STRATA AND THREE STORIES

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Transformations in Environment and Society

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By

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Introduction

The Anthropocene

The Anthropocene is in some ways an accidental concept, a high-profile improvisation made in 2000 by Nobel Laureate and atmospheric chemist Paul Crutzen (though the term and concept had a variety of antecedents). Accidental or not, it crystallized a growing perception of global change in the form of a proposed new geological epoch set in train by human activities. Just two decades on, overwhelming evidence has been assembled that in the mid-twentieth century our planet entered a distinct new chapter in its approximately 4.54-billion-year history. The complex, integrated Earth System has moved away from the relative stability of the Holocene epoch to another less stable and still evolving phase with, in many ways, no precedent in Earth's long history. Currently, within the geological community, evidence is being assembled toward a formal proposal of the Anthropocene. Should it be formally adopted, the Anthropocene would join the Eocene, the Pleistocene, and other such units on the great canvas of the Geological Time Scale (GTS). If this happens—and that is uncertain, as the barriers to formalization are high—then it would be a giant step, and not just for for geologists. The Anthropocene would not only be an addition to the classification of geological time and strata. These stratal constructs tell stories of how our planet functions—now, and (sometimes very differently) in the past.

Humans will not find it as easy to live in the Anthropocene as they did in the Holocene. It now seems clear that life as we have experienced it for the last ten millennia is going to be changing very rapidly and largely for the worse: the air carries a third more carbon dioxide and so the climate will, almost certainly, soon be hotter than it has ever been in the history of *Homo sapiens*. The seas are rising. Global biodiversity is shrinking. Fresh water is becoming more scarce. Topsoil is being lost at the rate of least 36 billion tons every year, endangering food supplies. The pressure on the systems that nurture, shelter, and fuel us will become ever more intense in the years to come. These intensifying pressures will impact our societies unevenly and unfairly, but no part of the globe will be unchanged.

The Anthropocene, with these novel ingredients, is a very new part of Earth's history. To make sense of it we need to place it in the context of our planet's past, beginning roughly 4.54 billion years ago. We also need to place it within human history, in which *Homo sapiens* evolved just some 300,000 years ago, slowly emerging as a dominant force, and ultimately exploding into a planet-changing species in the mid-twentieth century. The extraordinary transformations of the Earth System that we are seeing today took place, effectively, within a single human lifetime. In terms of the speed of change, the nearest comparison in the last half-billion years of the Earth's history is the meteorite impact that brought the Mesozoic Era to an abrupt close. Only now *we* are the meteorite, and often it seems just as difficult to alter our trajectory as it is to alter the course of a ten-kilometer-wide rock hurtling through space.

At heart, the Anthropocene is a geological concept, a means of showing the scale, speed, and particular character of Earth's recent, abrupt transformation. Yet over the last decade or so, the concept has grown to stretch the disciplinary boundaries of geology, perhaps even to breaking point. Geologists are used to pondering the geological effects of meteorites, volcanoes, and foundering continents, but not to how a rocky planet reacts to changes in tax law, to the shifting patterns of religious beliefs and advertising strategies, to innovations in agriculture such as the Green Revolution, to the ingenious manipulation of a silicon chip, or to myriad other baroque inventions of a desperately divided but now cumulatively gigantic human community. In this unprecedented situation, geology alone cannot encompass the reach and dynamics of the Anthropocene. The whole range of scholarly endeavor is needed to cope with—or, at least, to attempt to make sense of—the dangerous impact of human activities on Earth, and to devise means of creating a more viable future. The sciences, the humanities, the social sciences, and the fine arts all bring valuable perspectives to the table as the Anthropocene reverberates across many disciplinary divides—perhaps to the extent of making the boundaries between these disciplines more porous.

Narratives of the Anthropocene

This volume celebrates collaboration, exploring this potential new epoch through our human penchant for telling stories. We draw attention to the way almost all disciplines—scientific and otherwise—use non-fictional narratives to show how things change over time. The narrative form makes connections, highlighting continuities in some cases, and revolutionary change in others. The elements chosen as central to a story reveal what its authors find most important. These elements are the story's protagonists, the forces driving the plot, with the narrative shape conveying the authors' perspectives and values.

To craft the Anthropocene story as a tragedy is to reveal our partiality for the flourishing of humans, an entirely understandable if biased point of view. To avert the worst of this tragedy, we strive to imagine alternative storylines that might draw us away from a hothouse Earth and radically diminished biodiversity. Yet, from the perspective of life forms such as jellyfish, the Anthropocene may be a boon, a comedy with a happy ending as their numbers expand in the warming oceans. From the perspective of the planet as a whole, it is nothing more than another ironic twist in Earth's dynamic history: a single species run wild, ripping great shreds out of the fabric of life, and then vanishing quickly in the blink of an eye.[1] The concept of the Anthropocene conjoins the stories of strata and societies, alerting us to the intertwined destiny of Earth and humanity.

Understanding the Earth's new trajectory requires that we examine deep human history as well as the recent past. Our ancestral species' adaptations, such as bipedalism and the mastery of fire, provided the foundation for the rise of powerful Earth-altering human forces. More recent ideals, inventions, and social systems, from agriculture and aqueducts to democracy and dog breeding, have accelerated human dominion. By the mid-twentieth century, the mushrooming growth of economies, inequality, and human populations coalesced globally to produce the Anthropocene. All these stories are Anthropocene stories as seen through the lens of our current quandary. But, it's important to remember that although all human beings now live in the Anthropocene, not all human stories charted an inevitable course toward this moment.

1 For an analysis of the narrative form in history, see Hayden White, *Metahistory: The Historical Imagination in Nineteenth-Century Europe* (Baltimore: The John Hopkins University Press, 1973); *Tropics of Discourse: Essays in Cultural Criticism* (Baltimore: The John Hopkins University Press, 1978); and *The Fiction of Narrative: Essays on History*, Literature, and Theory 1957–2007 (Baltimore: The John Hopkins University Press, 2010).

From Aboriginal land stewardship practices to Pacific coast potlaches, from the asceticism practiced in religious communities to communitarian visions of shared sufficiency, many human stories can serve as counterpoints to the dominant narrative in which human activities push ever more forcefully against planetary boundaries, or behave as if those boundaries did not exist. These counterpoints suggest that our arrival at this new epoch in human and planetary history was not foreordained, and further, they provide political and cultural resources for reshaping our societies to mitigate the Anthropocene's harshest affects. If human activities are the equivalent of that ten-kilometer-wide rock hurtling through space, re-narrating our human stories may be one means of deflecting or softening the impact. In other words, Anthropocene stories are not just about how we got here, but also about how things might have been otherwise; a way of reading the past against the grain of the present in order to open up new possibilities for realigning our values, politics, and social practices to live within planetary constraints.

Steering Towards the Future

In the tandem experiment in these pages, we provide one example of trying to wobble a course towards the kind of multidisciplinary understanding that is needed to grasp—and perhaps to help cope with—our collective predicament. In the first essay in this volume, Jan Zalasiewicz—geologist and co-founder of the Anthropocene Working Group (AWG)—puts forth the startling evidence of human-induced global environmental change that is already being written in the Earth's strata, revealing the scale and extent of our inadvertently destructive enterprises. In the second essay, Julia Adeney Thomas, an intellectual historian, explores the ways scholars outside the sciences have interpreted the Anthropocene and three wildly different narratives they have created. For several years, the two of us have been working together with geologist and AWG member, Mark Williams, on *The Anthropocene: A Multidisciplinary Approach* (Polity Press, 2020), but it wasn't until the Rachel Carson Center's tenth anniversary celebration, held on 3 December 2019, that we spoke in tandem about our efforts before a live audience. That event, titled "How We Changed the Planet: Strata and Stories in the Anthropocene" was deftly and indeed brilliantly orchestrated by RCC Directors Christof Mauch and Helmuth Trischler, and then skilfully ushered into print by editors Harriet Windley and Kristy Henderson.

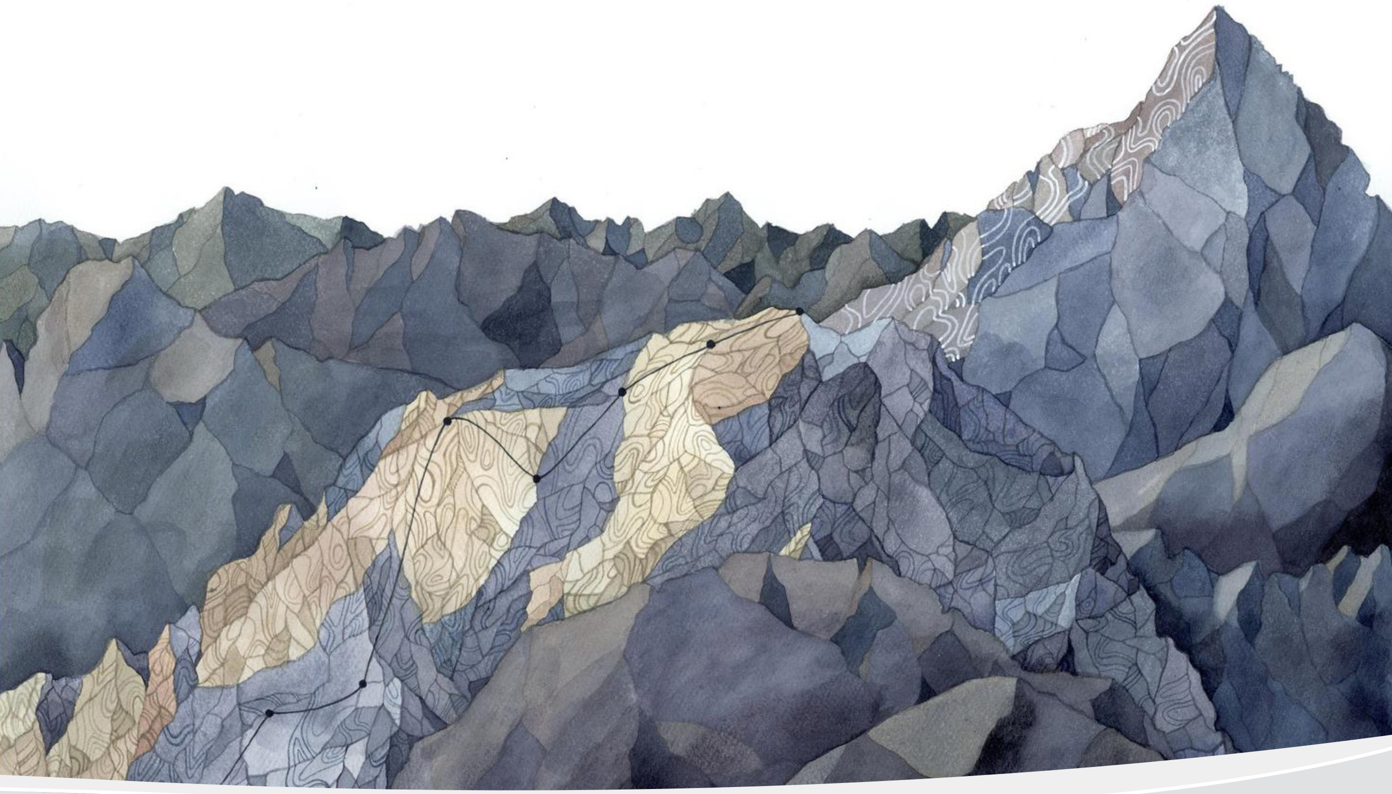
Their efforts allowed us to crystallize our thoughts and relate them to the extraordinary work done by environmental historians. The public response to our papers by Jane Carruthers, Honorary RCC Fellow and pioneering environmental historian of South Africa, illuminated an intellectual landscape in which scholars working on human impacts on particular environments can speak to those working on the collective human impact on the Earth System as a whole. The fields of environmental studies and Anthropocene studies, though distinct, resonate with each other.

While the RCC event highlighted our commitment to a multidisciplinary response to the Anthropocene, it also allowed us to reflect on the rifts and fissures inherent in this effort. In discussing our altered planet, we must contend with the ways disciplinary perspectives do not always fit comfortably together. Differing methods, questions, concepts, genealogies of thought, and scales of time and space can render us barely intelligible to one another. No effort at multidisciplinary work should elide these tensions. Indeed, self-reflection on the sources of friction helps us see just now challenging it is to produce the knowledge necessary to understand the Anthropocene with an intellectual tool-kit developed largely during the waning years of the Holocene with its siloed forms of investigation. Yet, these diverse forms of knowledge are not necessarily an obstacle; their heterogeneity may even be a source of resilience, providing more than one way to mitigate the hard times ahead. Thus, a multidisciplinary approach makes sense because the Anthropocene itself is multifaceted, multiscalar, and the product of a recent coalescence of human activities—some having very deep origins, such as the mastery of spears by our ancestral species, and others which are very recent, such as the rise of mass tourism. The Earth System and human systems have never operated separately—but now the human systems have overwhelmed the great forces of nature. Studying them separately obscures this critical conjunction.

Having many ways of knowing helps us address the unprecedented existential crisis in which humanity now finds itself. The encompassing reality of the Anthropocene dictates no single comprehensive planetary story; instead, there are many ways of looking back and, we hope, more than one way of moving forward. Our understanding of the Anthropocene should be as rich and complex as the human forces and physical forcings that produced it. We hope that the unlikely combination of perspectives in these pages provides a helpful picture of a world that, largely by accident, we have collectively pushed onto a new course.

Old and New Patterns of the Anthropocene

Jan Zalasiewicz



Progression, © Jill Pelto

In 2000, on that fateful day in Mexico, when Paul Crutzen gave in to a moment of irritation among a crowd of fellow scientists assembled to discuss the growing symptoms of a troubled Earth, he surely could not have foreseen the repercussions of his brusque intervention. What had got on his nerves was the constant reference to the Holocene Epoch, the interval of post-glacial geological time (in which we still, formally, live) and the new trends developing within it. These trends—of deforestation, of fundamental change to the chemistry of the atmosphere and the oceans, of accelerating biodiversity loss, of the onset of climate change—did not chime at all with the general concept of the Holocene. The Holocene, after all, is an epoch of relative stability, the latest of 50-odd interglacial phases of the 2.6 million years of the Quaternary Period (the Ice Age of common parlance); its conditions enabled humanity to burgeon. Here, one can see the growth of communities, towns, cities, and then empires, and all the marks of peace such as trade and farming, and of war, with its destruction and despoliation, alternating in seemingly endless cycles. All this is preserved in a rich archaeological record, extending through—and indeed before—the 11.7-thousand-year span of the epoch.

Underlying all this feverish human activity, the signals of the Earth as a planet were ones of dependability: of climate, of sea level—once the mighty polar ice-sheets had finished their latest prodigious melt phase, by some seven thousand years ago—of geography, and of animals (bar mostly the large land animals beginning to suffer the effects of hunting) and plants. This was a planet as bedrock, a backcloth so reassuringly stable and supportive for human activities, of such seeming permanence, that it could be assumed to be always there. And, whatever the destruction wrought by the latest war, or by the spread of patches of nature tamed as farms and towns, this stable Earth would heal, recover, and endure to support the next human adventure. Only—as Paul Crutzen then felt so acutely—at some recent time in history, around about the time when large-scale industrialization started, the human-wrought changes began to take on a quite different scale and order: of such a scale, indeed, as to threaten the planetary stability that supported both human civilization and the complex web of nonhuman life. Hence that outburst, that moment of inspiration and that on-the-spot improvised new word: the Anthropocene.[1]

1 Paul J. Crutzen and Eugene F. Stoermer, "The 'Anthropocene'," *Global Change IGBP Newsletter*, no. 41 (2000): 17. This journal issue includes several intimations, direct and indirect, of this new concept, which was later more widely broadcast in a vivid, one-page article: Paul J. Crutzen, "Geology of Mankind," *Nature*, no. 23 (2002): 415.

That word, as we now know, was to catalyze many things in a surprisingly short space of time (indeed, the catalysis continues, and at breakneck speed). One was simply the wider use of the term among the scientific community that Paul was part of, the Earth System science (ESS) community associated with the International Geosphere-Biosphere Programme. They simply voted with their feet, using the term matter-of-factly, as a vivid and useful conceptual addition to their discourse and wider communication.[2] These were for the most part chemists, physicists, ecologists, oceanographers, and so on, dealing with the present world. Aware of the Geological Time Scale (GTS)—of which the Holocene is the latest (and remains the latest) rung—they had, however, few dealings with the particular geological community that oversees the GTS; no more so than most scientists have day-to-day dealings with the kinds of committees that decide, ponderously and with infinite meticulousness, the precise length of the meter or exact weight of the kilogram.

Nevertheless, a few years after the Anthropocene began its spread through the scientific literature, this particular community of geologists became aware of this new word, which was being used just as if it was a standard geological time term. But, of course, it was not: it had not gone through the exhaustive, lengthy, detailed analyses and scrutiny—one would say ordeal, if we were dealing with a human—that a term must go through before it is finally, after passage through several increasingly powerful committees, agreed upon (at all stages) by a supermajority vote. The GTS is meant to be stable, to provide a common grammar for the discipline across both national boundaries and generations. It is only modified rarely and grudgingly, for real purpose; and quite a few proposed terms have never made it into formal use, having fallen at one or other of these hurdles. The Anthropocene is now being prepared for just such a trial in the next few years. There is no guarantee it will survive, formally.

While the formal lens provides only one perspective on the Anthropocene, there is also the question of the *reality*—the physical, chemical, and biological rationale that lay behind Paul Crutzen's intuition. These are all of course geological too, in that the Earth comprises all of these dimensions—dimensions that one may term respectively lithostratigraphical, chemostratigraphical, and biostratigraphical, in the jargon of the

2 This early adoption may be seen in, for instance: Michel Meybeck, "Global Analysis of River Systems: From Earth System Controls to Anthropocene Syndromes," *Philosophical Transactions of the Royal Society. Series B, Biological Sciences* 358, no. 1440 (2003): 1935–55; and W. Steffen, A. Sanderson, P. D. Tyson, et al., *Global Change and the Earth System: A Planet under Pressure* (Berlin: Springer, 2004).

trade. Through these prisms, one may process an almost infinite amount of data—the Earth is a large and complex phenomenon, after all.[3] But many of the various patterns of the Anthropocene betray a striking simplicity. This new concept is not subtle, and does not need sophisticated statistical analysis to reveal some vague hidden trend in a sea of variability. It is terribly straightforward.

