THE ANTHROPOCENE

A MULTIDISCIPLINARY APPROACH

JULIA ADENEY THOMAS
MARK WILLIAMS
JAN ZALASIEWICZ

Contents

Dedication

For Paul Crutzen, John McNeill, and Will Steffen, who first discerned the Anthropocene and the Great Acceleration, and opened the way for others.

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A Multidisciplinary Approach

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Preface

The “Anthropocene” is not the same as “climate change,” “global warming,” “environmental problems,” “pollution,” or a host of other terms that refer to changes on our planet. Instead, at its core, the Anthropocene is a geological concept. It integrates all these and many other phenomena and places them within the context of deep planetary time to indicate Earth’s recent, abrupt transformation. Suggested informally in 2000 by the Nobel Laureate and atmospheric chemist Paul Crutzen (1933–), and independently by biologist Eugene Stoermer (1934–2012), this term designates a proposed new geological epoch, set in train by human activities. Indeed, there is overwhelming evidence, laid out in this book, that in the mid twentieth century, our planet entered a distinct new chapter in its ~4.54-billion-year history. The complex, integrated Earth System has moved away from the relative stability of the Holocene Epoch, which began ~11,700 years ago, to another less stable, and still evolving, phase. This new phase has, in many ways, no precedent in Earth’s long history. It is also not as conducive to human wellbeing as the Holocene Epoch. In fact, evidence is mounting that life as we have experienced it for the last ten millennia is going to be changing very rapidly, and largely for the worse: the seas are rising; the air carries more carbon dioxide and particulates; global biodiversity is collapsing; the climate will, almost certainly, soon be hotter than it has ever been in the history of *Homo sapiens*. The pressure on the systems that nurture, shelter, and fuel us will become ever more intense in the years to come.

Currently, the geological community is in the process of accumulating evidence toward a formal proposal on the

Anthropocene. In 2016, an overwhelming majority of members of the Anthropocene Working Group (AWG) voted in favor of pursuing this proposal. In 2019, a binding vote by 88 percent of the AWG confirmed the earlier consensus that Earth has entered a new phase marked by a distinctive, near-global stratum. The causes of the recent transformation of our planet are the sudden rise in human population, globalization, and industrialization over the last 70 or 80 years. Should the Anthropocene be formally adopted, it would join the Eocene, the Pleistocene, and other such units on the great canvas of the Geological Time Scale (GTS).

The Geological Time Scale is the way geologists visualize the Earth's deep past. This tool for understanding changes over time shows the hierarchical arrangement of units, from relatively short ages to longer epochs, then to yet longer periods, which are encompassed within immensely long eras and finally organized into eons that may last more than a billion years. The Anthropocene, as currently proposed, is a potential epoch, which means it marks a bigger alteration in Earth processes than an age, but represents less change than a period. If confirmed by the International Commission on Stratigraphy, it would be the top line of figure 1, just above "Holocene." If you wanted to address a letter not to a place on Earth, but to a point in geological time, our temporal abode today is the early part of the newly proposed Anthropocene Epoch, in the Quaternary Period within the Cenozoic Era of the Phanerozoic Eon. That temporal address is cumbersome, but it would give clear directions for the planetary post.

