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Key Points:
- The Anthropocene goes beyond geology and needs a moral and public discourse
- Anthropocene science needs a genuine and real synthesis
- Anthropocene science requires strategically designed research

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Which Anthropocene is it to be? Beyond geology to a moral and public discourse

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The Anthropocene is a newly proposed geological epoch, the age of humans [Crutzen and Stoermer, 2000]. It acknowledges that human activity is in effect a geological process, and that we are generating a physical and biological environment that is distinct from anything before and that is likely to leave a substantial trace in the geological record of Earth's history. A long, well-established process has started to consider whether the Anthropocene should be formalized within the geological timescale, led by the Anthropocene Working Group of the Subcommission on Quaternary Stratigraphy [*Zalasiewicz et al*., 2010]. If the Anthropocene is to be acknowledged as a geological epoch, the AWG must demonstrate that there is a high probability that a distinctly Anthropocene stratal unit (with its attendant distinct environmental characteristics) may be recognized by Earth scientists working today, and will be preserved in Earth's future, and that a so-called golden spike marking the beginning of the Anthropocene can be agreed upon by the stratigraphic community. The result of that process will go to the Subcommission on Quaternary Stratigraphy and then to the International Commission on Stratigraphy (probably in 2016), hosted by the International Union of Geological Sciences, all of which will have to support the proposal if the Anthropocene is to be made official.

Let us present a small indication of how human activity can be seen as responsible for this new epoch. Geological epochs and other units are often well known for the globalization of their sedimentary environments [*Ager*, 1993]. The early Cambrian can be recognized across the world by the rich white quartzites that mark the beginnings of a global transgression. Similarly, the Late Cretaceous is recognized the world over by its distinctive and often cliff-forming chalk beds. We do not know what will ultimately characterize the Anthropocene epoch, because regardless of where the golden spike is eventually placed, we are essentially within its boundary. We do know that humans, through the construction of reservoirs, dams, and mills and through the need to maintain navigation in important waterways, have significantly impeded the flux of sediments to the continental shelf [*Walter and Merritts*, 2008; *Merritts et al*., 2011; *Syvitski and Kettner*, 2011]. Earlier than these technological influences, however, humans have also increased the flux of sediments through wholesale forest clearance [e.g., *Hoffmann et al*., 2010]. Indeed, humans are now responsible for the transport of more materials in the terrestrial environment from place to place than any non-human process [*Hooke*, 2000; *Wilkinson*, 2005]. And the transport vectors are increasingly of human design: we move things along roads, railroads, and shipping lines rather than along rivers or down hillslopes [*Haff*, 2010]. Further, the nature of deep ocean sediment is also likely to change as deep-sea mining (principally for rare earth metals) expands its footprint. Anthropocene sediments are also likely to have a different composition to earlier sediments, including so-called POPs or permanent organic pollutants (typically related to man-made derivatives of petroleum or other industry-related activity), and levels of C, P, and N that are distinctly different from preindustrial levels [*Vane et al*., 2011]. And there is also Anthropocene rock, one that has side-stepped the process of sedimentation and diagenesis. This is the so-called made-ground, an amalgam of various types of building foundation, underground infrastructure, solid waste sites, man-made islands, airports, and so on [*Price et al*., 2011]. Such made-ground may already be overlain by still more made-ground or by younger sediments, derived from expanding deserts and migrating rivers.

Stratigraphy concerns the events between its bounding surfaces as well as the nature of the boundary itself. The most significant stratigraphic boundaries separate distinctly different fossilized life assemblages. The best known of these, marks the demise of non-avian dinosaurs at ~66 Myr, with a loss of about 76%

of existing species. The most significant extinction event, however, took place at around 251.2 Myr. An estimated 96% of species were lost during a time interval between 2.8 Myr and 165 kyr. Other major extinction events occurred at 443 Myr (over a duration of 3.3–1.9 Myr) with a loss of ~86% of species; 359 Myr (over a duration of 29–2 Myr) with a loss of ~75% of species; and at 200 Myr (over a duration of 8.3–0.6 Myr) with a loss of ~80% of species [*Barnosky et al*., 2011]. In this context, the impending Anthropocene epoch has reason to resonate deeply, as it is likely to mark the sixth largest extinction event in the last 542 Myr of the Phanerozoic [*Barnosky et al*., 2011].

