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The Birth of the Anthropocene

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Introduction

This is a book about how to take the measure of a crisis. It is hard to grasp the scale of the modern environmental crisis, and part of the reason is that many things that had once seemed almost immutable are now changing rapidly.

The sea, for instance, is getting deeper. The world's oceans are likely to grow in height by between 40 and 120 centimeters before the end of the present century, letting them spill onto coastal land, where cities have always clustered. The cycle of the seasons is changing. The times are out of joint for plants like the early spider orchid, which has evolved to deceive mining bees into "pseudocopulation" as its only means of pollination: warmer springs mean that the bees emerge too early to be seduced by the flowers that depend upon them. Similar decouplings threaten many other lifecycles, like those of the birds who now hatch their eggs too late to catch the caterpillars that feed their young. Even the map of the world is being redrawn. The rivers that sustained the Aral Sea have been diverted for irrigation, shrinking it to barely a tenth of its former size. Sand and salt from the exposed lake bottom, mixed with pesticides, heavy metals, and defoliants, now blow onto the surrounding farmlands, making crop yields plunge and afflicting local farmers with asthma, tuberculosis, eye problems, typhoid, and cancer, and with kidney ailments from the saltiness of their drinking water.[1] Taken all together, this revolution that raises the oceans, reschedules the year, and turns water to land is bringing about a new epoch in the history of the world.

That last sentence might sound more declamatory than insightful, but in geology the word *epoch* has a specific technical meaning. A geological epoch is a midsize section of the planet's history. Students of the earth's biology and physical processes are now increasingly persuaded that the planetary system as a whole is undergoing an epoch-level transition. Earth's atmosphere, oceans, rocks, plants, and animals are experiencing changes great enough to mark the ending of one epoch and the beginning of another. The present environmental crisis is epochal in this particular, specialized sense. It is hard to comprehend its magnitude, but if we regard current environmental changes as the birth pangs of a new epoch, and if we give that epoch its place in geological time, in the long history of the earth itself, we might start to make sense of what we are facing. Recognizing what is now ending and what is beginning can help us respond to the predicament of living in the fissures between one epoch and another. The incipient new division of geological time has already been given a name: the Anthropocene. The idea of the Anthropocene epoch lets us understand the ecological crisis of the present day in the context of the distant past.

The central argument of this book is that the idea of the Anthropocene provides both a motive and a means for taking a very, very long view of the environmental crisis. It gives the ecological upheavals of the present day their proper place in the history of the planet. If you want to grasp the force, the scale, and the shape of the catastrophe as it unfolds, look for how it opens a fresh chapter in the long sequences of planetary time. To make sense of climate change, biodiversity loss, rain forest logging, and the rest, pay attention to how the current and imminent states of the world compare to those seen in the various epochs that went before.

If contemporary environmental changes add up to the birth of a new geological epoch, then earth scientists should ready themselves to adjust the geological timescale, the diagrammatic summary of the history of the planet upon which the whole science of geology rests. For now, the Anthropocene is not included on the official chart of the timescale that is maintained by its designated custodians, the International Commission on Stratigraphy. But a simplified and abbreviated version of that chart, with the Anthropocene added to it, would look like the diagram in figure 1.

Geological epochs such as the proposed Anthropocene are subsections of larger time units: periods, like the current Quaternary; eras; and ultimately eons. Epochs can themselves be subdivided into units called ages (not shown in this simplified diagram). All of these divisions and subdivisions come with fixed start dates and end dates, specified with greater or lesser margins of uncertainty according to the present state of geological knowledge. Evidently, when stratigraphers—experts in the physical sequences of rock strata upon which geological time sequences are built—postulate the beginning of a new epoch, they are making a quite specific claim. They envisage introducing one new piece, of a certain size and shape, into the carefully wrought mosaic of the geological timescale. The significance of the new interval, like that of all the older ones, would depend in large part on when it was said to have begun. Its hierarchical status, too, would matter greatly: to declare a new epoch would be a smaller step than creating an Anthropocene period, but an epoch would loom larger in geologic time than a mere Anthropocene age. So when it is used by stratigraphers, the word *Anthropocene* designates an interval that would occupy one particular place within the immense volume of geological time.

As yet the stratigraphers' debates about the Anthropocene, and the ins and outs of their conclusions, have never been examined at all closely from outside the tradition of the earth sciences. One of my aims in this book is to introduce other readers to the perspective on environmental history that has

EON	ERAS	PERIODS	EPOCHS
Phanerozoic *since 541 million years ago*	Cenozoic *since 66 mya*	Quaternary *since 2.58 mya*	Anthropocene
			Holocene
			Pleistocene
		Neogene *23–2.58 mya*	Pliocene
			Miocene
		Paleogene *66–23 mya*	Oligocene
			Eocene
			Paleocene
	Mesozoic *252–66 mya*	Cretaceous	*Subdivision into 31 epochs*
		Jurassic	
		Triassic	
	Paleozoic *541–252 mya*	Permian	
		Carboniferous	
		Devonian	
		Silurian	
		Ordovician	
		Cambrian	

Figure 1. Phanerozoic eon.

emerged from those debates. That perspective—which begins with an assessment of the geological traces that the last few centuries will leave behind in the distant future—has the potential to be enlightening for anyone concerned about the environment, not just geologists. But this book also has a much larger aim. I argue that the stratigraphers' version of the Anthropocene can yield a new way of understanding and responding to the modern ecological catastrophe. The catastrophe is so far-reaching that it cannot really be under-

stood without setting it in the context of geologic time. That means that the long view provided by geology can change the basics of environmental politics for the better. The Anthropocene of the stratigraphers opens a window onto the geological past, and the politics of the environment can be put on a new footing by the stratigraphic vision of the new epoch.

With contemporary politics in mind, the most immediate and most telling point of comparison for the Anthropocene is the Holocene epoch, the 11,700-year span of time that in the established version of the geological timescale still continues to the present day. I believe that in order to make sense of this comparison between the Holocene and the Anthropocene we will also need to look much further back into the geological past, where monsters abound. But the first crucial point is that introducing an Anthropocene epoch to the geological timescale (and placing its starting point somewhere in the last few centuries) would mean declaring that the Holocene is now arriving at its end. This book, then, will eventually be just as much about the terminal crisis of the Holocene as it is about the birth pangs of the Anthropocene, or rather, I emphasize that those two things are one and the same. The Holocene matters because it is the only geological epoch so far in which there have been symphony orchestras and hypodermic needles, moon landings and gender equality laws, patisseries, microbreweries, and universal suffrage—or, to put it plainly, the agricultural civilizations that eventually made all of those things possible. With its demise, the civilized rights and pleasures previously confined to the Holocene will have to negotiate radically changed ecological conditions if they are to endure, let alone if they are to be extended more generously to more people. That is the political problem of the Anthropocene.

It is always intellectually stimulating to find that you are positioned in the interstices of two different worlds. The idea of the Anthropocene makes this state of being in between epochs the starting point for political thinking. In the last chapter of this book, and in the conclusion, I argue that environmentalists should think of themselves as being caught up in the transition between two geological intervals, and that the goal of environmentalism should be to negotiate a way through this transition. That means demoting the ideal of "sustainability" from its status as the greens' highest objective. Instead, environmental movements will need to be concerned above all with environmental injustice and with fostering ecological pluralism and complexity in the face of the simplifying tendencies of the Holocene's final phase. The birth of the Anthropocene should be attended by vigilant resistance against the searing away of multifaceted socioecological systems and their replacement by vulnerable, saturated monocultures. Or to put it more positively, the jerky crossing between epochs can be cushioned by upholding states of life—both ecosystems and human societies—that are variegated, intricate, and plural, ones in which lively forces of all kinds contend with and interweave with one another.

The word *Anthropocene* is descended from the Greek ἄνθρωπος (*anthropos*), meaning either "man" or "human." It is a recent addition to the vocabulary of environmental politics: it was coined, or at least it came to something like widespread notice, only at the end of the twentieth century. But since then it has prospered in a remarkable way. In some academic circles it has lately become a much-used and fashionable term. In the most advanced circles of all it has already gone on to the next stage and is considered rather worn-out and déclassé. Among both the enthusiasts and the skeptics the word has been tossed into debate much more frequently than it has been explained or defined. More often than not, it has been used without the intention of any very specific allusion to the work of the stratigraphers that provides its significance in the context of this book. That's fine, of course. There is no reason why the word should not be used in a whole range of diverse, contested, and even incompatible ways. For the sake of clarity, however, I would like to set out, before going any further, some of the things that "the Anthropocene" will not mean in the pages that follow.

Firstly, the Anthropocene, in this book, is not the name of a fall from Eden. It does not describe the period in which human acts have brought about the end of nature by pollution and despoliation: it is not a rhetorical device to make clear the extent of human depravity. It follows that the Anthropocene is not the kind of thing that it is possible to "mitigate," like an oil spill. Secondly, and conversely, the Anthropocene is not a breakthrough from tedious natural stasis. It is not the transcendence of the earth's old limits, the sundering of its chains. It does not stand against all previous epochs and periods, looking glamorous and disreputable where they were worthy and dull. It is one epoch among many on the same footing, rather than one-half of the earth's history.

Thirdly, despite its name, the Anthropocene is not an anthropocentric concept. The epoch does not get its name because nature is now completely subordinated to human agency, as if clouds now form and swallows now fly only after getting permission from human beings. The name suits it because human societies exert a novel and distinctive degree of sway in the physical world, but other creatures still continue independently to exert their own powers and to pursue their own interests in this new field of action. Humanity is not at the center of the picture of the Anthropocene, opposing, by its powers of mind, the passive matter that encircles it. Instead, human societies are themselves constructed from a web of relationships between human beings, nonhuman animals, plants, metals, and so on. Nor, fourthly, is the Anthropocene a concept that reduces humankind to an undifferentiated mass. I will return—at some length—to that point. To say that the earth is undergoing an epoch-level physical transition, in which the activities of sundry groups of humans are playing key roles, does not imply in the least that all human beings have thus far acted in unison, or that they are all collectively responsible for the new state of affairs.

Finally, in arguing for the importance of looking at the environmental crisis in the context of geological time, I am not at all advocating a distanced, Olympian perspective on the human condition. Even though the requisite context is prodigiously broad, paying attention to it does not mean rising above the present emergency in a spirit of enlightened impartiality. It does not mean drawing a contrast between the mere fleeting turbulence of humankind's concerns and the eternal currents of the great stream of life, and then looking with cool equanimity to the remote past and future where civilization is as nothing. In fact, it can mean exactly the opposite. Against the facile amorality of the truism that nature will not miss humankind after humans' inevitable demise, the idea of the Anthropocene may yield above all a sense of locatedness in time, a sense of being caught in one particular historical moment.

In a word: no more clean breaks that put humans on one side and nature on the other and, thereby, merge each antagonist into a uniform blob. I argue in this book that the birth of the Anthropocene does something quite different. It redistributes agencies, reconfigures systems, and reorders the loops of consequence and assimilation out of which the workings of the earth are made. The transition from one epoch to another is a generalized disruption, a drawing up of new accounts.

The opponents of the Anthropocene (of whom there are already many) often worry that the new word implies a bleak and narrow-minded picture of the world. In that picture, the planet has become a merely artificial construct, passively molded by human activity, and the best remaining hope for humanity is to allow a scientific elite to administer global affairs from the top down, so that natural resources may be exploited in the most efficient way and affluent consumer lifestyles may be kept afloat for as long as possible. I share those critics' dislike of such a scenario. But this book puts forward a very different world-picture. Here, the world is seen as characteristically full of devious chains of cause and effect; of intricate braids that link economies to ocean currents and ecosystems to plate tectonics; and of what climatologists call "teleconnections," far-distant perturbations that prove to be coupled by hidden bonds—although here the teleconnections can take the form of trade routes and cash flows as well as seesaws in atmospheric pressure. Feedback circuits let subtle evolutionary and chemical modifications have worldwide effects. Human societies exert their influence on the planet and so provoke the latest twist in a chancy, surprise-filled geological history.

The recognition that the world is in the midst of an epoch-level transition is of a piece with the general tenor of earth science research over the last forty years. During that time, a conceptual framework usually called *neocatastrophism* has come to the forefront of the earth sciences. I propose in this book that the idea of the Anthropocene should be seen as another product of that neocatastrophist turn. Neocatastrophism has enlivened modern geoscience by dispatching the belief that the planet took on its current shape only through the gradual and continuous operation of familiar processes like erosion and sediment buildup. The new geology lets into the picture abrupt die-offs and bursts of species formation, climatic and geomorphological upheavals, and high-speed collisions with extraterrestrial bodies. Bit by bit, the life of the earth before human civilization has come to look ever more dramatic and incident-packed. There was no stately, teleological progress toward the arrival of humans. Instead, the story has been full of sharp twists and transformations. Built into the earth system are a multitude of concatenated feedback mechanisms. These feedback mechanisms have repeatedly amplified even comparatively small initial changes in unpredictable ways, making nonhuman history as contingent and chaotic as the history of kingdoms and empires.

This new understanding of the earth system has greatly influenced climate scientists, for instance. As they keep struggling to explain, the reason to be concerned about global warming is not that the composition of the atmosphere is now altering rapidly for the first time ever, or that it is disrupting the eternal harmony of the climate system to frighteningly unknowable effect. On the contrary, it is that the atmosphere and the climate have changed swiftly and mightily from time to time in the past. These changes have tended to bring with them a new configuration of living things, one that—however fine in itself—has been to the old one like a conquering army to a fallen city. That ominous historical record is the reason why contemporary perturbations to the climate system are at the heart of the dangers posed by the birth of the Anthropocene.

Neocatastrophism has introduced us to a whole list of geophysical forces—asteroids, ocean currents, volcanoes, and the like—that, under the right circumstances, can suddenly come to exert a much greater and more destabilizing influence than usual on the workings of the earth system. The idea of the Anthropocene, as I want to construe it, simply adds human agency to that list. The Anthropocene gets its name from humans, the *anthropos*, because its distinguishing characteristic (for now) is the dramatic influence that human societies are having on the physical world. It is not the case that human interventions in the earth's organic makeup, or in the processes governing its soil or water or atmospheric cycles, are still dwarfed by any mightier forces that transcend humankind's paltry strength. Far from it. Human societies are now among the most powerful of the ecological forces that operate on, above, and below the surface of the earth.

In this light, perhaps the most incisive account of the new epoch so far has come not from a scientist or a campaigner but from a poet, the Canadian Don McKay. McKay's rich body of work has been characterized most of all by his interests as a birder. In his two most recent collections, however—*Strike/Slip* and *Paradoxides*—his line of sight has turned lower and slower. Geology has become the keynote of his poetry, which has hunkered down among fossils, rocks, and tales drawn from deep time (that is, by analogy with "deep space," the abyss of time that stretches back from a few thousand years ago to the beginnings of the earth). McKay has written poems about hexagons of quartz that formed long before the first mathematics, about stumbling across a trilobite on the shore of the North Atlantic, about the

imponderability of hundred-million-year timescales and the wearing away of mountains. In a lecture in 2008 he reflected on the uses of the Anthropocene. "All poets take naming seriously," he observed, and for him, giving a name to the Anthropocene creates for us "an entry point into deep time." The preceding geological epochs seem to run backward from this new one "like rungs on a ladder" descending within a few steps into a time before human existence. With a quantity of blunt sarcasm, McKay lays out what seems to me the profoundest significance of the birth of the Anthropocene:

> If we think of ourselves as living in the Anthropocene Epoch, we realign our notion of temporal dwelling. Generally, time is viewed in relation to humanity's place in it, and consists of a present, where we live, and a recent past called history, which is felt to be important for informing the present and helping us understand ourselves better. When we speak of the past with reverence or chagrin, it is this shallow past we mean. Before history there is a vague distant past called prehistory, comprised of a jumble of relics and catastrophes, dinosaur bones mixed with clovis points, missing links, Lucy and The Flintstones cohabiting in the caves of Lascaux, Australopithecus confused with archaeopteryx, and the whole *mélange* construed as a sort of amniotic stew from which we, the Master Species, miraculously emerged. The name "Anthropocene," paradoxically enough, puts a crimp in this anthropocentrism, making the present a temporal unit among other epochs, periods and eras. . . . On the one hand, we lose our special status as Master Species; on the other, we become members of deep time, along with trilobites and Ediacaran organisms. We gain the gift of de-familiarization, becoming other to ourselves, one expression of the ever-evolving planet. Inhabiting deep time imaginatively, we give up mastery and gain mutuality.[2]

The Anthropocene sweeps humankind into the turbulent flow of geohistory. It announces a new intimacy with the older rungs on the ladder. "We"—and there will be much need to examine the implications of that collective pronoun—join the trilobites as actors in the long drama of life on earth: as another planetary force exerting its powers of survival and transformation. More than anything else, the Anthropocene is a way of thinking with deep time.

The best guides to this wild drama of deep time are the most fastidious and bookkeeping of figures in the profession of geology: the stratigraphers, who devote their labors to the precise demarcation and time-tabling of the deposition of rock layers all around the world. They have sought to measure the nascent epoch against the strict and cautious criteria that they have established for the formalization of geological intervals. The willingness of some stratigraphers to take on that task has given rise to the most vivid, the most radical, and the most disconcerting of all conceptions of the Anthropocene as it comes into being. It is their Anthropocene, a brand-new epoch to join the dozens that preceded it, that is my subject here.

In the first chapter that follows, I draw attention to the place of deep time in contemporary environmental news reporting. News stories often describe modern-day environmental changes as being unprecedented for thousands or even millions of years. That sounds not only sinister but also potentially confusing to anyone who is not an expert in earth history—a category that includes the great majority of people who are concerned about environmental issues. I criticize some unhelpful ways of imagining deep time, and describe how an alternative, geological perspective has grown up since the late eighteenth century. I also explore the question of just how much influence human societies currently have over the workings of the living planet. The idea of the Anthropocene itself enters the scene in chapter 2. Since the earth system scientist Paul Crutzen coined the word at the end of the twentieth century, its use has spread ever more widely. I trace the most important of those uses, and the backlash against the term that has developed in the last few years, before arguing that at least some versions of the Anthropocene are not guilty of the charges—of anthropocentrism and antidemocratic arrogance—that have been brought against it.

Chapter 3 looks in detail at just one way of thinking about the Anthropocene. This is the stratigraphic version of the term, the one that takes it literally as a potential new addition to the geological timescale. I explore how the implied relationship between the Anthropocene and the *anthropos* changes when the word is taken in a stratigraphic sense, and I describe the thought experiment that underpins the stratigraphers' approach: if alien geologists were to arrive on the earth in a hundred million years' time, what fossilized traces of present-day events would they find? I spend a long while on the seemingly hairsplitting question of when exactly the new epoch should be said to begin, because that question proves to be a way of addressing the crucial issue of how geological designations can reflect the environmental history of the world over the last several centuries.

Those first three chapters describe how the idea of the Anthropocene can open up a window on geological time. The final two chapters offer a look through that window. The main part of each one is a broad-brush narrative time line. Chapter 4 surveys the Phanerozoic eon, the 541-million-year interval within which the Anthropocene ultimately belongs, and chapter 5 surveys the Holocene epoch, the Anthropocene's immediate predecessor. The aim of those narratives is to give life and significance to the geological timescales that are the necessary points of reference for the new epoch, timescales that might otherwise look blankly intimidating to many environmentally conscious people who do not happen to be professional geologists. Along the way, chapter 4 considers the place of *Homo sapiens* in deep time, and chapter 5 considers the place of civilization in the period since the end of the last ice age. In the conclusion, I tease out the political implications of the idea of the Anthropocene epoch. It can be both a polemical slogan and a conceptual basis for environmental politics. Talk of sustainability, and of respecting the ecological limits to growth, tends to imply a forlorn attempt to escape from temporal constraints. In contrast, a stratigraphic perspective makes the specifics of the present crisis the point of origin for environmentalism. A politics grounded on the attempt to dwell within and to shape the terminal crisis of the Holocene epoch would be transnational in its spirit and committed to analyzing the inequalities of power that often trigger environmental catastrophe. Its aim would be to foster a raucously democratic pluralism in the ecosystems of the birth of the Anthropocene.

CHAPTER ONE

Living in Deep Time

The Anthropocene epoch offers a way to understand the present environmental crisis in the context of deep time, the realms of the distant geological past. And as a strange recent tendency in environmental news reporting shows, current generations are being plunged into deep time, like it or not, by the once-in-a-million-year environmental changes that are taking place around them. Climate change deniers share with some well-intentioned environmentalists a damaging and unrealistic view of the planet's deep past as an essentially static state of affairs. But since the end of the eighteenth century the sciences of the earth have developed a very different way of looking at the distant past, a perspective that has grown ever more clearly defined thanks to some major developments in geological thought during the last few decades. In this alternative view, geological time is historical through and through. Tracing its story reveals a dynamic narrative of floods, climate changes, and unpredictable evolutionary development. The birth of the Anthropocene epoch is best seen as the latest turning point within the swirling history of deep time. But if the story of the earth has always been so lively, one might wonder whether present-day change is in fact all that noticeable in the grand scheme of things. What, then, is the real scale of human-induced changes to the earth's systems as a whole?

THE LONG MOUNTAIN

Early in May 2013, at an observatory on the black volcanic slopes of Mauna Loa, Hawaii, the daily average concentration of carbon dioxide measured in the atmosphere rose above 400 parts in every million. The level declined by some 7 parts per million over the next few months as CO_2 was drawn from the sky by summer vegetation across the Northern Hemisphere, before it began to rise again in the autumn. The following year, the 400 ppm threshold was crossed in March. A year later, it was crossed in January.