Fundamental Pattern of the Anthropocene

Take, for instance, the pattern that was calculated last year by Clément Poirier, one of the Anthropocene Working Group (AWG) members, and then worked into the new logo of the AWG, courtesy of Astrid Kaltenbach and the Max Planck Institute for Chemistry in Mainz. It is an almost-horizontal line that, at its right-hand end, turns into an almost vertical line. It represents the rate of rise of carbon dioxide in the atmosphere from the earth/ocean system over the past 15,000 years.

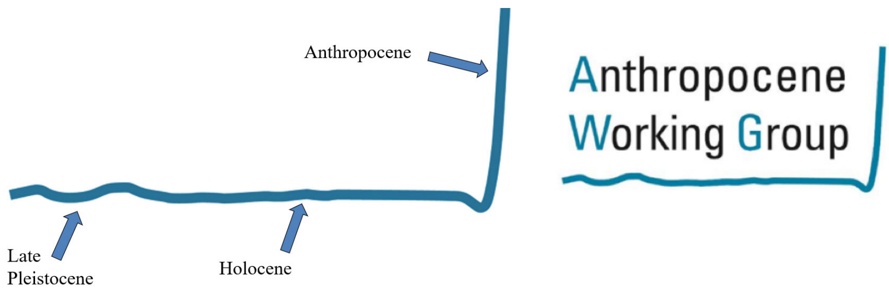


Figure 1. The AWG logo and its origin, based on the rate of change of atmospheric CO^2 over 20,000 years, as worked out by Clément Poirier.

For most of these fifteen millennia, this rate held almost steady. There are some slight wobbles in the first third of the line, representing the standard glacial-to-interglacial rise in atmospheric carbon dioxide from 180 to around 265 parts per million (ppm), largely due to outgassing from the ocean. This is quite a large rise, but it did take several millennia from start to finish, so the line does not depart much from the

3 A good deal of the evidence is very tightly summarized in C. N. Waters, J. Zalasiewicz, C. P. Summerhayes, et al., "The Anthropocene is Functionally and Stratigraphically Distinct from the Holocene," *Science* 351, no. 6269 (2016): 137.

horizontal trend, which then persists *almost* until the present. The sharp inflection towards the vertical is humanity's contribution, mostly from the burning of gargantuan amounts of fossil fuels. The near-vertical line is not quite straight; the first part is a little less steep and represents the time from about 1850 CE, the beginning of what is sometimes called the "thermo-industrial" revolution. The second, steeper part represents, from around 1950 CE, the time of the "Great Acceleration" of population, industrialization, and globalization, since which time more than 87 percent of the fossil fuels exploited have been consumed.[4] This is a large part of the reason why the human consumption of energy in the seven decades since 1950 CE is estimated to be greater than that in the previous 11.7 millennia of the Holocene combined.[5]

Carbon dioxide is just one parameter. A very similar pattern can be made from an analysis of human population growth, of atmospheric methane levels, and much else. The well-known "hockey stick" of Earth's temperature proposed by Michael Mann[6] and his colleagues is part of this suite, albeit a (so far) blurred and relatively poorly developed one, as Earth's surface temperature has yet to catch up with the effects of climate drivers such as increased atmospheric carbon dioxide (the Earth is a big object, and so it will take some centuries for the increased heat to work its way back through to the atmosphere—at the moment, most of the extra heat is being absorbed by the oceans). This fundamental pattern, therefore, divides the old epoch and the (proposed) new one. As a first approximation, the Holocene is horizontal, and the Anthropocene is vertical.

4 The diagrams that form the basis for the AWG logo are shown and described in Fig. 1 in J. Zalasiewicz, C. N. Waters, M. J. Head, C. Poirier, et al., "A Formal Anthropocene is Compatible with but Distinct from its Diachronous Anthropogenic Counterparts: A Response to W.F. Ruddiman's 'Three Flaws in Defining a Formal Anthropocene'," *Progress in Physical Geography* 43, no. 3 (2019): 319–33.

5 This analysis, which ranges wider than energy consumption, is in J. Syvitski, C. N. Waters, J. Day, J. D. Millman, et al., "Extraordinary Human Energy Consumption and Resultant Geological Impacts Beginning around 1950 CE Initiated the Proposed Anthropocene Epoch," *Communications Earth & Environment* 1, no. 32 (2020): 1–13.

6 Michael Mann is a climatologist at Penn State University, who has pioneered techniques for reconstructing the climate history of the past thousand years. The pattern he obtained, of a sharp twentieth century rise, is also shown by many other parameters of the Anthropocene.

Climate Context of the Ice Age

Is this striking pattern *geology*, though, or just a few millennia of environmental history? In other words, is the Anthropocene a blip, a minor fluctuation destined to be lost within the noise of Earth time, or is it something larger and more serious? Here, context is everything. The current rise in carbon dioxide can be grafted onto the record of carbon dioxide fluctuations over the last 800,000 years—an astonishing archive that is perhaps the most valuable treasure yielded to us by the great Antarctic ice-sheet in the form of fossilized air bubbles trapped in the annual ice-layers. Without this natural archive, we really would be groping in the dark to understand the significance of the modern rise, given how difficult it is to divine ancient atmospheric carbon dioxide levels from "normal" strata made of sand, mud, and lime.

The ice-layers clearly show the extraordinarily metronomic oscillations of carbon dioxide levels that took place during the Ice Age, and their exceedingly close correspondence with the temperature record deduced from other chemical properties of the ice archive: thus, we know that carbon dioxide levels regularly fluctuated between around 180 ppm in cold phases of the Ice Age to around 280 ppm in warm interglacial phases (of which the Holocene is the latest). On this scale, the modern outburst of carbon dioxide is clear as a near-vertical line, extending high above the upper limit of these oscillations. Hence, since 1850 CE, more carbon dioxide (approximately 130 ppm) has been added to the atmosphere than is exchanged in normal glacial-to-interglacial transitions of the Ice Age—and this has taken place more than a hundred times more quickly. It is, of course, still rising near-vertically. It may be the most rapid major change in atmospheric carbon dioxide levels in the Earth's history.[7]

The amount of "our" carbon dioxide is enormous when we try to think of it in real terms. Although we intuitively think of gases as weightless—indeed, "as light as air"—they do possess mass. That "extra" human-produced carbon dioxide weighs about a trillion metric tons; that's about the same as 150,000 Great Pyramids of Khufu, hanging in the air above us. Considered as a layer of pure gas around the Earth, it is about a

7 The grafting of the Anthropocene carbon dioxide (and methane) trend onto the almost million-year Quaternary pattern preserved in Antarctic ice layers is nicely shown in Fig. 2. in E. W. Wolff, "Ice Sheets and the Anthropocene," in *A Stratigraphical Basis for the Anthropocene*, ed. C. N. Waters, J. A. Zalasiewicz, M. Williams, et al. (London: Geological Society London Special Publication 395, 2014), 255–63 (except that the diagram now needs to be perceptibly amended after another half-decade's worth of growth in atmospheric carbon dioxide and methane). In more detail, the shockingly abrupt rise that (in effect) terminates Holocene air, can be seen in Fig. 2 in Zalasiewicz et al., "A formal Anthropocene," 323.

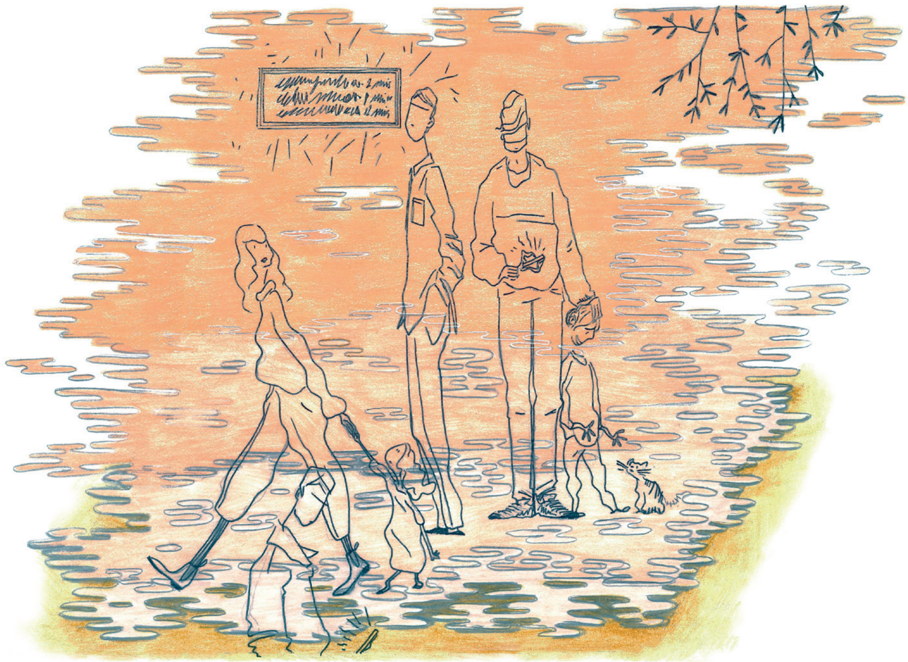


Figure 2.
The Exhaust © by Anne-Sophie Milon, 2020. The illustration portrays rising levels of atmospheric carbon dioxide that surround us all, invisibly, as we go about our daily lives.

meter thick, and so waist-high to an adult but already over the head of a small child. As it is now thickening at about a millimeter a fortnight, it will, at current rates, keep up with or outpace the growth of that child.[8]

Some gases have only brief life-spans in the atmosphere. Methane, for instance, although a much stronger greenhouse gas than carbon dioxide, is oxidized in the atmosphere (and converted into carbon dioxide) in a matter of a few years or decades. However, carbon dioxide stays in the atmosphere for many millennia until it is finally removed by the growth (and burial) of extra plant life, and by slowly reacting with rocks in what is termed "silicate weathering"—the latter probably being the most important (if slow-acting) thermostat-type control of Earth's temperature over geological timescales. The extra carbon dioxide added by humans so far has been estimated to be enough, already, to postpone the next glaciation of the Ice Age by some 50,000 years (with only modest further emissions being needed to prolong that to 100,000

8 These calculations, and other equally extraordinary ones relating to the Anthropocene, may be found in J. Zalasiewicz, M. Williams, C. N. Waters, et al., "Scale and Diversity of the Physical Technosphere: A Geological Perspective," *The Anthropocene Review* 4, no. 1 (2017): 9–22.

years). This kind of timescale is already taking the Anthropocene beyond the scale of a "blip," even a geological one.[9] As we shall see, some aspects of the Anthropocene will have a longevity far in excess even of this.

This current increase in carbon dioxide is largely responsible for the rise in the Earth's temperature over the last century, which is now a little over 1 degree Celsius above pre-industrial levels. The rise has been irregular, with pauses, largely because of the irregular way that heat is exchanged between the oceans and the atmosphere during natural climatic fluctuations, such as that of the El Nino–Southern Oscillation (ENSO). Overall, the Earth is still, just, within the "normal" interglacial temperature limits of the Ice Age, although both the oceans and the atmosphere are on a clear heating trend. If continued, later this century the Earth will break through into the kind of temperature regime last seen in the Pliocene Epoch some three million years ago, when the Earth was a couple of degrees warmer but albeit still an "icehouse" world with a substantial Antarctic ice-sheet. But if business-as-usual carbon dioxide emissions are continued for somewhat longer, then the world will be taken into the kind of world the dinosaurs enjoyed: a hothouse Earth without major polar ice-caps. This would be a fundamentally different kind of planet compared to the current one.[10]

As the Earth slowly warms in response to increased greenhouse gas levels, sea levels also respond, yet more slowly, to the increasing warmth,[11] partly by thermal expansion of seawater and partly through the melting of ice masses on land. So far, total sea level rise above the remarkably stable level of the last few millennia has been in the order of 20 centimeters, which is trivial (almost invisible) on the scale of deep geological time, but is nevertheless enough to result in perceptible changes to contemporary coastlines. The rate of sea level rise has accelerated from some 1 millimeter per year in the mid-twentieth century to around 3 millimeters per year early in this millennium, and up to approximately 4 millimeters per year in the last decade. This recent acceleration is largely due to the onset of major melting of Antarctica's and Greenland's ice-caps since

9 This forward projection—or at least a succession of alternative projections, depending on how much carbon dioxide we ultimately emit—is clearly illustrated in P. U. Clark, J. D. Shakun, S. A. Marcott, et al., "Consequences of Twenty-First-Century Policy for Multi-Millennial Climate and Sea-Level Change," *Nature Climate Change* 6, no. 4 (2016) 360–69.

10 This perspective, in the sixty-plus million-year record of the Cenozoic is shown in Fig. 1 of K. D. Burke, J. W. Williams, M. A. Chandler, et al., "Pliocene and Eocene Provide Best Analogs for Near-Future Climates," *PNAS* 115, no. 52 (2018): 13288–293.

11 The amount of extra heat entering the oceans from the greenhouse effect of carbon dioxide far exceeds the direct energy we gain from burning fossils fuels; estimates include those by L. Zannaa, S. Khatiwalab, J. M. Gregory, et al., "Global Reconstruction of Historical Ocean Heat Storage and Transport" *PNAS* 116, no. 4 (2019): 1126.

about 2000 CE—each has lost about 5 trillion tons of ice in that time, while some 10 trillion tons have been lost from mountain glaciers over a somewhat longer time period, stretching back to the last century.[12]

There is a telling geological context here, too. In the last warm interglacial phase about 125,000 years ago, when carbon dioxide levels were about 270 ppm and global temperatures were only slightly higher than today, sea level rose to somewhere between 6 and 9 meters above today's level, probably because of substantial ice melt on Antarctica as the waters around it warmed (sea levels during the third-from-last interglacial period, about 400,000 years ago, may have reached yet higher levels[13]). When considering overall oscillations in sea level over million-year time scales, 5–10 meters clearly represents a small fluctuation—one that might take place (or not) depending on relatively subtle differences in the configuration of Earth's "climate machine" at different times. Yet, as already noted, the human impact on this system has now moved, via the emission of greenhouse gases, well beyond the "subtle."

Today, trends in sea level are clearly pointing upwards. Projections suggest anything from a rise of some 65 centimeters to a couple of meters by the end of this century. Beyond this, the amount of further sea level rise will reflect whether carbon dioxide emissions are held back tightly (to allow preservation of most of the Greenland and Antarctica icesheets) or whether they continue to increase based on business-as-usual trends, triggering the ultimate loss of much or most of this ice and leading to a sea level rise of several tens of meters.[14] Given that many settlements on coastlines and deltas have been built to extend to the relatively stable sea level of the mid to late Holocene, even a 1–2 meter rise in sea level (still geologically very small) will inundate much densely populated land. The difficulties encountered in such a case will, therefore, not represent extreme Earth System change (in this respect at least), but will reflect how eagerly human populations have congregated around—and hardwired their enormous urban constructions into—the world's coastlines. These human

12 There have been a number of recent assessments of the accelerating ice melt, including J. Mouginot, E. Rignot, A. A. Bjørk, et al., "Forty-Six Years of Greenland Ice Sheet Mass Balance from 1972 to 2018," *PNAS* 116, no. 19 (2019): 9239; E. Rignot, J. Mouginot, B. Scheuchl, et al., "Four Decades of Antarctic Ice Sheet Mass Balance from 1979–2017," *PNAS* 116, no. 4 (2019): 1095; and M. Zemp, M. Huss, E. Thibert, et al., "Global Glacier Mass Changes and their Contributions to Sea-Level Rise from 1961 to 2016," *Nature* 568, no. 3 (2019): 382–86.

13 It seems that even parts of the "stable" East Antarctica ice sheet may be lost at such times—when, as was pointedly noted, carbon dioxide levels were not anywhere near as high as today's: T. Blackburn, G. H. Edwards, S. Tulaczyk, et al., "Ice Retreat in Wilkes Basin of East Antarctica During a Warm Interglacial," *Nature* 583, no. 7817 (2020): 554–59.

14 These scenarios and the feedbacks involved are discussed in J. Garbe, T. Albrecht, A. Levermann et al., "The Hysteresis of the Antarctic Ice Sheet," *Nature* 585, (2020) 538–44.

communities have often made their livelihoods more precarious, too, by settling in low-lying areas that are subject to local subsidence from land drainage and the pumping of groundwater, oil, and gas.[15] So, while sea level rise remains relatively small in relative geological terms, human populations have made themselves exceptionally vulnerable to even the slightest increases. This is a manufactured vulnerability and a natural part of an Anthropocene process.

A Mineral Epoch

While the processes behind Anthropocene climate change and sea level rise are pretty much as old as the Earth itself, other aspects are quite novel. The minerals that form our planet are its fundamental building blocks. Although intuitively one might think that the Earth's mineral assemblage has been more or less constant through its history, our planet has in fact undergone a profound and distinctive form of mineral evolution, the course of which has been elegantly described by the mineralogist Robert Hazen and his colleagues.[16] They demonstrated a succession of mineral eras and epochs that have essentially showed increased mineral diversity through time.