Much of the current threat is due to the loss of habitat or to overhunting related to human activities. Erle Ellis has suggested that slightly less than a quarter of Earth's terrestrial biomes are pristine (i.e., untouched by human processes), all of which is restricted to sparsely populated and uninhabited polar regions [*Ellis*, 2011]. Humans may also be responsible for the evolution of some species. Cliff swallows (*Petrochelidon pyrrhonota*) in southwestern Nebraska, for example, have developed shorter wing spans over the past 30 years, the result of natural selection in a species that has to contend with fast-moving traffic as a principal cause of fatalities [*Brown and Brown*, 2013]. Biodiversity may also be locally increasing in areas related to the rapid colonization of some invasive species, a process intimately coupled to human activities [*Ellis et al*., 2012].

Independently of its strictly stratigraphic meaning, the concept of the Anthropocene has had an impact well beyond geology. It has captured the imagination of the media and of a wide spectrum of academic disciplines, as well as the academic publishing industry. Four new academic journals that tackle the Anthropocene have emerged in the past year. The *Economist* featured the Anthropocene as its cover and lead article in its 26 May 2011 issue, which reported on an international meeting sponsored by the British Geological Survey and held at the Piccadilly headquarters of the Geological Society of London. That meeting was covered by the BBC (its own Anthropocene web page received more than 330,000 hits in its first day), *Der Spiegel*, two different editorials in *Nature*, and by the *New York Times*. In 2012, a group of students at Stanford University started a podcast series that they call *Generation Anthropocene*. To date, there are close to 100 podcasts available. At the time of writing, an Internet search using only the word *Anthropocene* yields more than half a million hits, and more than a hundred peer-reviewed papers have been published since 2000 containing the word *Anthropocene* in the title. The notion of the Anthropocene is even at the heart of the new strategy of the Natural Environment Research Council, UK's principal funding agency for Earth and Environmental Science, in which the principal driver is that "[p]eople are no longer bystanders examining a natural world; we are the dominant source of change" [*NERC*, 2013]. And the US National Science Foundation has long recognized, in its program in coupled natural and human systems, the importance of what constitutes the Anthropocene.

But why should a newly proposed geological epoch cause such excitement? Why has a generally obscure scientific process that will inevitably be mired in recondite committee proceedings touched the nerves of so many different and wide-ranging constituencies? It seems plausible that the "buzz" around the Anthropocene idea is linked to the idea's evocation of the notion that humanity has attained the status of a force of nature, a comparison that some will find flattering, and others appalling. But we maintain that this comparison misconstrues a crucial fact. For, unlike the workings of brute forces of nature, human beings act within the domain of morality: what human beings do is subject to moral evaluation and can, at least ideally, be guided by moral standards. Thus, we submit, the broad interest in the Anthropocene likely has a moral component, based on a coming to terms with human *responsibility* for the planet-wide changes the Anthropocene represents. Thus, for some, the Anthropocene idea offers an occasion for passing judgment on humanity's domination of nature. But for others it prompts a desire to engage with the processes that are contributing to those changes, in the hopes of shaping a future that is morally acceptable.

We hold, therefore, that the Anthropocene is a concept that has moral content at its core, rather than being only a scientific concept with a detachable moral significance. Our position has three important implications for the scientific study of the Anthropocene—what we will call Anthropocene science.

First, while study of the Anthropocene is firmly anchored in geology, it requires concepts and methodologies from disciplines well beyond the Earth sciences. Obviously, as our references to biological phenomena make clear, understanding the Anthropocene involves an essential contribution from the life sciences, in particular ecology and evolutionary biology. However, precisely because the Anthropocene

proposal is an acknowledgement of the decisive role played by human activities in characterizing the new epoch, understanding the Anthropocene requires substantial input from the social sciences. The human action that is producing the Anthropocene is, after all, the result of choices—from the uncoordinated choices by individuals that aggregate into collective action (directed by societal and cultural norms) to the social actions that are coordinated through formal or informal governance structures at local, national, and international levels. The legal system and the strength or weakness of regulatory policies are especially critical factors in the evolution of the Anthropocene [e.g., *Vidas*, 2011]. The structures that influence these choices are the subject of formal modeling within, for example, economics and political science. But to the extent that choices are influenced by cultural values and other social structures, the contributions of fields such as anthropology and sociology are directly relevant as well. Indeed, the exploration of the relation between values and action in philosophy and psychology has a role to play in understanding why human beings have acted in the way that has generated the Anthropocene. The representation of these processes in quantitative, predictive models of Anthropocene scenarios is going to be a significant challenge.