The air of Mauna Loa, the "long mountain" that ascends from the middle of the Pacific, has long been closely monitored. The mountain's remoteness, and the lunar barrenness of its upper slopes, mean that its bright clean air can serve to indicate the state of the whole planet's atmosphere. And because the chemical composition of the atmosphere has been an intensely political issue ever since the beginning of public concern about greenhouse gases in the late 1980s, the first crossing of the 400 ppm limit at the Mauna Loa station was widely reported. The rapidly increasing carbon dioxide level was understood to be the consequence of human activity, and to be cause for concern about the changing state of the climate. The newspapers that reported the story also felt the need to supply some historical context. As recently as the middle of the eighteenth century, journalists explained, CO_2 concentrations stood at around 280 ppm. Thus, given that no other factors can plausibly explain the increase, three-tenths of the current CO_2 level is attributable to the development of industrial society since the late eighteenth century.

In the complex field of climate science, what story could be clearer than this? After all, explanations of the contemporary world that look back as far as the late eighteenth century are perfectly familiar. That is most obviously

and especially the case in the United States, where two documents written shortly before 1800, the original Constitution of the United States and the Bill of Rights, still frame a remarkable proportion of everyday political discussion. It is also true more widely, however. The last decades of the eighteenth century were a formative period for European colonial expansion, so the influence of that era can still be seen in the basic shape of the modern world, its unequal distribution of wealth and poverty. Moreover, the period of the Industrial Revolution also witnessed the French Revolution, the founding event of the modern liberal state. Asked about its impact in the 1970s, the Chinese statesman Zhou Enlai is often—although perhaps mistakenly—said to have replied, "It is too soon to tell." Authentic or not, Zhou's aphorism is admired as a telling expression of a plausible idea: that the impacts of the French Revolution are still playing out, and that contemporary politics still takes place partly in the shadow of 1789. But what if Zhou had said the same thing about (for instance) the formation of the Isthmus of Panama—the clasping of hands between North and South America, which divided the Pacific from the Atlantic three million years ago? What sort of political event, if any, might realistically be placed in a framework that stretches back not hundreds of years, but millions?

That question arises because the newspapers that reported on the phenomenon at Mauna Loa did not look back only as far as the eighteenth century. The journalists writing up the story evidently felt that their readers would be poorly informed if they were confined to such a short-term perspective. What was so special, after all, about the carbon dioxide levels of the mid-eighteenth century, just before the rise of industrialism? To explain that, the *New York Times* broadened its purview spectacularly. "For the entire period of human civilization, roughly 8,000 years, the carbon dioxide level was relatively stable near [280 ppm]." No doubt many of the *Times*' readers in May 2013 felt that, as conscientious modern citizens, they should be able to appreciate the significance of the climate change story on the front page of their daily newspaper. But it seemed as if in order to manage that, they would need to take on board not a mere couple of centuries of historical background but eight thousand years. Or rather, even doing that would get them no more than a hundredth of the way to understanding the story.

As the *Times* coolly told them: "From studying air bubbles trapped in Antarctic ice, scientists know that going back 800,000 years, the carbon dioxide level oscillated in a tight band, from about 180 parts per million in the depths of ice ages to about 280 during the warm periods between." Ice ages, in the plural! The mountaintop sages of Mauna Loa began to sound like those Hindu scholars who reflect on the hundreds of thousands of solar years that make up a yuga, each one a part of the mahā-yuga cycles that form one seventy-first part of a twenty-ninth of a day in the life of Brahmā. But the *Times*' reporter went further still. He finally set the morning's news from the Pacific in its proper context when he observed that "the last time the carbon dioxide level was this high was at least three million years ago, during an epoch called the Pliocene."[1]

The *New York Times* was not alone. In Britain, the *Guardian* wrote up the story with an explanation that the new CO_2 level had "not been seen on Earth for 3–5 million years, [since] a period called the Pliocene." Brazil's *O Globo* noted that carbon dioxide had not reached the "marca símbolo" of 400 ppm for "3,2 milhões de anos." In France, *Le Nouvel Observateur* reported the upper figure: it was perhaps "cinq millions d'années" since "l'atmosphère terrestre" had contained so much carbon dioxide. Again and again, a story about rising carbon dioxide levels in the atmosphere prompted invocations of the ancient past. Why? What was at stake in explaining one very small number—400 parts per million, or 0.04 percent—by invoking a second very large number, five million years? Why was a period of time usually left peacefully to geologists, paleontologists, and evolutionary biologists suddenly everybody's concern?

The journalists were surely right to think that the significance of the 400 ppm concentration could not be grasped without making some reference to the last time CO_2 levels were so high. This pressingly topical issue, to which politicians and pundits were prompt to respond, really did demand to be juxtaposed with the deep geological past. And more strangely still, the breaching of the 400 ppm threshold was far from alone in this respect. Any number of recent environmental changes, familiar to anyone who reads the papers, exhibit just the same doubleness. On the one hand, present-day political salience. On the other, legibility only through deep time. Talking about the current environmental crisis seems to mean that one also needs to talk about very distant seasons in the history of the earth.

Stories about melting glaciers come with references to when the world was last free of ice sheets, tens of millions of years ago. A report that temperatures in the Arctic are at their highest for at least forty-four thousand years becomes headline news. Disputes about government agencies' handling of floods or forest fires are framed by quotations from experts who describe how rivers shift their courses back and forth over thousands of years, or how certain species of woodpecker have evolved over millions of years to feed on the grubs that colonize burnt trees. Conservationists argue that the baselines for what constitute fully functioning ecosystems may need to be set at tens of thousands of years ago, before most large mammals were driven to extinction. Campaigners against global warming describe it as madness to burn up within a few decades coal and oil deposits that accumulated over many millions of years. Newspaper features about biodiversity loss are given urgency by the suggestion that the world may be starting to experience only the sixth mass extinction of the past half a billion years. The most seemingly transient phenomena can turn the attention of a concerned public to times long ago, as with the news of a study showing that the Roaring Forties, the persistent westerly winds in the Southern Hemisphere, are blowing more strongly and on a more southerly track than at any time in at least the last millennium.

This tendency is probably obvious to anyone who pays even casual attention to news stories about environmental issues. Nonetheless, it is easy to overlook just how noteworthy the tendency is. Individual references to deep time in environmental reportage often appear incidental or ad hoc. They reveal their real significance only because of how frequently they recur. Taken as a whole, these opportunistic media allusions make a crucial point. That is: in order to understand the current environmental crisis you have to think about very long ago. From year to year, and from decade to decade, the world of the early twenty-first century is undergoing changes that can be grasped only by switching to timescales of tens of thousands or even millions of years. Facts that politicians and pressure groups are prone to argue about, to assign blame for, and to promise their electorates or their memberships to ameliorate—contemporary political facts, in other words—need to be explained by referring to eras long before any such thing as politics even existed. Climate change, biodiversity loss, chemical pollution, and so on have made journalists talking to the public invoke geological time spans as casually as if they were paleontologists engaged in conversation with glaciologists.

That poses a problem, surely. The environmental catastrophe has politicized deep time. So how are people who care about the environment, but who are neither paleontologists nor glaciologists, supposed to deal with these vast expanses of history? How can they understand them, imagine them, or make sense of day-to-day environmental changes that are placed in this startling context? If we read that the federal minimum wage in the United States has declined to a real-terms level last seen in the 1950s, or that the richest 1 percent of Americans and Europeans are well on their way to securing their largest share of national wealth since before the First World War—comparisons that have the same structure as the Mauna Loa report—it

is relatively easy to see the point that is being made. By contrast, the references to deep time bandied about in environmental news reporting are likely to be confusing and instantly forgettable for noninitiates. As one professor of geography wearily remarks, "It is common when asking new undergraduates about periods of past time when things may have happened . . . to find a random selection of answers that fails to differentiate between hundreds, thousands, hundreds of thousands and even millions of years."[2]

The single most memorable date in the ancient past—the equivalent, for the British, of the Battle of Hastings in 1066—is probably sixty-six million years ago. It was then that the terrestrial dinosaurs were eradicated by a comet or asteroid that struck the earth off what is now the coast of Mexico. With a few possible exceptions like that, there is no particular reason why ten million years ago should summon up mental images in the minds of nonspecialists that are very different from a hundred million years ago, or one million. If the last of those dates stands out, it might be only because of Hammer Films' *One Million Years B.C.*, with its stop-motion dinosaurs lurching toward underdressed cavewomen.

News reporters can mitigate the problem with nutshell explanations of the dates that they discuss. The *New York Times*' splash on the CO_2 levels at Mauna Loa included an explanation that three million years ago the climate "was far warmer than today, the world's ice caps were smaller, and the sea level might have been as much as 60 or 80 feet higher." That sort of gloss certainly helps, but only as a sort of decontextualized snapshot. Carbon dioxide concentrations and sea levels evidently do not correlate perfectly, and without a continuous narrative to hold on to, mapping the rise and fall of CO_2 and the oceans step by step over all this time, even the facts that the *Times* recorded might slip out of one's grasp. It could have been thirty million years ago that the earth was so warm and its air held so much carbon. It could have been a mere three hundred thousand. It's easy to forget.

One might object that something relatively similar is true of many news stories besides the one from Mauna Loa. Leafing through the newspapers, many of us, no doubt, would like to have a better grasp of the historical background to current affairs of all kinds, not just environmental ones. But those other stories are never quite analogous to the ones about the environment. Reading a headline about sectarian clashes in Northern Ireland, you might justifiably be far from certain about the year of the battle commemorated by the Orangemen's provocative marches on the twelfth of July, and only be able to hazard an estimate that it took place three or four hundred years ago. Still, no one thinks that the Battle of the Boyne took place thirty years ago, or three thousand. On the business pages, by contrast, misremembering figures by an order of magnitude is certainly possible: when AIG was bailed out during the crisis of 2008, did it cost billions, tens of billions, or hundreds of billions of dollars? But those fantasy numbers of the financial system operate by their own rules, and when they grow unmanageably large they become just one more example of stock markets' many arcana, not a main impediment to grasping the news of the latest crash or takeover.

The science pages might direct your attention back to the very origins of time, and describe the latest research into the Big Bang itself. But in that case the astrophysicists' conclusions (as opposed to the question of how their laboratory is funded) hardly sound like a political topic. Back on the news pages, demagogues on the ethnic-nationalist fringe assert one people's exclusive right to a territory on the basis that they have always been there. But even the most rabid and fantastical among them claim a tradition of ownership that goes back only a few thousand years at most. In the lifestyle section, you might read about the latest fad in dieting—paleo dieting—based on a theory about what "our hunter-gatherer ancestors" used to eat. But moralizing the distant past in that way (as evolutionary pop psychology also tends to do) is not quite the same as asserting that it has a pressing *political* relevance.

In short, politicizing deep time is a habit peculiar to environmentalism. Ecological politics struggles with the difficulty of imagining the distant past. Efforts to fix geological time in familiar, tangible terms only make it even stranger. At an inch to a year, the age of the earth is nearly equivalent to three circles round the equator. Or as one famously vivid illustration has it: "Consider the earth's history as the old measure of the English yard, the distance from the king's nose to the tip of his outstretched hand. One stroke of a nail file on his middle finger erases human history."[3] Certainly, the geological timescale can be learned: geology students need to do so in order to pass their exams. But it is hardly reasonable to make that memorization exercise a requirement for ecological good citizenship. Everybody is already overburdened with the weight of information available to them about the state of the planet. What is needed instead is some plausible way of coming to terms with the earth's bewildering antiquity, now that climate change and species loss have forced the subject forward into public attention.

TWO VERSIONS OF DEEP TIME

Something else makes it doubly urgent to find a rational way of setting environmental change in its deep-time context. Many previous allusions to the distant past in the context of ecological politics have been the very opposite of enlightening. Invocations of deep time are extremely common among those voluble bores who hold that climate science is a plot to improve researchers' access to funding grants or to impose a Marxist world government. The invaluable Skeptical Science website maintains a list of the most frequently exploited climate myths, and at the top of the list is a claim about deep time. That is: the climate is always changing, so climate change is not to be feared. "Climate has always varied; it is a special sort of narcissism to believe that only the recent climate is perfect," as the most highbrow of the global warming conspiracy theorists sneers.[4] Talk-show paleoclimatologists remark that the planet was warmer than today a thousand years ago (untrue), 8000 years ago (possibly true), 125,000 years ago (true, for now), indeed for the great majority of the time since the extinction of the dinosaurs (true by a large margin). Absurd, then, to worry about recent decades' correction back toward the long-term mean, given that deep time is full of warmer periods. This argument sometimes leads to the simple logical non sequitur that because past climate change was not caused by humans, neither is that of the present day. But the argument can also take a somewhat subtler route.

In this line of thinking, climate change is natural whatever its cause—aren't humans, too, a part of nature?—so there is no reason to worry about what the temperature is during any given period. Nothing natural is alien to the conspiracy theorists. Any climate recorded in the distant past is equally welcome in the future; the "alarmists" are only exploiting a superstitious fear of change. What underlies this way of thinking is a pretension to a standpoint of Olympian impartiality. To a totally disinterested observer, the climate regimen that humans have experienced for the past few thousand years is neither more nor less desirable than some tremendously hotter and wetter one. In those much hotter conditions, agriculture would fail and cities would drown, but palms and giant ferns would thrive. The world would be "lush" and "verdant." Objectively speaking, the earth would remain intact, no matter what the human death toll along the way. For the conspiracy theorists, then, the geological past serves as a universal stamp of validation, as a limitless repository of the natural.

What's more concerning is that a remarkably similar attitude to deep time can be seen among some well-meaning environmentalists. The use of deep time is often a way in which their beliefs coincide with the stratagems of their most cynical or most deluded opponents. Take the environmental thinker who has berated politicians for paying attention only to "desperately trivial twinklings of time" like the years and decades ahead. Colin Tudge writes, "It is impossible to contemplate the environment unless we think as a matter of course in very long periods of time indeed. In fact . . . *we cannot*

claim to take the environment seriously until we acknowledge that a million years is a proper unit of political time."[5] That is bound to seem hopelessly intimidating, unless it just sounds pretentious. If everyone who is so trivial as to worry about what the next decade has in store is letting the side down, then the only people who take the environment seriously are a handful of well-educated contemplatives, at once high-minded and perfectly ineffectual. To be a good environmentalist, Tudge believes, means adopting a perspective that is no less Olympian than the one advocated by the global warming paranoiacs.

The same applies to that genre of green aphorisms in which the scale of the earth's history is used to generate eye-catching observations about the relative suddenness of modern environmental change. The wilderness guru David Brower used to travel the world giving a speech in which he condensed the story of the planet into the biblical six days of creation. Life began at noon on Tuesday, and "the beautiful, organic wholeness of it" developed over the next four days, he would say. But on Saturday night, "at one-fortieth of a second before midnight, the Industrial Revolution began. We are surrounded with people who think that what we have been doing for that one-fortieth of a second can go on indefinitely. They are considered normal, but they are stark, raving mad."[6]

Brower's speech—his "sermon"—was famous in its era and milieu, and many variations on his theme have been designed, circulated, and retweeted ever since. But the attention garnered by this half-truth comes at an indefensible cost. Brower's story seeks to bring confusion rather than clarity, to sweep away understanding in a moment of panicked sublimity. In his sermon the Industrial Revolution becomes the only real event in the history of the planet, on the model of a fall from paradise. The last two hundred years are reduced to a single, momentary blitz of criminal stupidity, a view that is mirrored and enabled by reducing what went before to a nearly infinite period of tedium. Humankind, busy and dynamic, is set in opposition to the prehuman world, taken as passive and static. That separation could scarcely be more distant from an ecological perspective whereby all human life is enmeshed within a web of planetary forces. Brower's sermon rested on the hope that a working environmental movement could grow from a feeling of bewilderment, from a startled sense that humans do not really belong on the planet, rather than from informed ecological citizenship.

To be clear, there is no reason to hold back from angry denunciations of ecocide, or from gestures of mourning for what has been lost: both have always been important to the environmental tradition. Equally, there need be nothing disheartening about an awestruck recognition of the antiquity of the earth. Fusing the two together, however, means presenting recent environmental change according to a stupefying timescale that denies it any meaning except as an emblem of the infinite culpability of humankind.

Deep time forms a single, beautiful organic whole both for David Brower and for the global warming conspiracy theorists. According to their shared understanding of the geologic past, all changes in earth's history before those of the last few centuries were equally natural, and for that reason the world was until then essentially unchanging—that is, not really subject to history at all. Perpetual but undifferentiated change throughout the life of the planet blurs into an effective stasis that is simply the natural state of affairs. If deep time is imagined as a single, homogenous mass, then with only the slightest change in perspective it can seem to justify either a primitivist excoriation of the whole industrial era, or an impatient dismissal of any possible ill effects from it. There must be better ways than this to imagine the distant past.

The sciences of the earth invite us to think of geologic time in a different way: as a drama without any preestablished outcomes. It is not an arena in which stable natural processes endlessly reproduce themselves, but a field of action dense with contingent successes and catastrophes. A *geohistory*. Only partly by coincidence, this is a way of thinking that was first documented at

the very time and place of the start of the Industrial Revolution, at one proposed point of origin of the Anthropocene itself. Britain and France in the late eighteenth and early nineteenth centuries saw the emergence of what Roy Porter has called a "geological way of seeing." A new science, geology, arose from the idea that by examining rock strata one could discern both an irreducibly complex historicity and something, well, "spiritual." As Porter describes it, the geological way of seeing was an "analysis of the Earth in terms of great antiquity, the majesty of slow and profound process, the investigation of subterranean depths"; it meant that "to read the story of the strata was to read an autobiography of great revolutions, decay and restoration, the struggle of titanic Earth forces."[7] This was a perception that belonged in part to its historical moment, colored by Romantic landscape aesthetics and an unprecedented revolutionary impulse across Europe and America. It had, however, a permanently lasting effect. In the words of the preeminent authority on the subject, what took place was "the progressive transformation of the scientific study of the earth by the injection of historical ways of interpreting what can be observed: the earth, and by extension the natural world as a whole, came to be seen as having their own *histories*."[8]

The decades either side of 1800 saw a multifaceted change in how Europe's natural philosophers thought about the physical state of the earth. The older approach was predominantly Newtonian in spirit. Competing "theories of the earth" attempted to elucidate the natural laws whose operation must both explain the world's present-day form and determine the course of its future development. But during a period centered in the revolutionary decade of the 1790s, antiquarian history was imported into the study of the earth. By analogy with the archaeological exploration of the classical world, European savants came to search "nature's archives" for "nature's monuments" and "nature's inscriptions." What that implied was the simple but fertile idea that things could have turned out differently. The old supposed laws and principles might adequately label the forces acting on the world, but they could not explain how those processes had in fact played out over time. The course that affairs had taken should instead be regarded as a one-time-only matter of happenstance, impossible to predict from first principles. It was an epic adventure, a living drama (here lay the idea's "spiritual" quality) in which mighty forces had contended. The world as it now existed had been shaped by the outcomes of those clashes, which were as much a matter of fortune as the outcomes of battles between human armies. Landscapes and rock formations were so many monuments to those great events. This new way of seeing was, in short, "historical" rather than just "temporal." It remains a fundamental principle of the earth sciences today.

The Anthropocene, as I imagine it in this book, is a way of making current environmental change tangibly a part of this immense and circumstantial pageant. The Anthropocene does not put an end to natural history. On the contrary, it locates the present firmly within the geohistorical narrative first conceived of in the time of the French Revolution. Human history, having first been seen as an enlightening analogy for earth history, can subsequently be recognized as an increasingly forceful participant in it. Indeed, the idea of the Anthropocene is best thought of as part of a broader modern development in earth science, a development that has reinvigorated the historicizing impulse of the 1790s.

Some of the chancy, violent happenings of deep history were actually reconstructed in the age that first made conceptual room for them: before the middle of the nineteenth century Georges Cuvier convinced the scientific world of the controversial thesis of species extinction, and Louis Agassiz showed that the landscape had been pummeled into its present shape by a relatively recent ice age. But many other key elements of the drama were not. Darwin's theory of natural selection (as opposed to Jean-Baptiste de Lamarck's much less deeply historical "transformism") would not be made public until the second half of the century. More broadly, the new

geohistorical sensibility depended upon the thesis that the earth was extremely ancient but not eternal; and under the influence of Charles Lyell—the thinker most frequently regarded as the father of geology—acceptance of this long timescale had become fused with the acceptance of a "gradualist" constraint on the earth's historicity. That is, belief in deep time had seemed to be of a piece with believing that the world had always been formed by slow physical processes, like sedimentation and erosion, that we can see continuing to operate in the present.

Only in recent decades has gradualism finally been pushed aside. Both slow, continuous processes and cataclysmic change are now typically credited with decisive roles in the geohistorical drama. That new paradigm is the outcome of a "neocatastrophist" turn in the late twentieth century.[9] It means that the historical impulse in earth science has become livelier than ever. No single breakthrough is responsible for this change of approach, but the outstanding instance of the neocatastrophist perspective is the recognition, which established itself over the course of the 1980s, that the land dinosaurs were abruptly wiped out (or at the very least given their coup de grâce) by the impact of a comet or asteroid, the Chicxulub bolide. A classic earlier case was the acceptance of another seemingly outrageous theory, that the northwestern United States had been shaped by apocalyptically vast floods at the end of the last ice age. Cognate developments can be found in many other fields: in paleontology, for instance, Stephen Jay Gould and Niles Eldredge's model of "punctuated equilibria" in evolution, whereby spells of relative stability are occasionally interrupted by rapid allopatric speciation; in paleoclimatology, recognition of the extreme swiftness of global warming at the end of ice ages, and of the astounding jumps between an ice-covered "snowball earth" and a ferocious greenhouse climate around the time of the origin of multicellular life; in paleoanthropology, the contentious theory of a human population bottleneck associated with the Toba supereruption; and so on.