The process begins in interstellar space, where primordial minerals condense as dust grains following supernova explosions: about a dozen of these have been identified, including diamond and a few carbides and nitrides. As dust clouds gathered to build our solar system, these dust grains were heated and aggregated into the building blocks of planets: asteroids and planetesimals, where new minerals formed, including various silicates and oxides. About 250 minerals were present in this phase and can be identified in meteorites that land on Earth, which represent the debris from this planet-building phase. As the Earth grew and processes such as plate tectonics with volcanism and metamorphism began, planetary chemistry expanded further to give about 1,500 minerals, the natural complement of a dead rocky planet. When life appeared more than 3.5 billion years ago it initially made little difference to the Earth's mineralogy. But, when photosynthesis evolved to oxygenate the Earth's oceans and

15 J. P. M. Syvitski, A. J. Kettner, I. Overeem, et al., "Sinking Deltas Due to Human Activities," *Nature Geoscience* 2 (2009): 681–89.
16 R. M. Hazen, D. Papineau, W. Bleeker, et al., "Mineral Evolution," *American Mineralogist* 93 (2008) 1639–720.

atmosphere by about 2.5 billion years ago, a large suite of oxide and hydroxide minerals formed, taking the total towards approximately 5,000 minerals. Since that time, this composition stayed more or less stable—until now.

When humans entered the picture and began to manipulate the Earth's surface environment, they made new minerals too, or at least new inorganic crystalline compounds, which are minerals in everything but formal classification. The International Mineralogical Association, which sets the standards for such things, recently *excluded* synthetic, human-made minerals from their classification. This exclusion is in itself wholly contrived, but there is a practical kind of logic to it. Without it, mineralogists might have been overwhelmed by the flood of new materials for them to study.

What kind of "minerals" do humans make? Metals are one of the first examples. Pure "native" metals are rare in nature, with gold as the best-known exception. Native copper is occasionally found, and iron yet more rarely as meteorites (such iron was prized in ancient times, for instance meteoritic iron implements were even found in Tutankhamen's tomb). Most metals in nature, though, are bound within chemical compounds—and humans have become adept at separating them. Firstly copper, tin, and iron in ancient times, and much more recently others such as aluminum and titanium, which only exceedingly rarely occur as metal in nature, and molybdenum, vanadium, magnesium, and so on, which do not. Some metals are now separated in gargantuan amounts: the total amount of aluminum produced globally, which now exceeds 500 million tons (almost all since 1950 CE), is enough to cover the entire land surface of the United States and part of Canada in standard, kitchen aluminum foil. The amount of iron produced is well over an order of magnitude greater still. These novelties are therefore present in *geological* amounts—sufficient to help characterize Anthropocene strata, particularly in urban settings.

This phenomenon goes well beyond metals; it includes many inorganic crystalline compounds synthesized in laboratories worldwide for a wide variety of purposes, such as novel synthetic garnets for lasers, tungsten carbide for ballpoint pens, semiconductor materials, the abrasive boron carbide ("borazon") that is harder than diamond, and many others. An early 2014 study hazarded that the number of minerals *sensu lato* may

Figure 3. Total world aluminum as kitchen foil covering the United States, © Yesenia Thibault-Picazo.

have been doubled by the synthesizing activities of humans.[17] That was way off the mark. In a thorough 2016 assessment of "Anthropocene mineralogy," Hazen and colleagues[18] noted the existence of the Karlsruhe-based Inorganic Crystal Structure Database, which then had records of more than 180,000 such inorganic compounds! As of November 2019, there were more than 216,000 listed. Human ingenuity has, therefore, multiplied the number of "minerals" on Earth more than 40-fold, mostly over the last hundred years or so. In a commentary on this paper, the mineralogist Peter Heaney noted that while in most aspects the story of the Anthropocene was one of destruction and reduction in diversity, in this respect the Anthropocene represented a huge, extraordinary *increase* in diversity, one with no parallels on any other planet in the Solar System—and perhaps with any planet in the cosmos.[19]

17 J. Zalasiewicz, R. Kryza, and M. Williams, "The Mineral Signature of the Anthropocene," in *A Stratigraphical Basis for the Anthropocene*, ed. C. N. Waters, J. A. Zalasiewicz, M. Williams, et al. (London: Geological Society of London Special Publication 395, 2014), 109–17.
18 R. M. Hazen, E. S. Grew, M. J. Origlieri, and R. T. Downs, "On the Mineralogy of the 'Anthropocene Epoch'," *American Mineralogist* 102 (2017): 595–611.
19 P. J. Heaney, "Defining Minerals in The Age of Humans," *American Mineralogist* 102 (2017): 925–26.

Among the materials that we synthesize are the plastics. These are not quite minerals as such because they are organic compounds, with chemical compositions that can vary within fixed limits (nevertheless, there are organic "minerals" recognized in geology with which comparisons may be made, such as amber). But this family of modern "mineraloids" is rapidly growing to form a part of—or even overwhelm, some might say—the Anthropocene, with a capacity to become part of global geology that is in some ways greater than that of minerals *sensu stricto*. Plastics have a growth curve that closely resembles that of aluminum, with negligible pre–World War II production growing to roughly 1 million tons per year by 1950, and then rapidly to more than 300 million tons per year today.

Plastics are useful to us for a variety of reasons: they are light, strong, and resistant to abrasion, breakage, and decay, which is what makes them so geologically important. Once discarded (and much plastic is designed to be discarded immediately after a single use), plastic debris is easily transported by wind and water across landscapes and, with rivers as major conduits, to coastlines. From there, it is carried by ocean currents to distant shores and into the deep ocean. A major component recognized only relatively recently is microplastics, especially textile-derived fibers, which have been shown to contaminate sediment almost universally in the oceans—even sea-floor sediments in the very deep ocean, thousands of miles from land.

It is such a new and recently recognized global phenomenon that scientists are scrambling to get to grips with it. As a topic, it was barely on the radar when the AWG began its analysis in 2009; by 2015, it had become a major issue in environmental studies generally, and as one spin-off, plastics were emerging as an important characterizing element of Anthropocene strata.[20] There are still many unknowns—for instance, paradoxically, the distribution of plastics on land is far more complex and therefore more difficult to assess than it is in the oceans. The land is still by far the greatest store of plastics, and so will continue to leak them into the oceans for centuries, and likely millennia, to come. Those plastics are clearly becoming a damaging (and an indigestible and often lethal) part of the biological food chain, too, hence the rising public concern about them.

20 J. Zalasiewicz, C. N. Waters, J. Ivar do Sul, et al., "The Geological Cycle of Plastics and Their Use as a Stratigraphic Indicator of the Anthropocene," *Anthropocene* 13 (2016): 4–17.

The incorporation of plastics into the sedimentary record—that is, into far-future rock strata—is significant in demonstrating the geological character of this modern material. Contemplating the plethora of distinctive far-future fossils that will be produced—something that may intrigue some far-future paleontologist—may seem abstract. But there is a more immediate and practical significance here too, working in the short-term. When plastics are at the surface, it is clear that they can interact with the local ecosystem, almost always to its detriment. Once they are buried deeply enough to become part of some future stratum, they are removed from biological interactions, and may be thought to be safely and permanently sequestered. But it is the intervening stage—when plastics are buried out of sight for easy study but interacting with soil ecosystems on land and benthic ecosystems on the sea floor, and still capable of being reworked back to the surface—that is critical, biologically significant, and currently largely mysterious. This transitional phase, when plastics are *becoming* geology but have not yet become so, is ripe for study.

Bulk Materials

Plastics are one kind of newly created material that has been produced on a geological scale: the approximately 9 billion tons produced so far since the mid-twentieth century would allow the whole globe to be wrapped in somewhere between one and two layers of standard kitchen food wrap. But other materials have been extracted and dispersed by humans in far greater bulk—if perhaps not yet dispersed quite as widely as plastics.

Currently, something like 316 *billion* tons of material are moved and reworked annually by humans[21]—of which plastics are a one-thousandth part. Something more than a hundredth part is made up by concrete: a material that, although made (after a fashion) by the Romans, has become the signature synthetic rock of the Anthropocene, the graph of its seemingly inexorable rise in production[22] being remarkably similar to that of plastics, carbon dioxide emissions, "mineral" species, and many other of the aspects that Will Steffen, John McNeill, and their colleagues have demonstrated as showing the "Great Acceleration" of population growth, industrialization, and globalization in the mid-twentieth century.[23]

21 A. H. Cooper, T. J. Brown, S. J. Price, et al., "Humans Are the Most Significant Global Geological Driving Force of the 21st Century," *The Anthropocene Review* 5 (2018): 222–29.
22 See Fig. 1 in Waters et al., "The Anthropocene," 2262–62.
23 The original classic paper is: W. Steffen, P. J. Crutzen, and J. R. McNeill "The Anthropocene: Are Humans Now Overwhelming the Great Forces of Nature?," *Ambio* 36 (2007): 614–21. It was later updated: W. Steffen, W. Broadgate, L. Deutsch, et al., "The Trajectory of the Anthropocene: The Great Acceleration," *Anthropocene Review* 2, no. 1 (2015): 81–98.

A large part of this crescendo of earth and rock movement is in the digging for such things as coal, where one needs consider not only the mass of the material itself (with coal currently nearing 8 billion tons, or roughly double the mass of the annual production of concrete) but also the mass of the earth and rock "overburden" that needs to be shifted in order to get to the hydrocarbon mineral itself. For coal, this can currently be up to 20 times the amount of the mineral itself; for a high-value mineral like diamond, up to ten tons of rock might be processed to obtain a single gram of diamond. And then, more prosaically, there is the scale of landscape movement, as towns and cities are built and rebuilt—which is much harder to assess globally (and even locally). In the study that produced the 316-billion-ton estimate, the arbitrary figure factored in for such landscape reshaping was twice that of the concrete involved, likely a large underestimate, while such forms of earth movement as ploughing, deep sea trawling, and mountain road construction were omitted altogether to prevent the study, already gigantic in scope, from becoming endless and unfinishable. Hence the annual 316 billion tons calculated (the figure for 2015 CE, and now probably larger by a few billion tons) is likely to be a significant underestimate.

Nevertheless, the 316 billion tons comfortably exceeds—by some 24 times—the amount of sediment transported annually by rivers into the sea. Even this comparison has been skewed by the forces of the Anthropocene, for humans have interfered mightily with the world's fluvial plumbing in the construction of dams across most of the world's major rivers and a good proportion of the minor ones, with much sediment now being held back behind these dams, rather than reaching the sea.

Add all of this up, as another research group did—and this time to include the ploughlands, the trawled sea floor, and so on, all as part of what one might call the "physical technosphere" (more on the technosphere anon)—and a back-of-an-envelope calculation indicated that humans use, have used, and have discarded some 30 trillion tons of Earth material, most of it since the mid-twentieth century.[24] This is equivalent to a layer of rubble and soil averaging 50 kilograms on each square meter of the Earth's surface—land and sea. As a species, we are almost literally trudging ankle-deep though the debris of the Anthropocene, with progress becoming almost perceptibly harder each year.

24 Zalasiewicz et al., "Scale and Diversity," 12.

The Scale of Absent Life

While dealing with these multiples of billions of tons of mainly inorganic matter, we can note the comparison with the mass of life on Earth. This has recently been calculated—an extraordinary task!—with the error bars for some categories being very great. We know, for instance, that there is a "deep buried biosphere" of microbes with extremely slow metabolic rates living within fractures and pore spaces in rocks a kilometer and more below the Earth's surface—but how much of such cryptic, subterranean life is there? Estimates have ranged from amounts comparable with visible surface life to only a small fraction of this. Even weighing a forest, which can be imaged precisely with a satellite and walked through in "ground-truthing," is not a trivial task. Nevertheless, a figure was arrived at for the mass of all life on Earth, totaling 550 billion tons of carbon-equivalent.[25] Add in the other elements of which life is composed, and the water content too, and life on Earth weighs in at some 2.5 trillion tons (or, about a billion tons on a dry-mass basis, leaving out the water): a large figure, but dwarfed by the combination of our constructions and abundant cast-offs.

Much of this mass of Earthly life is made up of forests—and here there is a clear human impact too. The authors of the study suggest, in a throwaway remark, that humans have roughly halved this living mass, largely by replacing forests with biotas that, while more immediately useful to us—such as pastures and cornfields—possess much less living *avoirdupois*. This trend, of course, has been in progress throughout much of the Holocene, if intensifying in the Anthropocene.

Within this overall decline, there have been some substantial winners and a rather larger number of losers. The major winners show up clearly on mass estimates of medium- to large-sized terrestrial vertebrates. These are humans, who collectively now make up about a third of the entire total of this category of body mass—a remarkable ascendency for one species. Most of the remaining two-thirds is made of the animals we keep to eat: cows, pigs, goats, chickens, and others, though here the numerical abundance can only be regarded, for the animals concerned, as the most heavily qualified of victories.

25 Y. M. Bar-On, R. Phillips, and R. Milo, "The Biomass Distribution on Earth," *PNAS* 115, no. 25 (2018): 6506–511.

The geological baseline clearly shows just how large this skewing of the terrestrial fauna has been. The paleontologist Anthony Barnosky in 2008 reviewed the number of species of terrestrial megafauna (those weighing more than 44 kilograms) in the Pleistocene, before humans began to make an impact on their numbers.[26] Then, this terrestrial biomass was divided among some 350 species, including such iconic forms as the mastodon, mammoth, and woolly rhinoceros. Hunting by humans (largely) then roughly halved this number between about 50,000 and 7,000 years ago in what has come to be called the Quaternary Megafaunal Extinction, with the peak losses being clustered about 10,000 years ago.

This reduction in wild terrestrial vertebrates was later balanced and then outweighed by the growing stocks of domestic animals, a trend that was also caught up in the steep upswing of the Great Acceleration, notably when the synthesis of nitrogen-based fertilizers allowed the supercharged production of grain and increased pasture growth that allowed animals to be fed efficiently, so that they could be fed to us. By this means, the total bulk of large vertebrates globally has increased perhaps ten-fold over long-term baseline values, and continues to increase, while populations of wild mammals continue to fall.

One animal that symbolizes this ecological metamorphosis is the chicken, and specifically the broiler chicken. Grown for meat, it is now a staple of supermarkets and ready-made sandwiches globally. The chicken has a long history of domestication, reaching back perhaps 8,000 years in tropical south- and south-east Asia, where its free-running, long-lived ancestor, the red jungle fowl *Gallus gallus*, still lives. The domesticated version, bred for fighting as well as meat, was taken to the Mediterranean region and Europe (its bones being common at Roman archeological sites) and to the New World in the sixteenth century. Through all of this time, the bird did not differ greatly from its wild ancestor, at least as far as its basic skeletal infrastructure was concerned.

This changed in the early 1950s, with the Chicken-of-Tomorrow program spurring American-based competitions that led to intense breeding together with industrial-scale "vertical integration systems," putting breeding units, farms, slaughterhouses, and

26 A. D. Barnosky, "Megafauna Biomass Tradeoff as a Driver of Quaternary and Future Extinctions," *Proceedings of the National Academy of Sciences* (USA) 105, no. 1 (2008): 11543–48.

marketing into gargantuan combines that now dominate production in the United States and in many other parts of the world. As a result, the chicken has become by far the most numerous bird globally, with a standing stock of some 23 billion (by contrast, the population of sparrows is about half a billion, and of pigeons about 400 million), and indeed it outweighs all the other birds in the world *combined*, by a considerable margin.

Figure 4. Comparison of the limb bones of a modern broiler chicken (*left*) and its ancestor, the red jungle fowl of Asia (*right*), at the same age of ~6 weeks. The jungle fowl can go on to live for a decade or more, while the broiler chicken has reached slaughter age (and would not live much longer in any case). Image copyright of the Trustees of the Natural History Museum, London. The two specimens are held by the Natural History Museum London and the University of Leicester. Image reproduced here with permission.

Since the mid-twentieth century, it has also become a different bird, some three to four times larger in bulk than its wild ancestor: its bones are super-sized to match, and are now clearly distinct from those of both the wild ancestor and of the chicken remains recovered from pre-1950 archaeological sites. Paleontologists would call it a new morphospecies—and one of extraordinary abundance, for its hyper-abundance at any one time is combined with a life-cycle, from egg to abattoir, of little more than six weeks. There is a correspondingly huge flux of these hypertrophied bones, therefore, going from dinner plates to rubbish tips and landfill sites, where, buried, they are protected from immediate scavenging and decay, enhancing the prospects for long-term fossilization. Amid all of the complexity of biological change across the Holocene–Anthropocene interval, the sudden worldwide appearance of this monstrously overgrown chicken skeleton is one clear paleontological marker of the Anthropocene. To add to its distinctiveness, the bones are chemically recognizable too—the carbon and nitrogen isotope ratios are clearly distinct, reflecting the change from scratching around in farmyards and back gardens to a factory-controlled diet via multinational animal-feed suppliers.[27] It is yet one more consequence (a planned and earnestly desired one, this time) of the steep rise in fertilizer use, which fuels the new food chain designed for humans.

27 C. E. Bennett, R. Thomas, M. Williams, et al., "The Broiler Chicken as a Signal of a Human Reconfigured Biosphere," *Royal Society Open Science* 5 (2018): 180325.

As one food chain grows, another one diminishes. This is not a pre-ordained rule; but at least for some parts of Earth's biology, it is now empirical observation. The steep decline in large wild animals worldwide, the contemporary continuation of the megafaunal extinctions, is at least obvious; these are large targets. But the extraordinary decline in flying insects is less intuitive, as one thinks of flies, wasps, mosquitoes, and midges as the ultimate survivors, organisms that can survive and flourish in any circumstances. Hence, the palpable sense of shock that followed the beautifully conducted, if deeply sobering, study of the Krefeld Entomological Society that showed these age-old pests of humans to be sensitive and indeed acutely vulnerable to changes in the world around them.[28] The study is a classic example of painstaking, systematic, methodical—and, to be sure, highly tedious—data collection, with no guarantee that any striking scientific result will emerge. Indeed, it would have been much better in hindsight if the results had been as tedious and mundane as the research behind it.

The study was carried out annually from 1986, trapping flying insects in nature reserves in Germany, collecting them, and weighing them. Obtaining meaningful results in such a study is a decidedly non-trivial exercise. The insects were logged on average every 11 days at 63 different locations, giving a haul of 53.54 kilograms of insects (equivalent to, say, the body mass of a small adult human) from a "total trap exposure period" of 16,908 days (or just over 46 years). Cleaning out the Augean Stables, that legendary task of Hercules, seems to represent a light spring-clean by comparison. The weighing alone was a fraught exercise, as the insects were stored in alcohol: a full half-page of text is taken up outlining the careful protocol needed to weigh alcohol-sodden dead insects and extract a representative mass value from the results. And as for looking in more detail—trying to identify the insects taxonomically instead of treating them all together in their *en masse* laboratory grave—the researchers merely said that that was another task for another (yet longer) day.

