that the Anthropocene makes the Earth *less* predictable and controllable and that the impacts are a cause of lament rather than congratulation (Crutzen, 2002; Steffen et al., 2011). The views of some in the context of geoengineering are explored in Hamilton (2013).

We saw that some analysts have attempted to establish starting dates for the Anthropocene by viewing it through their own disciplinary lenses rather than as a change in the functioning of the Earth System. Others reject the concept altogether for the same reason. For instance, using data on alluvial depositions in the UK, Lewin and Macklin (2014) show that 'human impacts have been diachronistic, multifaceted and episodic' so that arriving at a single formal definition of the Anthropocene is impractical'. This argument, too, is rooted in the belief that the Anthropocene is an expression for 'the extensive record of anthropogenic impacts' on land surfaces, whereas in fact anthropogenic impacts on land surfaces, taken alone, have no bearing on the question. One cannot help but be struck by the number of published papers that miss the point of the Anthropocene completely.

The idea of the Anthropocene has met resistance from some traditional stratigraphers, who argue with some justification that the way some experts are thinking about it 'appears to undermine the standards of the revised Stratigraphic Code that has served us well in various forms since the 1930s' (Klein, 2015). Anxiety is a normal human response when we are asked to move out of our comfort zones (Bovey and Hede, 2001; Oldham and Kleiner, 1990), yet when new circumstances arise established disciplines might be marginalised if they refuse to change and insist on rigid application of trusted rules (Tagg, 2012), however well those rules may have served in the past.

Writing as 'practicing stratigraphers', Autin and Holbrook (2012) dismiss all discussion of the Anthropocene outside of stratigraphy as 'pop culture' (including presumably the work of Nobel Laureate Paul Crutzen), and it seems that their anxiety – shared by others (Lewin and Macklin, 2014; Visconti, 2014; Walker et al., 2015) – arises from the fact that the idea has spread into the wider community and has become 'political'. They impose the following condition for official endorsement of the proposed new epoch: 'a stratotype that records a continuous, preferably marine, sedimentation record and separates the Anthropocene from underlying units needs to be identified and correlated into the global time stratigraphy' (Autin and Holbrook, 2012). The implication is that we have to wait a million years for this condition to be met; yet a functional Anthropocene boundary is already present in recent strata, viz. spheroidal carbonaceous fly ash particles in lake sediments (Rose, 2015).

Those who insist that all scientific discussion must remain within the narrow confines of established stratigraphy have difficulty recognising the central claim of the Anthropocene – significant

human disturbance to the functioning of the Earth System. And so Walker et al. (2014) reject the Anthropocene by arguing that the 'Little Ice Age' did not warrant entry to the GTS so nor should the Anthropocene. They argue that all species modify their environments so there is nothing different about human impacts. And they say we must wait until there is unequivocal evidence in the stratigraphic record, ignoring the fact that the evidence is already available (Zalasiewicz, 2015a).[11] Each of these fails to recognise and engage with the central claim of the Anthropocene.

The science of geological periodisation is being challenged by the Anthropocene to rethink its borders. A new kind of 'anticipatory geology' is called for, one that considers how changes in the Earth System will leave traces in the rock record in the future (using classical geological techniques). This anticipatory process requires the expertise not only of scientists who study the rock record but also of those who study each of the spheres that make up the Earth System, which is why the AWG's composition is not limited to stratigraphers, and why the concept was put forward by an atmospheric chemist.

The challenge to narrow stratigraphic thinking may be illustrated by a thought experiment. Imagine humankind initiates a global thermonuclear exchange followed by a long nuclear winter that wipes out most species and completely transforms landscapes across the face of the Earth. All humans are killed except for an enclave of stratigraphers trapped on a formerly tropical island. They debate the question: Should a post-holocaust epoch or era be added to the GTS? Applying the traditional stratigraphic criteria, as laid out by Autin and Holbrook (2012) for instance, the answer would be no, not until a continuous marine sedimentation record can be identified.

A second way to think about it is as follows. The divisions in the GTS are often only proxies for more or less dramatic shifts in the functioning of the Earth System, because they result in new patterns within the strata that can, much later, be analysed by stratigraphers. As Zalasiewicz et al. (2015a) write: 'An effective geochronological and chronostratigraphical boundary often reflects a substantial change in the Earth system …'. Work is underway on the exciting task of mapping certain divisions of the Scale into much more holistic understandings of the corresponding changes in the Earth System. So what we are seeing in the case of the Anthropocene is the first instance of what, in principle, *should* be done, that is, begin from a characterisation of a shift in the Earth System and then move to stratigraphy as a means of analysing and constraining it, and – if the evidence points that way – of 'nailing it down' (with a golden spike!).

In an insightful contribution, Knight and Harrison (2014) argue that geology and geography are liable to approach the Anthropocene from a uniformitarian viewpoint, which may take either a strong form, according to which the natural processes and laws that have always operated are operating today, or a weak form, according to which observations of geological processes operating in the past can be used to interpret processes operating today. Adopting a phrase from Steffen et al. (2004), they argue that the Anthropocene is a 'no analogue state' in which we have moved into a period of *greater* uncertainty, a singularity whose unique nature means the Earth System has moved 'away from the process dynamics and controls expected of a typical interglacial' (Knight and Harrison, 2014: 74). If this is true then the Anthropocene cannot be properly understood using the traditional uniformitarian concepts and methods of stratigraphy.