The idea of the Anthropocene belongs in this context. Construed as a neocatastrophist concept, it is the reverse of the belief that industrial modernity is an alien power that has crash-landed in the still pond of the world. Instead, it makes the current suite of ecological changes the latest in an array of upheavals—some of them desperately harmful to the whole biosphere—that have emerged and reverberated within earth's systems. Framing the environmental predicament in that way ties it to the geohistorical narrative that has been increasingly well understood over the last two centuries. And this in turn makes possible a kind of understanding that might, one way or another, contribute toward well-judged actions in the face of the crisis.

CYCLES, GYRES, AND FEEDBACK LOOPS

On the other hand, if the planet's fundamental biological and chemical processes are always so dynamic, it is reasonable to ask whether current human influences on the environment really stand out among other types of changes to the earth. The signal of human activities must be remarkably strong if it is not to be lost in the noise of geological time. Admittedly, it is not hard to find indications of how far human influence has spread. The current depth record for a piece of litter is held by a can that was noticed by a submersible more than seven kilometers underwater in the Ryukyu Trench of the northwest Pacific. At the other end of the world, on the South Shetland Islands of Antarctica, the two native seed plant species have now been joined by a third, invasive one, annual bluegrass, a robust turfgrass elsewhere favored for putting greens.[10] But drink cans may decay, and the species compositions of ecosystems are always changing. Examples like these do not tell us what proportion of the planet, in total, has been shaped or ravaged by human activity. Perhaps, though much is taken, much abides: the highly visible scars might be far outweighed by the healthy tissue. After all, the earth is a big place. Before we can start to decide whether a new

geological epoch might really be coming into being, or whether "the Anthropocene" is a plausible name for it if so, we need to assess the scale of contemporary anthropogenic changes to the earth system, measured against the size of the planet as a whole.

At 50 kilograms per person, the total mass of all living human beings is more than 350 million metric tons. When comparing quantities of biomass, however, scholars do not usually concentrate on raw figures like these (most of that 350 million tons is just water). Instead they calculate the mass of the carbon that organisms' bodies contain, because carbon is the key ingredient of all life on earth. Looked at this way, human bodies contain over 64 million tons of carbon, while, at the beginning of this century, domesticated animals contained more than 120 million tons of carbon, mostly in cattle. In contrast to those large numbers, the total for *all* wild terrestrial mammals, from armadillos to elephants, was about 5 million tons. The divergence is only increasing. On the other hand, all mammals combined are hugely outweighed by the land plants, which might hold a total of some 550 billion tons of carbon. There too, however, human influences have been transformative. Anthropogenic deforestation and land use change mean that that figure, large as it is, represents an estimated decline of 200 billion tons in two centuries.[11]

The situation at sea is more uncertain. The ocean holds more than 1.3 billion cubic kilometers of salt water (that is, more than 1.3 billion billion metric tons), all but 0.03 billion cubic kilometers of it black as night, and the sediment layer beneath—which is ten kilometers thick in places—constitutes another gigantic habitat. The microbial ecosystems of the dark ocean and its bed really have been largely beyond human perturbation so far. They are enormous, but they are not so big as to dwarf the human-dominated systems on land, and perhaps not so big as to match them. A high estimate puts the quantity of carbon contained in simple prokaryotic organisms (bacteria and the like) living in the sediment at the bottom of the oceans at 300 billion tons. A more recent estimate reduces that figure almost tenfold, however, while the number of prokaryotes living in the dark ocean itself might be not much more than a tenth again of that lower figure. The dark ocean also contains some fish and other macrofauna, of course, but the reality is that it is comparatively ecologically empty. Biomass concentrations decrease by 99 percent beneath the relatively narrow light-receiving upper layer, where two-thirds of the ocean's primary biological productivity takes place.[12]

The ocean's fertile regions are the surface waters and continental shelves, and human impacts there have been much more purely destructive than on land. A conservative estimate near the end of the twentieth century had it that bottom-trawling vessels—which pulverize the seabed by dragging a heavily weighted net over it—covered an area equivalent to half of the continental shelf each year.[13] In total, 90 percent of marine species live on the continental shelves, and over a third of all primary biological production there is now co-opted by fisheries. But that is still far too little to sustain the fishing industry. Wild fish populations are in what looks like terminal decline, which is why the total global catch has been decreasing steadily since the late 1980s despite ever fiercer industrial harvesting. The North Sea has been virtually emptied: the number of large fish there—anything bigger than four kilograms—has fallen by more than 97 percent. Populations of sea cows, sea turtles, oysters, large whales, and large marine predators in general have all fallen by 85 percent or more, worldwide. Caribbean monk seals were once so abundant "that all of the remaining fish on Caribbean coral reefs would be inadequate to sustain them"; they are now extinct.[14] Caribbean coral cover itself has fallen by nearly four-fifths.[15] Predatory fish biomass in the North Atlantic, already severely depleted by the middle of the twentieth century, decreased by another two-thirds by the century's end; whale biomass in the Southern Ocean fell sevenfold in the eight decades to 1985. The implication is that "marine capture is at or near its theoretical

limit": most fisheries have now been overexploited, and perhaps soon more fish will be farmed (or caught to feed farmed fish) than can be hunted.[16]

Major Holocene marine ecosystems were centered on extensive food webs in which sharks, cod, tuna, and the like preyed on diverse populations of shoaling forage fish. The world ocean's emergent new state is characterized by a flattened food pyramid and by boom-and-bust population cycles of algae, dinoflagellates, and jellyfish. The destruction of shallow-water habitats and the rifling of deep oceans by subsidized fishing fleets; the massive summertime dead zones around the continents produced by the runoff of subsidized fertilizers and pesticides; the multiplication of ticks, parasites, and invasive species; ocean acidification; contamination from aquaculture; the suppression of upwelling deep water through warming of the upper ocean: the synergies between these effects favor opportunist scavenging species whose abundance is controlled by diseases and seasonal resource exhaustion, at the expense of long-lived predators and intricate reef communities.

In sum, the total number of nondomesticated vertebrates alive in the world (individuals, not species) declined by some 52 percent over the period 1970–2010. Half of all wildlife. Three-quarters, among freshwater animals.[17]

So much for the broad trends in population structures. What about the physical surface of the planet? Overall, a minimum estimate for the proportion of ice-free land currently devoted to human activity is 29 percent, a figure that counts only settlements, croplands, and woods cut down for pasture. A broader definition yields an estimate that 7.8 percent of all non-icebound land is "densely settled"; 16 percent consists of essentially cropland ecosystems in which at least a fifth of the land is actually under cultivation; 33.5 percent is more or less loosely managed rangeland, at least a fifth given over to pasturage; and 17.5 percent is seminatural land, "significantly transformed" but less than one-fifth covered by urban or agricultural ground. Added together, that leaves just a quarter of the continents—mainly the least biologically productive parts—for what could reasonably be called "wildlands." In the United States, the total area given over to turfgrass lawns alone is roughly equal to the size of Iowa.[18]

Estimates of the amount of matter deliberately moved by humans each year in mining and construction range from 30 to 57 billion metric tons. That sum is comparable to the amount of sediment carried into the oceans by all the world's rivers: somewhere in the range of 8 to 51 billion tons annually.[19] But humans cause much greater movements of sediment in a less direct fashion, through the erosion of agricultural soil. All in all, the "net anthropogenic denudation rate" of sediment and rock is estimated at ten times that due to all other factors combined.[20] Not surprisingly, this has practical consequences. Soil erosion forces the abandonment of some hundred thousand square kilometers of cropland—an area the size of South Korea—each year, meaning that in the last fifty years erosion has caused the loss of productivity in a third, perhaps more, of the world's cropland. To that must be added the losses following from the overgrazing of pastureland and from deforestation. Subsistence farmers on marginal lands are the worst affected, and they have the least access to the petroleum-based fertilizers that must be pumped in to generate adequate food on the remaining land. Soil degradation combines with water shortages and aquifer depletion, climate change, bureaucratic parasitism, agricultural surplus dumping, and civil strife to drive a constant flow of humanity into the toxic peri-urban slums of the global South, where populations rose from 760 million at the start of the millennium to 862 million by 2012.[21] Thus soil erosion and social violence are deeply interlinked, a connection made vivid in 2014 when the landslides that followed floods in the Balkans unearthed and detonated mines left over from the civil war.[22]

Food production and anthropogenic erosion now dominate some of the fundamental biogeochemical cycles of the earth system, like the cycles of

nitrogen and phosphorus, both of which are essential to all forms of life. Modern agriculture is made possible by perhaps the largest modification of the planet's nitrogen system "since the major pathways of the modern cycle originated some 2.5 billion years ago." Humans have almost doubled the global rate of production of reactive nitrogen through their cultivation of legumes, fossil fuel burning, and, primarily, the manufacture of fertilizer through the Haber-Bosch process. Fertilizers also consume around 14 million metric tons of phosphorus each year, obtained by mining nonrenewable phosphate rock. Fertilizers make up the bulk of the 23 million tons of phosphorus added to cropland each year, while a larger quantity, 33 million tons annually, is removed, partly in food but mostly (20 million tons) through soil erosion. That erosion is the principal cause of eutrophication: blooms of waterborne phytoplankton gorge on the phosphorus and suck in the surrounding oxygen, turning affected waters luridly green and uninhabitable. Worldwide, two or three times as much phosphorus flows into the oceans as in preagricultural times. Thus, a one-way mining-erosion-eutrophication flow has broken open the essentially closed loops of the phosphorus cycle. The flow will exhaust known phosphate reserves in about 120 years at current speeds, and in the meantime the soils of countries where the fertilizers are unaffordable suffer from acute phosphorus deficiencies.[23]

Sewage from animal feedlots produces still thicker concentrations of phosphorus. The farm animals of the United States alone generate about 40 metric tons of shit per second.[24] Smithfield, America's largest pork producer, directs the outflow from its facilities into what it calls "lagoons," some more than a hectare in area and over nine meters deep. The shit is routinely sprayed on surrounding fields and intermittently lost in seepage, ponding, and immense river and wetland spills. It contains hydrogen sulfide, cyanide, various heavy metals, and "more than 100 microbial pathogens that can cause illness in humans," as well as stillborn piglets, afterbirths, and residues of the drugs that keep the tortured pigs alive. The complex chemical composition of industrial pig waste means that the stinking lagoons are not brown but pink. (Smithfield responded to an exposé of its practices by saying that "a pink lagoon is a healthy lagoon," and by boasting that "there are no known examples of the federal government forcing, or even asking, Smithfield to modify waste lagoon systems.")[25]

Far out in the ocean, one sampling of the surface waters of the North Pacific Central Gyre, better known as the great Pacific garbage patch, found that plankton were outweighed six times over by particles of plastic, which pass up the food chain to toxic effect through filter-feeding organisms, fish, and birds. Anthropogenic carbon dioxide emissions have increased the concentration of hydrogen ions in surface waters—that is, the water's acidity—by a menacing 26 percent.[26] Extensive research has been devoted to the possibility that the ongoing melting of the Greenland ice sheet could bring an abrupt halt to the downwelling of water in the North Atlantic, the hub of the entire ocean circulation system that drives the way in which energy moves around the surface of the earth.

Given the scale of these changes to the structure of the biosphere and the surface of the earth, it might be a surprise that fewer than 1 percent of all species are thought to have been altogether exterminated in recent times. Even though extinction casualties in the last few decades include two of the three Indonesian tiger subspecies, along with subspecies of ibex, otter, tortoise, and rhinoceros, and species of seal, sea lion, and dolphin, the present wave of extinctions is, so far, small compared to the five great extinctions in the history of complex life on earth, those when the number of living species fell by 75 percent or more.

But the headline extinction rate tells only a small part of the story. Many more species have undergone population crashes, or disappeared from large parts of their ranges, or otherwise become at risk of extinction. Suppose, then, that all the species currently recognized as "critically endangered," and no others, were to become extinct over the next hundred years—by no

means a pessimistic scenario—and that extinctions then continued at the same rate. In that case, it would take roughly 1,500 years for three-quarters of all mammal species to be wiped out, 2,300 years for three-quarters of birds, and 890 years for three-quarters of amphibians. Humans are still some way from causing a sixth great obliteration of genetic diversity, in other words, but they are on course to do so within a geologically brief spell.[27] So far, counting both the critically endangered and those whose disappearance seems less imminent, the Red List prepared by the International Union for the Conservation of Nature identifies 25 percent of mammal species, or 1,143 in total, as threatened with extinction. The figure for birds is 13 percent (1,308 species), and for amphibians, 41 percent (1,950 species). In total, over 21,000 of the species whose extinction risk has been evaluated have been listed as under threat.[28] Gigantic and expanding pools of a few caged produce species have taken the place of those shrunken wild populations. The dominant tendency is the obliteration of diversified ecosystems and their replacement by close-packed monocultures, swarmed by pests and infections, through which maximal nutrient flows can be driven. Music becoming white noise.

Species extinction and human immiseration go hand in hand. Some two hundred species of fish that were unique to Lake Victoria have been eradicated since Nile perch were introduced there in 1954. The perch were intended to make possible a large commercial fishery, and they have done so. But around the lake's shores malnutrition is so severe that four-tenths of children experience stunted growth. The reason is that capitalizing on the giant perch requires expensive vessels, processing factories, and access to rich-world markets. The owners of the gear have absorbed the profits and proletarianized the fishermen. The children of the lake are cared for and given food mainly by their mothers, but women are largely denied access to the fishery and restricted to marginal activities like the processing of fish waste, or sex work in the brothels of the jerry-built shoreline boomtowns. In this way, the slow-burning ecological and humanitarian disaster of Lake Victoria entangles the feeding habits of Nile perch with the workings of ethnicity, nationality (the lake is shared between Tanzania, Uganda, and Kenya), class, and gender.[29]

And then there's climate change. Over the course of two decades of fatuous hardball in international climate change negotiations, colossal extra quantities of heat—equivalent, infamously, to four Hiroshima bombs each second—have amassed in the oceans and atmosphere. Most of Colombia's glacier cover has now gone, Mount Kilimanjaro has lost 80 percent of its snows, and the Chacaltaya glacier in Bolivia, once the world's highest ski run, has melted away completely. The 2479 square kilometers of the Larsen B ice shelf in West Antarctica, an area the size of Luxembourg or seven Grenadas, took less than three weeks to disintegrate into a swarm of icebergs when its warming reached a tipping point in early 2002.[30]

As yet, however, we have seen only the beginning of the climate system's jump from one state to another. Anthropogenic fossil-fuel burning and land use change released 555 billion metric tons of carbon into the atmosphere in the form of CO_2 between 1750 and 2011. Two hundred forty billion tons stayed in the atmosphere; half of the rest was reabsorbed by terrestrial ecosystems, and the other half was absorbed by the oceans.[31] For comparison, the end of the last ice age saw about 200 billion tons of carbon added to the atmosphere from the oceans. That was the linchpin—although not the sole cause: then as now, many positive feedback mechanisms were involved—of a change in the planet's temperature of at least 4.9°C between twenty-two thousand and eight thousand years ago. The older date represents the last glacial maximum, when ice sheets, more than three kilometers thick in central Canada, covered three-tenths of the world's land surface and Arctic tundra stretched from the north face of the Alps to Mongolia. The more recent date was the warmest point of the early Holocene, when the world was about 0.7°C hotter than it was just before the Industrial Revolution.[32] At

present the world's total indicated fossil fuel reserves hold another 780 billion tons of carbon, and the global economy rests on the curious supposition that all of it will shortly be extracted and burned.[33]

It is painful to say that efforts to keep climate change to even minimally tolerable levels may well be futile by now, if only because that sounds like a self-fulfilling prophecy. But the feedback mechanisms already triggered mean that no human power whatsoever can halt the changes that are now under way. Across western North America the heat is exhausting pine trees and invigorating mountain pine beetles. A plague of the beetles an order of magnitude larger than any previous one has persisted since the end of the twentieth century. Hundreds of thousands of square kilometers of pine forest from Colorado north to the edge of the Yukon have been desolated, and as the forest dies it releases its stores of carbon, raising temperatures still further. This single beetle outbreak might add something more than a quarter of a billion metric tons of carbon to the air.[34] On its own, this is, by present standards, a drop in the bucket: one ugly example amid countless others.

The largest climate feedback machines, where tens of billions of metric tons of carbon are at stake, lurk in tropical rain forests and peatlands and in the far northern tundra. Gargantuan stocks of carbon have accumulated in permafrost regions, where millennia of cold have hampered the ordinary recycling of organic matter. But global warming is fastest at high latitudes, and the tremendous frozen peat bogs of Siberia are melting into sodden plains from which carbon is bubbling forth, often in the form of methane (a much more intense greenhouse agent than carbon dioxide). The cruel thing about these feedbacks is that their effects will be most pronounced if direct anthropogenic emissions are limited. Suppose that the earth proves to be markedly sensitive to climate forcings, and that, in response, fossil fuel emissions are after all slashed heroically in the next few years. In that case, self-perpetuating permafrost disintegration may on its own add 0.73°C of global warming by the end of this century, and 1.62°C within three centuries—this according to a conservative model that assumes all the emissions are only of CO_2, not methane. The climate system is bristling and seething with new sources of energy. High-speed global warming is not an imminent threat but the new condition of the earth. The first fourteen years of the twenty-first century were all among the sixteen hottest since instrumental records began in 1880. The two interlopers were the El Niño years of 1997 and 1998.[35]

Some of the transformations now taking place are, precisely, biblical in scale. Over a quarter of Hong Kong's urban land, sixty-seven square kilometers of it, has been reclaimed from the sea. China's South-North Water Transfer Project will, if completed, carry forty-five billion cubic meters of water a year across a vast stretch of the country, becoming the single largest construction project the world has ever seen.[36] The first hurricane ever recorded above the warming waters of the South Atlantic made landfall in Brazil in 2004. Above the most inaccessible land on earth, East Antarctica, snowfall is increasing in the context of a general poleward shift in precipitation patterns.

And God said: *who* shut up the sea with doors, when it brake forth, *as if* it had issued out of the womb? Who hath divided a watercourse for the overflowing of waters, or a way for the lightning of thunder; To cause it to rain on the earth, *where* no man *is; on* the wilderness, wherein *there is* no man?

And Man said: I did, actually.

CHAPTER TWO

Versions of the Anthropocene

Since the beginning of this century, one way of referring to the crisis that I described in the previous chapter has become ever more popular and ever more controversial. The word *Anthropocene* has come into fashion, and in doing so it has picked up a variety of incompatible meanings, each implying different concepts and commitments. The word's complexity means that there is little to be gained by talking about "the Anthropocene" without specifying which version of it you mean. It is especially unfruitful to denounce the word in blanket terms if your real target is only one particular way of using it. Even so, and for understandable reasons, the concept of the Anthropocene has recently been indicted wholesale by a number of writers. Hostile critics have accused it of a domineering universalism: of downplaying the differences between Albertan oil barons and Malagasy subsistence fishers by suggesting that it is human beings in general who are responsible for ecological degradation. Thinking historically about how planetary systems operate, however, sheds a different light on the central issues in that controversy. I believe that one version of the Anthropocene in particular might prove to be a useful and enabling one for contemporary green politics. The stratigraphic approach to the Anthropocene, which contemplates introducing the word as the name of a new interval in the geological timescale, provides a way of thinking about power relations as they exist both among human beings and between all kinds of geophysical forces.

"WE'RE NOT IN THE HOLOCENE ANYMORE"

As witnesses tell the story, it goes like this. At a conference on earth system science outside Mexico City, early in the last year of the twentieth century, participants talked about the Holocene, the geological time span that officially includes the present day. One listener apparently felt a sudden, curious revulsion. Paul Crutzen was an illustrious scholar of the earth sciences, most celebrated for work that enabled the discovery of the hole in the ozone layer. He had received the Nobel Prize in chemistry a few years earlier. Now he was struck simultaneously by a novel idea and by a word to express it. "Stop using the word *Holocene*," he told the conference delegates. "We're not in the Holocene anymore. We're in the . . . the . . . the Anthropocene!" (The precise form of his words varies slightly from telling to telling.) The room fell quiet; "everyone was shocked." Then a buzz of conversation arose. "Someone came up to Crutzen and suggested that he patent the term."[1]

The anecdote about Crutzen's impulsive declaration offers a seductively memorable starting point for the study of the Anthropocene, a name evidently intended to mean something like "the human epoch." But historians of science are constitutionally skeptical of Eureka moments, and the most convincing accounts of how scientific paradigms change usually give low priority to singular flashes of inspiration such as this. In this case, Crutzen himself has worked to make it clear that the emergence of the concept was more drawn-out and more complicated than the story about the conference might suggest. He swiftly wrote up his vision of the Anthropocene in the modest setting of the in-house newsletter of the International Geosphere-Biosphere Programme (the organizers of the Mexico conference) for May 2000. That brief article was coauthored with Eugene Stoermer, an American

ecologist—a student, principally, of photosynthesizing algae—because Crutzen had learned that Stoermer had been using the same term informally since the 1980s. Together, Crutzen and Stoermer listed earlier analogues to their theory: George Perkins Marsh's prescient conservationist treatise *Man and Nature; or, Physical Geography as Modified by Human Action;* the declaration of the "Anthropozoic era" by the Italian geologist Antonio Stoppani in 1873; and the work of Vladimir Vernadsky, the pioneering theorist of the biosphere and of its culmination in a noosphere, or "sphere of reason." Later they adduced the biologist E. O. Wilson, and the science writer Andrew Revkin, who offhandedly proposed an "Anthrocene" age in the early 1990s. Others have traced similar ideas back to the dawn of geological science, in the work of the eighteenth-century naturalist the Comte de Buffon.[2]

Crutzen and Stoermer's article in the *IGBP Newsletter* made clear the grand scope of their idea. Barring some global catastrophe, they wrote, "mankind will remain a major geological force for many millennia, maybe millions of years to come." Thus, "it seems to us more than appropriate to emphasize the central role of mankind in geology and ecology by proposing to use the term 'anthropocene' for the current geological epoch." In their view the new epoch began in the late eighteenth century, when an appreciable rise in atmospheric methane and carbon dioxide levels began the season in which "the global effects of human activities have become clearly noticeable." They added, "Such a starting date also coincides with James Watt's invention of the steam engine in 1784."[3] It would turn out that the question of how to define the beginning of the Anthropocene could not, by any means, be resolved as easily as that. Even so, this first sketch of the human epoch is a document of enduring significance.