As it happens, there was probably no need for such hair-splitting exactitude: the results are not in the least bit subtle. Over that 27-year period, the mass of flying insects in *nature protected areas* (not farms, towns, or cities) declined by three-quarters—and in summer by over 80 percent. It is a striking reduction in organisms near the base of the food chain. Was it just a regional phenomenon in a highly urbanized central European

28 A. Hallmann, A. Sorg, E. Jongejans, et al., "More Than 75% Decline over 27 Years in Total Flying Insect Biomass in Protected Areas," *PLOS One* 12, no. 10 (2017): e0 185809.

country with modern agriculture? No—similar patterns and similar levels of insect decline have been reported elsewhere,[29] in the tropical forests of Puerto Rico as well as in Denmark and the United Kingdom. The precise reasons remain unclear. In Europe, factors such as pesticide use, habitat loss, and light and noise pollution are cited; in Puerto Rico, it's suggested that a warming climate is largely to blame.

Something big is clearly going on—indeed, on a geological scale, with reverberations beyond the insect world, as concomitant declines in insectivorous birds are being reported too. *But*, most of these extraordinary studies, like those of the Krefeld community, began towards the end of the twentieth century, well after the phenomena of the Great Acceleration were underway, and so insects were likely already in considerable decline even at the start of these studies. Indeed, as landscape changes from agriculture and urbanization date back well into the Holocene, it is likely that insect communities were beginning to change thousands of years ago.

The trouble comes when trying to get a sensible idea of the scale of these changes. For this, one would need to have a *long-term* baseline measure of flying insect abundance, in the way that ice cores provide a marvelous record of atmospheric carbon dioxide measurements, and the way that cores of lake sediment can show when long-lived pesticides such as DDT, dieldrin, and aldrin began to become widely dispersed, even in remote environments, in the mid-twentieth century.[30] Insects and paleontology, though, do not go together as easily as, say, mollusks (or even dinosaurs) and paleontology; the insect exoskeleton is marvelously adapted to serve these organisms in life, but many are too small and frail to help transfer into the fossil record after death. And so this particular kind of biological change is not easily inscribed into the usual geological archives.

That is not to say that insects do not fossilize at all. There is that almost fabled record of fossilized dragonflies with half-meter wingspans from the coal forest swamp strata of Carboniferous times, for instance (the fable turns out to be true in this case—albeit very rarely encountered). And there are some well-established paleontological cottage industries among the many forms of science done on the deposits of the Ice Age: the

29 For example: P. Cardoso, P. S. Barton, K. Birkhofer, et al., "Scientists' Warning to Humanity on Insect Extinctions," *Biological Conservation* 242 (2020): 108426.
30 Scotland's Lochnagar is a nicely studied example: D. C. G. Muir, and N. L. Rose, "Persistent Organic Pollutants in the Sediments of Lochnagar," in *Lochnagar: The Natural History of a Mountain Lake, Developments in Paleoenvironmental Research*, ed. N. L. Rose (Dordrecht: Springer, 2007), 375–402.

fossilized wing-cases of beetles and head-capsules of midges are among the kinds of biological proxy used to help reconstruct the scale and speed of climate change in the past. But it is one thing to do this kind of science where the discovery of just one fossil specimen can provide a clue to past climate, and quite another to use these patchy finds to work out the total biomass of all flying insects in the region at some prehistoric time. The power of the Anthropocene concept in providing deep-time baselines can therefore vary markedly, depending on the "fossilization" potential of each component phenomenon within the Earth System. Will some ingenious paleo-entomologist ever manage to work out a technique to provide a plausible baseline against which the modern insect decline can be placed? That would be a fascinating, and indeed important, development in paleontology.

The Rise of Technology

The driver of all of these changes is, of course, in one sense the ingenuity, social nature, and manipulativeness of the growing number of humans on this planet, as the term "Anthropocene" implies. But, for all of the extraordinary powers of the human brain, individually and collectively, and of the opposable thumb, there is much more to it than that. To take over a planet, one needs the proper tools. Given the potential of those two human organs, these tools came to be.

Technology is clearly a means to ratchet up human ability to win and use resources for our species' benefit. This has been the case from the Stone Age times of the late Pleistocene onwards, with the ubiquity of flint arrowheads and axe heads and progressive developments in the use of metals, textiles, and other materials through the Holocene. But as technology has vastly diversified and become more powerful, sophisticated, and pervasive since the Industrial Revolution, one might say that it is now arguably the key driver of Anthropocene change.

Geologist Peter Haff speaks of it in terms of the *technosphere*,[31] and makes several points about this new "sphere" on Earth. One is that it is not just the sum total of all our technological objects, interpreted widely to be not just machines but also buildings,

31 P. K. Haff, "Technology as a Geological Phenomenon: Implications for Human Well-Being," in *A Stratigraphical Basis for the Anthropocene*, ed. C. N. Waters, J. Zalasiewicz, and M. Williams (London: Geological Society of London Special Publication 395, 2014), 301–9. See also: P. Haff, "The Technosphere and its Physical Stratigraphic Record," in *The Anthropocene as a Geological Time Unit: A Guide to the Scientific Evidence and Current Debate*, ed. J. Zalasiewicz, C. N. Waters, M. Williams, and C. P. Summerhayes (Cambridge, UK: Cambridge University Press, 2019), 137–55.

roads, dams, reservoirs, and farms (part of the farm machinery is now that supermarket chicken, a technological construct, quite unable to survive in the wild and fated to endure its short existence within a still-biological and sentient frame). Humans, in this view, individually and collectively, are also components of the technosphere: utterly dependent upon it—for without our various technological aids the Earth could not support more than a few tens of millions of people, living as in the Pleistocene as hunter-gatherers. Much human effort is now directed to maintain and ever further develop the already gigantic, and growing, technological construct on this planet. And the technosphere is taking on—perhaps not quite a life (yet)—but at least a momentum and dynamic of its own.

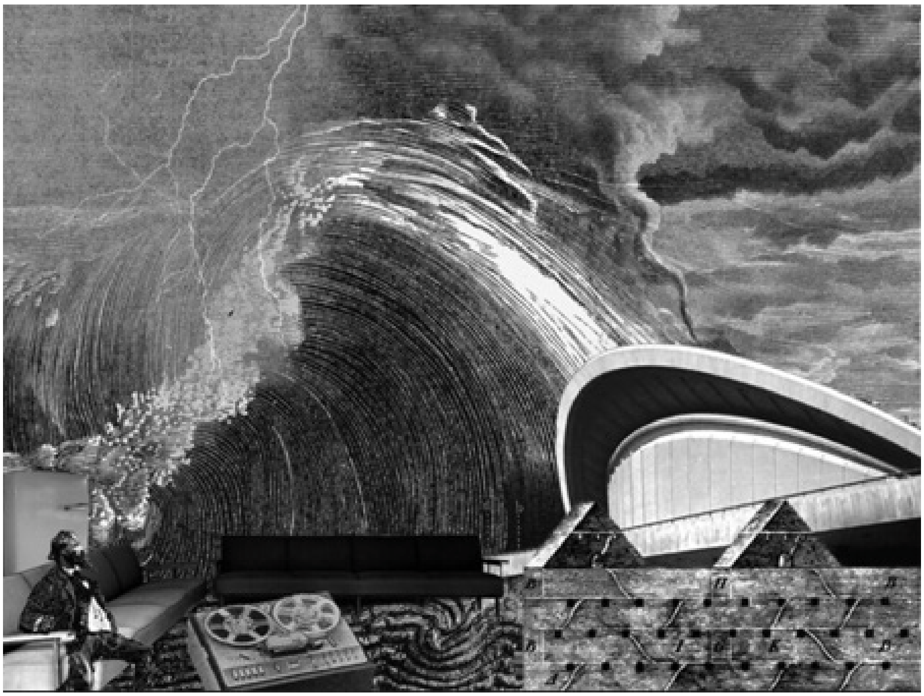


Figure 5.
Image is from the Technosphere Interview Collages created by Nina Jäger for the magazine *continent.*, Issue 5.2 (2016). CC BY 2.0, available from *continent.* via flickr.

The technosphere is greater than the sum of its parts. In the same way that the biosphere is not just the total tally of all the animals, plants, and microbes on earth, but includes all of the fluxes and interactions of matter and energy between them—and also between it and the rocks of the lithosphere, and the water and air of the hydrosphere and the atmosphere. The technosphere includes all of these interactions and is now large and powerful enough to change the nature of these other spheres. It unfolded from the biosphere, and is now growing rapidly at the expense of it.

The rate of growth and evolution of this planetary novelty is extraordinary. The biosphere can change and show major innovations too, of course, and the nature and rate of this change can be tracked in the geological record. Of famously rapid transitions, the most iconic is the development of a complex ecosystem of multicellular animals, following the billions of years of microbial domination of Earth. This half-billion-year-old transition, the "Cambrian explosion" that so puzzled Charles Darwin, is indeed a step change in the Earth System. And yet, anatomized in real time as generations of geologists have pored over the critical intervals of strata, this "explosion" turns out to have taken some thirty million years, encompassing, as stages within it, the emergence of burrowing animals, the development of hard skeletons, and the appearance of those poster-child fossils, the trilobites, that went on to dominate the sea floors of the Paleozoic Era. As Preston Cloud, that noted savant of Precambrian times, observed, it was more like a "Cambrian eruption."

The development of a technosphere, now becoming comparable in mass and energy consumption to the whole of the biosphere, took by contrast a matter of a few millennia (if one wants to include its early, locally dispersed stages) or a few centuries if one considers it as an interconnected planetary system. Most of its growth and diversification has happened since the mid-twentieth century Great Acceleration. How can one appreciate its scale and scope? Considering it in terms of human technological history puts it in a category that is *sui generis*—phenomenal, but isolated, with nothing to compare it to in the natural world. But considering it as something that lies within the reach of paleontology does provide a certain kind of context.

The manufactured objects of the technosphere are artifacts to an archaeologist or historian, putting them firmly within the human realm. But thinking of them as biologically constructed, potentially fossilizeable objects—technofossils[32]—brings them into the realm of ichnofossils, also known as trace fossils, where they share conceptual space with fossilized burrows and footprints. Perhaps more particularly, technofossils may be compared to some of the more elaborate constructs of the animal world. Among the million-year old volcanic strata of Tenerife, for instance, there are fossil soils among which can be found hundreds of acorn-sized and -shaped nests made by burrowing wasps, constructed of carefully selected pumice fragments as precisely and neatly assembled as any of the stone huts made by our ancestors. And on a larger, more collective scale, there are the mega-skyscrapers of the insect world: the termite nests that entomologists marvel at, with their myriad internal passages and heat regulation and air conditioning systems, which can be up to 10 meters high and a thousand cubic meters in volume. These extraordinary structures can be fossilized too—fine examples have been found in Africa and South America, ranging back to Jurassic antiquity. Such structures yield little to the Empire State Building in sophistication—and suggest that thinking of the technological constructions of humanity through a paleontological lens may not be completely outlandish as an exercise.

The petrified early Jurassic termite nests of South Africa show “advanced” construction, according to their discoverers.[33] Hence, this iconic kind of animal architecture has existed on Earth for some 150 million years, having evolved from simpler constructions that have been found amongst the strata of the Triassic Period, formed some 50 million years previously. The hardware manufactured by these organisms is therefore evolving at rates comparable to biological evolution, where individual species spans are typically a few million years and more fundamental changes in the biological ground plan—the appearance of plankton communities with calcium carbonate skeletons, for instance (also an invention of Jurassic times)—take place every few tens or hundreds of millions of years. The “technology” of nonhuman animals is thoroughly a part of their biology, and the complex behaviors that allow such constructions are as much under direct genetic control as are the biochemical processes that make up their tissues and skeletons—and have also been integrated over geological timescales into the ecological webs of the Earth’s biosphere.

32 J. Zalasiewicz, M. Williams, C. N. Waters, et al.,“The Technofossil Record of Humans,” *The Anthropocene Review* 1 (2014): 34–43.

33 E. M. Bordy, A. J. Bumby, O. Catuneanu, et al., “Advanced Early Jurassic Termite (Insecta: Isoptera) Nests: Evidence from the Clarens Formation in the Tuli Basin, Southern Africa,” *Palaios* 19 (2004): 68–78.

Figure 6. A random selection of discarded technofossils left between the cobbles of a street in Padua. In a form of technological selection, their presence has been determined by their size, shape, and density to escape the street cleaning process, while myriad of their local kin have been carried to a landfill site or incinerator. The cobbles, though more ancient, are now artisanally cemented into place to become technofossils in their own right. Photograph by the author.

Human technology has departed from this long-established pattern. The earliest human technologies—indeed, pre-dating our own species—remained much the same over many millennia. Technology and the nature of artifacts evolved, in fits and starts, more quickly over the Holocene. But, an eighteenth-century human, even one living, say, in the heart of Paris, Berlin, or London, could not have foreseen the speeding—the *zoom*, as the science journalist Andrew Revkin has put it—of the rate of this kind of evolution, nor the rate of increase in the diversity and sophistication of the technological objects that were to come. Now, one human lifetime can encompass the change from typewriters and fountain pens to computers and the internet; one human decade can see the introduction of a novelty like the mobile phone, and see it spread across the entire world and undergo several generations, each more sophisticated then the last. Technological evolution is now completely divorced from the biological evolution of the humans that make the technology. It might even be argued that it is at least partly detached from the cultural evolution of humans (while technological evolution may be, rather, to a greater extent, driving cultural evolution).

Whatever the social and technological processes at the heart of this, the *paleontological* record will be one of the sudden appearance of an almost surreal hyper-diversity of fossilizeable objects. There are now likely hundreds of millions of distinct "technospecies," many of which are built for robustness and durability[34]—and hence, fossilizeability.

34 See discussion in Zalasiewicz et al., "Scale and Diversity," 19–20.

This far exceeds the standing stock of biological species; of the order of ten million biological species exist today, many if not most being soft-bodied and therefore not easily fossilizeable. And, the novel technospecies are now evolving several orders of magnitude more quickly than organisms have evolved at any time in Earth's previous history. The rate of evolution is, indeed, so great that few strata, natural or human-made, will be capable of preserving its precise pattern into the far future. Even a single landfill site may span all of humanity's electronic revolution. Any paleo-archaeologist of the far future[35] will see a transition as abrupt as the Cretaceous-Tertiary boundary, but expressed as an evolutionary radiation—at least of technofossils (and minerals too)—rather than as a mass extinction.

Possibilities

The possibilities here—of what a far future paleo-archaeologist might see in the strata that will represent our immediate future and will come to overlie the ones we know—seem too various now to project, perhaps even to enumerate. The trajectory of global warming, of sea level rise, of ocean acidification, even of mass biological extinction, can be modelled and projected, based in part on solid physico-chemical principles and in part on the many examples we can read from ancient strata, reflecting the times when the Earth has gone through comparable crises. But when dealing with one of the true novelties of the Anthropocene, the global spread and intensification of the technosphere, we have nothing to go on.

Will the technosphere's evolution be brought to a rapid halt, overwhelmed as its waste products destabilize Earth's heat balance and stifle the capabilities of its human intermediaries to maintain it? Will it undergo a succession of boom-bust cycles before attaining some kind of stable relationship with the biosphere, instead of (as at present) parasitizing and weakening it? Can it become independent of humans—and indeed come to behave as if the biosphere was expendable? Silicon intelligence (that does not necessarily have to be sentient) coupled with technological agency is a wild card in Earth history that makes narrative options alarmingly open.

35 The perplexities of a far future paleontologist are explored in J. Zalasiewicz, *The Earth After Us: The Legacy That Humans Will Leave in The Rocks* (Oxford: Oxford University Press, 2008), 272.

What will determine which, if any, of these planetary options, which seem more like lurid sci-fi than respectable Earth System science, will emerge? How different will the emerging Anthropocene be from the Holocene—and from all the preceding geological epochs? The pathways, at least for now, still largely seem to depend on the interplay of human forces (that in turn determine the physical *forcings* affecting the planet), within familiar political, economic, and social arenas. These are the forces that will be discussed next, as Julia Adeney Thomas takes this narrative further and deeper. *Much* further and deeper, indeed, into realms that are far more complex and mysterious than anything that this simple narrative has produced.

Part of this leap in what one might call the scale of perplexity is the difference between tackling problems of cause and effect. It is a difference that is seen in geology, too. For instance, the end-Cretaceous mass extinction is now pretty well tied down to a giant asteroid impact on Mexico, 66 million years ago. The effects are uncomplicated enough: a whole lot of fossil species disappear at that stratal level, and new ones slowly begin to appear in the younger levels above; a thin layer at the disappearance level appears with more iridium than is seemly, with tiny particles of physically-shocked mineral, and so on. It took a lot of steady work to pin down this physical succession (impatient scientists need not apply for this kind of task), but the techniques are generally straightforward, and the resulting patterns are as simple as you please—just as sharp and simple as are the Anthropocene patterns of a sudden flood of plastic particles and a sharp jump in atmospheric carbon dioxide levels, and so on. The resulting picture is clearly defined and about as subtle as a brick.

Ah, but, working out quite *why* the Mexico impact was so lethal is another matter entirely. There were other large impacts in the geological record that did not generate anything like so much mayhem within the biosphere—so what particular combination of blast forces, chemical fallout, climate feedbacks, ecosystem responses, and so on (one can carry on adding potentially significant factors for quite some time) were responsible for the scale of the mass kill, and how did they work? This conundrum is still a work in progress.