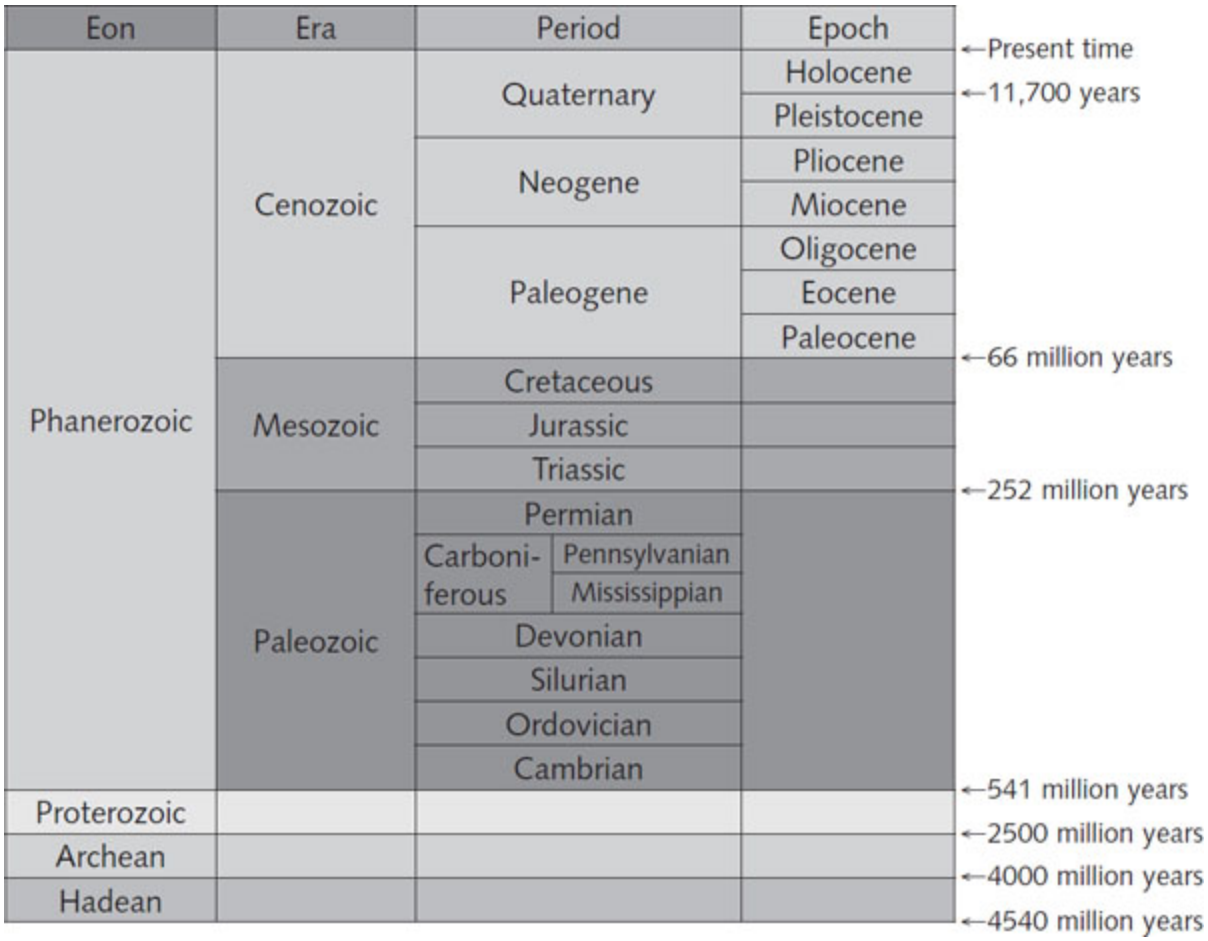

Figure 1 Simplified Geological Time Scale. The figure shows the beginning of the Holocene Epoch commencing 11,700 years ago. Epochs are only shown for the Cenozoic Era.

Although the Anthropocene is a very new part of Earth's history, to make sense of it we need to place it in the context of our planet's past, beginning 4.54 billion years ago, then tracing the emergence of different life forms over many millions of years. The main protagonist of this story, *Homo sapiens*, evolved a mere ~300,000 years ago, slowly emerged as a dominant force, and ultimately became a planet-changing species by the mid twentieth century. The extraordinary transformations of the Earth System that we are seeing today occurred, effectively, within a single human lifetime, driven by cultural, political, and

socioeconomic factors and fueled by technological changes that continue to press the planet beyond Holocene norms at an ever-accelerating rate. Understanding this recent human impact also requires a deep human history that, while shallower than planetary deep history, witnessed the rise of powerful forces. The ideas, inventions, and political and economic systems accelerating Earth's transformation, and those that resisted this destructive trajectory, are also stories of the Anthropocene. In other words, to come to grips with the Anthropocene, one needs to span the enormity of geological time and its processes, and also delve into the complexities and sheer quirkiness of human behavior and institutions on more intimate timescales – hence, our plea for a multidisciplinary understanding.