In January 2002 Crutzen recapitulated his view of the Anthropocene in a far more widely circulated journal, *Nature*. It is this article that best marks the emergence of the concept into widespread scientific awareness. To date, it has been cited well over a thousand times. Although it was even shorter than the *Newsletter* discussion and said many of the same things, Crutzen found room for two important new points. The first was a brief acknowledgment, missing from the first piece, that the changes apparently bringing about a new epoch "have largely been caused by only 25% of the world population." The second was a bold gesture toward the kind of "environmentally sustainable management" that might be suited to the Anthropocene: "This . . . may well involve internationally accepted, large-scale geo-engineering projects, for instance to 'optimize' climate."[4] Both of these themes—the need to recognize that people in different parts of the world have made very dissimilar contributions to global change, and a distinct inclination toward geoengineering as a way of dealing with global warming—would remain prominent in discussions of the Anthropocene.

Crutzen's seminal *Nature* article is the canonical statement of the first version of the Anthropocene. The tone is clear, humane, and confident; cognizant of the power of technology; socially engaged, although not polemical; pessimistic but not despairing in its assessment of the state of the planet; and magisterial in the way that it evaluates the sum of human environmental influence. The concept of humanity's epoch struck a chord, and the idea quickly began to circulate, filtering into a whole range of earth science disciplines and, before long, beyond them. Crutzen's term began to appear in articles about human geography and geopolitics and in books for general audiences by environmental writers.

Many readers have continued to find things of value in the idea of the Anthropocene as it stood in those two early articles. But it is essential to any serious engagement with the Anthropocene to recognize that Stoermer's and Crutzen's first brief sketches do not by any means represent the only possible version of the concept, its unchanging real essence, or its true scientific meaning. On the contrary, the idea has been fissiparous from the start. Different fields have received it in various different ways. We can

perhaps speak of more or less mainstream accounts—provided we keep in mind that the consensus about what constitutes the mainstream can alter rapidly—but no single version of the Anthropocene can reasonably be described even as a generally dominant one.

The clearest illustration of that principle is the fact that Crutzen's own ideas have changed significantly. In collaboration with the environmental historian John McNeill, among others, he came to argue that the Anthropocene began in a more piecemeal fashion than he had proposed at first. In his revised account, atmospheric CO_2 continues to serve as "a single, simple indicator to track the progression of the Anthropocene," but the new epoch is said to have emerged in two stages. Stage 1 began in "the 1800–1850 period," with the breakthrough development of fossil-fueled industrialization in Britain. But the revised account acknowledges that, until the middle of the nineteenth century, CO_2 concentrations did not in fact pass outside the range within which they had been fluctuating for ten thousand years. More generally, the new model characterizes stage 1 human environmental impacts as burgeoning rapidly rather than growing explosively. Truly vertiginous economic growth, in this account, was incipient in the period of high Victorian liberalism from the 1850s onward but was held back by the world wars and Great Depression. Stage 2 of the Anthropocene, then, begins with a "Great Acceleration" after 1945, when the momentum of the "human enterprise" multiplied precipitately. This analysis is based on a dozen much-reproduced graphs that show levels of population, worldwide GDP, fertilizer consumption, paper consumption, foreign direct investment, international tourism, and so on undergoing a nearly vertical takeoff in the middle of the twentieth century. For Crutzen and his colleagues, these graphs represent the Anthropocene's transition from its larval to its adult stage, because they correlate with the exponential increase of human pressures on "Earth's life-support system."[5] The Anthropocene in its full sense is even younger than it had at first appeared.

NEW MEANINGS

Crutzen's two versions of the Anthropocene were not alone. In the decade after the term was coined it was put to many other uses, and these embraced a far wider range of definitions. While Crutzen was moving the Anthropocene's start date closer to the present, another distinguished student of the planet's atmosphere was carrying it much further back. "The Anthropocene actually began thousands of years ago," William Ruddiman argued, "as a result of the discovery of agriculture and subsequent technological innovations in the practice of farming." Ice-core records seem to show anomalous greenhouse gas concentrations during the current interglacial, or warm spell between ice ages, compared to preceding ones. Guided ultimately by changes in the earth's position relative to the sun, these concentrations should have reached a peak not long after the last ice age and then trended downward, but instead CO_2 levels (from eight thousand years ago) and methane levels (from five thousand years ago) show a small, unexpected rise.

Humans, in Ruddiman's view, were responsible. Forest clearance in Eurasia for agriculture and fuel explains the CO_2 anomaly, an extra forty parts per million in the preindustrial atmosphere, and East Asian rice paddies produced the additional methane. Thus, preindustrial farmers unwittingly postponed the next ice age, which would otherwise have begun to take hold in northeast Canada thousands of years ago.[6] It is a startling hypothesis, and one that has provoked much debate. At present the developing consensus is against it. Interglacials other than those on which Ruddiman focused provide better analogues to the present one, and they seem to make the changing composition of its air appear much less anomalous. Ruddiman himself, however, continues to hold the line on his early Anthropocene hypothesis. This version of the Anthropocene does have one important similarity to both of those proposed by Crutzen. In all three cases, the new epoch is understood as the time since human activities took atmospheric carbon dioxide levels outside the range they would have occupied in humans' absence. The enormous difference in the dating of that change, however, points to the two scholars' radically opposed assessments of how humans have influenced the way the world works.

Many other early Anthropocenes, distinct from Ruddiman's, have also been proposed. One extreme in the dating of the epoch, at least so far, places its origin at 1.8 million years ago, at an earlyish date for the mastery of fire by hominins. The rationale is that this was the crucial technological achievement—because cooking renders the digestion of animal protein more efficient—that allowed for the evolution of a new line of large-brained, tool-using apes. Elsewhere the Anthropocene has been defined as the interval since the extinction of most genera of megafauna over most of the world, between about fifty thousand and ten thousand years ago, at the hands of newly arrived human hunters. Another, less bleak option identifies its onset with the domestication of animals and plants, making the Anthropocene approximately coeval with the Holocene and just a little older than Ruddiman suggested. Or the Anthropocene could be two millennia old and recognizable in the changes to much of the world's soil—through manuring, irrigation, terracing, and so on—associated with the empires of the time of Christ.[7]

Decisions about historical periodization very often encode deep interpretive commitments. In this case, the general rule is that the earlier the proposed starting date for the Anthropocene, the more emphasis its proponents place on human actions themselves, as opposed to the ecological consequences that follow from them. Bruce Smith and Melinda Zeder—supporters of an Anthropocene defined by species domestication—are the thinkers who take this position most explicitly. Smith and Zeder believe that one should identify the Anthropocene with the emergence of "significant human modification of the earth's ecosystems on a global scale," rather than looking only for "massive and rapid . . . human impact" like that seen in the past two centuries. This lower bar implies a conceptual reversal. In a word, "the focus should be on cause rather than effect, on human behaviour [rather than] environmental degradation." For them, the Anthropocene is a way of naming the whole interval during which humans around the world have significantly shaped or engineered their habitats. Whereas Crutzen and Stoermer proposed the term as a framework for assessing the general state of the planetary system, Smith and Zeder employ it as a heuristic device for "gaining a greater understanding of the . . . role played by human societies in altering the earth's biosphere."[8] Their focus is on the human capacity to change the world, not on the changes themselves.

Another version of the Anthropocene came about as the concept was picked up in the humanities. For scholars of politics and culture, the most obvious questions to ask are less about the origins of human environmental impact and more about the implications of the Anthropocene for social organization. The landmark contribution in this vein has come from the historian and postcolonial theorist Dipesh Chakrabarty. For Chakrabarty, the Anthropocene's significance lies in the fact that postcolonial and Marxist scholars' radical critiques of globalization, capitalism, and imperialism are all inadequate in confronting the idea of a new geological epoch. No matter how compelling they are on their own terms,

> these critiques do not give us an adequate hold on human history once we accept that the crisis of climate change is here with us and may exist as part of this planet for much longer than capitalism. . . . A critique that is only a critique of capital is not sufficient for addressing questions relating to human history once the crisis of climate change has been acknowledged. . . . Whatever our socioeconomic and technological choices, whatever the rights we wish to celebrate as our freedom, we cannot afford to destabilize conditions (such as the temperature zone in which the planet exists) that work like boundary parameters of human existence.[9]

The Anthropocene, in this reading, means recognizing the fact that the environmental crisis constitutes a major challenge for the kind of politics

that resists the inequities of the existing world order. Yet Chakrabarty is not so cynical as to say that analyses of social and economic injustice must be abandoned under the pressure of the Anthropocene. "Critiques of capitalist globalization have *not*, in any way, become obsolete in the age of climate change," he insists. But climate change means that on their own they are no longer enough. What he proposes instead is a double perspective, an attempt "to mix together the immiscible chronologies of capital and species history." Historians still need to tell "the story of capital, the contingent history of our falling into the Anthropocene," with its themes of liberation and injustice and its chronological range of several hundred years. At the same time, however, they now need to trace another longer, deeper history of humankind as a species, and of human interactions with the rest of the planet's life, over timescales of thousands and millions of years.

In the course of making this argument, Chakrabarty turned back to the first presentation of the idea of the Anthropocene. He cited, with qualified approval, the last two sentences of the article in the *IGBP Newsletter* with which Crutzen and Stoermer introduced the concept. That article concluded with a flourish. "To develop a world-wide accepted strategy leading to sustainability of ecosystems against human induced stresses will be one of the great future tasks of mankind," Crutzen and Stoermer had written. "An exciting, but also difficult and daunting task lies ahead of the global research and engineering community to guide mankind towards global, sustainable, environmental management."[10]

When Chakrabarty reproduced those sentences, the idea of the Anthropocene ran into trouble—because there is much to take issue with in the political standpoint implied by Crutzen and Stoermer's words. A truly global community of researchers and engineers can hardly be said to exist, given how unevenly the money to support scientific research is distributed across the world. And it is plain that no one appointed such a community to the task of guiding "mankind" anywhere. The relevant researchers are a disputatious body of thinkers and investigators, not vatic universal steersmen. Crutzen and Stoermer's hope that a single strategy for sustainability will be accepted worldwide likewise appears utopian at best. Who would have the power to declare that the world had accepted any given strategy, and what would happen to those who remained unwilling to agree? Perhaps most importantly, the pair's proposals for "environmental management" seem like exactly the way of thinking that the Anthropocene undermines. How can we plan for the "sustainability of ecosystems *against* human induced stresses" once we have recognized that most ecosystems have already been profoundly remodeled, with human activities placed in a central role? "Human induced stresses" are a part of the system, like the stresses brought on by the changing of the seasons. The managerialist belief that it is humankind's duty to regulate the natural world from the outside sits oddly with the recognition that the fundamental biogeochemical matrices of the planet are now fused with human activity. But when Chakrabarty repeated Crutzen and Stoermer's words in an essay on the future of postcolonial studies, it became clear that this line of thought was a tenacious feature of the discourse on the Anthropocene.

Chakrabarty's brief for a dual approach to environmental analysis, linking a critique of capitalist globalization to a longer history of humans as a species, was plainly an exciting one. But several of his readers came to suspect that the two strands of his approach could not readily be woven together in the way that he envisaged. Intertwining them sounds welcome, but what if the latter (species-based) one just encircles and subsumes the former (political) one? Chakrabarty's initially unwary invocations of the "shared catastrophe that we have all fallen into" as the basis for a "new universal history of humans" suggested that that danger was real. "Unlike in the crises of capitalism," he wrote, "there are no lifeboats here for the rich and the privileged (witness the drought in Australia or recent fires in the wealthy neighborhoods of California)."[11] A rich Californian whose house burns down

faces emotional trauma and a home insurance excess, but she hardly shares the experience of a drought-stricken cattle pastoralist in South Sudan. "No lifeboats"? As Chakrabarty's critics have been happy to point out, this is untrue both literally and metaphorically. The militarization of disaster areas like Katrina-struck New Orleans, and the financialization of catastrophe through disaster reinsurance, have already proved capable of preserving—indeed reinforcing—capitalist hierarchies in zones of ecological emergency. In the eyes of his critics, then, Chakrabarty had been drawn away by Crutzen and Stoermer's seductive idea from some of the indispensable tenets of postcolonial studies.

THE BACKLASH

Chakrabarty's groundbreaking discussions of the Anthropocene have become a lightning rod for attacks on the whole concept of the human epoch. In the years since his first essay on the subject appeared in 2009, the idea of the Anthropocene has become both much more widely employed and much more widely criticized. The concept started to reach the mainstream in 2011. A collection of essays on the topic appeared that year in a themed issue of the *Philosophical Transactions of the Royal Society*. There, Crutzen and his collaborators reflected on how the word had spread over the previous decade. "Since its introduction," they wrote, "the term Anthropocene has become widely accepted in the global change research community, and is now occasionally mentioned in articles in popular media on climate change or other global environmental issues."[12] Had they been writing a few years later, they could have noted much more than such occasional mentions. The year 2011 itself saw a flurry of major conferences, as well as enthusiastic feature articles in *Science*, *National Geographic*, the *Economist*, and elsewhere, and the term began to crop up regularly in newspapers for the first time. Since then, there have been museum exhibitions and radio programs, academic research networks and chapters in textbooks, and, most remarkably, no fewer than three new scholarly journals: students of the new epoch may now turn to the *Anthropocene Review* (which has swiftly become the leading forum for discussion of the concept), *Anthropocene*, and *Elementa: Science of the Anthropocene*.

The Anthropocene has become fashionable in academic circles—very fashionable, in fact. In principle any discussion of anything that has taken place in the last few hundred years or so can be tagged with the phrase ". . . in the Anthropocene" and thereby made to sound (however transiently) up to date. The organizers of the latest conferences on the topic struggle to accommodate presentations of the most diverse and miscellaneous kind. Various words have been coined on the Anthropocene model: *Capitalocene, Sustainocene, Cosmoscene, Econocene, Homogenocene*. Some scholars, inevitably, have even decided that the time has come to speak of the "post-Anthropocene." And as the word itself has come into prominence, so the backlash has developed. If the concept has been associated with the idea that the whole world must be "guided" into adopting a single approach to environmental management, or with the claim that global warming's floodwaters will bear "no lifeboats" for the rich, then some suspicion is understandable. The opponents of the Anthropocene have warned that the whole notion may be politically naive if not implicitly unjust, and may diminish rather than improve the chances of equitable and efficacious responses to ecological crisis.

The argument against the Anthropocene is by now well established.[13] In two words, the accusation is that the idea is universalist and technocratic. It is universalist because it makes it sound as if we are all in this predicament together. It neglects humanity's division into a multitude of unequal social groups, and the ways in which wealth, nationality, ethnicity, gender, class, and so on mediate the relationships between those groups. In its simplifying view, the human species—the *anthropos* in general—becomes instead an abstract, homogeneous mass, collectively damaging the planet through

vaguely defined habits of industrialization, resource exploitation, and overconsumption. Those habits are supposed to put at risk the well-being of the whole human race, meaning that the only solution is to set aside class resentment and work together as one for the greater good of the whole. The Anthropocene wrongly implies that humanity is united in culpability, in vulnerability, and in the need for self-protection. For the opponents of the concept, that makes it an essentially bourgeois idea. It performs the archetypal bourgeois maneuver of representing the sectional interests of a single group as being in everybody's interests. It comforts the prosperous with the thought that blame attaches collectively to all human beings. Thus it lends itself to a blinkered preoccupation with overpopulation as the supposed root of all the world's ills, which means blaming the poor for a crisis to which they have in fact contributed very little.

According to this critical view, scholars of the Anthropocene rely upon a simplified, one-step model of historical change whereby the Holocene epoch was replaced everywhere and all at once by a human-controlled earth system. Their attempts to attach a date to that transition are bound to prove futile, because in reality different parts of the world have undergone very different experiences of modernization and development at very different times. But the Anthropocene deals only in aggregate environmental consequences, pushing the subtleties of causation into the shadows. That makes it deterministic: it presents human nature itself, the technological impulse of the *anthropos*, as a full and adequate explanation for the course of history. The Anthropocene theory of history is correspondingly depoliticized and preoccupied with scientific inventions. It fetishizes the Industrial Revolution as the sole origin of modernity; and in doing so, it misrepresents that revolution as simply a technological leap forward, neglecting industrialization's economic underpinnings. In a skeptical analysis, this habitual occlusion by Anthropocene enthusiasts of the politics of empire and capitalism is itself a deeply political act. Choosing this way of understanding the crisis predetermines the kind of solutions that will be proposed: modernist, high-tech, top-down ones. It is no coincidence that Crutzen himself has been among the world's most prominent advocates for geoengineering. The discourse of the Anthropocene is technocratic because it makes it sound as if there is no alternative to the rule of experts. It is a counsel of despair, sacrificing freedom and wilderness to managerial diktat. It implies that if we are to survive, then those who make political decisions must defer to a scientific and technical elite, who can specify the objective physical constraints on how humanity may make use of its life-support systems.

For those reasons, its critics charge, the concept of the Anthropocene can be suspected of a general affinity with approaches to rationing—of carbon emissions, fish quotas, and so on—that suit the developed world much better than the poor. It is an intellectual bedfellow of those hapless regulatory regimes that seek to conserve ecosystems by commoditizing them, like ecosystem-services markets and the European Union's chaotic emissions-trading scheme. At worst, it could lend an air of respectability to a process of environmental triage that would calmly sacrifice Tuvalu and the Marshall Islands to the greater good. Most fundamentally, though, it plays a philosophical double game. It pretends to describe human beings merging into nature as a geologic force, but in fact it is deeply dualistic. In portraying humans as a unified species—as the bearers of a singular human essence—it singles them out from the rest of the world. It sets the Anthropocene, the artificial age made by humans, squarely against the entire natural history of the world that preceded it.

That, or something like it, has been the standard critique of the Anthropocene so far. Gerda Roelvink sums it up: "In their announcement of the Anthropocene, scientists are calling us to consider ourselves not as a number of different groups but as a single, universal, and transhistorical collective—as a species. . . . This understanding of species fits all too easily with the modernist assumption of human mastery over nature."[14] Humanity reduced

to an undifferentiated species, and such species thinking as a warrant for depoliticized, technology-driven management of "nature": that is the danger of the Anthropocene.

Yet Roelvink's complaint can be turned straight back against her. Her accusation itself takes "scientists" for nothing other than "a single, universal, and transhistorical collective" serving the interests of human mastery over nature. As we have seen, the reality is that researchers who have worked with the idea of the Anthropocene are, emphatically, members of "a number of different groups" much given to disagreeing with one another and to changing their minds about things. Not all takes on the Anthropocene are the same. Some are universalist and technocratic. Others, I argue, are quite the contrary. The crucial flaw in the case against the Anthropocene has been a widespread failure to recognize that the word *Anthropocene* does not express any single, agreed-upon idea. Instead, by the time the backlash started the term had already taken on a considerable number of mutually irreconcilable senses. Worse still, critiques of the politics of the Anthropocene have mostly aimed their fire at the simplest and most sketchily formed version of the concept, the first-draft Anthropocene of Crutzen and Stoermer's original *Newsletter* article and Crutzen's brief 2002 follow-up in *Nature*. Otherwise thoughtful dissents have taken those two texts as adequate representatives of Anthropocene thinking as a whole, or even been so naive as to assume that what is found there *is* the theory of the Anthropocene, its only possible form. The stronger charges may well be unfair even to those texts, which are provisional and suggestive enough to be interpreted in several different lights. But in any case there is little to suggest that every possible version of the Anthropocene is politically compromised in the same way.

The skeptical responses to the Anthropocene from some theorists of politics and social difference need not persuade anyone to abandon the term, but they should make researchers who draw on it refine and sharpen their analysis. The charges that the idea of the new epoch might stigmatize the poor, pander to elitist technocratic fantasies, disguise political or historical realities, or work against equitable responses to environmental problems are unsettling ones. They demand to be taken very seriously indeed. Any worthwhile version of the Anthropocene has to be underpinned by a historically nuanced account of how power relations operate, both across the earth system as a whole and between human beings. Scholars working in fields like postcolonial studies can make a vital contribution to that way of framing the new epoch. In what follows I have kept in mind the radical critique of the Anthropocene and sought to avoid speaking of humankind as an undifferentiated whole.

After all, there is still plenty to gain from rethinking the meaning of the Anthropocene. Even if the term has already passed further into popular awareness than any other geological concept since plate tectonics, its rise is probably far from complete as yet. Certainly, it is a sufficiently large and bold idea to bear a level of scrutiny many times greater than it has received so far. At the time of this writing, journalists still never use the word for a general audience without glossing its meaning, and it was canonized by an entry in the *Oxford English Dictionary* only in the summer of 2014. The environmental crisis has pushed into the limelight a whole series of words and phrases that condense the meaning of various contested concepts. All problematic in their way, they nevertheless show how language has been reshaped in the effort to come to terms with that crisis: *global warming*, *acid rain*, *the hole in the ozone layer*, *biodiversity*, *sustainable development*, *carbon footprint*. As yet, all of those terms are far more familiar than *the Anthropocene epoch*, even though the latter is as far-reaching a concept as any. But it remains to be seen whether the Anthropocene will exert a galvanizing force on public debate, as talk of the ozone hole did in the 1980s, or if it will instead become distracting and even misleading, as has become the case with invocations of "sustainable development."