There are many such riddles in geology, where one has to try to puzzle through the workings of physical, chemical, and biological processes. But none so far, where one has to also factor in investment decisions by brokers, political ambitions, military strategy, religious ideals, community traditions, football team allegiances, tax policy, advertising revenues, agricultural subsidies, women's rights, levels of economic inequality (and here one can go on for *much* longer than in considering the workings of Cretaceous times). All these socio-economic and political factors are in the process of producing geology, some on a huge scale. This is something quite new and quite bewildering for geologists, who are not so much fish out of water here, as fish tipped into outer space on the far side of some distant asteroid.

This is where the kind of narratives developed by Julia Adeney Thomas in the following pages are so important, in beginning the task of making sensible and useful patterns out of this ever-changing and growing maelstrom of human activity. It really is key to understanding, and seeking to come to terms with, the Anthropocene. Such stories, as she says, matter.

And if, all in all, among these stories, amid this interlacing of age-old and terribly new power struggles, the Earth is seen as a player and not simply a stage, then perhaps the Anthropocene can still remain Holocene-like enough to remain a mere epoch, rather than growing monstrously into a period, era, or eon. If it remains modest, it might perhaps remain, also, a friend to us.

The Anthropocene Earth System and Three Human Stories

Julia Adeney Thomas

Detail from *Climate Change Data*, © Jill Pelto

People tell stories, and always have. Now that geologists are signaling a new chapter in Earth's story, humanists and social scientists are chiming in with their versions of the Anthropocene narrative.[1] The resulting cacophony can be distilled into three types of narrative, all portraying humanity in relation to Earth in the Anthropocene. The first might be called "Anything Goes" because it makes little reference to the science. The result is an array of imaginative terms and alternative planetary visions. But, because this way of talking about the Anthropocene maintains the traditional separation between Earth's condition as understood by scientists and the stories told by humanists and social scientists for the past two hundred years, it is deeply conservative. The Anthropocene changes little or nothing about the old ways of plotting stories and judging protagonists.

The two other types of narrative take Earth System science (ESS) seriously. Both recognize the new epoch's fundamental challenge to the ways we've thought about human values and destinies. They also acknowledge the non-negotiable limits it puts on our potential plotlines. What I will call the "Singular Story" aims at interdisciplinary synthesis, making geology, poetry, politics, and everything else speak the same language so that humanity can be included in large-scale computational models of the Earth System. From this perspective, the human story—the evolution of our species, animal domestication, the efflorescence of agriculture, complex political societies, economic forms, and values—evolved within the Earth System story until the mid-twentieth century when, as a species, we started overwhelming the great forces of nature. Now our collective activity is calculated alongside ocean dynamics, terrestrial ecosystems, tropospheric chemistry, and a host of other powerful forces.

A third group of stories promotes a "Democracy of Voices." While taking the science seriously, it argues that our best hope is not to insist on a single tale, but to play up the diversity of perspectives that has been the strong suit of our species as well as the ace card of the humanities and social sciences. This multiplicity retains the resilience-building pluralism of diverse cultures, *but only to the extent warranted* by planetary boundaries. Both the "Singular Story" and the "Democracy of Voices" accept that humanity's Anthropocene stories are constrained in ways they never were in the

1 Helmuth Trischler highlights the speed with which the concept of the Anthropocene entered non-scientific fields and the lively debates it has engendered. See Trischler, "Introduction," in "Anthropocene: Exploring the Future of the Age of Humans," ed. Helmuth Trischler, *RCC Perspectives: Transformations in Environment and Society*, no. 3 (2013), doi.org/10.5282/rcc/5603.

Holocene. Back then, the time and space for experimentation appeared limitless. Now, our time is short and our planet feels smaller. As we struggle to bend the Earth System's trajectory toward a stabilized state, we will need both the singular global story and small-scale textured tales of Anthropocene experiences. We need both the global narrative incorporating everything, as well as many diverse, redundant experiments in resilience that might provide ballast as we lurch over thresholds and tipping points. Unlike the "Anything Goes" approach, both these types of story are radical in their commitment to understanding Anthropocene science. In short, they aim to be true both to our new reality and to our old powers of invention. Below I explore these three types of stories, focusing especially on the second and third in relation to the Earth System's trajectory in the Anthropocene.[2]

Storytelling

The point I want to make about the Anthropocene is, fundamentally, a humanist's point: reality does not dictate the stories we tell ourselves. Even the reality of the Anthropocene, all-encompassing though it is, gives rise to more than just one storyline. I'm not talking about fiction. With the true stories of history, anthropology, economics, and much else, reality has constrained narrative possibilities only loosely, if at all. For instance, it's a fact that we all die, but tales of transcending death and attaining immortality of one sort or another are everywhere. The discipline of history, philosopher Hannah Arendt argued, was founded by the ancient Greeks to ensure that some mere mortals—the heroes among us—might become as gods, living forever through verse.[3] It's also true that water flows downhill, but we dream up pulleys, pumps, and water wheels to move it in desired directions, telling ourselves tales about our conquest of nature.[4]

2 Will Steffen et al., "Trajectories of the Earth System in the Anthropocene," *PNAS* 115, no. 33 (14 August, 2018): 8252–59.

3 Hannah Arendt, "The Concept of History," *Between Past and Present: Eight Exercises in Political Thought* (New York: Penguin Books, 2006).

4 David Blackbourn, *The Conquest of Nature: Water, Landscape, and the Making of Modern Germany* (New York and London: W. W. Norton and Company, 2006) tells a fairly positive story of human interventions in Germany's riverways. Mark Cioc's history is rather grim. Mark Cioc, "The Rhine as World River," in *The Environment and World History,* ed. Edmund Burke III and Kenneth Pomeranz (Berkeley and Los Angeles: University of California Press, 2009).

This talent for stories is both a boon and a danger because stories aren't just glosses on reality: they also mold the real world. Undeniably, the story of modernity with its narrative of individualism, infinite progress, and endless economic and technological growth did much to create the Anthropocene, however unwittingly. For precisely this reason, as humanists and social scientists respond to the new Earth story of Jan Zalasiewicz and his colleagues from the Anthropocene Working Group (AWG), we need to consider our narratives. Better stories will help us understand how human activities came to wreak such havoc and also how we might navigate the perilous conditions ahead. In this way, Anthropocene stories, like all good true stories, connect past, present, and future. But there's something fundamentally different about a good Anthropocene story as opposed to earlier stories in the humanities and social sciences. To be useful, they must contend with a much more restricted future. The dizzying range of stories once thought possible is narrowed by the Anthropocene. Indeed, our previous surfeit of true stories may well be an artifact of the Holocene itself, a form of "epistemological anarchy" only possible in the probabilistic universe of a relatively stable Earth System. Yet even so, even under the constraints of this fearsome new epoch, choices remain. The Anthropocene constricts potential plotlines, but does not dictate them, at least not yet.

For now, the humanist imperative to craft stories that open on future possibilities still rules. At root, the commitment to narrative potential is a commitment to liberty. Stories are about choices. They describe a situation and show us how the protagonist navigated the Genii's offer of three wishes or dealt with a threat to national security. Believing in the human capacity for decency and justice along with our talent for cruelty and destruction means believing in more than just one true story. The tradition of critical thought, as literary critic Ian Baucom rightly observes, "has long understood its vocation as simultaneously descriptive and transformative: a method oriented to mapping the situation in which we find ourselves and to making something emancipatory of that situation."[5] The truest stories of the Anthropocene will map our altered planetary system in accord with the science and, dire though the situation is, still try "to make something emancipatory" of it. These narratives need to emerge from a conversation across disciplines—geologists and Earth System scientists, on the one hand, and humanists and social scientists on the other. Each side has to listen hard for the new rhythms of this dialogue. We could think of this conversation as learning to ride a bicycle built for two where both cyclists need to pedal in the same direction at approximately the same speed, discussing where to go as they ride.

5 Ian Baucom, *History 4⁰ Celsius: Search for a Method in the Age of the Anthropocene,* Vol. 2 of *Specters of the Atlantic* (Durham: Duke University Press, 2020), 8.

Figure 1. Three seems particularly good for adventures and parables: we tell tales of the three sisters (weird and otherwise[6]), the three wishes, the three ages of man (and woman) from infancy to old age, and the three aspects of the Christian god. Here we have a scroll depicting the three vinegar tasters (the Buddha, Confucius, and Lao-tzu). Each samples the same vinegar—in other words, the same reality—but one finds it bitter, the next sour, and the last sweet. The Anthropocene, being both an epic adventure and a morality tale, has also spawned triplicates: ones I have dubbed "Anything Goes," the "Singular Story," and a "Democracy of Voices." Naturally, this typology is highly artificial (which typology is not?), but if stories are important both for making sense of the world and for world-making, then analyzing our stories is essential. Depicted here is the traditional Asian allegorical image "The Vinegar Tasters (The Three Teachings)," ca. 1802–1816 (Edo period), by Kanō Isen'in, Edo period, c. 1802–1816, Honolulu Museum of Art, accession 6156.1

Story #1: Anything Goes

The "Anything Goes" group, taking its cue from the eponymous musical, is the most imaginative. With a pell-mell playfulness that often sets ESS and stratigraphy aside, writers have responded inventively to the new word. Some adopt defensive postures, attacking the proposed geological epoch as a threat, even an existential threat, to their understanding of the world. Conversely, a few in this group take "Anthropocene" as inspiration for an Ecomodernist utopia where infinite growth and progress continues, uncoupled from the biogeophysical planet. Of this "Anything Goes" group, it may truly

6 The three weird sisters appear in Shakespeare's *Macbeth*, and less weird sisters appear in Giambattista Basile "The Three Sisters" (an Italian fairytale) in his 1634 work, *The Pentamerone.*

be said that "the Anthropocene is a concept that has as many definitions as the authors who write about it."[7] Essentially, the "Anything Goes" stories try to shoehorn our new Earth System reality into old Holocene categories.

The Anthropocene is not the first scientific recasting of human history to spark a hundred disparate tales. A century and a half before Paul Crutzen proposed "Anthropocene" in 2000, Darwin stirred up a hornet's nest with "evolution." Humanists and social scientists danced dizzy tangos with the idea that humans were descended from apes. Reformers Herbert Spencer and Beatrice Webb applied natural selection in the form of Social Darwinism to society. Anglo-American triumphalists applied the phrase "survival of the fittest" (one that Darwin had originally borrowed from Spencer) to justify empire and "their sort." Germans, with a keener grasp of Darwin's meaning, recognized that the form of "fitness" driving evolution had less to do with mastery of gunboats, finance, and colonies, and more to do with sex. Yet carnal love and the maximization of offspring were hardly suitable for state-sponsorship, so German authorities also banned evolution from school books.[8] Japanese leaders redefined the term in yet another way, arguing that their up-and-coming nation could hop, skip, and jump over evolution's intermediary stages to join Western Imperial Powers.[9] Some of these Meiji oligarchs eagerly presented their 1890 constitution, the first such instrument of government in modern Asia, to Spencer himself. The great Sage of the Tennis Courts (said to dictate his sprawling books while knocking balls) immediately dismissed the Japanese effort as far too advanced for such a backward people. Ironically, the Japanese document had originally been penned in German and was primarily modeled on the Prussian constitution. The descent of social theory based on misconceptions of the "descent of man" is too well known, and too grim, to bear repeating, as eugenics exemplifies. Darwin's theory, or at least some its terms, were reimagined by social scientists as grounds for many things including selfish individualism, imperialism, racism, classism, utopianism, sexual passion, and social engineering. In response to evolutionary theory, anything went.

7 Roblynne Mellor, *Review of Economic Development and Environmental History in the Anthropocene: Perspectives on Asia and Africa* edited by Gareth Austin; *The Birth of the Anthropocene* by Jeremy Davies; and, Jedediah Purdy, "After Nature: A Politics for the Anthropocene," *Journal of World History* 30, no. 3 (September 2019): 441–448, here page 441.

8 Alfred Kelly, *The Descent of Darwin: The Popularization of Darwinism in German, 1860–1914* (Chapel Hill, NC: The University of North Carolina Press, 1981).

9 For Herbert Spencer's 1892 letter to cabinet minister Kaneko Kentar (1853–1942), see Herbert Spencer, *On Social Evolution*, edited and with an Introduction by J.D.Y. Peel (Chicago: University of Chicago Press, 1972): 253–257. See also, Julia Adeney Thomas, *Reconfiguring Modernity: Concepts of Nature in Japanese Political Ideology* (Berkley and Los Angeles: University of California Press, 2001).

As with Darwinism, so too with the Anthropocene. It also threatens long-held beliefs about the place of humanity in the world, the production of knowledge, and the possibilities for our future. One response is to deflect attention from the concept by focusing on the word. The giddy multiplication of alternative terms for "Anthropocene" make Humpty Dumpty look like an amateur in the world of wordplay.[10] In 2013 in French and then in English in 2016, the pioneering book *The Shock of the Anthropocene* presented chapters on the Thermocene, Thanatocene, Phagocene, Phronocene, Agnotocene, Capitalocene, and Polemocene.[11] But even so, this compendium looks scant compared with the more recent, encyclopedic list of alternative coinages gathered by Clémence Hallé and Anne-Sophie Milon. These include Manthropocene, Chthulucene, Heterocene, and on and on.[12] Each word initiates a different storyline, featuring different protagonists, causes, and goals.[13]

Foreswearing wordplay but still insisting that "Anything Goes," some social scientists have repurposed "Anthropocene" to accord with their own discipline's imperatives. For instance, anthropologist and political scientist James C. Scott refers to a "thin Anthropocene" that dates "from the use of fire by *Homo erectus* roughly half a million years ago and extends up through the clearances for agriculture and grazing and the resulting deforestation and siltation." However, as he admits, "there is no particular reason to insist on the label 'Anthropocene'." His point is "to insist on the global environmental impact of the domestication of fire, plants, and grazing animals," not

10 Scientifically grounded precursors and additions include the following: In 1992, science journalist Andrew Revkin used the term "Anthrocene" in a book on global warming (Andrew C. Revkin, *Global Warming: Understanding the Forecast* [New York: Abbeville Press, 1992]). In 1999, entomologist Michael Samways coined "Homogenocene" to highlight the unprecedented scale and transglobal nature of species invasions (Michael Samways, "Translocating Fauna to Foreign Lands: Here Comes the Homogenocene," *Journal of Insect Conservation* 3 [1999]: 65–66). In 2000, Paul Crutzen's proposal of "Anthropocene" at a conference was unpremeditated, although he subsequently learned that freshwater ecologist Eugene Stoermer had been using the term informally since the 1980s, which led to their joint publication (see Will Steffen, Jacques Grinevald, Paul Crutzen and John McNeill, "The Anthropocene: Conceptual and Historical Perspectives," *Philosophical Transactions of the Royal Society*, 369 [2011]: 842–67, doi.org/10.1098/rsta.2010.0327). Fisheries biologists Dirk Zeller and Daniel Pauly suggested "Myxocene" in 2005, an age of jellyfish and slime, to reflect human-driven changes to the oceans (Dirk Zeller and Daniel Pauly, "Good News, Bad News: Global Fisheries Discards are Declining, but So Are Total Catches," *Fish and Fisheries*, no. 6 [2005]: 156–59, doi.org/10.1111/j.1467-2979.2005.00177.x).

11 Christophe Bonneuil and Jean-Baptiste Fressoz, *The Shock of the Anthropocene: The Earth, History and Us,* English translation by David Fernbach (Brooklyn, New York: Verso, 2016). The original French version (2013) did not include chapters on "Agnotocene" and "Capitalocene."

12 Clémence Hallé and Anne-Sophie Milon, "The Infinity of the Anthropocene: A (Hi)story with a Thousand Names," in *The Science and Politics of Landing on Earth,* ed. Bruno Latour and Peter Weibel (Cambridge, Ma: MIT Press, 2020), 42–43.

13 See Elizabeth M. DeLoughrey, *Allegories of the Anthropocene* (Durham, North Carolina: Duke University Press, 2019).

to reorganize the Geological Time Scale. As scientists point out, having global environmental impact is not the same as producing a new geological epoch or altering the Earth System.[14] In a similar vein, global historian John McNeill observes “the customs of historians” over those of geologists, in arguing that “the Anthropocene began at different times in different places. Some places, for example Venice or Mexico City, were well into their local Anthropocenes by 1750. People transformed swamps into cities in both places. Other places, such as the peaks of Patagonia or the depths of the Marianas Trench, which are (I imagine) very much as they were in recent centuries, may not have entered it yet.” His use of the concept, as he correctly says, “would not suit geologists” whose standards require near-synchronous global impact.[15] These appropriators of “the Anthropocene” part ways with Earth System scientists, happy to leave them to their own devices, while social science continues on its accustomed way.

Others in the “Anything Goes” camp are not so generous to geologists. For them, “the Anthropocene” is a provocative red cape waved by a devilish matador. The AWG and the discipline of geology are denounced as misguided, if not downright malicious, enterprises. Instead of ceding to stratigraphers their own conventions on planetary time and letting Earth System scientists have their say about the Earth System, this group presents them with a catalog of their errors. Among the misdeeds of the AWG is “defining the Anthropocene in order to meet stratigraphy’s requirements.”[16] Another is “the geologists’ slow motion—dare one say glacial—assessment of the Anthropocene’s claims,” a pace said to have “eroded their authority over the outcome.”[17] An environmental historian charges them with ignoring the biosphere: “in the rapid ascendency of planetary earth science, and the subsequent displacement of ecology as the *sine qua non* of environmental sciences, we risk losing sight of life, in all its diverse forms, human and nonhuman, that have shaped the planet.”[18] But these supposed errors of geologists are nothing compared to their ethical lapses. Anthropocene scientists

14 James C. Scott, *Against the Grain: A Deep History of the Earliest States* (New Haven: Yale University Press, 2017), 19–20.

15 John McNeill, “Energy, Population, and Environmental Change since 1750,” in *The Cambridge World History, Volume 7: Production, Destruction and Connection, 1750–Present,* Part 1: Structures, Spaces, and Boundary Making, ed. John R. McNeill and Kenneth Pomeranz (Cambridge, 2017), 52.

