A PELICAN BOOK

The Human Planet

How We Created the Anthropocene

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INTRODUCTION

The Meaning of the Anthropocene

> 'What it lies in our power to do, it lies in our power not to do.'
>
> ARISTOTLE, *NICOMACHEAN ETHICS*, *c.* 350 BC

> 'The conquest of the earth ... is not a pretty thing when you look into it ...'
>
> JOSEPH CONRAD, *HEART OF DARKNESS*, 1899

If you compressed the whole of Earth's unimaginably long history into a single day, the first humans that look like us would appear at less than four seconds to midnight. From our origins in Africa, we spread and settled on all the continents except Antarctica. Earth now supports 7.5 billion people living, on average, longer and physically healthier lives than at any time in our history. In this brief time we have created a globally integrated network of cultures of immense power.

On this journey we have also exterminated wildlife, cleared forests, planted crops, domesticated animals, released pollution, created new species, and even delayed the next ice age. Although geologically recent, our presence has had a profound impact on our home planet.

We humans are not just influencing the present. For the first time in Earth's 4.5 billion year history, a single species is increasingly dictating its future. In the past, meteorites,

super-volcanoes and the slow tectonic movement of the continents radically altered the climate of Earth and the life-forms that populate it. Now there is a new force of nature changing Earth: *Homo sapiens*, the so-called 'wise' people.

The influence of human actions is more profound than many of us realize. Globally, human activities move more soil, rock and sediment each year than is transported by all other natural processes combined. The total amount of concrete ever produced by humans is enough to cover the entire Earth's surface with a layer two millimetres thick. We have manufactured so much plastic that it has made its way as tiny fibres into almost all of the water we drink.

We are disrupting the global cycling of the elements necessary for life. Factories and farming remove as much nitrogen from the atmosphere as all Earth's natural processes do. Since the dawn of the Industrial Revolution we have released 2.2 trillion metric tonnes of carbon dioxide into the atmosphere, increasing levels by 44 per cent. This is acidifying the world's oceans and raising the Earth's temperature.

We are also directly changing life on Earth. Today, there are about 3 trillion trees on Earth, down from 6 trillion at the dawn of agriculture. This farmland annually produces 4.8 billion head of livestock and a further 4.8 billion tonnes of our top five crops: sugar cane, maize, rice, wheat and potatoes. We also extract 80 million tonnes of fish a year from the oceans, with another 80 million tonnes being farmed.

Almost every living creature is affected by human actions. Populations of fish, amphibians, reptiles, birds and mammals have declined by an average of 58 per cent over the last forty years. Extinctions are commonplace, running at 1,000 times the typical rate seen before humans walked the Earth. On land, if you weighed all the large mammals on the planet

today, just 3 per cent of that mass is living in the wild. The rest is made up of human flesh, some 30 per cent of the total, with domesticated animals that feed us contributing the remaining 67 per cent. In the oceans, low-oxygen dead zones have appeared across 245,000 square kilometres of coastal waters. We live on a human-dominated planet.[1]

The implications of these statements are profound. The cumulative impacts of human activity rank alongside other planetary-scale geological events in Earth's history. And for us, the unusually stable environmental conditions that began about 10,000 years ago, when farming emerged and increasingly complex civilizations developed, are over. We have entered a time of greater variability and extremes, the repercussions of which are only now beginning to be understood. Can humans flourish on a rapidly changing planet, or is the future one of grim survival, or even our own extinction?

Combining the Greek words for 'humans' and 'recent time', scientists have named this new period of time the Anthropocene. It describes when *Homo sapiens* became a geological superpower, setting Earth on a new path in its long development. The Anthropocene is a turning point in the history of humanity, the history of life, and the history of the Earth itself. It is a new chapter in the chronicle of life and a new chapter of the human story.

The stakes could not be higher. Yet the idea of the Anthropocene is so immense it can be debilitating. It is hard to comprehend a geological epoch. Each successive epoch in Earth's history marks an important change to the Earth, usually encoded in the life-forms that live at that time. Epochs typically last for millions of years. It is doubly difficult to grasp the reality of a human epoch. Can we even conceive

of environmental changes driven by us that will last longer than our species has existed?

Although many people use the Anthropocene as a synonym for climate change or global environmental change, it is much more than these critical threats. People began to change the planet long ago, and these impacts run deeper than just our use of fossil fuels. And so our responses to living in this new epoch will have to be more far-reaching.

As Naomi Klein said of rapid global climate change: this changes everything.[2] The Anthropocene embraces even more than this, encapsulating all the immense and far-reaching impacts of human actions on Earth. It says: this changes everything, for ever.

There is no single entity called 'humanity' that drives the changes to our home planet: specific groups of people cause each impact. Nevertheless, an analysis of these behaviours raises the question of whether humans, as a particular type of animal, are special. Other species consume resources until natural limits stop that growth – whether food supplies, nesting sites, or some other essential need. With access to vast new resources – think of the uncontrollable growth of bacteria in a Petri dish or an algal bloom in a lake – these communities grow exponentially and then collapse as resources are exhausted.

Although anatomically modern humans had emerged by about 200,000 years ago, it wasn't until 1804 that our numbers reached one billion. It then took only a single century to pass two billion people. The sixth to seventh billion was added in just twelve years. Over the long run the human population has grown faster than exponentially – the amount of time taken to double the population has been getting shorter – although rates have slowed since the 1960s. Of course, our impacts also relate to what, and how much, people produce

and consume. In the past fifty years the global economy increased six-fold, whereas the human population only doubled. The resulting explosion in resource use and environmental impacts is out of all proportion to our numbers. So can the human enterprise, the economy included, continue to expand indefinitely given the vulnerabilities of the land, oceans and atmosphere that constitute our planetary life support system? Can we escape the exponential growth–collapse cycle of other species? Or is the Anthropocene the terminal phase of human development?