GEOLOGICAL LIFE

Worthwhile accounts of the Anthropocene will be ones that illuminate instead of obfuscating the patterns of human-caused environmental change. Those patterns are political through and through. To find a way forward, then, it might be best to go back to the most important texts in the controversy about the politics of the Anthropocene and to reread Dipesh Chakrabarty's work. No objection to the Anthropocene has yet found a way of dealing with the central challenge that Chakrabarty poses. He recognizes that resistance to current forms of capitalist globalization, and to their profit-driven exploitation of disempowered communities and vulnerable ecosystems, is a prerequisite for the creation of a livable and equitable world. But he insists—convincingly—that anticapitalist resistance is not sufficient to that end. The environmental disaster is bigger than capitalism. It destabilizes "boundary parameters of existence" that are independent of the logic of capitalism. It involves climate changes that will almost certainly continue for far longer than capitalism as we know it. It has been caused by industrializing socialist states as well as by the Western powers.

For Chakrabarty, the Anthropocene signifies the division and incompatibility between the two problems of "globalization and global warming." The latter problem exists on a deeper level than the former, and it affects humankind en masse. Just revealing potential ill effects of the Anthropocene narrative, as Roelvink and others try to do, does not get rid of that division. In other words, even if the Anthropocene really does have unwelcome political consequences like stigmatizing the poor and promoting antidemocratic techno-fixes, it still might accurately describe the grim implications of the fact that all living conditions on the planet are under threat. So it looks as if we are faced with an impasse. Justified hostility to the claim that "we're all in it together" versus justified recognition that equal fossil-fueled prosperity for everybody appears ecologically impossible. The time of modernity versus the epoch of humankind. The political history of capital versus the geophysical history of carbon. Is this deadlock the end of the road for the idea of the Anthropocene?

No. The alternative is to reconceive the Anthropocene not as a signal of built-in contradiction and conflict between radical social critique and species thinking but as the very concept that unites the two. The birth of the new epoch is, precisely, an opportunity to think about human and nonhuman power relations simultaneously. The way to revise Chakrabarty's analysis, and to take it forward in a new direction, is to question or destabilize a distinction that was implicit throughout his early work on the Anthropocene. This is the distinction between life and nonliving matter. That distinction seems at first to constitute a stable and unambiguous binary opposition; but in another light, life and nonlife appear only as different moments within the interwoven cycles through which the earth system functions.

We can see the importance of the life/nonlife distinction to Chakrabarty's thought in passages like the following: "Climate scientists posit that the human being has become something much larger than the simple biological agent that he or she always has been. Humans now wield a geological force. . . . Humans are biological agents, both collectively and as individuals. They have always been so. . . . But we can become geological agents only historically and collectively."[15] This conception lies at the heart of the story that Chakrabarty tells. The Anthropocene, for him, is the result of this rupture in which humans were transformed from merely "biological" agents into a power that is both biological and "geological." Marxist, postcolonialist, and environmental-justice thinkers deal adequately with humans insofar as they are biological creatures like all other species, but their approaches are inadequate to humans considered in their modern collective or "universal" form as a geological force. To put it more explicitly still: as well as our biological existence, "we now also have a mode of existence in which we—collectively and as a geophysical force and in ways we cannot experience ourselves—are 'indifferent' or 'neutral' . . . to questions of intrahuman

justice." Humans have become a "nonhuman, nonliving agency," in "a collective mode of existence that is justice-blind."[16] The opposition that Chakrabarty set up between the Anthropocene and the politics of liberation stemmed fundamentally from the way he envisaged this historical switch from the biological to the geological, from the living to the nonliving.

This seemingly clear binary contrast is, nonetheless, an incomplete, temporary, and conditional one. We can see that by thinking about the agencies that actually participate in the earth system. It might appear that the planet's workings are (or that they were, before humans) made up firstly of an inanimate geological base or framework, composed of phenomena like plate tectonics, volcanism, climate, erosion, and sedimentation; and secondly of a decorative organic superstructure, both supported and determined by the geophysical realities to which it is obliged to accommodate itself. It is true, after all, that the earth's biomass is tiny compared to the mass of its atmosphere, water, or rock layers. Nonetheless, that way of thinking has to a great extent been swept away by recent students of the earth's systems. Earth, in contrast to dead planets like Venus, has remained far out of chemical equilibrium for billions of years. It does so because life has now been an integral part of the planet's makeup for more than three-quarters of its existence.

Living organisms are concentrated at the active interfaces between the atmosphere, hydrosphere, and lithosphere. And chemical processing in the biosphere is usually far more rapid than elsewhere, as organisms photosynthesize, eat, respire, excrete, and die. For those reasons, many of the main cycles through which the planet functions are *biogeochemical* ones in which life and inorganic processes are inextricably combined. The earth operates in entangled loops of carbon, nitrogen, calcium, oxygen, water, phosphorus, and so on. Those loops involve journeys that pass through living bodies or that are facilitated by organic processes. The erosion of rock is the deep, fundamental driver of the carbon cycle and is a basic part of the plate tectonic cycle. It is forcefully accelerated by the bacteria, lichens, and fungi that eat away at stone surfaces. The atmosphere contains reactive oxygen only because oxygen has been excreted by bacteria for more than two billion years. The production of free oxygen, alongside other biological processes, brought perhaps as many as two-thirds of the earth's (nonanthropogenic) minerals into being.

Living things shape rivers and coastlines by colonizing and stabilizing sediments. They accumulate into landscape-size geological features: soil, peat bogs, coal seams, limestone cliffs. The hydrological cycle involves plant transpiration, water capture in vegetation-dependent soils, and gas emissions from algae that inflect cloud formation. Ice ages seem to be brought about partly through the operation of a "biological pump." In this mechanism, small changes in the earth's position relative to the sun increase the heat differential between tropics and poles, so that stronger winds blow between them and carry more iron- and nutrient-bearing dust into the oceans. That dust fertilizes microorganisms whose calcium- and carbon-rich bodies and shells sink when they die (or when they are eaten and excreted), thus sequestering carbon from the atmosphere and chilling the whole planet. The albedo, or reflectivity, of a land surface depends upon the vegetation by which it is covered; its albedo partly governs temperature and precipitation levels, and these climatic factors in turn influence the evolution of the vegetation. The presence or absence of large herbivores can dramatically alter the ground cover. Thus those herbivores too are geological forces, just like earthworms and beavers.

In short, life has *always* been a geophysical force; equally, the geology of the earth, unlike that of Venus, has been influenced by the laws of biological evolution for an inordinate length of time. The "biological agents" to which Chakrabarty referred have always been "geological agents" as well, and it is a rare "nonliving agency" that does not have a trace of life about it. (Indeed, the very existence of life demonstrates that self-replicating systems can

emerge out of inorganic chemical processes.) Living things on the one hand, and geophysical things like rocks and climate on the other, are, at root, inseparable parts of the ecological cycles that operate on and around the surface of the earth. Biological and geological phenomena are not two different kinds of being upon which two different regimes of politics might be founded. Although the birth of the Anthropocene does change the way in which the forces of life and of geophysics are arranged, it does not affect their underlying unity.[17]

Chakrabarty conceived of the human species as leaping across a divide from the biological to the biological-and-geological, and he proposed that one side meant politics whereas the other side meant both politics and apolitical collective action. A consideration of the makeup of the earth's biogeochemical systems obliterates that divide. What looked at first like a difference of kind between life and nonlife becomes only a difference of scale between kindred geophysical forces—and indeed Chakrabarty's own recent work has turned to focus more explicitly on such questions of scale.[18] The consequence is that the deadlock between politics and the Anthropocene no longer stands. As that deadlock vanishes in the stronger light of history, it becomes possible to see plainly both the drawback of Chakrabarty's analysis and the great importance of his central insight. He was right—and boldly pioneering—to declare that emancipatory politics in the twenty-first century must undergo a challenging alteration as the result of an upheaval in the geological condition of the earth. But it is not the case, thankfully, that such geological upheavals belong on a plane entirely different from that of the normal struggles for advantage that go on constantly between living things. On the contrary, the two have always been knitted together throughout the planet's ecological systems. And struggles for advantage between living things are what politics deals with.

Politics is the right mode in which to address geological problems after all. It need not be circumscribed or replaced by a geological way of seeing that treats species as undifferentiated wholes, because the geological way of seeing is itself political. Instead of opposition, there is continuity. Struggles between humans, from wage bargaining in Cuba to electoral corruption in Albania, are plainly political matters. Struggles involving both human and nonhuman lives, from the patenting of rice genes in America to the seizure by gunmen of South Korean ships fishing illegally off Somalia, are equally political. And no less political than either of these are struggles involving geophysical forces, from earthquakes triggered by groundwater extraction in Spain to the effects of pollution on the Indian monsoon. Normative analysis, blind neither to justice nor to injustice, is equally relevant at every stage. The birth of the Anthropocene is a many-sided disruption and reconfiguration of innumerable relationships within the earth system. Nothing about it should tempt us to ignore the fact that human-to-human relationships are among those being disrupted and reconfigured.

The Anthropocene does not, after all, require a turn away from the critique of sociopolitical power relations (globalization, capitalism, imperialism, and so on) toward a universal history of the human species. Instead, to understand the Anthropocene means widening the focus of sociopolitical critique and working toward *an analysis of the power relations between geophysical actors, both human and nonhuman*. It is much easier to propose this wide-angled analysis than to put it into practice, of course. But at least it does not mean abandoning the core concerns of postcolonial studies and global justice movements.

Understanding the Anthropocene depends on getting beyond interpretations of contemporary world politics that remain confined by the idea of the human (by a concern with economics, discourse, identity, and so on defined solely in human terms)—but broad interpretations of modernity that fail to take environmental factors into account are plainly inadequate, anyway. By contrast, even if political ecologists and scholars of the Anthropocene have started off on the wrong foot, they can get back on good terms

as soon as both sides agree that when they talk about power relations they will sometimes mean the relations among geophysical forces, and sometimes the relations among people (which are also a type of geophysical force). They will pay attention to power relations like those determining the energy content of Hadley cells as they yield or withhold rain over water-stressed grasslands, and the balance of forces between friction and gravity in glaciers as they head toward the sea. They will recognize that contests like those cannot neatly be separated these days from other power relations, like the fluctuating influence of the Dinant Corporation over the democratic process in Honduras, the capacity of Dow Chemical to obstruct Indian corporate liability law over Bhopal, or the ability of Thai fishing peoples to defy government efforts to seize their land in the wake of a tsunami.

As I have stressed throughout this chapter, though, different conceptions of the Anthropocene have very different implications. If we want to trace the birth of the new epoch as a shifting, interwoven play of ecological powers, we will need to choose carefully the version of the Anthropocene that best enables such an analysis. No doubt there are plenty of options. If there are many interpretations of the Anthropocene, and if only some of them are politically counterproductive or philosophically incoherent, then there should still be several different ways of thinking about the Anthropocene that are stimulating and worthwhile. I do not want to be exclusive, then, but only selective, if from this point onward I focus on just a single conception of the new epoch.

We have seen that the unnerving conclusions drawn by Dipesh Chakrabarty can be set to one side by reflecting on geohistorical processes. That suggests it is well worth considering the Anthropocene specifically as a phenomenon in earth history. The rest of this book deals with a version of the Anthropocene that takes Crutzen's original proposal more literally than Crutzen himself seems to have intended. Perhaps a new epoch is indeed beginning, in the formal geological sense of that word.

THE STRATIGRAPHIC TURN

"We are assembled," wrote the stratigrapher Jan Zalasiewicz in December 2009, "to critically consider the case for a formal Anthropocene, and to make recommendations to our parent body (the Subcommission on Quaternary Stratigraphy [SQS] of the International Commission on Stratigraphy [ICS]), through them to the ICS itself, and then on to its parent body, the International Union of Geological Sciences (IUGS)." The fellowship assembled for this purpose was the new Working Group on the Anthropocene, chaired by Zalasiewicz. The significance of its remit was out of all proportion to the simplicity of its organization ("We do not have a budget," the chair reminded the group).[19] For that reason, this nested thicket of abbreviations is well worth disentangling.

The IUGS is one of the world's major scientific organizations, the professional representative body of a million earth scientists. The Commission on Stratigraphy is its largest constituent part, an organization that is essentially dedicated to finessing the one-page diagram that underpins geological science. That diagram is the International Chronostratigraphic Chart, the embodiment of the geological timescale that sets out how the history of the earth is formally divided.[20] Condensing the whole body of stratigraphic research, the chart defines, names, and dates each recognized major interval of geologic time and determines their hierarchical status and the way in which they fit inside one another. (Even putting the Anthropocene aside, disputes about where the divisions should go sometimes convulse the geological community. Stratigraphers, like poets, take naming seriously.) Definition ideally involves selecting a change—usually the appearance or disappearance of a fossil species—in a single column of rock somewhere on earth that can represent an interval's starting point. Take the Oligocene epoch of 34 to 23 million years ago, in which the mighty tropical rain forests of the postdinosaur epochs receded and the modern Antarctic ice sheets formed. The Commission on Stratigraphy defines its moment of origin as that of the

formation of a layer of rock now found partway up a quarry on Mount Conero, Italy, "at the base of a greenish-grey 0.5m thick marl bed."[21]

The Commission on Stratigraphy operates some sixteen subcommissions. The correlation of stratigraphic data for the last 2.6 million years is the job of the Subcommission on Quaternary Stratigraphy. It was at the request of this last body that Zalasiewicz and the paleobiologist Mark Williams—then occupants of next-door offices at the University of Leicester—set up the unfunded Anthropocene Working Group, which in practice consists of forty academics, Crutzen among them, communicating mostly by email. "The work involved should not be onerous," they told potential participants. "However, it should be interesting, and of use to the scientific community."[22] With this gentle flattery, the idea of the Anthropocene underwent a crucial transition.

Crutzen's inspired outburst, "We're not in the Holocene anymore. We're in the . . . the . . . the Anthropocene!" had implicitly been a claim about stratigraphy, an alternative to the definitions laid down by the International Commission on Stratigraphy. But it is clear from his two foundational articles that assembling a brief for an actual revision of the Commission's great chart of earth time was by no means his priority. His own expertise was in atmospheric chemistry, and as the concept percolated through specialist literatures over the next few years, geologists themselves used the term relatively infrequently. The move toward stratigraphic formalization began with an article coauthored by twenty-one members of the Geological Society of London—not as large as the IUGS, but the oldest geological society in the world—with Zalasiewicz at their head. What had hitherto been a "vivid but informal metaphor," they wrote, could equally be scrutinized according to the "criteria used to set up new epochs." If the Anthropocene met those criteria, as seemed quite possible, the International Chronostratigraphic Chart might be amended accordingly.[23] The article marked a significant new departure from Crutzen's original idea and from all the ways in which that idea had previously been received. The working group was the result of that proposal.

Many things follow from this attempt to take the Anthropocene so literally as to incorporate it into the geological timescale, to turn it into a formal unit of geohistory. In Smith and Zeder's terms, it makes for an Anthropocene that is defined by *effects* rather than by *causes*—and by its effects not primarily for human beings but for the earth's ecological assemblage as a whole. What Zalasiewicz contemplated, in essence, was a way in which to carry out a profound displacement of the human in thinking about the Anthropocene. One would start not with human influences on the environment, not with an attribution of responsibility or blame, but with the fact of ecological change as such. So many changes, of specified magnitude, to this or that geophysical phenomenon: the sedimentation of rivers, the population distribution of phytoplankton, the acidity of oceans, the pollen content of the air. This suite of changes would then be weighed and interpreted, and their interactions reconstructed—at this stage analyzing the interspecies and intraspecies relationships of one very populous hominoid species would be crucial—in order to assess whether, and in what way, they could be said to constitute the beginning of a new epoch. Look at the earth system changes first, and let them lead you, as they undoubtedly will, to an ecology of the human species. Then pass beyond the confines of the human again, in order to grasp these processes of transformation in the terms of geologic time. This is what the stratigraphers proposed.

In order to carry out this immense conceptual displacement, a certain indirectness is needed. Instead of assessing the type and scale of present-day ecological change directly, and deciding on that basis whether the Anthropocene label is justified, one must imaginatively transfer oneself to the far future. After all, the beginning of every other epoch has been defined in distant retrospect. Stratigraphers of the Anthropocene must concentrate much less on how dramatic any given environmental change is at present

than on how readily discernible it will be millions of years from now, which largely means how well traces of it will be preserved in sedimentary rocks. Some bureaucratic oddities follow from this. For instance, because marine and lacustrine deposits are usually much better preserved than those on land (which the weather erodes), stratigraphers generally focus their attention on the rock layers that build up at the bottom of oceans and lakes. Likewise, stratigraphy prioritizes hard-bodied organisms, which fossilize far more readily than soft-bodied ones, and it emphasizes the species at the base of past food pyramids over the much less abundant apex predators.

Songbirds, squid, and big cats, for those reasons, are in themselves poor stratigraphic markers for the Anthropocene. Environmentalists who are justifiably concerned about their survival might be perplexed by stratigraphers' preoccupation with fluctuations in the distribution of calcareous and siliceous marine microorganisms. But the infinitely complex interlocking of ecosystem processes means that this is much less of a problem than it first appears. Disturbances at one level will often have repercussions in another. The near-total collapse of the gargantuan Newfoundland cod population, caused by industrial overfishing, might be visible in the fossil record not directly but through changing species compositions near the bottom of the food web, where zooplankton numbers have come under pressure from booming populations of the foraging capelin that the cod once preyed upon. Levels of world GDP and of foreign direct investment—things to which Crutzen and McNeill's version of the Anthropocene gave priority—do not fossilize. By circuitous routes, however, they affect the things that do. The stratigraphic approach to defining the indicators of the Anthropocene is at once the subtlest and the most concrete of the many that have been proposed.

A second concomitant of the stratigraphic method might be equally hard to swallow at first. Stratigraphers like the dates for the beginning of new intervals to be singular, worldwide, and as exact as possible. In the present case, they have generally envisaged a formalized Anthropocene with one particular year specified as its starting point. And although a variety of candidate years have been discussed, all of them are relatively recent ones. In line with the Smith and Zeder rule that a focus on worldwide environmental effects rather than causes implies a young Anthropocene, the stratigraphers' proposed start dates all fall within the last few centuries. Opponents of the Anthropocene have generally denounced this way of dating the new epoch as a gross simplification, one that neglects both the deep roots of ecological change and the gradual and geographically variable nature of industrial modernization. But perhaps those opponents have not yet asked themselves whether they really wish to accuse geologists of being intellectually uncomfortable with the idea of long-drawn-out change. As we will see, the stratigraphic version of the Anthropocene does not remotely imply a one-step model of environmental transformation.

I have argued in this chapter that several different versions of the Anthropocene are possible. Still other uses of the term will no doubt emerge in the future. But the turn toward stratigraphic formalization provides the most fertile way so far to interpret this epoch-making play of power relations among human and nonhuman forces. The stratigraphic approach reinvents the Anthropocene by giving it a place amid the complex mosaic of the geological timescale. What remains is to elucidate the stratigraphic conception of the new epoch and to use that conception as a way of changing the debate about the politics of the Anthropocene. Taking our cue from the geologists will mean paying attention to the lineaments of a history that goes back much further than 1784, even if a date like that eventually proves to be a good candidate for the epoch's formal starting point. To interpret the Anthropocene stratigraphically means placing it in the context of geological time. This is the method that will help us see why contemporary environmental problems have started to load the pages of daily newspapers with references to the events of a hundred thousand or three million years ago.

CHAPTER THREE

Geology of the Future

In a nutshell, my argument so far has been as follows. There are several versions of the Anthropocene, so if you want to talk about it, you have to specify the version that you mean. The environmental crisis of the present day plunges those living through it back into deep time, and one version of the Anthropocene—the one that takes literally the possibility of defining it as a new geological epoch—provides a way of coming to terms with that disturbing encounter with the distant past. In other words, thinking through the implications of adding the Anthropocene epoch to the geological timescale is a way of locating the current crisis within earth history.

That means that there is much to be learned from the activities of the ICS Anthropocene Working Group, the volunteer corps of Jan Zalasiewicz and his colleagues. For one thing, the significance of the name *Anthropocene* shifts when it is understood as a stratigraphic term. If the new epoch's name works in the same way as the names of other units in the geological timescale, then it is free from many of the unwelcome overtones of which it has been accused. The stratigraphers' research program begins not with any assertions about who is responsible for environmental disaster, but with a leap of the imagination. What traces might the events of the recent past leave on the earth thousands or millions of years into the future, they have asked, and what does that tell us about where contemporary changes belong in the long narrative of earth history?

The formalization of the Anthropocene epoch within the geological timescale will require more than just predictions, however. It will depend on evidence that one can already recognize substantial, well-defined changes to the composition of the earth that have come about in recent decades or centuries. The key to the stratigraphic Anthropocene is a tightly specified starting point: a "base," in the jargon. Various candidates for the base of the Anthropocene have been proposed, and the strength or weakness of those candidacies will determine whether the new epoch can be formally ratified. More importantly, it is through the evaluation of those candidates that the stratigraphic study of the Anthropocene intersects with, and shines a light on, the environmental and economic history of the last five centuries. Each of the main candidates offers us a distinctive way in which to understand the place of the modern crisis within deep time.

THE NAME OF THE ANTHROPOCENE

The Anthropocene is a brilliantly provocative label for the new epoch. If the epoch is formalized in the geological timescale, it will certainly be given the name that supposedly came to Paul Crutzen in a flash, rather than being called *the Econocene*, *the Cosmoscene*, or anything else. And this pointed name is undoubtedly one of the main reasons for the concept's viral spread. It condenses into a single word a gripping and intuitive story about human influences on the planet. It works, on the most basic level, as a kind of shock tactic: the planet has changed so much that many scientists believe we have entered a whole new geological epoch! Or rather, its message seems at first blush to be: *humankind has changed the planet so much that it has created* a new geologic epoch. The Anthropocene has often been considered a counter-Copernican idea. Whereas Copernicus displaced human beings from their

privileged place at the geographical center of the universe, the Anthropocene, in this line of thinking, puts human beings back at the center of the physical world.