Our book begins by explaining why the clunky term "multidisciplinary" is more precise than "interdisciplinary" for what we do here (Jensenius 2012). Interdisciplinarity synthesizes and harmonizes approaches. The result is that everyone, ultimately, asks the same questions and comes up with the same coordinated and coherent way of knowing. For instance, myrmecologist E. O. Wilson (1998) has argued for an interdisciplinary unity of knowledge that he calls "consilience." On the other hand, "multidisciplinarity" means that people from different disciplines work together to address the same issue, which in our case is the geological reality of the Anthropocene. Participants in a multidisciplinary conversation will always have to contend with the friction among their perspectives, because they bring to the table distinct methods, questions, and archives, with differing scales of time and space. No single story can ever capture the complex whole. To us, a multidisciplinary approach makes sense because the Anthropocene itself is multifaceted, multiscalar, and the product of a recent coalescence of human activities – some having very deep origins, such as the mastery of fire by our

ancestral species, and others which are very recent, such as the rise of mass tourism. To assume that the Earth System and human systems operate separately is to misunderstand what is happening. Yet to suggest that no difference exists between the scales, methods, and questions important to geologists, social scientists, and humanists is to oversimplify the situation and suggest that a single understanding – and even a solution to this problem – is within reach.

After explaining our approach, our narrative opens with the deep history of the Earth, the fundamental context of the Anthropocene. In chapters 2 and 3, we discuss the Anthropocene in its geological context and as a time unit, explaining how the concept arose and the weight of the evidence behind it. Chapters 4 and 5 explore two crucial facets of the Earth System: climate and the biosphere, respectively. Both climate and the biosphere impact – and are impacted by – human activities. Indeed, according to Earth System science, Earth is one, integrated system where the atmosphere, hydrosphere, cryosphere, lithosphere, pedosphere, and biosphere (including, of course, human beings) mutually impact one another in complex ways. From this holistic perspective, the tomatoes you ate on Saturday can't be separated from the formation and movement of soil, rocks, ice, water, and air over billions of years. Earth System scientist Tim Lenton dates the contemporary idea of an integrated Earth System to the 1960s and early 1970s, with the Gaia hypothesis of scientist James Lovelock and microbiologist Lynn Margulis, though it had many forerunners (2016, p. 5). This application of systems science to Earth acquired the name "Earth Systems science" in the 1980s when NASA became interested in "human-driven ozone depletion and climate change" (Steffen et al. 2020, p. 56). In 1986, NASA developed the Bretherton Diagram showing that human

activities play an integral role in the physical and biological processes of our planet (National Research Council 1986). This schematic diagram became “an important driving force for the conceptualization of subsequent Earth system research programs” (Mooney et al. 2013, p. 3666). Beginning in the 1990s, powerful computers allowed scientists to begin to model Earth’s complexity with greater sophistication, though there is still much work to be done. Gradually, as the evidence piled up, it began to dawn on some Earth System scientists that Earth was no longer functioning within Holocene norms. Tellingly, in 2000, when Crutzen improvised the term “Anthropocene,” it was at a meeting in Mexico City of Earth System scientists, rather than at a gathering of geologists.

The geological community became involved a few years later, initial analysis showing that the idea was feasible. As interest in the idea grew, the AWG was formed and went to work in 2009. Along with an array of geological specialists, the AWG also included some Earth System scientists and, because of the unprecedented importance of human factors, archeologists, historians, and a legal scholar. After much unpaid evidence-gathering and intense debate, the consensus grew that human activity had indeed abruptly altered the trajectory of the Earth System and etched a durable mark on the planet’s crust. According to a 2019 press release by the AWG, “Many of these changes will persist for millennia or longer, and are altering the trajectory of the Earth System, some with permanent effect. They are being reflected in a distinctive body of geological strata now accumulating, with potential to be preserved into the far future.” The Anthropocene’s beginning, they announced, “would be optimally placed in the mid-20th century, coinciding with the array of geological proxy signals preserved within recently accumulated strata and resulting from the ‘Great

Acceleration' of population growth, industrialization and globalization" ("Working Group" 2019; see also Zalasiewicz et al. 2019b).