16 Jean-Baptiste Fressoz, “Does Political Ecology Need the Approval of Geologists?,” *IPPR Progressive Review* 24, no. 3 (2017), 172.

17 Rob Nixon, “The Anthropocene: The Promise and Pitfalls of an Epochal Idea,” in *Future Remains: A Cabinet of Curiosities for the Anthropocene,* ed. Gregg Mitman, Marco Armiero, and Robert S. Emmett (Chicago: University of Chicago Press, 2018), 15.

18 Gregg Mitman, “Hubris or Humility? Genealogies of the Anthropocene,” in *Future Remains: A Cabinet of Curiosities for the Anthropocene,* ed. Gregg Mitman, Marco Armiero, and Robert S. Emmett (Chicago: University of Chicago Press, 2018), 61.

stand accused of ascribing moral culpability to everyone equally, promoting a "human species-supremacist planetary politics," echoing "biblical dominion," and promulgating a "deeply problematic" and "ignorant" "philosophy of history."[19] Anthropologist Kathryn Yusoff believes that this science "is a praxis of exploitation, dispossession, subjection, and othering, closely tied to the slave mode of production."[20] "White Geology" seems a greater enemy than an altered planet.

Responding to these concerns on scientific grounds has availed little. Explanations of stratigraphy's standards and processes fall on deaf ears. For instance, producing geology's foundational tool of global comparison—the Geological Time Scale—requires widespread agreement and precise forms of physical evidence, making stratigraphy the very heart of that enterprise, something that necessarily takes time. One might point out that the AWG's deliberations look almost swift if we remember that the Holocene was first proposed in 1867, formally submitted to the International Geological Congress in Bologna in 1885, and officially ratified by the Committee of the International Union of Geological Sciences (IUGS) only in 2008. The idea that ESS ignores the biosphere has no basis. Most of what we know about Earth's life forms and their evolution is written in the rocks, so geologists rarely lose sight of life. The power of the biosphere to shape the planet's chemistry and geology is encapsulated in the very term "biogeophysical."[21] As Zalasiewicz et al. explained in 2014, five years after the AWG was established:

> The significance of the Anthropocene . . . lies not so much in seeing within it the 'first traces of our species,' but in the scale, significance, and longevity of change to the Earth System. Humans started to develop an increasing, but generally regional and highly diachronous, influence on the Earth System thousands of years ago. With the onset of the Industrial Revolution, humankind

19 Eileen Crist, "On the Poverty of Our Nomenclature," *Environmental Humanities* 3 (2013), 129 (See also Eileen Crist, *Abundant Earth, Toward an Ecological Civilization* [University of Chicago Press, 2019]). David Wallace-Wells, *The Uninhabitable Earth: Life After Global Warming* (New York: Tim Duggan Books, 2019), 20; Daniel Hartley, "Anthropocene, Capitalocene, and the Problem of Culture," in *Anthropocene or Capitalocene: Nature, History and the Crisis of Capitalism,* ed. Jason W. Moore(Oakland, CA: PM Press, 2016), 154–55.

20 Kathryn Yusoff quoted on H-Environment, Call-for-Papers: Conference on "Inhuman Memory: Race and Ecology across Timescales," 26 October 2019, https://networks.h-net.org/node/19397/discussions/5170380/cfp-conference-inhuman-memory-race-and-ecology-across-timescales. See also Kathryn Yusoff, *A Billion Black Anthropocenes* (Minneapolis: University of Minnesota Press, 2019); Heather Davis and Zoe Todd, "On the Importance of a Date, or, Decolonizing the Anthropocene," *ACME: An International Journal for Critical Geographies* 16 (December 2017): 761–80.

21 For ways in which ecology is key to the Anthropocene, see Sharon Kingsland, "The Importance of History and Historical Records for Understanding the Anthropocene," *The Bulletin of the Ecological Society of America* 98 (2017): 64–71, doi.org/10.1002/bes2.1296.

> became a more pronounced geological factor, but in our present view it was from the mid-twentieth century that the worldwide impact of the accelerating Industrial Revolution became both global and near-synchronous."[22]

These explanations of scientific protocols and scientific definitions are brushed aside by adherents to "Anything Goes."

Ecosocialist Ian Angus has attempted to explain to detractors that "Anthropocene" refers not "to all humans, but to an epoch of global change that would not have occurred in the absence of human activity."[23] The term does not blame everyone (nor indeed anyone); it does not relish *Old Testament* dominion; it does not propose a theory of human history; and nothing in the AWG's reports suggests that the proposed new epoch is cause for celebration or self-congratulation. The reason for calling it "Anthropocene" is the accelerating dominance of human activities driving the Earth System. It should also be noted that the names geologists give to intervals of time in Earth's long history aren't meant as the be-all and end-all of their analysis. In fact, these names are sometimes whimsical. For instance, the Silures, a fierce tribe who gave Roman invaders a hard time, are the namesakes of the Silurian Period (443 million to 416 million years ago) simply because the nineteenth-century Scottish fossil hunter Sir Roderick Murchison (1792–1871) remembered his Tacitus while digging in Wales. In no way was Murchison suggesting that he had discovered evidence of Welsh triumph in the layer of rock representing deep, trilobite-haunted seas. Naming the most recent strata formed on Earth's crust "Anthropocene" is certainly not a celebration of human supremacy. While a group called "Ecomodernists" proclaim a "Good Anthropocene" where "resource-efficient technologies" decouple humanity from reliance on planetary systems, the majority of AWG members reject the idea that human beings can go our merry way without need for a rich biosphere, breathable air, and fresh water. They stress that we are irrevocably part of the Earth System, and few are sanguine about our future. In fact, some Earth System scientists are resorting to uncharacteristically emotive words like "emergency" and looking with dread to looming social, political, and economic dislocations.[24] There is nothing triumphalist about their bleak view.

22 Jan Zalasiewicz et al., "When did the Anthropocene Begin? A Mid-Twentieth Century Boundary Level is Stratigraphically Optimal," *Quaternary International* 383 (2015): 196–203, here 201.
23 Ian Angus, *Facing the Anthropocene: Fossil Capitalism and the Crisis of the Earth System* (New York: Monthly Review Press, 2016), 232.
24 For example, the term "emergency" is used by Timothy Lenton et al. to describe out current situation. T. Lenton et al., "Climate Tipping Points—Too Risky to Bet Against," *Nature* 575 (2019): 592–96, here 596.

So what are we to make of the frivolity, obtuseness, distress, and even anger of the "Anything Goes" stories? Perhaps there is an understandable reluctance to spend time digesting the complexities of the emerging science. It's easier to fall back on more familiar terms like "the environment" and "climate change" in the rushed atmosphere of publish-or-perish. It's also easy, and more readily rewarded within the academic world, to adhere closely to disciplinary protocols and ways of thinking. When humanists and social scientists stray into geology and ESS with their odd forms of citation, multiple-authored articles, and strange ways of telling stories, their colleagues are often bemused. The approach characterized here as "Anything Goes" may also reveal a sublimated fear of the situation illuminated by the AWG. Perhaps the *ad hominem* attacks on geologists confuse the messengers for the message. In any case, these "Anything Goes" narratives, at their heart, are not about science.

What is most striking about "Anything Goes" is its deep conservatism. These stories often feature familiar villains and victims. Scientific hubris is once again denounced.[25] Disciplinary prerogatives are protected from the challenge posed by the Anthropocene which, like evolution, brings the study of humans and of the rest of nature together in deeply uncomfortable ways. "Anything Goes" relies on the siloed forms of knowledge institutionalized in late nineteenth-century universities, and resists reimagining the relationship among them. Many adherents seem to hint that somewhere, somehow, there *must* be a way of retaining the old dream of ever-growing abundance for everyone. The Ecomodernists who denounce environmentalism as putting limits on human desires even insist that we can be headed toward greater opulence.[26] The old concepts of justice and liberty, the old economic forms, the old ways of thinking of our lives and what they mean must not be challenged, or so they imply. Don't listen to the scientists, don't take on this unprecedented vision of human impact on the planet, don't let the band stop playing.

25 Historian of science Naomi Oreskes, a member of the AWG, argues that this distrust of science is often politically generated. The trustworthiness of science arises from the social practices surrounding the vetting of its claims rather than abstract reliance on the "scientific method." The more inclusive these practices are in terms of the types of evidence and social perspectives of the people involved, the better the science will be. See Naomi Oreskes, *Why Trust Science?* (Princeton: Princeton University Press, 2019).

26 Ted Nordhaus and Michael Shellenberger, *Breakthrough: From the Death of Environmentalism to the Politics of Possibility* (New York: Houghton and Mifflin, 2007). For a critique of ecomodernism, see Clive Hamilton, "The Theodicy of the 'Good Anthropocene'," *Environmental Humanities* 7, no. 1 (2016): 233–38. doi.org/10.1215/22011919-3616434.

As AWG secretary Colin Waters notes (and the evidence of "Anything Goes" shows), "Anthropocene" has come to mean different things as it has spread to different groups, a situation that can only end in headaches: "We need a common understanding."[27] That common understanding needs to come from the science. In the preceding essay in this volume, Jan Zalasiewicz laid out the evidence for the Anthropocene, defining it carefully. That understanding is now widely, though not universally, accepted within the geological community. As Zalasiewicz acknowledges, the proposed new epoch, ultimately, may never be formalized by the IUGS. But even if it doesn't become a formal term for geology, the evidence of ESS reveals that the planet as a whole is functioning in a dangerous way.[28] ESS is a fairly new science that looks beyond the discrete phenomena of biodiversity loss, human population growth, altered chemical cycles, climate change, land-use patterns, and much else to treat Earth as a single integrated system with emergent properties above and beyond any one of these environmental challenges.[29] As a whole, our planet is at or very near a state shift, moving from one way of functioning to another, never before experienced in the history of our species. ESS, in accord with the geology of the Anthropocene, tells us we're heading for a rough ride. As stratigraphy's bureaucratic process plays itself out one way or the other, humanists and social scientists should engage with the AWG and the ESS community to shape a common understanding of the Anthropocene. For my part, I think that crafting stories on the basis of a common understanding of reality is our best hope. If the Anthropocene is truly as dangerous and unprecedented as it seems to be, taking guidance from the scientists on what it is and then forging a concerted way forward is surely the wisest route.[30] Humanists and social scientists can't critique the science unless they understand it, or analyze its political and moral implications.

27 Quoted in Ian Sample, "Anthropocene: Is This the New Epoch of Humans?," *The Guardian*, 16 October 2014, https://www.theguardian.com/science/2014/oct/16/-sp-scientists-gather-talks-rename-human-age-anthropocene-holocene.

28 Anthony D. Barnosky, et al., "Approaching a State Shift in Earth's Biosphere," *Nature* 486 (7 June 2012): 52–58. See also Will Steffen, et al. "The Emergence and Evolution of Earth System Science," *Nature Reviews Earth & Environment* 1, 54–63 (2020), doi.org/10.1038/s43017-019-0005-6. Steffen 2020.

29 See Tim Lenton's marvelously incisive *Earth System Science: A Very Short Introduction* (Oxford: Oxford University Press, 2016)

30 For an insightful analysis of why political science should take Anthropocene science seriously, see Manuel Arias-Maldonado, "Bedrock or Social Construction? What Anthropocene Science Means for Political Theory," *The Anthropocene Review* 7, no. 2 (August 2020): 97–112, doi.org/10.1177/2053019619899536.

New Stories for a New Reality

What would happen to our stories if we took Anthropocene science seriously? To explore this question, I'll focus on one paper, "Trajectories of the Earth System in the Anthropocene," which appeared in *PNAS* in 2018.[31] With this matter-of-fact title, Earth System scientist Will Steffen and his co-authors do not ring alarm bells, at least not initially. They begin by laying out the evidence that the planet has left not only the relative warmth of the Holocene's interglacial interlude, but perhaps even the glacial–interglacial cycles of the Quaternary Period beginning 2,588,000 years ago. Our planet, they say, is on a new trajectory toward "Hothouse Earth."[32] If the planet continues along the current business-as-usual pathway, feedbacks, tipping points, and nonlinear dynamics may plunge the Earth System across a dangerous threshold. Crossing this threshold, possibly reached when the globally averaged temperature rises 2 degrees Celsius (3.6 degrees Fahrenheit) above pre-industrial levels (as is expected to occur well before the end of the century), is "likely to produce uncontrollable and dangerous conditions."[33] To cross it "poses severe risks for health, economics, political stability (especially for the most climate-vulnerable) and, ultimately, the habitability of the planet for humans."[34] At that point, all bets are off.

The better hope is to stabilize the Earth System before that threshold is reached. Success wouldn't return us to the Holocene. This *PNAS* paper is not modeled on the trope of the Prodigal Son. There is, alas, no way to "repeal the Anthropocene."[35] Instead, "stabilized Earth will likely be warmer than any other time over the last 800,000 years at least" and probably won't avoid the activation of some triggers that would lead to "abrupt shifts at the level of critical biomes that support humanity."[36] What this means is that in the best-case scenario we should expect green and pleasant lands to become deluged scenes of death and places that once were merely lethargically hot to be scorching and unlivable for ourselves and many other species. Perhaps most frightening of all is that the Earth System does not tend to be stable at approximately 2 degrees Celsius

31 Will Steffen et al., "Trajectories of the Earth System in the Anthropocene" *PNAS* 115, no. 33 (14 August, 2018): 8252–8259.
32 These cycles have waxed and waned throughout the past 2.6 million years known as the Quaternary Period (National Oceanic and Atmospheric Administration [NOAA], https://www.ncdc.noaa.gov/abrupt-climate-change/Glacial-Interglacial%20Cycles).
33 Steffen et al., "Trajectories," (2018): 8256.
34 Steffen et al., "Trajectories," (2018): 8256.
35 Marcia Bjornerud, *Timefulness: How Thinking like a Geologist Can Help Save the World* (Princeton, 2018), 177.
36 Steffen et al., "Trajectories," (2018): 8257.

above preindustrial levels. A stabilized Earth at that temperature would be highly artificial. Constructing and maintaining it would require orchestrating all our social systems to manipulate the Earth System and deflect it from the business-as-usual trajectory. That said, it would be better than the Hothouse alternative.

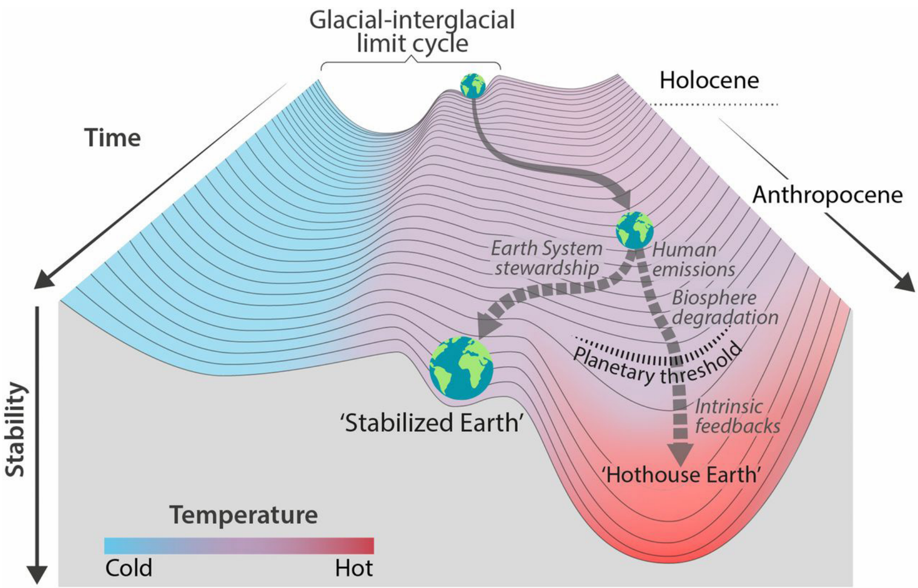


Figure 2. Stability landscape showing the pathway of the Earth System out of the Holocene and thus, out of the glacial–interglacial limit cycle to its present position in the hotter Anthropocene. The fork in the road in Fig. 2 is shown here as the two divergent pathways of the Earth System in the future (broken arrows). Currently, the Earth System is on a Hothouse Earth pathway driven by human emissions of greenhouse gases and biosphere degradation toward a planetary threshold at 2 °C (horizontal broken line at 2 °C in Fig. 2), beyond which the system follows an essentially irreversible pathway driven by intrinsic biogeophysical feedbacks. The other pathway leads to Stabilized Earth, a pathway of Earth System stewardship guided by human-created feedbacks to a quasi-stable, human-maintained basin of attraction. "Stability" (vertical axis) is defined here as the inverse of the potential energy of the system. Systems in a highly stable state (deep valley) have low potential energy, and considerable energy is required to move them out of this stable state. Systems in an unstable state (top of a hill) have high potential energy, and they require only a little additional energy to push them off the hill and down toward a valley of lower potential energy. Image and caption from Steffen et al., "Trajectories," reproduced here with kind permission.

In storytelling terms, what's interesting about this study is that it provides only two plotlines. Unlike research based on climate models that project a range of intermediate scenarios, the authors of "Trajectories of the Earth System" argue that nonlinearities in feedback processes reduce potential pathways—or plotlines—to two. Our choice is either a bucking Hothouse Earth marked by abrupt state shifts, "a much higher global average temperature than any interglacial in the past 1.2 million years," and "sea levels significantly higher than at any time in the Holocene" with a markedly diminished biosphere, or, on the other hand, a carefully managed Stabilized Earth, uncomfortable, fragile, and different from anything our species has ever known. In other words, the tale ends either horrendously or less horribly. These severely reduced options are about as far from "Anything Goes" as you can get. No kick lines here. No songs by Cole Porter. No jokes from P.G. Wodehouse.[37]

How might we achieve the less horrible Stabilized Earth? The scientists' answer entails more than science-and-engineering since, they say, "a fundamental reorientation of human values, equity, behavior, institutions, economies, and technologies is required."[38] This revolution in all human systems is a tall order, made more so because it needs to happen right away: "gradual or incremental change . . . will likely not be adequate."[39] Given this expansive view of the problem, this paper is an open-handed invitation to collaborate. If we accept this mapping of our situation, the question is how to twist human plotlines to bend the trajectory of the planetary system toward the limited freedom of a harsh but habitable planet. The so-called *positive* feedback loops pushing the Earth System along its dangerous business-as-usual trajectory must be turned, somehow, into *negative* feedback loops producing a stabilized state. (To be clear, "stabilized" in this sense means being relatively constant within certain variables. In no way does it imply stasis or lack of circulation.) The story we need to figure out how to tell will not be a comedy, but it could avoid tragedy. The quest, in other words, is to avoid the tyranny of "Hothouse Earth" and create something emancipatory even of this terrible exigency.