The theme of a transition between geological epochs would never have commanded so much attention, so far beyond the profession of stratigraphy, had it not brought human activity to the foreground in such a compelling way. On the other hand, it is clear that the mere choice of name is also one of the main reasons why so many critics have rushed to declare that the Anthropocene tout court is an unacceptably universalist and totalizing idea. For its opponents, as we have seen, naming the new epoch "the Anthropocene" is tantamount to dismissing all differences between groups of human beings and thereby blaming the whole world's population indiscriminately for environmental catastrophe, in a way that can only lead to the adoption of counterproductive and antiegalitarian solutions. Evidently, a great deal depends upon what exactly the relationship is between humankind, the *anthropos*, on the one hand, and the Anthropocene epoch on the other.[1]

Zalasiewicz and his collaborators have been happy to persevere with Crutzen's name for the epoch, even though their conception of the Anthropocene is subtly but fundamentally different from his own. We need to understand the sense in which the word *Anthropocene* is being used when it is employed as a part of the specialized terminology of stratigraphic science. What happens to the relationship between the Anthropocene and the *anthropos* if the new word is taken literally as the name of a geological interval? If we consider how the names of geological intervals are usually formed, we will see that the stratigraphic approach implies a much less exclusive relationship between the two than many interpreters have assumed. Speaking of the Anthropocene certainly does not mean, in this context, that human beings are singlehandedly the creators of a new phase in earth's history.

The Carboniferous period gets its name from the Latin *carbō* (charcoal, or coal) because one distinctive feature of the time between 360 and

300 million years ago was the accumulation of massive coal deposits. The Cretaceous period was so called because many large and striking formations of chalk (in Latin, *crēta*), such as the White Cliffs of Dover, date to the last 80 million years before the extinction of the land dinosaurs. Coal deposition was an important part of the Carboniferous, and chalk accumulation was important to the Cretaceous. But it would make no sense to imagine that the whole Carboniferous period was an inherently coal-centered one. Nor did the volcanoes or the ankylosaurs of the Cretaceous have any kind of chalky essence about them. In both periods, ecological processes went on in their own ways: tectonic plates shoved and buckled; the sun burned off vapor from the seas; insects buzzed between stands of fern. Meanwhile dead trees were crushed underground into coal, and the calcium carbonate shells of marine creatures built up in chalky layers. At certain times the latter two processes left such heavy traces in the rock record that nineteenth-century geologists used them to provide names for slices of earth's history. But this Victorian nomenclature does not make them any more special than that. Many other deposits of coal and chalk were laid down outside the periods that bear their names, just as the Cryogenian period (from the Greek κρύοσ, "frost") was a remarkably cold interval, but by no means the only one in which glaciers formed. In each of these cases, conceptual priority lies with the interval itself, considered as a span of time with certain distinguishing characteristics, more or less dissimilar to the times before and after. Only afterward was some characteristic feature of the interval pressed into service to supply a name for the whole thing.

The point is, of course, that all this applies to the Anthropocene too. The belief that the *anthropos* must be the essence or metaphysical centerpiece of the Anthropocene is without foundation. When the word is used as the name of a stratigraphic unit, it does not imply that the Anthropocene is the "epoch of humanity" in the sense that it contains nothing other than human agency, or in the sense that all the rest of the world is subordinated to human

dominion. If the physical world has changed so much in recent centuries that a fresh geological epoch can be said to have begun, then a name like *Anthropocene* seems appropriate, because human activities have been extremely prominent among those changes. Nonetheless, these ecological reconfigurations have let other players besides the *anthropos* exert themselves too, unbidden by humans and not reducible to their desires.

The Anthropocene includes volcanic eruptions and undersea landslips as well as mountaintop removal mines. *Leptinotarsa decemlineata*, the Colorado potato beetle, first evolved to eat potatoes in the nineteenth century, and it has eaten them in great numbers ever since, having developed resistance to an array of pesticides. Chlorine atoms climbed to the stratosphere in CFCs, each unraveling thousands of ozone molecules there, decades before anyone below conceived of such processes. Humans made those transformations possible, but they can hardly be said to have had them under control. Colorado beetles and chlorine atoms, like gray squirrels and kudzu, are among the powers of the Anthropocene. They are just as real as human beings, and just as capable of exerting themselves within their own spheres of influence. The idea of the Anthropocene puts all of them on the same ontological plane. Humanity, in this epoch, does not absorb or command some merely passive nature, issuing orders from a central throne to the dull physical substance that surrounds it. On the contrary, human societies are only the most vigorous and distinctive among an irreducibly various array of altered forces. Thus the turn to stratigraphy helps one assess the status of the *anthropos* within the Anthropocene in a realistic and levelheaded way.

In this light, the claim that the Anthropocene is an innately dualistic concept loses its force. Jason W. Moore, the Anthropocene's sharpest and most accomplished critic, sees the whole concept as resting on an unacknowledged binary whereby "humanity" is seen as interacting with a "nature" from which it remains essentially separate and independent. It is certainly true that some individual writers on the new epoch have been snared by such dualist habits of thought, but that tells us little about the Anthropocene in its stratigraphic sense. Compare the Devonian period, the predecessor to the Carboniferous. Unless that period implies that reality is fundamentally divided into two, and only two, parts—with the pleasant English county of Devon forming one half of reality, and everything else in existence, from the rings of Saturn to mental states in Penzance, crammed into the other half—there is no reason to think that the Anthropocene rests on a philosophical division between humans and nature.

All of this makes a difference to the practical definition of the Anthropocene. As we have seen, proponents of an "early Anthropocene" define the beginning of the new age by focusing, as Bruce Smith and Melinda Zeder put it, "on cause rather than effect, on human behaviour." For them, the difference between the world of the Anthropocene and all the rest of the earth's history is that the former is marked by human presence. Of course there is nothing to stop them using the word in that way, but as cogent as Smith and Zeder's version of the Anthropocene is on its own terms, it is not a stratigraphic concept. Geological units mark collective, worldwide transformations, rather than private milestones in the career of one species. Members of the Anthropocene Working Group clarified that point in the course of rebutting an otherwise forgettable attack on the concept: "We do not believe that it is necessary to seek a 'boundary stratigraphic marker' that reflects the time 'since anthropogenic change began,'" they wrote. "The issue here is not the presence or absence of human traces in strata. It is whether Earth's stratigraphic record—and the processes that shape it—have changed sufficiently to make a new unit justifiable and useful and, if so, to seek the most effectively traceable boundary horizon for it."[2]

The stratigraphers' concern is with the suite of geophysical changes that constitute the latest discontinuity in the history of the earth, not with the beginnings of human influence on the planet as such. For that reason, they always envisage a relatively recent starting date for the Anthropocene: they

regard it as beginning only with the radical changes that the workings of the world have undergone in the last few centuries. They see no reason why the epoch should embrace the entire time during which humans have had a significant impact on the state of the planet, especially given that "significant" seems almost impossible to define in that context. *The Anthropocene* is not a suitable name for the new epoch merely because human beings are an ecological force in it. It has long been understood that humans were also one of the ecological forces that molded the Pleistocene epoch, and by the same token, beavers, bacteria, and bryophytes are still ecological forces in the Anthropocene. The point is that transformations that may well be great enough to justify the declaration of a new epoch have taken place within the last three centuries, and that it seems appropriate to christen that epoch "the Anthropocene" because human agency is outstandingly prominent among its novel biogeochemical assemblages.

What we now think of as the Anthropocene could even be a unit of geologic time that endures long after humans' deliberate influence on the planet has largely been lost. The Working Group's members have been clear about this mordant implication of their thinking as well. As some of them put it: "It may be misleading . . . to think of the Anthropocene just as the 'human epoch.' The key factor is the level of geologically significant global change, with humans currently happening to be the primary drivers: future, potentially yet more pronounced change may be primarily driven by Earth system feedbacks such as methane release, and yet would still clearly be part of the same phenomenon."[3]

In that grim scenario, the epoch that has now begun would ultimately prove to be characterized much more by the destabilization of methane clathrates than by intentional human modification of ecosystems. Human activity could be brutally curtailed by a species-wide population collapse in the early part of the epoch, whereas methane outgassing could leave a much deeper geological trace via a process of rapid greenhouse warming, ice sheet melting, and sea level rise—a series of events that has taken place several times in the past. In geological terms, the two parts of the process would form a single act in the drama of geohistory, regardless of the fact that one was consciously driven by human beings and the other was not. And even in that scenario, *the Anthropocene* could still be a reasonable name for the epoch, if anyone is around to bestow it. Humans would at least have initiated the chain of events that characterized the epoch, although under those circumstances no one could imagine that the name meant they were its masters.

The Anthropocene of the geologists is not an anthropocentric concept, nor one that separates humankind from the rest of nature. The name *Anthropocene* describes the most distinctive aspect of the new epoch, not its single essence. And if the Anthropocene does not put any human beings at the ontological center of the world, then it is certainly not guilty of putting all of them there in a lump. That is, if the new epoch is not a dualistic concept, then the further accusation that it reduces the diverse human populations of the world to an undifferentiated mass, all collectively responsible for current environmental despoliation, also loses its power. The geological Anthropocene is neither universalist nor technocratic, and neither deterministic nor antipolitical. Rather than designating a general human footprint on the natural world, it implies only a network of evolutionary developments and ecological interactions.

GEOLOGISTS FROM SPACE

The stratigraphic conception of the Anthropocene begins with a thought experiment. "Let us admit, though eccentric it might be, the supposition that a strange intelligence should come to study the Earth in a day when human progeny . . . has disappeared completely." That strange intelligence would be able to understand the world "only by putting in all his calculations this new element, human spirit. . . . So that future geologist, wishing to study our epoch's geology, would end up narrating the history of human

intelligence."[4] Thus wrote one of the forefathers of the Anthropocene, Antonio Stoppani, in the 1870s. In recent years, the thought experiment that he envisaged has actually been conducted in the writings of Jan Zalasiewicz and his colleagues.[5] The defining signals of the stratigraphic Anthropocene are not the rising levels of GDP and international tourism emphasized by Crutzen and his coauthors, or even the shares of land and biological productivity presently co-opted by humans that I described at the end of the first chapter. Instead, they are all those changes to the earth that might be discernible in the distant future, because of the way in which they alter the layers of sediment and snow that will be stacked and compressed into rocks and ice sheets.

Suppose that human civilization were to fade from existence over the coming years, so that its final geological footprint was similar to that which it would leave behind today. What would happen if aliens were to land on the earth a hundred million years from now and study it with geological techniques like those of the present? Zalasiewicz has argued that even at that distant time the planet would still harbor the records of human technology, in a distinctive layer of rock that would in effect constitute the lower bound of the Anthropocene epoch.

In a hundred million years' time, most of the sedimentary rock strata being laid down today will have disappeared irretrievably, having been scoured by ocean currents, eroded in the air, or dipped into the earth's molten interior. The remainder will mostly be buried deep underground or underwater, and virtually inaccessible. Nonetheless, some will happen to be at or near the surface, just as some rocks formed from hundred-million-year-old sediments are visible today. And just as those mid-Cretaceous rocks make possible the reconstruction of part of a colorful narrative when they are read in juxtaposition to those above and below them, so too will the rocks of the human interval. They will not appear utterly different in kind to every other layer of stone on the planet's surface, but nor will they be dully identical to all the rocks around them. Instead, they will record one unique moment among many others in the course of geohistory.

As Zalasiewicz imagines it, the alien geologists of a hundred million years' time would only gradually have their attention drawn toward the strata currently being laid down. Tracing the history of the planet on which they had landed, they would reconstruct the contrasting fossil assemblages of successive ages and grow particularly interested in the turning points between them. Most of the major turning points would be mass extinctions, and as we have seen, modern times are yet to witness a full-scale mass extinction. Nonetheless, the rocks laid down above those of the present day would hold arrangements of fossils that were radically different from those below. The difference would arise mainly from a geographic redistribution of species unprecedented in the record of complex life. The effects of that redistribution would be permanent, since future evolution would have taken place on the basis of the new arrangements.

Introduced flora now make up close to half of the plant species found on remote islands like New Zealand and Hawaii, and more than 20 percent even in places like Britain, Canada, and New England.[6] Introduced species dominate overwhelmingly the fauna of Australia and the Americas, where they constitute (for instance) up to 99 percent of the biomass in San Francisco Bay. The alien geologists would be able to discern many of these introductions directly, when fossilized skeletons, leaves, footprints, or pollen showed up far outside the range recorded in earlier rocks. The workings of fossilization would mean that the clearest such records would be those of abundant shell-forming shallow-water organisms, typically dispersed worldwide in ships' ballast water. But many other, subtler traces of the relocations could also be found. In the wetlands of the Great Plains, for instance, the Eurasian common reed has displaced native willows, and the fine-grained, silica-rich sediments that have built up among the stands of reeds may provide the raw material for distinctive sedimentary rock layers. New species have arisen

through hybridization with interlopers, or in response to them, like the five moth species that have evolved to feed on bananas in Hawaii. Others have been altered, like the soapberry bugs in Australia that have evolved longer beaks in order to feed on invasive balloon vines.[7] The strata of the present day would carry the evidence of innumerable near-simultaneous ecological modifications like these. Standing out among them would be the geological sites that bore witness to the unceremonious simplification of ecosystems that is associated with the most destructive invasions: by cane toads, chestnut blight, wolf snails, fire ants, rats, rabbits, chytrid fungus, zebra mussels, Nile perch, Japanese knotweed, and the like.

This paleontological merry-go-round would very probably be synchronous with the leveling-off of many of the Brobdingnagian limestone plateaux that are formed by coral reefs. Corals can live only in sunlit upper waters, and rising seas at a time of miscellaneous hardship—the world's corals are being overheated, acidified, poisoned with industrial waste, muddied by sediment from deforested shores, blanketed by seaweed fed on agricultural runoff, and dynamited for fish—currently appear set to drown them. (More than half of the world's reef-building corals have already been lost, a decline unprecedented for tens of millions of years.) The flat-topped limestone mountains left behind should be starkly visible to the aliens.

Once the aliens had identified the turning point—the biohorizon—at which the transplantations and the coral wipeout began, they would have good reason to examine closely the strata of the present day. They would find there an episode of global warming (reflected by changes in the proportions of different isotopes of oxygen in ocean sediments) that might mark the start of a 130,000-year hiatus within a spell of cold climate that had begun about 2.6 million years earlier.[8] They would probably identify a rise in sea level, a phenomenon that always transforms the distribution of sediments beneath wide expanses of the sea, not just the newly flooded land. Recent sea level rise has been negligible by geological standards, but the destruction of the

West Antarctic ice sheet is now considered inevitable.[9] If the Greenland sheet follows, that is already a rise of twelve meters, which would have potentially long-term visibility.

The pollen grains trapped in the strata would reveal further distinctive qualities: signs of rapid deforestation despite the warming climate, combined with exceptional worldwide abundance for just a handful of plant breeds. (These would be the domesticated staple crop grasses; the global spread of corn, which produces an abundance of pollen, would be especially noticeable.) The shells of marine microorganisms would contain an unusual mix of carbon isotopes, having taken up the carbon released by burning fossil fuels. Despite the comparative patchiness of the fossil record of large animals, the skeletons of domesticated vertebrates should certainly be found. There would be a strange paucity of limestone in ocean sediments, replaced by a layer of clay: evidence of acidification. Some evidence of modern-day iron and especially steel production—a combined total of 15 billion metric tons so far—might have been preserved, and several of the formerly rare minerals now found in enormous quantities in cement, bricks, and ceramics would probably have survived robustly. Deep boreholes, mines, and underground nuclear test sites and storage facilities might well remain virtually intact, and even collapsed mines would still exist as channels of brecciated, or fragmented, rock.[10]

This thought experiment is the basis for the claim that the Anthropocene may legitimately be introduced as a new geological unit. The distinctive character of contemporary strata can already be specified with considerable confidence, even though events still to come will affect the way that they would appear to far-future observers. The particular nature of the changes that mark the beginning of the Anthropocene will be unique, as is always the case. But the *types* of changes will mostly fall into categories with which stratigraphic analysis is perfectly familiar. The lower bound of the Anthropocene will be marked by worldwide evidence of things for which geologists

have a well-honed jargon: a climate transition, a marine transgression (i.e., sea level rise), a "reef gap," an episode of mineral diversification, a carbon isotope excursion, and distinctive bioturbation (the spoil heaps and boreholes, analogous to animal burrows). The boundary will be marked especially clearly as the base of numerous assemblage zones (the species relocations), and in palynological (pollen) analysis. The proponents of the stratigraphic Anthropocene have always claimed that they are not asking for any special treatment in the recognition of the new epoch. They argue that—although of course it is an unusual case in many respects—the Anthropocene epoch meets the regular criteria normally required for the ratification of geochronological units.

THE HUMAN STRATUM

The case for formalizing the Anthropocene in the geological timescale rests on changes to the composition of rock strata that would take place worldwide. Few of the changes that I have described would necessarily reveal much about the primate species whose activities link them all together. In principle, the alien geologists could identify the present day as a significant turning point while learning very little about the part played in it by Stoppani's "new element," *Homo sapiens*. Recognition of the Anthropocene does not—this point can hardly be stressed too heavily or too often—mean asserting that the whole world is now subordinated to human agency. It just means that a suite of changes significant even in a deep-time perspective is taking place in planetary systems.

That said, Zalasiewicz has argued that even in a hundred million years' time, clear records of human existence probably will remain on earth. Having become interested in present-day strata, he supposes, the hypothetical aliens would track the sediments laid down in today's oceans into shallower and shallower water. Then, by carefully tracing present-day shorelines, they could hunt down what Zalasiewicz calls the "Urban Stratum": the remnants of coastal cities. (Urban areas now cover 3 percent of the land surface, concentrated in preservation-friendly coastal and deltaic locations.) The cities' state of preservation would depend on how rapidly sea level rise had sunk them beneath the erosional surf zone, but if fossilized dinosaur bones can survive a hundred million years underground then so, a fortiori, can artifacts of ceramic and lead. The aliens would be able to excavate the rubble of concrete buildings, now turned "decalcified and crumbly"; car parts crushed into "irregular patches of iron oxides and sulphides"; lines of "softened brick"; opaque fragments of glass.[11] They would even, Zalasiewicz hazards, be able to reconstruct the gross anatomy of the species who built the cities. Humans are extraordinarily numerous for a megafaunal species, and formal burial multiplies skeletons' chances of survival as well as preserving them in tellingly ordered rows.

Geologists who proceeded that far would evidently have recognized the traces of intelligent beings. But they would probably be able to deduce much less about the conscious life of the species that they studied than about its characteristic behavior. Zalasiewicz shows how humankind could stand revealed in the geologic record as a single, herding, migratory species, omnivorous in diet (much of its food web could be reconstructed) and technological in habits (mines would give evidence of fossil fuel use). The age structure of the fossil assemblages would suggest that juveniles were cared for. Conversely, some skeletons might reveal evidence of deliberate killing, so the aliens would have no reason to envisage the species as Gerda Roelvink's undifferentiated "universal and transhistorical collective," but could guess at intergroup violence and war. But the aliens would be limited, Zalasiewicz says, to analyzing human beings in "broad ecological terms" like these. "It is hard to think how the normal workings of geology and taphonomy [fossilization] can capture anything that one might describe as embodying the essence of humanity," he observes, given that the works of Mozart and Schubert, Shakespeare and Goethe, Michelangelo and Rodin, will be definitively irrecoverable in a

hundred million years.[12] That is true enough in itself, but what should be added is that the aliens' lack of access to the ideas bound up in human books and paintings might bring with it certain benefits as well as losses.

As Zalasiewicz says, the aliens' viewpoint would necessarily be an "ecological" and nonhumanist one. Theirs would be an interpretation of the human species derived from the shape and intensity of its material interactions with other beings and forces—coal, rice, coral, nitrogen, iron—and not from its inward self-imagining. That interpretation would without doubt be incomplete, but it could be thought of, too, as a rigorous and disenchanted one. Because, despite what Zalasiewicz implies, even unhindered access to the masterpieces of the Western canon does not put one in touch with "the essence of humanity." Even Schubert and Shakespeare were products of their time and place, not mediators of a timeless human spirit. Such a spirit or essence finally has no more reality for us than for the alien geologists of the distant future. What the aliens would lack is just the *illusion* of a transcendent human essence. It is worth trying to see the world somewhat in the same way as those imaginary aliens, then. Doing so could make a difference to the ecological politics and criticism of our own time.

The thought experiment that gives rise to the stratigraphic Anthropocene tries to understand the present by imagining its geological traces. Far from planting the essence of humanity at the dead center of the world, it humbles all such humanist pretensions. The alien perspective of the far future would be one in which plastics, grasses, humans, plankton, and carbon dioxide molecules were all bundled together. Those geologists' object of inquiry would necessarily be the entire ecosystem that had collectively given rise to the rock record that they studied. In their eyes, each factor in the planetary system would be neither more nor less real than every other. Ecological thinking that learns from the aliens' example could never be a matter of making "man" and "nature" grind perpetually against one another like Chinese medicine balls.

The planetary forces addressed by this ecological thinking would be those that actually exist at the time of the Anthropocene's birth. Everyone has heard the claim that green politics is special because is concerned with the future: that environmentalists, unlike others, look beyond the next electoral cycle to worry about the interests of future generations and about the state of the planet that we will hand on to our grandchildren. But that claim is largely bogus. Secular politicians of every stripe likewise promise their voters a better future and a more prosperous life for their children. A genuinely emancipatory green politics would mistrust this rhetoric of kinship and patrimony, and would go in fear of sacrificing the interests of the living and impoverished to the interests of the unborn children of the West. The attitude to future time implied by the stratigraphers of the Anthropocene is exemplary in this respect. They do indeed look to the future. But they look much, much further into the future than most environmental thinkers, and they do so precisely as a way of looking back on the present. Their concern is not the well-being of the planet in a hundred million years, but the current state of the biosphere, which they want to situate in its deep-time context so as to understand it better. Imagining how the earth will look in remote ages becomes a way in which to focus on concrete realities that are immediately at hand.