As all this shows, although the Anthropocene is fundamentally a geological concept, its context, origins, and impacts cannot be understood solely through the discipline of geology, or even through the sciences alone. The box labeled "Human Activities" in the Bretherton Diagram needs to be opened and its contents analyzed. Chapter 6 takes on this challenge, exploring the *anthropos* of the Anthropocene from the perspectives of paleoanthropology, archeology, anthropology, and history, followed by a discussion in chapter 7 of the economics and politics of planetary limits. We close by showing that having many ways of knowing helps us address the unprecedented existential crisis in which humanity now finds itself. In short, the central argument of our multidisciplinary approach is that reality, even the encompassing reality of the Anthropocene, dictates no single comprehensive planetary story; instead, there are many ways of looking back and, we hope, more than one way of moving forward.

Here in this book, even stretching ourselves thin, we do not cover all the modes of understanding that might be brought to bear on the Anthropocene. For instance, we say little about the visual arts or music, about religion or ethics, about psychology or poetry – or, indeed, about pathways in sedimentology, engineering, and geophysics – that might profitably be followed. These exclusions should not be taken as dismissals but as invitations. There is, and always will be, much more to say. The web of scientific and humanistic knowledge brought together here reveals that the Anthropocene gestated over many centuries, and even millennia, via a complex array of factors with no single smoking gun. When the twentieth-century forces of human population growth, globalization, and economic

development, with its increasing disparities of wealth and power, combined to push the Earth System beyond Holocene norms, they struck a match to a long-primed powder keg. Our understanding of the Anthropocene is not reductive, but aims to be as rich, complex, and tension-filled as the human forces and physical forcings that produced it.

For us, creating this multidisciplinary portrait of the Anthropocene has been a fascinating and rewarding adventure. Putting together two British geologists with one American intellectual historian of Japan was an experiment that might have gone very wrong. It could have resulted, like oil and water, in a stand-off of mutual incomprehension. Alternatively, there could (with different personalities) have been pyrotechnic explosions. But this didn't happen either. We three share a deeply congruent understanding of the central challenge facing our world today, despite our differences in training and interests. What we hold in common is a desire to understand Earth and our human circumstances, a respect for evidence, and a keen sense of the urgency and importance of communicating what the Anthropocene means. How Polity Press knew all this when it orchestrated our collaboration is a happy mystery.

As you'll see in the chapters that follow, speaking in multidisciplinary tongues is not – and, we argue, should not be – a soothing, oceanic experience of seamless translation. Different disciplines use words differently. Take the word "Earth" for instance. For scientists, Earth is a planet in our solar system and should always be capitalized; for humanists and social scientists, the "earth" may refer to the world inhabited by human beings, our societies, or the spaces we move through, the landscape with its creatures. When Hamlet comments to his friend, "There are more things in heaven and earth, Horatio, than are dreamt of in

your philosophy," he is not making an observation about the upper atmosphere of the third planet from the Sun. To take another example, both historians and geologists are concerned with dividing time into units of study and worrying about how one moment relates to the next. Yet the words "revolution," "age," and "epoch" take on a completely different valence in history than they do in geology. Between the Ediacaran Period and the subsequent Cambrian Period, there was, according to geologists, a "revolution." But few historians would use this term for an event longer than a century, let alone one that had a duration of 30 million years. Even calling this an "event," in philosopher Hans Gadamer's sense, would be problematic, given the time horizon. Arguments, too, are constructed differently. When we speak of debates within anthropology, history, and other social sciences and humanities, we commonly quote the language of others, because meaning lies in the specificity of their words and the resonance of their phrases with the phrases of other writers. Since value lies at the heart of humanistic enterprises, persuasive arguments often rely on precise and compelling word choice rather than on physical evidence and experimentation. In the sciences, the work of others is acknowledged in the references usually without extensive quotation.