So how do we choose the less bad option? "Trajectories of the Earth System" suggests two ways to avoid tragedy. Primarily, Will Steffen and his co-authors call for the Singular Story: a "deep integration of knowledge from biogeophysical Earth System science with that from social sciences and the humanities."[40] Although they foresee that unifying diverse fields will be difficult, they hope it will produce "more effective governance at the Earth System level."[41] To many, this pronouncement will look like support for top-down global governance, a form critiqued by many political scientists. (This is a

37 The musical *Anything Goes* had input from both Porter and Wodehouse and featured a love affair between a wall street broker and a girl named Hope.
38 Steffen et al., "Trajectories," (2018): 8258.
39 Steffen et al., "Trajectories," (2018): 8258.
40 Steffen et al., "Trajectories," (2018): 8258.
41 Steffen et al., "Trajectories," (2018): 8258.

problem to which I'll return.) But, on close reading, the essay also calls, more quietly, for a second type of story, one that encourages diverse, local efforts directed toward the same shared end, the very reverse of top-down governance.[42] Since the tipping points caused by nonlinear dynamics cannot be forecast with any degree of certainty, no global dictate can ensure survival. More flexible, community-controlled measures with lower built-in costs will help build resilience. These "resilience-building strategies," the authors say, "include developing insurance, buffers, redundancy, diversity, and other features:" a multiplicity of efforts more nimble in the face of the unforeseeable surprises inherent in a destabilized system. In other words, alongside the recommendation that we commit to the "Singular Story," this paper also recognizes the value of a "Democracy of Voices." Both approaches are true to the science, but they suggest very different humanistic narratives, the first founded on the logic that equates the single stabilized Earth System with a single humanity and even a single governing authority; the second encouraging a range of human systems, all resonating with the Anthropocene imperative of redirecting Earth's trajectory but in different ways. In political terms, we might call the first "benevolent totalitarianism" and the second a "multicultural empire" where pluralism *up to a point* is permitted. Neither of these are ideal political forms according to most late Holocene logics, but then no society in the Anthropocene will enjoy the latitude of Holocene conditions.

Story #2 The Singular Story

Particularly on large scales, the human story is easily integrated into the biogeophysical one. The evidence is everywhere. From this perspective, we are fundamentally beings of rock, water, and air. Like all our fellow creatures, we arise from the Earth System. Our species' story of perhaps 300,000 years fits snugly within the Earth's approximately 4.5-billion-year history.[43] In the very *longue durée*, the mastery of fire in Africa by our ancestral species *Homo erectus*, the domestication of the dog, our handprints

42 Critiques of top-down governance include: Giovanna Di Chiro, "Environmental Justice and the Anthropocene Meme," in *The Oxford Handbook of Environmental Political Theory,* ed. Teena Gabrielson, Cheryl Hall, John Meyer, and David Schlossberg (Oxford: Oxford University Press, 2016); John S. Dryzak and Jonathan Pickering, *The Politics of the Anthropocene* (Oxford: Oxford University Press, 2019); and, Mark Beeson, *Environmental Populism: The Politics of Survival in the Anthropocene* (Singapore: Palgrave MacMillan, 2019).

43 David Christian has led the way in developing "Big History," which puts the human story within the larger story of Earth and even the universe. See Christian with William McNeill, *Maps of Time: An Introduction to Big History* (Berkeley and Los Angeles: University of California Press, 2005); with Cynthia Stokes Brown and Craig Benjamin, *Big History: Between Nothing and Everything* (New York: McGraw-Hill Education, 2014) and *Origin Story: A Big History of Everything* (New York: Little, Brown Spark, 2018). For an incisive critique of this form of history, see Ian Hesketh, "The Story of Big History," *History of the Present* 4, no.2 (Fall 2014): 171–202.

on cave walls from Borneo to Spain; the traps dug to capture and kill mammoths in Mexico some 15,000 years ago, and the invention of pottery and agriculture in many different places, all attest to creativity. Our abilities to bend our environments to meet our desires has conquered oceans, leveled mountains, and rearranged the living world from fungi and microbes to flora and fauna. We have invaded every continent with our companion species, some purposely brought along, some hitch-hikers with their own destinies. As historian Kyle Harper shows, we've both accumulated disease-causing viruses and bacteria in extraordinary numbers compared with our chimpanzee cousins (who have only about two dozen), and also worked, both consciously and unconsciously, to disinfect the planet and build up immunities, allowing our population to soon soar beyond 8 billion.[44]

We struggle. We create. We colonize. We dominate, like all species, to the extent that we can until the environment can no longer support our activities. Our foods taste of the soils in which they are grown, from the *terroir* of French wines to the volcanic sting of true wasabi; our bodies, in the words of the English burial service (and a David Bowie song) go "from ashes to ashes." Few humans eat rocks *per se*, but we are not all that far removed from the newly discovered type of shipworm that munches stone.[45] When we integrate the human story and the Earth System story, we orchestrate vast scales of time and space along with intimate biogeophysical interactions. I don't doubt that the story can be told this way.

This story's giant protagonist is the combination of humanity-and-Earth-System that has been lumbering for millennia toward the Anthropocene, "the sum total of human impacts on the system" which needs "to be taken into account for analyzing future trajectories."[46] To study this Leviathan, proponents of the "Singular Story" argue for the merger of disciplinary perspectives and a unity of knowledge. Sometimes this integration takes the form of collaboration among human and natural scientists with new institutions to support their joint work.[47] Sometimes an even more intense synthesis

44 Kyle Harper, "What Makes Viruses Like COVID-19 Such a Risk for Human Beings? The Answer Goes Back Thousands of Years," *Time*, 11 March 2020, https://time.com/5800558/coronavirus-human-civilization/; and Ariane Düx et al., "The History of Measles: From a 1912 Genome to an Antique Origin," (preprint, March 2020) bioRxiv 2019.12.29.889667; doi.org/10.1101/2019.12.29.889667.

45 Bob Yirka, "Shipworm that Eats Rock Instead of Wood Found in River in the Philippines," *Phys.Org,* 19 June 2019, https://phys.org/news/2019-06-shipworm-wood-river-philippines.html. For more information, see J. Reuben Shipway et al., "A Rock-Boring and Rock-Ingesting Freshwater Bivalve (Shipworm) from the Philippines," *Proceedings of the Royal Society B: Biological Sciences* (2019), doi.org/10.1098/rspb.2019.0434.

46 Steffen et al., "Trajectories," (2018): 8252.

47 E. S. Brondizio et al., "Re-Conceptualizing the Anthropocene: A Call for Collaboration," *Global Environmental Change* 39 (2016): 318–27.

is promoted, one that "fully integrates different approaches and different types of scholarly experience."[48] This unity of knowledge has been long heralded. In *Economic and Philosophic Manuscripts of 1844*, Karl Marx prophesized, "Natural science will in time incorporate into itself the science of man, just as the science of man will incorporate into itself the natural science: there will be one science."[49] Recent conferences and policy forums also emphasize "the need for radical interdisciplinary collaboration between the nature and the human sciences."[50] Along these lines, but from a slightly different perspective, geoscientist Peter Haff adds up all human-Earth interactions, describing the aggregate as the "technosphere." Borrowing an approach from the physical sciences called "coarse graining," Haff adopts a level of resolution in his analysis that captures the overall system's behavior, beyond the operations of its individual components. This technosphere, he claims, has now become autonomous, appropriating mass, energy, and information on its own.[51] Human beings must either serve the technosphere or suffer the consequences. The aim of unifying knowledge is to master the planet more thoroughly—or in Haff's terms, cope with the technosphere more skilfully—so as to help guide us away from the current Hothouse trajectory. This unified story both *maps* our situation and *makes something emancipatory* of it. The "Singular Story" and "governance at the Earth System level" offer an escape route away from the deterministic business-as-usual road leading us to ruin.

But there are cautions too, from many sides. One warning points to the wondrous complexity of ourselves and our planet, and asks how we can know enough to govern from above. Such coarse-grained analysis of the total Earth System discounts the contingencies of myriad small-scale entanglements, yet it is doubtful that the Earth System functions independently of them. Certainly human existence cannot be understood only in global aggregate. The world, to borrow poet Louis MacNeice's phrase, is "incorrigibly plural," socially, but also physically and biologically. E. O. Wilson argues that mathematical models in ecology, as in economics, are of limited use given

48 Michael A. Ellis and Zev Trachtenberg, "Which Anthropocene is it to Be? Beyond Geology to a Moral and Public Discourse," *AGU Publications, Earth's Future Commentary* (2013): 124.

49 Quoted in Jürgen Renn, *The Evolution of Knowledge: Rethinking Science for the Anthropocene* (Princeton: Princeton University Press, 2020), 408.

50 Poul Holm and Verena Winiwarter, "Climate Change Studies and the Human Sciences," *Global and Planetary Change* 156 (2017): 115–22, here 115.

51 Peter Haff, "Technology as a Geological Phenomenon: Implications for Human Well-Being," in *A Stratigraphical Basis for the Anthropocene Special Publications* 395, ed. Colin Waters, Jan Zalasiewicz, Mark Williams, Mike Willis, and A. N. Snelling (London: Geological Society, 2014): 301–309, here 301. Peter Haff, "Humans and Technology in the Anthropocene: Six Rules," *The Anthropocene Review* 1, no. 2 (2014): 126–36.

the "ubiquitous nonlinearities that twist and turn like escaping eels when you put together the actions of real players." "Overall," he says, "theorists have not been able to grasp the near-bottomless complexity of the real world."[52] These intricate dynamics will not easily submit to a single master narrative, and even if they might, the costs of a mistake would be high. Committing to the wrong global governance regime or megascale project could very well lead to higher costs and horrific suffering. The dangers of geoengineering have been detailed by Clive Hamilton who warns against "Promethean recklessness."[53] Megaprojects can produce megadisasters that are harder to correct than smaller-scale, more locally controlled schemes.

Another related caution is the untranslatability of one form of knowledge to another. If translating among human languages poses irresolvable difficulties (just compare English-language versions of the *Tao Te Ching!*), then translating, for instance, the language of rocks into the language of social justice is bound to throw up obstacles. What language, what mode of representation is appropriate for a single narrative combining histories of human endeavors with changes in the Earth System? Policy attempts to combine knowledge from the natural and human sciences have produced mixed results. For instance, the languages of the humanities and the metrics of climate models rarely mesh. The official remit of the United Nations International Panel on Climate Change (IPCC) includes considering "socio-economic" factors, but in practice, as historians Poul Holm and Verena Winiwarter have shown, the IPCC resists "major insights from cultural theory and historical analysis."[54] Holm and Winiwarter quote a particularly revealing passage from the 2014 IPCC report complaining that research on social change can't be used because of "the difficulty in representing these processes in models."[55] This dismissal appears to have deeper roots than the difficulty posed by modeling social change. Some in the IPCC community are ideologically wedded to a narrow range of technical solutions. One editor, responding to an external reviewer's comment on the need for more social science to understand people's conduct, declared, "Changes in behavior may play a role; maybe not. . . . it is really tech change that

52 Edward O. Wilson, *Half-Earth: Our Planet's Fight for Life* (New York and London: Norton, 2016), 102. Wilson, interestingly, confuses the ecomodernist view of the Anthropocene for that of the AWG and therefore argues against the concept of the Anthropocene.
53 Clive Hamilton, *Earthmasters: The Dawn of the Age of Climate Engineering* (New Haven: Yale University Press, 2013).
54 Holm and Winiwarter, "Climate Change Studies," 115.
55 Holm and Winiwarter, "Climate Change Studies," 120.

matters."[56] In short, calls for collaboration, if not outright disingenuous, frequently insist that the humanities and social sciences conform to scientific modes of research and representation. To the extent that humanistic knowledge can be made to conform, an interdisciplinary approach may work at the global level with discrete problems such as eliminating ozone-depleting fluorocarbons. Al Gore's 2006 film, *An Inconvenient Truth*, created just such a story. Benevolent totalitarianism, or what some call "eco-authoritarianism," may have its uses in limited arenas. However, for many of the more complex challenges of the Anthropocene, a better way is a "Democracy of Voices." The fact that the Anthropocene is global, systemic, and near-synchronous is not—and should not be taken as—a prescription for a single global, systemic, and near-synchronous solution. A "reorientation of human values" cannot begin at the Earth System level. Reality, even the singular reality of the Anthropocene, does not dictate only one human story.[57]

Story #3 A Democracy of Voices

The aim of Anthropocene storytelling is to bend Earth's trajectory away from the worst of all possible worlds, but we hamper ourselves if we insist only on unified knowledge, a single protagonist, and an integrated narrative synthesizing all disciplinary perspectives. There is only one Earth System, but there are many textured, contingent, and small-scale stories within it, both human and otherwise. Some of these stories are congruent with the global story; others are not. The problem begins, I think, with defining the Anthropocene as "the cumulative history of local and regional social change operating in various and evolving forms of connections to global processes."[58] While partly right, this cumulative history necessarily ignores all the things that people did that never contributed to the forcings on the Earth System. Many still do these things: a fallen branch becomes a flute played at dawn, a community gathers to deliberate water rights, milkweed is planted to nourish monarch butterflies. These alternative stories point elsewhere. Although these actions are now overwhelmed by the dread teleology of the Anthropocene, which cannot be reversed, they still inscribe

56 Quoted in Holm and Winiwarter, "Climate Change Studies," 121.
57 Lisa Sideris, "Anthropocene Convergences: A Report from the Field," *RCC Perspectives: Transformations in Environment and Society*, no. 2 (2016): 89–96, doi.org/10.5282/rcc/7450.
58 Eduardo S. Brondizio et al., "Re-Conceptualizing the Anthropocene: A Call for Collaboration," *Global Environmental Change* 39 (2016): 318–27, here 323.

other trajectories, ones we might usefully recuperate as practical guides to new negative feedback loops. A final point in their favor is political. A cumulative politics to contend with the outcome of history's cumulative processes pulls power out of local hands and centralizes it, but putting decision-making about how to accord with ecological constraints in local hands allows for a "Democracy of Voices" and a wider range of inventive possibilities.

In showing how the human story could be integrated into the biogeophysical one in the previous section, I gave examples of our species' restless, avaricious, and inventive actions, which have led us to dominate the planet, moving out of Africa and spreading across all continents, even to some extent to Antarctica. From hastening the extinction of megafauna to salinizing the soil in ancient Sumer, from fouling the air with coal fumes to producing computers requiring rare earth metals, this cumulative history can be arraigned against us. But not everything done by everyone everywhere worked against the feedback loops that kept our planet within Holocene boundaries. Take ideas. Not all people want to accumulate ever-greater wealth at the cost of social cohesion and their environment. The Bushman of the Kalahari guarded against community-destroying jealousy by establishing protocols for the distribution of food, especially meat, throughout the group.[59] The First Nations of the Canadian and American Pacific Coast strengthened coastal management regimes and much else by great feasts called potlatches where the powerful gave away or destroyed valuables. The Aboriginal people of Australia went further, not just creating sustainable communities but actively managing the whole continent to produce a bounteous, variegated landscape through the skillful deployment of fire. According to historian Bill Gammage, strategic burning allowed them to encourage desirable plants and preferred animal habitats so that people "travelled to known resources and made them not merely sustainable, but abundant, convenient, and predictable."[60] This coordinated management of an entire continent to foster enhanced biodiversity, moisture-retaining soils, cleaner water, and a range of habitats is an example of what paleogeologist and AWG member Mark Williams terms "mutualism." Going beyond sustainability, mutualism is the active creation of a richer environment.

59 Elizabeth Marshall Thomas, *The Old Way: A Story of the First People* (New York: Picador, 2006), 101–103.
60 Bill Gammage, *The Biggest Estate on Earth: How Aborigines Made Australia* (Crows Nest, Australia: Allen and Unwin, 2012), 3.

More recent examples of the human potential for enforcing negative feedback loops include the highly developed use of night soil as fertilizer in early modern Japan, which resulted in cleaner, healthier cities and better farmland.[61] Early modern Japanese also appear to have taken active measures to ensure population stability in the eighteenth century. Family size was calibrated to the goal of providing for the next generation by limiting births through a range of methods including late marriages or compulsory non-marriage for younger siblings, young people working away from home, abstinence, and infanticide. The cumulative result was a steady population slightly below 30 million for a century.[62] But we need not look back to premodern periods for alternatives to today's "business as usual." In 1950s America, some corporations worked with the concept of "fair profit" rather than Milton Friedman's "maximization of shareholder value" model. Even today, there are examples of alternative story lines discordant with the overall trajectory. While industrial agriculture diminishes soil quality and biodiversity, and creates ocean and river dead zones due to chemical fertilizer runoff, an estimated 50 percent of the world's population still depends on smallholder farms, some of which are now being managed to produce better soils, more nutritious crops, and stronger local communities.[63] This movement has sprung up in developed countries such as Japan, Germany, and the United States as well as less developed countries.[64] Cities can foster wildlife beyond squirrels and rats by new building techniques. Even universities can become green oases as the forty-year-long effort of Tsai Jen-Hui, architect at the National Taipei University of Technology, has shown.[65] These projects exemplify the "slow hope" that Christof Mauch recommends as our best way of putting the skids on business-as-usual.