The stratigraphers of the Anthropocene thus take a view of deep time exactly opposite to the Olympian pretensions that, in chapter 1, we saw shared by Colin Tudge, David Brower, and Matt Ridley. For their different reasons, the latter three all at times have declared great tracts of history to be much of a muchness and insisted on disregarding the challenge of living amid the particular circumstances of the present. The idea of the Anthropocene, by contrast, is a way of sharpening one's focus on the dangers and transformations that are peculiar to the contemporary world. Those dangers stand out most clearly against the backdrop of geologic time. That is why it is crucial to remember that the Anthropocene Working Group's object of study

is not the Anthropocene epoch as a whole but only the very earliest fraction of this new unit of time. Whereas its beginning is all around us, the later course of the epoch (which we may imagine lasting millions of years into the future) is almost completely unpredictable. It might be dominated by an intense methane-driven thermal maximum and a mass extinction, as in the Working Group's gloomy scenario described above. Equally, it might happen to be a more equable time than many other geologic epochs. But in either case, *Homo sapiens* may well disappear from the fossil record somewhere in its lower reaches. So there is no particular need for anyone to worry about the distant upper stages of the Anthropocene (let alone the "post-Anthropocene"). What humankind has to deal with is only the pressing reality of the epoch's lower boundary: its birth pangs.

GOLDEN SPIKES

Looking back over a distance of a hundred million years, geologists are hard pressed to distinguish dates more precisely than to the nearest hundred thousand years or so. To Zalasiewicz's imagined aliens, the manufacture of Aurignacian flint tools and the building of the Burj Khalifa in Dubai would look more or less simultaneous. In their eyes, the beginning—the "base"—of the new interval might just be a single human event layer. But if they could somehow reconstruct human history as precisely as present-day scholars are able to, when exactly would they place the start of the epoch?

We saw in the previous chapter that debates about what the Anthropocene *is* often take the form of debates about when the Anthropocene *begins*. Everyone agrees that the earth's ongoing change of state is a drawn-out process taking place over centuries, at least, with antecedents that go back much further still. Nonetheless, the boundaries between the various components of the geological timescale always have to be fixed somewhere, or the study of earth history would descend into a morass of terminological confusion. That means that if the proposed new interval is to be represented on the International Chronostratigraphic Chart, then some particular date must be picked out to represent the moment of change from the Holocene epoch to the Anthropocene. Given how short the relevant timescales are, it has seemed to most workers that a single year ought to be chosen as the turning point. Trying to decide on the most apposite year might seem like splitting hairs when we compare it to the perspective of Zalasiewicz's aliens. But in fact the debate about the starting date deserves all the energy that is being expended upon it. The attempt to assign a precise date to the new epoch is what brings the concept of the stratigraphic Anthropocene up against the specifics of global environmental history.

The base of the Anthropocene could be defined in one of two ways. The simpler option would be to assign to it some appropriate numerical age, so that the epoch would begin in, say, 1784 or 1950. This method—the selection of a Global Standard Stratigraphic Age (GSSA)—is the one used for defining early intervals in earth's history, before the development of complex life, because of the paucity of paleontological evidence. Stratigraphers of the Anthropocene face some similar challenges for the opposite reason, a superabundance of data, while they also have the advantage of being able to choose a date based on precisely known historical records. For both reasons, there is much to be said for defining the Anthropocene directly via a GSSA.

In the main, however, an alternative method is preferred, one based on real-world reference points. With this approach, some specific change in a sedimentary archive—like the beginning of that green-gray marl bed in an Italian quarry—is chosen to represent the transition between geological intervals and is named as a Global Boundary Stratotype Section and Point, or GSSP. Practicalities allowing, a golden metal marker may then be hammered into the relevant layer of rock: for that reason, GSSPs are often referred to as "golden spikes." The interval is defined by the change in the rock record where the golden spike is fixed. The timing of the interval is then derived by investigating the date of this tangible alteration in the composition of the

earth. Geologists are currently completing the process of fixing all other geochronological boundaries for the last half a billion years on the basis of GSSPs. If the Anthropocene too is to be based on a golden spike, in line with this preferred approach, then a signal that represents its beginning must be picked out from among the multitude of recent transformations in the makeup of the planet.

The perfect stratigraphic marker for demarcating a unit of earth history would be one that was found all over the world, and that was unambiguously visible to every trained observer. It would appear everywhere in the stratigraphic record at the same moment, and it would be possible to date that moment precisely. It would be preserved within continuously deposited layers of rock, so that the preceding and succeeding environments could be thoroughly compared, and for extra security it would come with a cluster of independent auxiliary markers. It would appear likely to survive indefinitely into the future.

Not surprisingly, perfect markers for stratigraphic boundaries do not exist. Most boundaries are associated with the first or last known appearance of particular fossil species. The fossils chosen for this purpose are always common, widespread, and well-recognizable ones. Even so, imprecision is inevitable. The earliest and latest known specimens are almost certainly not the first or last members of the species ever to have existed. The species must have originated in one part of the world before spreading more widely, a process that may have taken many thousands of years, and the dates assigned to its appearance in any given location may have uncertainty ranges of hundreds of thousands of years. The species will have flourished only in a limited range of habitats, only a small proportion of those habitats will have been preserved so as to be accessible for study, and a still smaller proportion of them will actually have been studied. The standard of preservation even in those sites will be variable; in particular, the amount and type of contextual evidence preserved alongside the reference species will fluctuate enormously. The most readily accessible exposures will often be susceptible to being eroded away over time.

Given all those commonplace uncertainties, prospective markers of the Anthropocene should not be held to a standard of perfection that other golden spikes do not reach. It is not an argument against the idea of the Anthropocene to say that there is no unambiguous marker of its beginning or even a single candidate clearly superior to all the others: the representative of its lower bound will inevitably have to be selected through a process of debate. The rules of that debate, however, can at least be specified in advance. Established stratigraphic procedures provide the criteria by which proposed indicators of the new epoch can be judged.

Some thoughtful observers doubt that any prospective marker of the Anthropocene will be able to meet the usual criteria for the ratification of geological epochs. In this line of thinking, there is insufficient justification (at least so far) for introducing a new epoch to the geological record, and the Anthropocene ought not to be formalized by the institutions of stratigraphic science. These skeptics are not persuaded that the geological formalization of the Anthropocene would fulfill the most fundamental requirement, that of usefulness. After all, the history of recent centuries is recorded in infinitely more detail in written records than in layers of ocean sediment. The relevant sedimentary layers might be too thin and too ambiguous as yet to provide a robust basis for a new epoch. The justification for the Anthropocene involves predictions about how well the traces of current humans will be preserved, and how clearly they will stand out to future observers, but it is at least conceivable that "another extended interval of voluminous flood basalts or another large asteroid impact [might yet] overwhelm any sedimentological/stratigraphic record of human activities."[13]

Furthermore, without diminishing any of the scientific evidence indicating the gravity of anthropogenic change, one might wonder whether a clear geological break from the preceding Holocene epoch can yet be seen,

especially remembering that the Holocene, too, has always been marked by intensifying human impacts. The current wave of extinctions—fewer than 1 percent of all species, as we have seen—is not yet epochal in scale; there has yet to be a geologically significant rise in sea levels; the biggest effects of climate change are still to come; and the worst effects of many regional crises of pollution, overfishing, and habitat destruction might still be ameliorated if sufficient political will is brought to bear. Conversely, if current environmental pressures appear set to further intensify and converge, that too might be an argument against a precipitate declaration of the Anthropocene. Demographic trends suggest that the human population will not reach a plateau before the second half of the present century, at somewhere on the order of ten billion souls, and there seems every reason to predict a sharpening of conflicts related to climate, energy, water, pollution, and land use into at least the 2020s and 2030s. If most aspects of the world crisis currently have such strong momentum behind them, it may be wise to wait before ratifying the new epoch. A compelling candidate for the base of the Anthropocene might lie unforeseeably in the future: an exchange of nuclear weapons, say, or a transformative program of geoengineering.

In short, it may be premature at best to inscribe the Anthropocene in the Chronostratigraphic Chart. In the absence of institutional ratification, the word could continue to be used in an informal and relatively loose fashion, and this flexible approach might be the most pragmatic and illuminating option.

Without being persuaded by it, I can see the force of that argument. Equally possible is a subtle variation on the skeptical viewpoint that ultimately has quite different implications. Suppose you agree that it is too early to declare the beginning of the Anthropocene, because the most appropriate boundary for a new geological epoch may perhaps lie in the future, possibly centuries away. You might (without inconsistency) hold that view while also thinking that current evidence already justifies the claim that the world is irreversibly locked into the process of undergoing an epoch-level transition. That is, you might believe that the transition to the next epoch is not yet complete while also agreeing with Paul Crutzen that the world has already changed so much that the Holocene cannot outlast the present crisis in any meaningful sense.

According to this variation on the skeptical view, either the Anthropocene has already begun, or the Anthropocene *will* begin. If the Anthropocene has not yet arrived, the reason for that can only be that it will arrive differently—still more forcefully, or still more decisively—at some future time. In that case, the world is now precisely in the marginal state between two geological epochs. Perhaps the generations living today are not exactly witnessing a process of transition, in the sense of being able to measure and track it. Perhaps instead (and at the risk of sounding paradoxical) what they are witnessing is the very impossibility of witnessing that transition. They are living through a time so disruptive, and a change so great, that it will be possible to make sense of it, and hence to reliably date the birth of the Anthropocene, only in retrospect. Even the most astute contemporary observers are seeing the new epoch in such tight close-up that they can scarcely see it at all. The implication is that the border between the Holocene and the Anthropocene is not just somewhere close at hand but is itself the defining feature of the contemporary world. Until we can look back and say that the birth of the Anthropocene has been completed, that its beginning has come to an end, we seem to be neither in one geologic epoch nor in the other, but in a fissure between the two.

That argument, like the full-scale skeptical one, involves rejecting the stratigraphic formalization of the Anthropocene, at least for now. If the argument sounds appealing, it is a reminder that the possibility of ratification by the IUGS is not the most important thing about the stratigraphic version of the Anthropocene. (The most important thing is the opportunity that it provides to grasp the environmental crisis by putting it in the context of

deep time.) But despite all the difficulties, a strong case is steadily being assembled for a formalized Anthropocene based either on a calendrical date (a GSSA) or on a golden spike in the existing sedimentary record (a GSSP). Much of that case is contained in a landmark publication by the Geological Society of London, a volume called *A Stratigraphical Basis for the Anthropocene* assembled by a group of scientists led by the geologist Colin Waters, the secretary of the Anthropocene Working Group and one of its key organizers. Assessing the various candidates for the golden spike means looking at how the idea of the Anthropocene runs up against the last five hundred years of world environmental history.

THE CANDIDATES (I): CORN, TUNNELS, COAL

The Anthropocene in its stratigraphic sense will not have a premedieval starting point. We have seen William Ruddiman and others propose Anthropocenes that began many thousands or even millions of years ago, having used the word in some other sense. Lake beds, deltas, and pollen assemblages record millennia-old evidence of deforestation, soil erosion, and soil modification, sometimes over wide areas. A layer of elevated lead concentrations in Greenland ice cores bears witness to Carthaginian and Roman mining in southern Spain.[14] But changes like these do not constitute an epoch-level transformation in the earth system as a whole. They are scattered widely in time, their long-term visibility is often limited, and they nearly all took place on a less than continental scale. All plausible epoch boundaries fall well within the last millennium.

Indeed, the editors of *A Stratigraphical Basis for the Anthropocene* are inclined to rule out any starting points preceding the Industrial Revolution. That might be too hasty, however. The Columbian exchange—the ecological fusion of Afro-Eurasia and the Americas across the Atlantic and, later, the Pacific—presents candidates for the Anthropocene's golden spike that deserve more consideration than they have yet received.[15] Thinking only in terms of progressively increasing human mastery over the nonhuman world makes it harder to see what took place. In the Columbian exchange, human agency took on a slightly different role, one to which it is especially well adapted: humans acted as a conduit. The voyages of Christopher Columbus and the *marinheiros* provided a means for Afro-Eurasian and American land biota to become entangled with and act upon one another. Their ships reestablished a low-latitude connection between the two continental clusters that—as we will see below—had been separated by oceans for millions of years. An event that is novel on a million-year scale is exactly the sort of thing that might be expected to mark an epoch-level boundary, and the circulation of crops, weeds, animals, and diseases that it enabled did indeed have immense consequences for the stratigraphic record, as well as for the course of human history.

The effects were most drastic in the Americas. American landscapes (as well as those of the Old World) were already heavily influenced by human societies: in the Andes and Amazonia, Mesoamerica, southwestern North America, and the Eastern Woodlands by more or less intensive food-producing cultures; and elsewhere by hunter-gatherer chiefdoms and bands that held down populations of keystone prey species and managed the land with fire. European colonizers, however, introduced radically new environmental regimes with remarkable speed. Human populations crashed in disease epidemics, war, and forced-labor enterprises; the continents and their seas were stripped of beavers, otters, whales, fur seals, and cod; soils were pillaged for cash-crop monocultures of sugar, cotton, coffee, and tobacco; forests were consumed in timber and shipbuilding, or regrew prolifically over the ruins of destroyed civilizations; weeds and feral horses, cattle, and pigs spread far beyond the settler zones; and older hydrological and fire regimes were transformed by dams, irrigation, and antiburning laws. Meanwhile, American crops spread through Afro-Eurasia. The biggest uptake of New World staples, and perhaps the most rapid, took place in the most

populous and advanced region of the world: China, where the adoption of corn (maize), sweet potatoes, and peanuts helped the population to more than double during the Ming dynasty (and then keep rising, a boom that in time brought with it chronic soil erosion and geopolitical vulnerability). Corn and cassava became African staples. Potatoes, complemented by corn, fed Europe's peasantry.

In their different ways, all these changes left behind enduring geological traces that might serve for stratigraphic purposes. If the Anthropocene was taken to begin in the era of the Columbian exchange, 1492 would be the obvious date for a definition by GSSA (the assignation of a fixed starting date). A GSSP (a real-world reference point, or golden spike) for the Anthropocene could be based on an assemblage zone arising from the first appearance of corn pollen in Eurasian sediments, or from the first appearance of Old World domestic fauna—horses might be the most suitable species—in the archaeological record of the Americas.[16] That seems apt, given that species relocations are such an important part of the Anthropocene's geological signal.

Nonetheless, the geological imprints of the Columbian exchange are still markedly "time transgressive," spreading from region to region over the course of centuries. It would be a mistake to place too much emphasis on 1492 as the year in which the modern world was born. The way in which the Western European states exploited the Americas was not a given, but was in part the outcome of their economic transformation during the previous century, and of several external adventures that had their own stratigraphic implications, including a dress rehearsal in the invasion of the Canary Islands. It is even more important to note that the colonization of the New World did not by any means produce a European-centered world economy and ecology straight away. Instead, its first effect—still an extremely significant one—was to incorporate the Americas into the peripheral or hinterland region of a global trade network that remained centered on the Indian Ocean and East Asia. Even with the expropriation of the ecological resources and precious metals of the New World, it took until about the end of the eighteenth century for any European states to achieve parity in development with the most advanced regions of China and India.

William Ruddiman and his sympathizers hold that American reforestation produced a measurable decline in atmospheric CO_2, contributing to the Little Ice Age, but aside from that controversial hypothesis the effects of the transoceanic exchanges were largely confined to the biosphere, as opposed to the atmosphere or hydrosphere. And although the ecological changes that took place were almost certainly the most dramatic since the end of the last glacial period more than ten thousand years earlier, it might be hard to argue that they were of an epochal magnitude in a stratigraphic sense of the word. A starting point in the fifteenth or sixteenth century would be at the outer limits of possible datings for the new epoch. On the whole, the golden spike is probably better placed somewhere further down the road.

At a minimum, however, the socioecological upheavals of this period make it an essential precursor to the birth of the Anthropocene. The best approach might be to regard the later fifteenth century not as the start of the Anthropocene per se but as the beginning of the transitional phase between the Holocene and its successor.

The fifteenth and sixteenth centuries saw the emergence of the European capitalist regime of globalizing commodity chains and of capitalism's concomitant exploitation and degradation of successive regional ecologies all around the world. To students of world history, this period has often seemed to constitute the decisive rupture that marks the beginning of the modern world system. Thus, when Jason Moore, the most eloquent opponent of the concept of "the Anthropocene" (in fact, only of Crutzen's first-draft Anthropocene), presented his "Capitalocene" as an alternative, the single most obvious difference between the two was that the Capitalocene was supposed to begin in the "long" sixteenth century, whereas Crutzen's Anthropocene

was originally dated to the late eighteenth century. The idea of a transition into the Anthropocene that has been under way since the second half of the fifteenth century would bring the theme of the Anthropocene disarmingly close to Moore's own way of seeing.[17] In Moore's analysis, the crisis of the medieval world produced a coalescence of interests between Europe's monarchical state bureaucracies, postfeudal seigneurs, and mercantile city-states in favor of capitalist geographical expansion, and this in turn initiated an enterprise that required the rapid commodification and depletion of the ecological wealth of the Atlantic islands, West Africa, the Caribbean, Brazil, the Indian Ocean spice islands, and so on. That coalescence of interests was the spark; the Holocene-Anthropocene transition was the explosion. Geologists speak of the "end-Permian event" or the "end-Triassic event" at the close of older geological intervals. A geological perspective invites us to conceive of the postmedieval world system in its entirety as what we could similarly call the *end-Holocene event*—an event that is still playing itself out.

The Anthropocene Working Group has given far more attention to possible starting points for the Anthropocene on the other side of the seventeenth-century world crisis, ever since Crutzen's initial proposal that the epoch might be best dated to 1784 and one of James Watt's patents on steam engine design. The much-discussed idea of linking the base of the Anthropocene to the British Industrial Revolution certainly has its merits. However, a somewhat narrow understanding of industrialization has so far constrained most of the debate about placing a GSSA or GSSP in the long nineteenth century. According to this model, the Industrial Revolution was initiated by the invention and deployment of new technologies; it began in Britain and then rippled outward, starting to affect other nations only once their own industrialization began. That diffusionist hypothesis has in turn given rise to concerns that a late-eighteenth- or early-nineteenth-century golden spike would be hopelessly Eurocentric. But understanding the Industrial Revolution in a different way, as an event in world economic history, can dispel those fears of Eurocentrism. Britain's textile and iron-smelting sectors were indeed pioneers of industrial production, but their rapid evolution was only one element of the general restructuring of a trade system across all five major continents, a system that metabolized South American silver, Caribbean sugar, North American cotton, African slaves, and the consumer goods that flowed into and out of the advanced population centers of northwest Europe, China, and India.

At the heart of the economic and demographic factors that drove Britain's pioneer industrialization were the high price of labor there relative to energy, and its colonial strong-arm tactics. England had retained a relatively high-wage economy since the Black Death—when fewer peasants meant stronger bargaining powers—partly because its non-rice agriculture made feeding workers costlier than it was for its Asian peers. Its readily accessible northeastern coalfields made energy cheap. The imbalance arising from that coincidence made it uniquely worthwhile there to invest in technology that substituted machine power for labor time. It was especially worth doing so in the cotton sector, because British manufacturers could extract cheap raw cotton from slave-worked plantations in the Caribbean and the American South and export finished textiles to the New World at a handsome profit. There still resulted little in the way of breakthrough conceptual innovations, by James Watt or anyone else (in fact, the heroic age of the European physical sciences was the seventeenth century, not the eighteenth). Instead, however, a stream of technological refinements and efficiency gains succeeded one another until British manufactured goods had become cheaper than their rivals' worldwide. Thus Britain's industrialization had what climatologists call a teleconnection to deindustrialization in India.

For most of the eighteenth century, China and India retained their longstanding competitive advantages over the polities and markets of Europe. But in the first half of the nineteenth century, after the destruction of the Indian princely states by the East India Company (exploiting the

eighteenth-century fission of the Mughal empire), the subcontinent was transformed. Previously an advanced competitor economy—India, not Britain, had been the world's leading cotton manufacturer—it was reduced to serving as another source of raw materials, and another destination, unprotected by trade tariffs, for British manufactured goods. China, too, was broken open in the middle of the century, in a cycle of economic decay, peasant rebellion, and Western incursion, preceded by environmental disasters and spearheaded by the armed drug dealers of the British empire. By 1820, Britain's empire incorporated more than a quarter of the world's population. That colonial hinterland was fundamental to the conditions—a strong central state and ample capital, as well as high wages and vast open markets—that impelled it toward mechanized and coal-fueled production.

In short, the geological traces of industrialization in early nineteenth-century Europe (the Low Countries, as well as Britain) are shaped fundamentally by the manufacture of goods for export to other continents, goods that displaced non-European manufacturing in the aftermath of military assaults and colonization. A golden spike in the early nineteenth century, even one based on ecological changes that were local to western Europe, could have real legitimacy. It would reflect a worldwide economic, demographic, and political restructuring, rather than an exclusively European phenomenon.