Theorizing the origin and character of the Anthropocene requires a collaborative effort across a wide range of scholarly disciplines. This is perhaps the principal challenge that Anthropocene science faces. The approach we currently bring to tackle complex problems of this kind is to develop an *interdisciplinary* project in which a number of specialists get together and attempt to do the job. It is clear, however, that this is not working well. Frequently what results are contributions which run parallel, i.e., where each specialist approaches the problem from his or her own distinct perspective, but they never intersect to provide a comprehensive understanding. Thus, others have suggested that what may be needed are more generalists and fewer specialists. Or more bluntly, we need to develop a scientific culture in which young scientists are encouraged to solve difficult, complex problems, rather than search for problems that are suited to their own specialist skill set. Tackling the Anthropocene demands a much more synthetic approach to science that fully integrates different approaches and different types of scholarly experience.

Second and coupled to the need for a synthetic approach is the need to be strategic about the development of research programs: the need to keep an eye on the big problem in what will inevitably be a long haul to its resolution. Strategic research outside of the commercial world is typically designed and funded by research organizations charged with delivering a national or public good (e.g., geological surveys and public health institutes), philanthropic organizations (e.g., the Bill and Melinda Gates Foundation), and in various guises by national and multinational governmental science funding agencies. We suggest that Anthropocene science needs a similar but even more broadly based strategic approach, guided by the need to deliver an emergent international public good: a habitable Anthropocene.

The obstacles to this kind of strategic, cross-disciplinary integration are daunting. At the purely intellectual level, investigators who have mastered a particular discipline must be convinced that their knowledge of the Anthropocene is by definition only partial. We propose, as a first step, a frank conversation among scholars from different fields about why their respective disciplines are essential to an adequate understanding of the Anthropocene—but also about the gaps their disciplines leave which must be filled by others. Perhaps an even harder challenge is to develop institutional structures, in and out of the academy, that facilitate and reward work specified by a common, overarching and definitively wicked problem [cf. *Rittel and Webber*, 1973], rather than by a paradigm embedded in a specific discipline. What habits, not just of mind, but of the organization of scholarly activity, must be overcome to create patterns of interaction that yield a genuine strategic intellectual synthesis?

Third, the moral core of the Anthropocene concept challenges Earth scientists (along with others who study it) to acknowledge that their subject matter demands a kind of moral engagement. That the Anthropocene emerges from human activity, we have argued, means that it is the product of choice—not of a choice to create the Anthropocene, but as the by-product of the multiplicity of choices that humans have already made in order to live in the manner to which they aspired. The Anthropocene proposal implies that these past choices have already had a global impact, i.e., that we are bound to live in a future we have shaped. It seems, then, that we have no choice but to live in *an* Anthropocene. Nonetheless, the choices we make going forward can have some influence on the precise shape of the future we are entering. To some extent, that is, we can choose *which* Anthropocene will actually happen.

We maintain that Anthropocene science, in the broad, synthetic sense suggested above, is cast in the vital role of helping people make the choices that will realize a morally acceptable future. This role should not be a passive one, restricted to objectively predicting outcomes, or even posting warnings about bad choices. We envision a more active role for Anthropocene science, in which it identifies good (or at least better) outcomes and proposes pathways for attaining them. Those proposals will be made at scales from local projects to international agreements—and they cannot ignore the social and political contexts in which choices are made by the people involved; in particular, the full range of stakeholders must be respectfully acknowledged. On this view, we can speak of Anthropocene science as engaged in the project of designing the Anthropocene. For, none of the choices we are describing can take the Earth out of the Anthropocene; they are all about which version of the Anthropocene we will inhabit.

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