But what is perhaps most striking are the convergences among us. All three of us approach categories and concepts as provisional means of organizing evidence in response to particular questions. For instance, the time intervals on the Geological Time Scale, including the proposed Anthropocene, are tools for thinking about how the Earth changes and why. So too in the social sciences and humanities, concepts such as "origin," "culture," and "economic system" serve as a means for understanding continuity and change in human societies. Evidence is

crucial, whether it comes from rocks, artifacts, or archives, but the categories and concepts that organize the evidence are not inherent in the evidence itself. They are crafted through conversations and debates within and across disciplines, in society more broadly, and across the generations. Sometimes, one of the lucky few will have a flash of insight that helps make sense of the evidence with a new compelling conceptual tool such as the "Anthropocene." We hope our unlikely combination of human forces and different fields provides a fuller picture of our changing world that, largely by accident, we collectively have pushed on a new course.

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The Multidisciplinary Anthropocene

Alexander von Humboldt (1769–1859), the great Prussian polymath, exemplifies the mix of scientific and humanistic knowledge required to comprehend the Anthropocene in all its complexity. An intrepid explorer, venturing across Siberia and traveling through South America, Humboldt gathered information on species occurrence, air temperature, ocean salinity, and much else. His goal was to integrate this information into global patterns. Only by uncovering these larger patterns could phenomena such as climate, ocean circulation, earthquakes, volcanism, and geomagnetism be understood – or so he argued. To achieve this global perspective, he mined travelers' accounts, interviewed indigenous people, and collected sailors' anecdotes, ultimately organizing a worldwide network of correspondents providing data. But his interests were also humanistic and political. He was intrigued by cultural differences, fascinated by the variety of ideas and customs, just as he was by the variety of plants and animals. Humboldt even argued that all the diverse peoples of the world were a single species, with no peoples or cultures a priori superior to or dominant over others. Ahead of his time, Humboldt "was a passionate and vocal opponent of imperialism, colonialism, and slavery" (Jackson 2019, p. 1075). On the one hand, he compiled measurements and descriptions of nature that were valuable for their accuracy and their systemic interrelatedness. On the other hand, he appreciated the rich, often incommensurate, ideas about society, gods, and time that give human lives meaning. In short, he wanted both data and stories. His model of

genuine, wide-ranging, and generous multidisciplinarity serves today as the best approach to the Anthropocene.

The Anthropocene was born multidisciplinary. Early on, many types of scientists, along with social scientists, humanists, art critics, artists, journalists, and activists, sensed that something outlandish was happening, and then, in their various ways, went to work to try to figure out how and why the planet was changing. From all these perspectives, Earth, which had once seemed boundless and bounteous, began to seem girdled, befouled, and, above all, strange. As subsequent chapters show, progenitors of the idea that human activities have abruptly altered the planetary system include people as different from one another as eighteenth-century French naturalist Georges-Louis Leclerc (the comte de Buffon) (1707–88), nineteenth-century art critic John Ruskin (1819–1900), and Russian scientist Vladimir Vernadsky (1863–1945). More recently, science journalist Andrew Revkin, archeologist Matt Edgeworth, historian of science Naomi Oreskes, activist Greta Thunberg, and historian John McNeill, among many others, have drawn attention to Earth's radical transformation. In journalist Bill McKibben's view, we no longer live on Earth but on a different planet he calls "Eaarth" (McKibben 2010). While assessing the physical evidence of new, geologically significant strata and a shift in the Earth System is the job of geologists and, more broadly, Earth System scientists, the questions of how and why human activities propelled the planet on a dangerous trajectory concern everyone. Likewise, while the decision about adding the Anthropocene Epoch to the Geological Time Scale will be made within the geoscientific community, decisions about how to live in these harsher, unfamiliar conditions fall to us all. Our new Eaarth requires new forms of knowledge, drawing from the widest possible range of sources.