Whether a robust stratigraphic marker can be found anywhere in the long nineteenth century is another matter, however, especially given the absence of any starting point for the period that is as comparatively clear-cut as the *marinheiros'* ocean navigations. If coal-based industrialization is seen as a defining characteristic of the age, then the contamination of lacustrine, peat, or coastal sediments by the fine particles released during fossil fuel combustion is an apt candidate for the golden spike (although localized pollution from coal burning can be identified much earlier, and the scale of the contamination would accelerate more sharply at a later date). Another candidate is the coal residue, or clinker, tossed overboard from nineteenth-century steamships, which created distinctive geological traces in the sediment-accumulating, and previously relatively untouched, seabed. There were some substantial population rises—the population of Britain and Ireland doubled in the sixty years to 1841—with commensurate expansions in agricultural production, livestock holdings, and urban areas, and a further increase in the spread of invasive species. To contemporaries, deforestation was the most visible and alarming sign of environmental change in Eurasia, with the loss of trees already a significant concern in China (especially the south) and Japan as well as large parts of Europe—Britain, the Low Countries, the German lands, and the Mediterranean—by 1800. All those changes had their effects on fossil assemblages, pollen records, and the sedimentation of rivers, lakes, and deltas, some of which might provide sources for Anthropocene stratotypes.

The growth and increasing architectural complexity of cities make for an especially interesting candidacy. One of the most fundamental divisions in the geological timescale, that between the Proterozoic and Phanerozoic eons, is marked by the burrows of a little-understood wormlike creature, which stratigraphers treat as a metonym for the emergence of newly complex animal behavior. The base of the Anthropocene could be marked in the same way, by the increasing complexity of humans' burrowing in their urban habitats. Thus, a group of researchers led by Mark Williams has suggested a possible golden spike located in one of the original stations of London's underground Metropolitan Railway, dating the birth of the Anthropocene to 1863.[18]

The nineteenth century differs from the early modern period in the spread of lasting anthropogenic traces from the biosphere into the atmosphere. That opens up the possibility of a golden spike defined by reference to ice sheets, speleothems (especially stalagmites), or the chemistry of the shells of marine microorganisms. We could, after all, endorse Crutzen's initial idea of defining the Anthropocene by the increasing atmospheric concentration of CO_2, or more directly by shifts in carbon isotope ratios in the

bodies of marine organisms. Changes in atmospheric carbon have the advantage of being unarguably global, but the downside is that, on a year-to-year scale, CO_2 concentrations change smoothly rather than discontinuously, so the golden spike would have to reflect an essentially symbolic milestone, such as atmospheric CO_2 levels surpassing three hundred parts per million soon after 1900.

A final option provides a useful reminder that there is no reason why the golden spike for the Anthropocene has to have a human origin at all. In April 1815, one of the largest volcanic eruptions in recent millennia issued from Mount Tambora in Indonesia, reflected in a deep red tone in the sunset paintings of J. M. W. Turner and afflicting most of the world's population with three years of abysmal weather and catastrophic crop failures. The eruption left sulfate peaks in the ice at both poles and in tropical glaciers, as well as a layer of tephra particles stretching for thousands of kilometers (although not worldwide).[19] Having taken place during the Congress of Vienna and Napoleon's Hundred Days, the eruption coincides precisely with the beginning of the stable reactionary order that underpinned stage 1 of Crutzen and McNeill's two-stage Anthropocene. If it is chosen as the Anthropocene's golden spike it would usefully press home the point that the new epoch cannot possibly be characterized by the abolition of nonhuman influences on the geologic record. But perhaps, ultimately, no single nineteenth-century candidate really stands out clearly from the rest. Potential dates for the base of the Anthropocene are scattered rather loosely through the long nineteenth century; many of the potential markers are in some sense localized rather than global; and in most cases their long-term geological visibility must be in some doubt.

THE CANDIDATES (II): CONCRETE, LEAD, PLUTONIUM

With potential golden spikes from the fifteenth century to the early twentieth looking plausible but not compelling, stratigraphers have increasingly focused on the prospect of a still more recent date for the birth of the Anthropocene. Potential starting points within the last generation have scarcely been discussed, because the sedimentary layers would in that case be desperately thin. But the mid-twentieth century is another matter. The idea of dating the Anthropocene to somewhere around 1950 is currently in the ascendancy. Doing so would acknowledge just how recent the arrival of the modern world-ecological order really is, and how dramatically the human-influenced changes to the planetary system have multiplied in the last seven decades. The human population in 1950 was about 2.5 billion. In 2011, it reached 7 billion. Total economic activity increased elevenfold over the same period, as global average GDP growth per capita accelerated after the body blows of the world wars and the Great Depression, from less than 1 percent annually in 1913–50 to nearly 3 percent in 1950–73. The techniques and intensities of the environmental exploitation that underlay that growth developed beyond all recognition. (At the outset of World War II, for instance, even British farms used ten times as many horses as they did tractors.)[20] Perhaps it was only now that an epoch-level shift in the world's workings really gathered pace.

One significant component of the boom was that other advanced nations caught up to the levels of affluence, and of investment in capital-intensive technology, that the United States had already achieved by 1945. Another was the effect, in the same countries, of progressive economic planning and of a working social compact between capital and labor. But very much as with the Industrial Revolution, it is possible to take too narrow a view of the *trente glorieuses* of the mid-twentieth century. It might be imagined that the new economic order began in the most developed countries and affected the rest of the world only once it rippled out from them to the regions that lagged behind. In reality, since worldwide trade integration was by now a long-established fact, a more global and systemic perspective on the economic and ecological structure of the Great Acceleration is required.

The Cold War partition of the world into U.S. and Soviet spheres provided a new way to manage the terms on which the global South participated in the world economy. That economic periphery was essential in enabling the core manufacturing economies of the North to function as they did, with their ever-higher wage levels and ecological throughput. In the underdeveloped nations, regulatory obstacles to the expropriation of communal assets were weak. That made them the indispensable suppliers of cheap industrial raw materials and biological assets (including oil above all), of low-skilled labor reserves, and of dumping grounds for pollution and surplus production. That is why—as John McNeill's environmental history of the twentieth century shows in compelling detail—the sites of ultrarapid ecological alteration and degradation in the postwar era were scattered all around the world, rather than being confined to the neighborhood of the most profitable industrial zones.[21] The wretched of the earth were not excluded from the Great Acceleration but an integral part of it, albeit on terms set by the economic elite. Very much as with the Industrial Revolution, the implication is that potential stratigraphic markers in this period that are immediately derived from the rich world's industry, technology, urbanization, or (it's worth underlining) military and geopolitical strategy need not be considered Eurocentric or NATO-centric. Rather, they reflect structural changes that affected states and populations all around the world.

The biggest difficulty with placing the Anthropocene's golden spike in the period after World War II is the brevity of the timescale. The base of the Anthropocene would be associated with unconsolidated surface sediments, teetering on the upper edge of the geologic record and still highly vulnerable to disturbance. In the deep oceans, where disturbances are fewer, only tissue-thin layers of Anthropocene-epoch material would as yet have accumulated. Boundaries set some centuries or even millennia earlier would still face similar problems, however, and the counterbalancing advantages of the postwar period are the increased size and long-term visibility of alterations in the earth system, and their tighter synchronization around the world.

The many plausible candidates for a golden spike in these decades all have their own benefits and downsides. The exponential postwar growth of megacities provides a potential marker, as does the construction of a world-encircling paved road network (now greater in extent than the iridium-rich clay layer, formed by the dinosaur-killing Chicxulub impact, that divides the Cretaceous period from the Paleogene). The golden spike could pick out alterations in sediment dynamics caused by unprecedented dam-building, earthworks, irrigation, and bottom-trawling. It could reflect the intensification of mining and drilling activities, or the larger carbon isotope excursion resulting from accelerated fossil fuel burning. A group of candidates referring to offshore drilling, deep-sea litter, and disturbance of the ocean bed has the advantage that transformations beyond the continental shelf began from something more like a standing start in the mid-twentieth century, but the disadvantage that because sediment accumulation rates in the deep ocean are usually very slow, it is hard for finely datable layers to form. Potential golden spikes based on mineral diversification likewise cluster in the postwar period, given the huge multiplication then in the production of cement, plastics, iron, steel, bricks, glass, ceramics, and so on: 98 percent of aluminum production has taken place since 1950, for instance.

Many of the strongest contenders have a biological basis, among them the devastation of coral reefs. Species relocations had already changed the world, as we have seen, but the paleontologist Anthony Barnosky argues that "it is likely that 1950 would closely approximate the time at which mixes of native and non-native species became widespread in the sedimentary record." Again, small marine animals and pollen-heavy plants—barnacles, mussels, clams, grasses—are the introduced species most significant for stratigraphic purposes. Barnosky also proposes a possible Anthropocene lineage zone: "palaeontologists of the future" should be able to recognize the

first appearance of supersweet strains of corn, which were bred for the first time at midcentury.[22] Microfossils, the fundamental currency of most stratigraphic analysis, are better suited to abundance-zone approaches, which pay attention to changes in the population sizes of species in a given location rather than to their first occurrences. The midcentury saw a general proliferation of microfauna and microflora "tolerant of eutrophication, hypoxia, metal pollution, water acidification [and] salinity change."[23] Foraminifera, beloved by paleontologists for their well-fossilized shells; ostracods, tiny crustaceans; diatoms, photosynthetic algae; and the cysts produced by whip-propelled dinoflagellates all sensitively record the pollution, salinization, eutrophication, and warming of bodies of water. The dominant influences on these microorganisms are usually local to their catchment areas. But selecting one such local incident as representative of the global transition between epochs is less problematic when near-simultaneous pollution episodes are taking place around the world.

Even snowbound lakes in the Rockies and the high north, far from the sources of pollution, show well-synchronized alterations after 1950. Rainfall and snowfall have carried the effects of the recent doubling of the world's reactive nitrogen supply all the way to those remote lakes. Specifically, that contamination can be identified via a decrease in the proportion of a particular nitrogen isotope, nitrogen-15, within the total quantity of nitrogen in lake-bed sediment samples. That decrease is a strong candidate for the golden spike, again dating to the postwar era: the use of nitrogen fertilizer increased ninefold from 1960 to 2000.[24] Other globally dispersed chemicals provide comparable reference points. The concentration of lead in Greenland ice peaked in the 1960s at two hundred times background levels (it has since declined with the switch to unleaded gasoline). Antimony concentrations tell a similar story, except that they are continuing to increase. The burning of coal and fuel oil at temperatures above a thousand degrees Celsius creates a unique particulate form of black carbon, and such particles have scattered into lake beds, peatlands, and ice around the world. Human industry appears to be their only source, so they represent directly a principal driver of global change, and their rate of accumulation increased sharply in the middle of the twentieth century. They have excellent preservation potential.[25]

Finally, and most persuasively of all, there is the possibility of a definition based on nuclear explosions. Two papers by members of the Anthropocene Working Group have set out what look, for now, like the leading candidates for definitions by a GSSA and a GSSP. If a boundary is chosen based on a calendrical age, or GSSA, it could be set with unimprovable specificity on July 16, 1945, "at 05:29:21 Mountain War Time (± 2 s)."[26] This is the moment of the Manhattan Project's first nuclear weapon test, Trinity: white light in the predawn New Mexico desert. The bombing of Hiroshima followed three weeks later. The Trinity test is as clear and discrete a marker as any that could be imagined. It was an objectively new physical phenomenon: the first runaway nuclear reaction on the surface of the earth. Its significance was plainly global rather than localized, even if American victory in the Pacific was already inevitable by the summer of 1945 and the bomb's main strategic effect lay in the way that it shaped the Cold War world. A GSSA set in mid-July 1945 might not help dispel concerns that proponents of the Anthropocene are too preoccupied with high technology and with events in the rich countries of the West. But its military quality should surely dispatch the objection that the concept of the Anthropocene involves thinking of all humankind as an undivided mass. The best thing of all about this choice of a base would be its lucid simplicity.

The Trinity test cooked the white sands of the desert below it into a novel kind of rock, Trinitite. Its geological impact did not extend beyond the test site itself, however, so it does not supply a potential golden spike. There is much to be said for the straightforwardness of a definition by a fixed chronological age, but basing the Anthropocene on a GSSA would put the new

epoch problematically at odds with the current preference for establishing the geological intervals of the last half a billion years (and, ideally, older ones as well) on the solid basis of tangible physical markers in the constitution of the earth.[27]

An alternative is to formulate a GSSP, or golden spike, by looking to the radionuclide fallout from nuclear tests. The fission bombs of the 1940s, horrifying as they seemed at the time, were tiny compared to the fusion or thermonuclear weapons that were tested from 1952 onward.[28] For six years, test shots by the United States, Soviet Union, and United Kingdom in the tropical Pacific and Kazakhstan spread increasing volumes of radioactive fallout all around the world. A moratorium on nuclear testing from 1958 to 1961 brought a dip in soil radioactivity levels, but that truce progressively unraveled until, in October 1961, the Soviet Union set off the largest of all human-made explosions, the Tsar Bomba, at its Arctic island test site. There followed two years of intensive open-air testing, conducted in a spirit of geostrategic posturing during the era of the Cuban missile crisis rather than simply for research purposes, and a corresponding surge in plutonium fallout. In 1963 the Limited Test Ban Treaty required that explosions take place underground, as public fears about fallout—and the superpowers' desire to restrict access to the nuclear club—grew stronger. The fallout peak came in 1964, just after the signing of the treaty. A steep decline followed, down to indiscernible concentrations in the early 1980s.

Open-air thermonuclear tests dispersed radioactive isotopes of cesium, strontium, americium, plutonium, and carbon as high as the stratosphere before they settled down into soils and sediments worldwide. Of these elements, plutonium is the most significant for stratigraphic purposes (indeed, it is already sometimes used by environmental scientists in the dating of sedimentary records). The half-life of plutonium-239 is 24,110 years; it binds tightly to soil particles, and its preanthropogenic concentration in the earth's crust was extremely low. With the use of accelerator mass spectrometry techniques, the twentieth-century spike in plutonium levels will remain detectable in sediment samples across much of the earth for a very long time: not the next hundred million years, but at least the next hundred thousand.

The quality of the plutonium record will vary between sedimentary archives. Worms, plowing, and rainfall will blur the fallout pattern in ordinary soils. A less compromised trace will survive in marine and coastal sediments, stalagmites, and coral cores. There will be a still crisper one in ice sheets and glaciers, and in lake beds that are largely free from sediment runoff: notably the beds of those dazzling lakes that form in the craters of extinct volcanoes, which are filled from the air rather than from watersheds. The crater lakes with the best-preserved records will be those with the least oxygen and hence the fewest living things in their lower reaches, minimizing disturbance of the smooth layers of sediment. Those located in the mid-latitudes of the Northern Hemisphere, where nuclear fallout was heaviest, will have an extra advantage. The golden spike could be placed there: in a sediment core drilled from beneath such a lake, and preserved in some university or museum, a sliver of compressed mud would serve as the birth certificate of the Anthropocene.

If plutonium-239 radionuclides are chosen as the marker of the base of the Anthropocene, it might seem logical to date the new epoch to the year of maximum fallout, 1964, making it coincide with the beginning of the Swinging Sixties. Standard practice, however, is to place stratigraphic boundaries at the start rather than at the peak of the isotope anomaly that defines them, since the former is usually more easily identified (even though in this case one might stretch a point, since the 1964 peak is very pronounced).[29] That would place the birth of the Anthropocene in 1952, at the beginning of the rise in worldwide plutonium concentrations. Instead of originating in the year of Brezhnev and Beatlemania, the Anthropocene would have been born amid postwar high modernism and decolonization: in

the year of John Cage's *4'33"*, Le Corbusier's Unité d'Habitation, and Ralph Ellison's *Invisible Man;* of Nasser's coup in Egypt, civil disobedience by the ANC in South Africa, and the Mau Mau rising in Kenya.

To underscore a basic point: this does not mean that plutonium-239 fallout from the Ivy Mike test shot in November 1952 pushed the world from one geological epoch into another. On its own, the fallout's ecological significance is not remotely great enough for that. But the radionuclides that it dispersed could be selected as the emblem of a suite of co-occurring upheavals in the biosphere, atmosphere, hydrosphere, and pedosphere: changes that, taken as a whole, constitute the end of the Holocene and the start of the Anthropocene. A still more basic point: it *should* go without saying that fixing the base of the Anthropocene in 1964 would not imply that *With the Beatles* was released into a world that had seen no significant human impacts on the earth system, and would not imply that by the time *Rubber Soul* came out the planet was an exclusively human construct. Instead, 1952 or 1964 would be adopted as the indicator of a passage between geological epochs (not at all a passage between nonhuman and human worlds) that has been hastening toward completion ever since the fifteenth century, and that still has further to run. The plutonium-239 spike would be the synecdoche for an ongoing end-Holocene crisis that may be identified with the emergence of the capitalist world order.

We need to take a step beyond Dipesh Chakrabarty's opposition between the story of capital and the story of geology (or "globalization and global warming") in order to see capitalist modernity in this new light, as the very process of transition between the Holocene and the Anthropocene. The plutonium fallout record is the best available reference point—albeit no more than that—for this transitional phase. Chronologically, the fallout spike might in the end prove to lie roughly midway between the voyage of Columbus's *Santa María* and the final disappearance of the West Antarctic ice sheet. Wherever the boundary layer is finally placed, it should always be remembered that other ways of dating the epoch had been possible. But let's say, for argument's sake, that the Anthropocene epoch began in 1952.

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It's time to take stock. The pair of chapters that conclude this book are quite different from the preceding three, so I will finish this first part of the book by boiling down the version of the Anthropocene that I have developed here to five key maxims or principles. I have said that the word *Anthropocene* has a variety of possible and legitimate meanings; for this reason, it is always worth being clear about the way in which it is being used. Here is a reminder of the meaning that it has in this book.

Firstly, the Anthropocene, in this context, is a neocatastrophist term. It belongs within the late twentieth century's paradigm shift in understandings of how the earth system works. Planetary systems that were once regarded as stately and slow-moving now appear to be characterized by unstable feedback loops; biological and climatic processes are deeply interlinked, and both are susceptible to abrupt changes of state. That explains how an epoch-level transition can take place in just a few centuries, and how a single species can be preeminent among the drivers of change. It follows that the birth of the Anthropocene is not a fall from Eden or an unnatural acceleration of the old, slow, boring regimes of geohistory. Instead, it means stumbling into another of the fissures that crisscross deep time like crazy paving.

Secondly, it is not the case that the special properties of human beings are the ultimate cause or origin of the Anthropocene. The Anthropocene is not "the interval in which humans play a significant role in shaping the earth system" (what can "significant" possibly mean there?). Instead, the epoch can be defined only through its differences from other epochs: the Anthropocene begins when the characteristic conditions of the Holocene no longer exist. The new epoch emerges through a particular configuration of

ecological agencies that has, among other things, temporarily multiplied the effectiveness of *some* human actors. The thought experiment about the alien geologists reminds us that those humans are just one among innumerable forces that shape the fossil record: it cautions against a dualism that would split humans off from "nature." One consequence is that even the death of the human species would not necessarily mean that the world was anywhere near the end of the Anthropocene, or that the "post-Anthropocene" had begun.

Thirdly, the strongest force at work in the birth of the Anthropocene is best thought of not as humankind per se but as human *societies*. An extravagantly disproportionate degree of world-making power attaches to only a minority of the world's people. No adequate account of the Anthropocene can begin by lumping all human beings together, as if they are all equally the cause of global change and all identically vulnerable to its effects—not even if one subsequently bolts on an acknowledgment of socially differentiated responsibilities. The reason is that the idea of the Anthropocene is all about a new configuration of biogeological struggles, conflicts, and incursions, and that (in line with the second principle) there is no justification for excluding human-versus-human struggles from the list of those conflicts that are disrupted and reworked. The stratigraphic version of the Anthropocene offers no excuse for neglecting the role of class relations or transnational inequality in environmental change, because it is precisely focused on the changing power relations throughout ecological assemblages of all kinds.

Fourthly, the politically salient issue is the time of transition into the Anthropocene, not the new epoch as such, because it is almost idle to worry about what the world will look like in a hundred thousand years. The idea of the Anthropocene does not give any succor to those who would adopt a pose of godlike detachment from the mere transient life of the present day. Instead, stratigraphic science provides a model of earnest engagement with the particular characteristics of singular moments in the history of the earth. The stratigraphic Anthropocene places the present crisis in its deep-time context only so as to let its distinctive features be seen more clearly and to help in assessing its significance. It has the potential to foster a deeper sense of entanglement in immediate historical circumstances, rather than an indifferent acceptance of the fact that nothing lasts forever. Who could be more fully immersed in geohistory than the witnesses to the birth of a new epoch?

Fifthly, the reason why the idea of the Anthropocene can make a telling contribution to contemporary politics is that geological time has already become a political factor. Atmospheric CO_2 concentrations have reached levels not seen for three million years; Arctic temperatures seem to be at their highest for more than a hundred thousand years; and the sixth great extinction in the history of complex life may be getting under way. It is news like this that makes the Anthropocene something more than an exercise in stratigraphic whimsy or the latest piece of fashionable academic jargon. Even granted that the word may be used in multiple senses, it is nonetheless a waste to use *the Anthropocene* merely as a modish way of referring to environmental degradation in some ill-defined slice of the recent past. The term is urgently needed for a different purpose: as a way to help us get a grasp on the fact that green politics now has to confront the role that human societies play in deep time itself.

These five maxims sum up my argument so far. Elaborating the idea of the Anthropocene epoch is a way of opening a window onto deep time, to help in taking the measure of the planetary crisis. What remains is to actually take a look through that opened window. The remaining two chapters of this book describe what the history of the earth looks like from the vantage point of the Anthropocene. This sketch of earth history will introduce some new complications. It will uncover a deep ambivalence in the very idea of a geological epoch; it will mean acknowledging that there is nothing new,

after all, about humans being entangled in deep time; and it will involve not only intervals far longer than epochs but also some other geological time units that are surprisingly human-size. It should also, however, illuminate everything that has gone before. We have seen Don McKay describe how earlier epochs seem to run backward from the new arrival "like rungs on a ladder," leading the mind's eye swiftly away to a time before human existence. We need to know a little about those rungs on the ladder before we can really understand the Anthropocene of the stratigraphers.