A new paradigm

It is sometimes said: 'Why bother policing the concept of the Anthropocene? Let people interpret it as they will'. For example, Maslin and Lewis write that there should be 'multiple definitions' of the new epoch including a historians' Anthropocene, a political scientists' Anthropocene and a philosophers' Anthropocene (2015: 109, 114). This is a curious claim at odds with the genesis of

the concept, that is, as a proposed addition to the GTS. Would they argue that the Jurassic has no privileged definition, so that anyone is free to define it as they choose? Of course, there may be legitimate disputes among experts about the Jurassic's delineation, as there may be among Earth System scientists over the Anthropocene. But they are disagreements within accepted kinds of scientific evidence and analytical methods. If a philosopher wanted to discuss the meaning of the Jurassic it is hard to know where he or she would begin other than with the formal definition of the period.

It is true that in the social sciences and the humanities 'the Anthropocene' is now used in a broader sense to describe the overall impact of humankind on the Earth, where 'the Earth' has a range of conceptions and connotations, usually unstated (Hamilton et al., 2015). Some confusion would be avoided if a different term were adopted ('the Technocene' perhaps). And much of the looseness with which the term is used would be tightened if the half dozen or so most important scientific papers on the topic received greater attention. Even so, it is vital that the broader sense is not confused with the formal geological meaning of the term; the broader usage is certainly of no value to the deliberations of the International Commission on Stratigraphy.

The new paradigm of Earth System science has been coaxed into existence by the appearance of a new 'object', the Earth System taken as a whole, as opposed to localised ecosystems or global processes (such as the water cycle) considered in isolation. But this has been recognised only by a relatively small community of Earth System scientists and a few pioneers in science studies, including Grinevald (2007). Others treat the Earth System and thus the Anthropocene as if it were a further articulation of the old object (landscapes or ecosystems) and its study the continued development of established environmental sciences (Kuhn, 1962: 34). They believe that they are adding to the accumulation of knowledge within their disciplines whereas, in truth, Earth System science is not a further development, not a cumulative addition, but a break, a new start with a new object that has appeared.

If Earth System science is, in Kuhn's terms, a 'scientific revolution' – defined as 'those non-cumulative developmental episodes in which an older paradigm is replaced in whole or in part by an incompatible new one' (Kuhn, 1962: 91) – it is one inaugurated by the appearance of this new object rather than by a growing disenchantment with the inadequacies of the old one. This makes life harder for the new paradigm's advocates because those wedded to the old one are not resisting the rise of the new but are treating it as a further expression of what they already know. Rather than countering it, they are co-opting it. There is therefore no sense yet of intellectual crisis.

Unlike the 'typical' scientific revolution, it has not been the case that the new evidence contradicted the prevailing theory, but that the focus of interest shifted because of the appearance of new phenomena – in particular the rise in global CO_2 concentrations, measured warming, links between the two in the ice-core record, the importance of stratospheric ozone and its breakdown, and the sixth mass extinction. These are Earth System processes that transcend the bounds of ecosystems and operate at a global level. These new phenomena required a new object. For this, new concepts were needed and they began to be created by the global change community centred on the International Geosphere-Biosphere Programme in the 1980s and 1990s (Hamilton and Grinevald, 2015). When, in the year 2000, Paul Crutzen named the Anthropocene it quickly became the conceptual pole around which Earth System science constellated.

Of course, established environmental sciences remain just as relevant to the old objects; but they can shed only limited light on the new object and the questions it throws up. In Kuhn's words, the 'existing paradigm has ceased to function adequately in the explanation of an aspect of nature to which that paradigm itself had previously led the way' (Kuhn, 1962: 91). When used as the lenses through which to study the Earth System as a whole, not only are those sciences unable to

shed enough light, when they are used to appropriate the Anthropocene they may actually obscure it, as I hope I have shown. They obscure it not only as a concept; they deflate the scale and severity of human disruption of Earth System processes captured in the concept of the Anthropocene. Although these disciplines remain invaluable for our understanding of how parts of the complex system work, or have worked in the past, when applied to the Earth System as a whole they risk diminishing the significance of the Anthropocene because the new epoch no longer appears as a *rupture* in the Earth System inviting a new understanding of the human relationship to the Earth.

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Notes

1. With thanks to Jacques Grinevald for helping me to refine these definitions.
2. Will Steffen has pointed out that much practical ecological analysis can and does use cause-and-effect thinking.
3. As I argue in Hamilton (2013: chapter 8).
4. Puzzlingly, Ellis is a member of the Anthropocene Working Group and is a co-author of the Zalasiewicz et al. (2015a) paper he criticises.
5. Note that for James Lovelock (1979, 2006) changes in the biosphere – which he uses in the narrow sense of the biota – matter *because* they interact with the atmosphere and change the climate system.
6. I am grateful to the anonymous referee for making this point.
7. Parts of the commentary in this section reprise Hamilton (2013).
8. Many references could be given to support this statement, perhaps starting with Anderson and Bows (2010), Hansen et al. (2015) and Anderson (2015).
9. For various critiques, albeit from the perspective of environmental science, see Wuerthner et al. (2014).
10. With thanks to the anonymous referee for reminding me of this point.
11. Walker et al. (2014) conclude by declaring '[o]ur position remains that we continue to live within the formally-defined and ratified Holocene', and one gets the impression they will stay there no matter what the ICS decides.

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