Most of us know something about the unprecedented conditions we face on our transformed planet. The US National Aeronautics and Space Administration (NASA) says that the level of carbon dioxide in the atmosphere is higher than at any time in at least the past 800,000 years – well before our species evolved – and it is causing the atmosphere to warm. Our strangely unfamiliar planet now has more than 193,000 human-made "inorganic crystalline compounds," which vastly outnumber Earth's ~5,000 natural minerals; more than 8.3 billion tonnes of plastics; amounts of fixed nitrogen roughly doubled since 60 years ago, with the nitrogen cycle perhaps more sharply impacted than in the last 2.5 billion years; novel kinds of nuclear radiation from bomb tests and power production; a biosphere undergoing rapid transformation; and much else. So, too, human societies are radically transformed. Our systems of communication, transportation, and manufacturing are global as never before. Never has the planet been so crowded with human beings. In 1900, there were around 1.5 billion of us; in the 1960s, around 3 billion; today, there are upwards of 7.8 billion. Our "anthropomass" (as Vaclav Smil calls it), combined with the mass of our domesticated animals comprise an astounding 97 percent of the total zoomass of terrestrial mammals, leaving wild mammals to make up a miserly 3 percent (Smil 2011, p. 617). Never before have most human beings lived in cities, especially in megacities such as Guangzhou, China, home to 25 million people. Needs multiply; desires grow; the capacity of Earth to renew resources shrinks. Extraordinary as each factor is on its own, the concept of the Anthropocene brings all of them – and others – together. It helps us see Earth as a single reverberating system, made up of feedback loops and tipping points that we cannot yet predict, and of thresholds we cross at our peril.

A Predicament, Not a Problem

No single way of knowing has a monopoly on understanding how and why some human activities coalesced to produce the Anthropocene in the mid twentieth century, or on the best responses to this unprecedented and unpredictable situation. Why is this the case? The reason is that the Anthropocene presents not a *problem*, but a *predicament.* The difference is important for our multidisciplinary project. A problem may be solved, sometimes using a single physical or conceptual tool produced by experts in the only appropriate field, but a predicament presents a challenging situation requiring resources of many kinds. We don't solve predicaments; instead, we persevere with more or less grace and decency.

Any hope of persevering with grace and decency on our transformed and increasingly inhospitable planet obliges us to draw on everything that might be useful in humanity's great storehouse of contentious wisdom. "The question," as historian Libby Robin notes, "is how people can take responsibility for and respond to their changed world. And the answer is not simply scientific and technological, but also social, cultural, political and ecological" (2008, p. 291). In the same vein, the historian Sverker Sörlin argues that one of the major problems is that "all relevant knowledge is not sufficiently considered as expertise." The contributions of the humanities and social sciences remain under-acknowledged, even though they should be central to "the sustainability endeavor, since their realm of expertise is precisely about value formation, ethics, concepts, decision-making, and other matters" that are essential to coping with immense global change (Sörlin 2013, p. 22). And social scientists and humanists are not the only people arguing that responding to the transformation of the Earth System requires more than scientific and technological

understanding. Earth System scientist Will Steffen and colleagues point to the need for expansive change, including rapid “decarbonization of the global economy, enhancement of biosphere carbon sinks, behavioral changes, technological innovations, new governance arrangements, and transformed social values” (Steffen et al. 2016, p. 324). New economies, politics, and values are at least as important as science and technology.

From its beginning in 2009, the Anthropocene Working Group (AWG), set up to study the potential new geological time unit, included non-geologists among its members. This was an unusual move for a body of the International Commission on Stratigraphy. International governmental organizations, such as the UN’s Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), are also adopting this multidisciplinary approach (Vadrot et al. 2018). Recent academic initiatives around the world encourage geologists, Earth System scientists, historians, anthropologists, engineers, artists, and literary critics (among others) to talk and work with one another. These include The Anthropocene Project, a collaboration of the Haus der Kulturen der Welt cultural center in Berlin with the Max Planck Institute for the History of Science; the Center for Energy and the Environment in the Human Sciences at Rice University in Texas; the Integrated History and Future of People on Earth (IHOPE) in Sweden; the AURA project at Aarhus; the Vienna Anthropocene Network at Universität Wien; the Quotidian Anthropocene project; RIHN (the Research Institute for Humanity and Nature) in Kyoto; and the Center for Anthropocene Studies at KAIST in South Korea.