61 See, for instance, Susan Hanley, *Everyday Things in Premodern Japan* (Berkeley and Los Angeles: University of California Press, 1997); Kayo Tajima, *The Marketing of Urban Human Waste in the Edo/Tokyo Metropolitan Area: 1600–1935* (Tufts University, 2005); and David Howell, "Fecal Matters: Prolegomenon to a History of Shit in Japan," in *Japan at Nature's Edge,* ed. Ian J. Miller, Julia Adeney Thomas, and Brett L. Walker (Honolulu: University of Hawai'i Press, 2017), 137–51. See also Donald Worster, "The Good Muck: Toward an Excremental History of China," *RCC: Perspectives: Transformations in Environment and Society*, no. 5 (2017), doi.org/10.5282/rcc/8135.

62 See Fabian Drixler, *Infanticide and Fertility in Eastern Japan: Discourse and Demography, 1660–1880* (Cambridge MA: Harvard University Press, 2008).

63 Sarah K. Lowder, Jakob Skoet, and Terri Raney, "The Number, Size, and Distribution of Farms, Smallholder Farms, and Family Farms Worldwide," *World Development* 87 (November 2016): 16–29.

64 Examples of these experiments include Fukuoka Masanobu, *The One-Straw Revolution: An Introduction to Natural Farming* (Emmaus, Pennsylvania: Rodale Press, 1978); Barbara Kingsolver, *Animal, Vegetable, Miracle: A Year of Food Life* (New York: Harper Perennial, 2007); Liz Carlisle, *Lentil Underground: Renegade Farmers and the Future of Food in America* (New York: Penguin Random House, 2015); Vandana Shiva, *Soil Not Oil: Environmental Justice in an Age of Climate Crisis* (Brooklyn: South End Press, 2008); Ramachandra Guha, *The Unquiet Woods: Ecological Change and Peasant Resistance in the Himalaya* (Berkeley: University of California Press, 2000).

65 Christof Mauch, "Slow Hope: Rethinking Ecologies of Crisis and Fear," *RCC Perspectives: Transformations in Environment and Society*, no. 1 (2019), 21–23, doi.org/10.5282/rcc/8556.

As we look to the future, harnessing local ingenuity to build multiple, redundant systems of different sorts in different environments at different levels may provide the capacity we need to cope better with tipping points and unexpected events on our destabilized planet. Most especially, if we are to galvanize communities to work toward the goal of ecological reflexivity, drawing on useful patterns in their pasts that accord with their particular ecosystems can help meet the global goal.[66] In this way, bringing together the new reality of our planetary situation with the diversity of human behaviors at local, regional, and national levels allows for greater input and gives us more than just one Anthropocene story. More voices, more stories, more options.

In case this plea for multiple stories seems like advocacy for culturally bound humanistic knowledge as opposed to universal scientific approaches, let me give an example from climate change science which also highlights the importance of the local and particular. Take, for instance, something as superficially uncontroversial as tree-planting on a global scale to reduce carbon dioxide in the atmosphere. The headline-grabbing research of Thomas Crowther's lab promoted an "additional 0.9 billion hectares of canopy cover . . . as one of the most effective solutions at our disposal to mitigate climate change," yet this work sparked dissension due to its global level of analysis.[67] *Science* published six critiques, many pointing to regional and local "environmental or socioeconomic constraints," including different soils and rural communities.[68] The Olympian perspective of a global computer model of forests may help, but it is limited, perhaps severely, by the incorrigible pluralism of interactions between life-forms and inorganic cycles at non-global levels. When we move away from the narrowness of a climate change analysis to the more complex, systemic problem of the Anthropocene, there's an even stronger imperative to tell stories with many protagonists, each with different impulses and aims.[69] What works at one level in some places may not work at all universally.

66 John S. Dryzek and Jonathan Pickering, *The Politics of the Anthropocene* (Oxford: Oxford University Press, 2019)

67 Jean-Francois Bastin et al., "The Global Tree Restoration Potential," *Science* 365 (2019): 76–79, here 78.

68 Eike Luedeling et al., "Forest Restoration: Overlooked Constraints," *Science* 366 (18 October 2019): 315. For a general overview of this controversy, see Gabriel Popkin, "Growing Pains: Ecologist Thomas Crowther is Having a Bumpy Rise to Prominence," *Science* 366 (25 October 2019): 412–15.

69 For the importance of the difference between climate change and the Anthropocene, see Julia Adeney Thomas, "Why the 'Anthropocene' Is Not 'Climate Change' and Why It Matters," *AsiaGlobal Online: Asian Perspectives/Global Issues*, 10 January 2019, https://www.asiaglobalonline.hku.hk/anthropocene-climate-change, and Michael Ellis, "Climate-Change and the Anthropocene," *Inhabiting the Anthropocene*, 23 January 2019, https://inhabitingtheanthropocene.com/2019/01/23/climate-change-and-the-anthropocene/.

Questions of scale are at the heart of the difference between a "Singular Story" and a "Democracy of Voices." Defining the Anthropocene as the total accumulation of all human behaviors puts everything on one hierarchical scale and proposes the "Singular Story." Defining the Anthropocene as the result of some actions, systems, and institutions, but not all, maps a non-hierarchical web of connection that resists scaling in the conventional sense. Elements are only partially connected with one another.[70] The friction and sometimes the incommensurability of these ways of knowing and doing make it impossible to represent them all in a single coherent narrative or model.[71] At the global level, where agreement on the nature of the biogeophysical threat is essential, this diversity poses a problem. But, once agreement as to the overall goal is established, the diversity of means is, I think, all to the good. The more stories we have, the more ways forward we might be able to imagine, and the more resilience and redundancy we'll build into our ways of doing things as we aim to stabilize the Earth System.

There is no doubt in my mind that the Anthropocene requires a closer relationship between science, on the one hand, and the humanities and social sciences on the other. However, as I have argued here, this imperative does not mean that all forms of understanding must now conform to the questions and methods of biogeophysical science. In *The Evolution of Knowledge*, historian of science Jürgen Renn lays out a similar case. Instead of reducing human knowledge to scientific models, he argues for "realigning science with the challenges of the humanities." Knowledge, now, must focus "on the limits, the intrinsic complexities, and the historical dynamics of systems, be they ecological, societal, or cognitive. Our main concern is no longer universalizing the local (as it was in the modern period) but of localizing and contextualizing the supposedly universal."[72] We should heed these words. The Anthropocene tells us that we have a single Earth System, but we still need many voices and many disciplinary tools to tackle it.

70 Marilyn Strathern, *Partial Connections.* Updated edition. (Savage, Maryland: Rowman and Littlefield, 1991).
71 Julia Adeney Thomas, "History and Biology in the Anthropocene: Problems of Scale, Problems of Value," *American Historical Review* 119 (2014): 1587–1607. See also Anna Tsing, "On Nonscalability: The Living World is not Amenable to Precision-Nested Scales," *Common Knowledge* 18, no. 3 (2012): 505–24.
72 Renn, *The Evolution of Knowledge*, 408.

Conclusion

My essay puts a brave face on things. I have tried to convince you—and myself—that there are stories that do not end in Hothouse Earth. I have tried to make the case that our first step—everyone's first step—is to grasp the nature of our challenge as described by the AWG and Earth System scientists. Then, and only then, can we begin to craft useful human stories of how to navigate the singular reality of the Anthropocene. That reality, limiting though it is in comparison with the Holocene, is not yet deterministic. There is still more than one possible true story, and even more than one possible *emancipatory* story. Collectively, we must attempt to steer the Earth System by mirroring its totality with a system of global governance and technological initiatives. This story is an epic on the largest scale, unifying all forms of knowledge, peoples, and planet. But, alongside this epic tale, we can—and indeed must—attempt to foster a thousand experimental parables. Each could make changes to local systems, values, and institutions so that they don't push us ever more rapidly into dangerous territory. I tend to think that the more stories we have, the better our chances. These allegories of local goodness need to be orchestrated toward the same end of stabilizing the Earth System, and that can only be done on the grounds of science. Despite their contrasting protagonists, both the "Singular Story" and "Democracy of Voices" begin and end with a shared understanding of our daunting new reality.

All the while, as we ponder our way forward, the business-as-usual storyline swiftly propels us toward the Niagara Falls of a planetary threshold. If the *PNAS* article by Will Steffen and his co-authors is correct, we have little time and much to do. Once the Earth System cascades over the precipice, there's no crawling back. Our collective story at that point, on an uninhabitable planet, can offer no emancipatory narrative for human societies. Responding to the Anthropocene with an "Anything Goes" attitude that refuses to take the science seriously is complicit in business-as-usual. If this approach, the "normal one" we're used to, prevails, tragedy looms. For individuals amid the tumult of Hothouse Earth, I can imagine stories of both courage and failure: A few will face death with the clarity of a Stoic or a Buddhist; many will be kind to fellow sufferers; but most, in the words of W. H. Auden, will "die as men before their bodies die."[73] After that, all our stories are over.

73 The phrase is from "The Shield of Achilles" but the past tense of the poem is, here, made future.

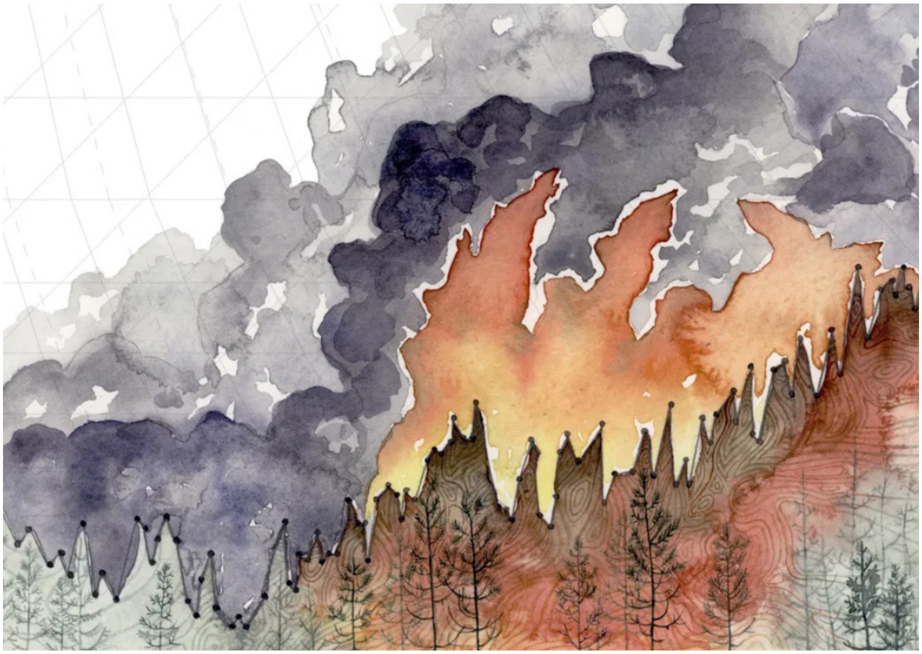


Figure 3. *Increasing Forest Fire Activity*, © Jill Pelto. Scientist and artist Jill Pelto uses data about sea level rise, glacier volume decline, increasing global temperatures, and the use of fossil fuels to create images that depict the planet's rapidly changing environments. See the artist's website for further works and information, http://www.jillpelto.com.

About the Authors

Julia Thomas grew up in the coal country of southwest Virginia. Her interest in environmental questions comes from her love of those mountains. As an intellectual historian of Japan, Thomas writes about concepts of nature and the Anthropocene, political thought, historiography, and photography as a political practice. Her publications include *Reconfiguring Modernity: Concepts of Nature in Japanese Political Ideology* (University of California Press, 2002, winner of the AHA John K. Fairbank Prize). She is also co-editor of three books, *Japan at Nature's Edge: The Environmental Context of a Global Power* (University of Hawai'i Press, 2013); *Rethinking Historical Distance* (Palgrave Macmillan, 2013); and *Visualizing Fascism: The Twentieth-Century Rise of the Global Right* (Duke University Press, 2020) as well as over thirty-five essays including "History and Biology in the Anthropocene: Problems of Scale, Problems of Value" (*American Historical Review*, 2014). She is currently working on *The Historian's Task in the Anthropocene* (under contract, Princeton University Press). With colleagues around the world, Thomas seeks to bridge the divide between the humanities and the sciences to address our global environmental crisis. She teaches history at the University of Notre Dame.

Jan Zalasiewicz is Emeritus Professor of Paleobiology at the University of Leicester. Also growing up in coal country (of Lancashire, UK), he is a generalist scholar, with field geology, palaeontology, and stratigraphy on his pallet of research topics. Alongside an enduring enthusiasm for mud and mudrock, long-dead plankton, and the enigmas of ancient climates, an interest in human-made geology started by chance, then became inescapable. He has written books such as *The Earth After Us, The Planet in a Pebble and Geology: A Very Short Introduction* (Oxford University Press, 2018), and (with Mark Williams) *Ocean Worlds and Skeletons* (both with Oxford University Press, 2014 and 2018 respectively). With Julia Adeney Thomas and Mark Williams, he recently co-authored *The Anthropocene: A Multidisciplinary Approach* (Polity Press, 2020). As member of the Anthropocene Working Group of the International Commission on Stratigraphy, he is also co-editor of the group's summary *The Anthropocene as a Geological Time Unit: A Guide to the Scientific Evidence and Current Debate* (Cambridge University Press, 2019).

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Cover image: *Landscape of Change*, 2020 © by Jill Pelto, www.jillpelto.com. Artist and scientist Jill Pelto uses climate change data to create poignant images of the world's environmental transformations. Reproduced here with kind permission.

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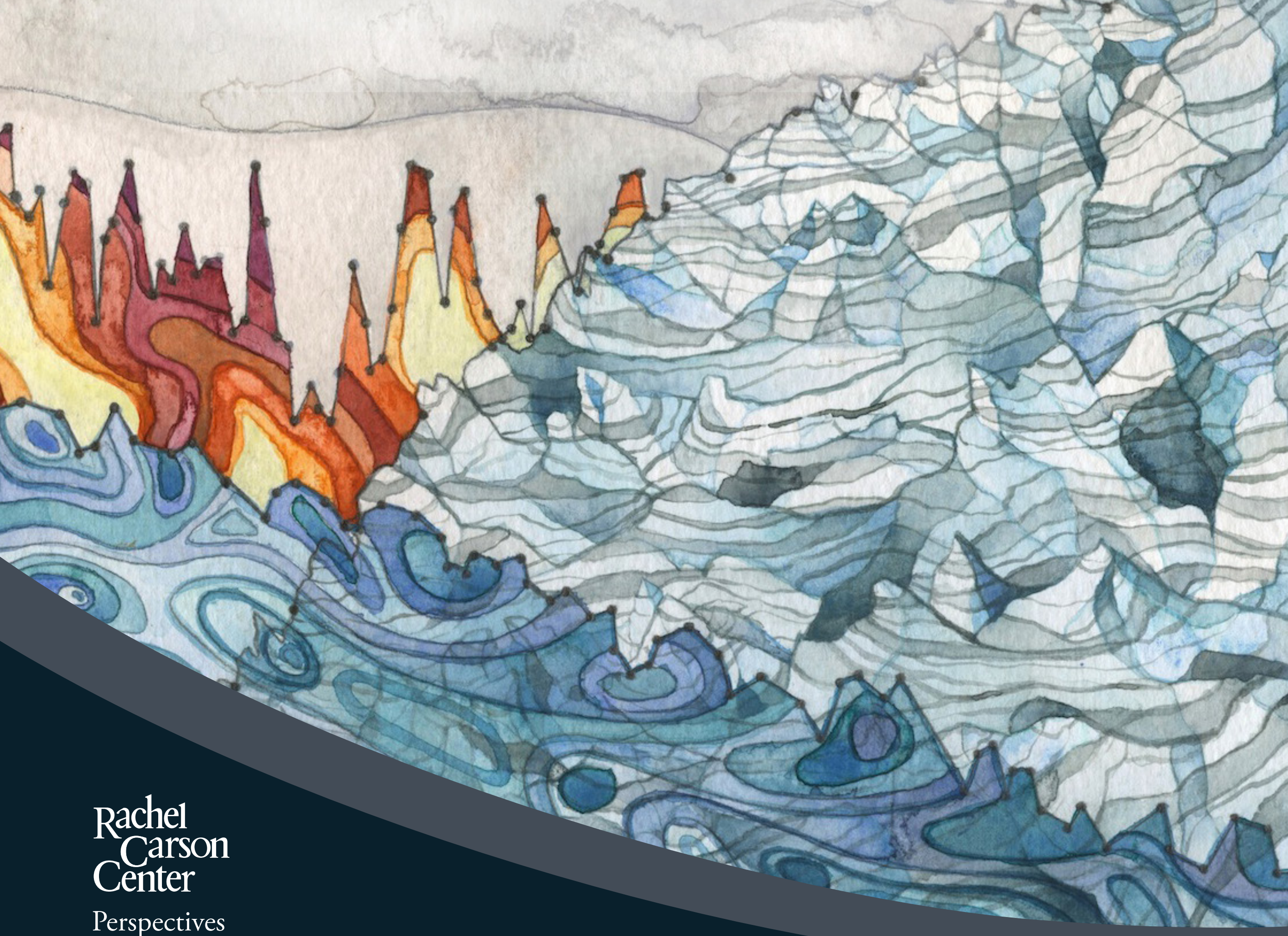
As we hurtle towards a less habitable Earth, we need to take stock of the possibilities for moving forward: first by understanding what we face, and then identifying how we might tackle the challenges ahead.

In this final issue of *RCC Perspectives*, geologist Jan Zalasiewicz provides compelling evidence for the Anthropocene as a proposed geological epoch, highlighting the daunting trajectories that humans have aligned for the Earth System. But the course is not yet set, as we see when historian Julia Adeney Thomas looks beyond the science to explore three types of narrative that are guiding perceptions of the Anthropocene, and in doing so illustrates the power of storytelling for shaping the future.

This tandem effort calls for multidisciplinarity as our best bet in building resilience to the complexities of a rapidly changing world.



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