This volume also ventures beyond the sciences to some of the many disciplines concerned with humanity, the *anthropos* of the Anthropocene. Listening and learning across the frontiers of knowledge is far from easy. Each

field has its own coherence, its own questions, protocols, genealogies of debate, and modes of argument. Even our citation styles differ. In an ideal world, navigating these differences might take the form imagined by paleobiologist Norman MacLeod, as meetings “of equals who possess complementary skills, data, and knowledge, who are open to the idea of having their views challenged constructively, and who can engage in the critical cut and thrust of robust debate because they are comfortable in their own intellectual skins” (2014, p. 1618). Creating such conversations is our aim too, not least because the stakes are so high. No one field can address all questions from all perspectives. No single group – be they geologists, anthropologists, geo-engineers, or anyone else – has all the answers.

Some have argued that the aim of multidisciplinary conversations is to dissolve disciplinary boundaries. E. O. Wilson (1998) calls this dissolution “consilience,” and assumes that it is not only possible, but necessarily better than a multitude of perspectives and a democracy of effort. This book argues against consilience. Certainly, an interdisciplinary approach can work well when addressing some questions, but only those with one right answer. The hardest questions of politics, ethics, and aesthetics usually have more than one right answer. Not all approaches are compatible. Indeed, some are outright incommensurate due to considerations of scale, or because they represent fundamentally different forms of knowledge. Some fields produce verifiable information whereas others craft judgments (Thomas 2014; Kramnick 2017). The drawback of interdisciplinary consilience is that it ultimately gives priority to one perspective and a single style of analysis, with its circumscribed body of acceptable evidence. Only rarely do those seeking one unified story explain why the form of knowledge they have chosen is more valuable than

other forms – why, for instance, we should always favor the worldview of rationalists over animists, or numbers over poetry. In the face of unprecedented challenges, we need the rigor of established disciplines to ensure expertise and to assess evidence, but we also need these disciplines to be self-reflective and to engage with work not just in adjacent fields but in distant ones. The goal is to create networks of knowledge, all focused on the reality of the Anthropocene but using their own lenses. The more this sort of multidisciplinary collaboration occurs, the more fruitful will be the debate on how we arrived at this crisis and how to navigate the tough choices ahead.

Stumbling Blocks of Scale, Causality, and Meaning

Yet even with the best will in the world, multidisciplinary conversations about the Anthropocene seem particularly difficult. Why is this so? Two factors seem central: the problem of scale and the issue of causality. A word about these two stumbling blocks is in order because scale and causality are central to all practices and disciplines, yet all approach them differently.

Let us begin with scale. In some ways, the Anthropocene is necessarily gargantuan. It is a “hyperobject,” in literary critic Timothy Morton’s evocative term, meaning that it is “massively distributed in time and space relative to humans” (2013, p. 1). The anthropogenic forces now acting on the Earth System are redirecting the planet away from the glacial–interglacial cycles that have waxed and waned for the past 1 million years and more. Potentially, these forces could redirect Earth’s trajectory beyond the cycles of the Quaternary Period (the past 2.6 million years). Evolutionary pathways are being abruptly altered as many species go extinct and the populations of others dwindle.

Greenhouse gas (GHG) emissions have transformed the climate, not just for the next few centuries but for many millennia to come. The atmospheric changes have delayed the next Ice Age, previously forecast for 50,000 years from now, and possibly even the one after that, which was formerly “scheduled” for ~130,000 years in the future (Stager 2012, p. 11). Understanding the Anthropocene means traveling in hyper-time, going deep into the past and far into the future, while contending with a disjointed present.

Likewise, its spatial scale must be planetary; if it were happening only in East Dulwich, it wouldn’t be happening. The Anthropocene is the transformation of the entire Earth System, not alterations to particular spots on Earth. Its significance lies in the scale, magnitude, and longevity of change to the Earth System, not the discovery of the “first traces of our species” (Zalasiewicz et al. 2015b, 201). Human beings started to develop a regional and highly diachronous influence on the Earth System thousands of years ago. With the European Industrial Revolution in the early nineteenth century, some societies became a more pronounced geological factor, but it was only from the mid twentieth century that the impact of accelerating population growth and industrialization became both global and near-synchronous (Zalasiewicz et al. 2015b).

Along with its enormous temporal and spatial scales, the Anthropocene is also a hyperobject in the sense that conceptualizing the Earth System is possible only through data collection of colossal proportions, and computer modeling (Edwards 2010). Without these tools, we would be blind to the magnitude of the Anthropocene, the Great Acceleration, and the overshoot of planetary boundaries. In the last few years, managing this immense amount of data has in itself become a problem of scale. Grappling with even one factor of the many that make up the

Anthropocene requires the labor of thousands of scientists and extremely powerful computers. For instance, Jan Minx reported in 2018 that members of the International Panel on Climate Change (IPCC) had been struggling to prepare for the sixth Assessment Report, due in 2021, because of the sheer volume of scientific data; as of 2018, the relevant new literature since 2016 was somewhere between 270,000 and 330,000 publications. He called for machine reading and other techniques as the only way to corral and digest all this new information (Minx 2018). Notably, Minx's estimate includes only those papers that concern climate change and not those on such aspects as landscape transformation or biodiversity loss. Big data just keeps getting bigger. There is so much information that integrating it into a single planetary model becomes a steep challenge. Figuring out how the hyperobject of the Anthropocene – at odds with human scales of time and space, and our capacity to absorb information – can become "thinkable" in terms of human values, politics, and economies is an even steeper challenge.

And that's the rub. The scales of geological significance and the scales of social significance are not the same. Earth System scientists work on immense canvases of time and space; human communities suffer or celebrate the Earth's changes within varied local ecologies and cultural systems, measuring our lives in hours, days, and years. Connecting the Earth System with tonight's avocado salad, voting rights in Peru, next month's paycheck, or Aboriginal artwork means traveling up and down scales of time, space, and evidence. And yet, before the next decade is out, so as not to provoke dangerous tipping points and push Earth toward a "Hothouse state" (Steffen et al. 2018), Earth System scales and human scales must be calibrated together.

Two Types of Scale

Clarity requires distinguishing between two types of scale: one neatly integrated and nesting, and the other sprawling and tangential. The integrated scale permits us to slide fairly easily from “little” to “big.” Constructing this type of scale showcases the similarities shared by each unit. We might think of this as the Russian doll view of scales, with little dolls fitting neatly inside the bigger ones, producing a monstrous, all-encompassing *babushka*. The second way to construct scales rejects neatly nesting units, and results in a messy web of connections and contrasts. Instead of looking only at the shared similarities, this approach accounts for differences as well; each unit shares some characteristics with neighboring units, but not all. The movement among units is uneasy, and startling new relations may be visible at different levels. In trying to capture the friction between orders of magnitude as well as their harmony, sprawling scales retain more of the world’s complexity but lose the clarity provided by the encompassing *babushka*. The important point is that both types of scale can help us understand the transformation of the Earth System and its human entanglements. The first type of scale reveals the integration of the Earth System and its human components, while the other underscores the variety of quite different experiences of – and perspectives on – this phenomenon.

The first type of scale rests on proportional equivalences. For instance, quotidian time is measured with seconds fitting into minutes, hours, days, and weeks. All smaller units are neat subsets of larger units. Anthropologist Anna Tsing (2012) refers to this as “precision-nested scaling.” Creating such coherence is far from easy, as historian of science Deborah Coen shows in her study of late Habsburg Empire climate science. Coen defines the aim of scaling as