This is only one story that acknowledging the Anthropocene can tell. To some a new human epoch symbolizes a future of superlative control of our environment and our destiny. Perhaps we have become a 'god species', *Homo deus*, with the clever deployment of technologies solving our problems. To others a human-driven epoch is the height of hubris, the ultimate folly of the illusion of our mastery over nature. Perhaps we have prodded Earth one too many times and awoken a monster. Whatever our view, just beneath the surface of this odd-sounding scientific name, the Anthropocene, is a heady mix of science, politics, philosophy and religion linked to our deepest fears and utopian visions of what humanity, and the planet we live on, might become.

These are not abstract concerns: the story we choose to tell matters. At one extreme, if the Anthropocene began when people first began using fire or farming crops, environmental change is merely part of the human condition. At the other extreme, if human activity transformed Earth only in recent decades, we need to question the role of technology and the development of consumer capitalism. More concretely, the changes we are making to the planet needs a response. This is because the release of carbon dioxide from fossil fuel use has

already pushed Earth outside the 10,000 year period of relatively stable climate. The resulting increasing variability and extremes of weather will increasingly affect people's health, security and prosperity. What should our response be?

One answer is to stop using fossil fuels. Another could be to use geoengineering – deliberate major interventions in how our planet functions – to stabilize Earth's climate. But might such intentional large-scale interference with Earth's natural processes, such as reflecting some of the energy coming from the sun back into space, have severe unintended consequences? Could other solutions that stabilize Earth's climate, with differing planetary impacts, be better? There are no easy answers, but increasingly society will be confronted with questions like these. Once we recognize ourselves as a force of nature, we will need to address who directs this immense power, and to what ends.

Our home planet functions as a single integrated system: the oceans, atmosphere and land-surface are all interlinked. This 'Earth system' can be thought of as consisting of physical, chemical and biological components. The biological component, beginning some 4 billion years ago when life first emerged, has had planet-changing impacts which continue today. First micro-organisms, and later plants have radically altered Earth's development, with *Homo sapiens* being a recent biological addition. This book charts the rising environmental impact of this large-brained animal, from our pre-human ancestors to the present day. The chapters proceed chronologically, beginning with the birth of Earth and ending with a look into the future.

The book is based around four main themes integral to the Anthropocene. Firstly, that the environmental changes caused by human activity have increased to a point that today

human actions constitute a new force of nature, increasingly determining the future of the only planet known to harbour life. And as in past episodes in Earth's long history, this new human epoch is captured in Earth's natural data storage devices, geological sediments, that will become the rocks of the future. These changes and the resulting indelible markings, when carefully compared to past changes in Earth's history, show that the Anthropocene is a genuinely new and important phase. This is the usual focus for scientific investigations of the Anthropocene.

Yet understanding this new chapter in Earth's history requires a deeper investigation than merely comparing today's planetary changes to those of the distant past. The Anthropocene is the interlacing of human history and Earth's history. To understand the creation of the human-dominated planet we live on, we also need to take a fresh look at our history of changing the environment around us, and the legacy of these changes. As scientists, we re-interpret human history in a new way, looking through the lens of Earth system science.

This brings us to our second theme in the book. As we trace human societies from our march out of East Africa through to today's globally connected network of cultures, there are four major transitions – a pair relating to patterns of energy use and a pair relating to the scale of human social organization – that fundamentally altered both human societies and our environmental impacts on the Earth system. We call this the 'human development double two-step', with each transition leading to ever larger impacts on the Earth system.

Human societies spread worldwide as hunter-gatherers. The first transition, beginning roughly 10,500 years ago, resulted from learning to farm. By domesticating other species to serve human ends people captured more of the

sun's energy. Within a few thousand years foraging had been replaced by agriculture almost everywhere. These farmers transformed landscapes, and over time changed the chemistry of the atmosphere so much that they stabilized Earth's climate. Serendipitously, farming created environmental conditions across our home planet that were unusually stable. This gave time for large-scale civilizations to develop.

The second of the four transitions was organizational: in the early sixteenth century Western Europeans began colonizing large areas of the rest of the world, creating the first globalized economy. A new world order driven by the search for private profit was born. These new trade routes linked the world as never before. Crops, livestock, and many species just hitching a ride, were moved to new continents and new oceans. Called the Columbian Exchange, this cross-ocean exchange of species began an ongoing global re-ordering of life on Earth. This reconnecting of the continents, for the first time in 200 million years, has set the Earth system on a new developmental trajectory. Beginning in 1492, the collision of Europe and the Americas was a watershed event resulting to a new global economy and a new global ecology. Like the original agricultural revolution, this newly emerging capitalist mode of living would spread and eventually encompass almost all of humanity.

The third transition was driven by another leap in the energy available: people learned to mine and use large quantities of old concentrated stores of the sun's energy. These fossil fuels were a key component of the late eighteenth-century Industrial Revolution. Large-scale production could be centralized around factories, and humans became an increasingly urban species. One critical planetary change was the rise in emissions of carbon dioxide

from fossil fuels. For 2.6 million years Earth has cycled through cool glacial and warm interglacial phases, but over time human actions have done something remarkable: delayed the next scheduled ice age and created a new planetary state, a state warmer than an interglacial – a super-interglacial. Fossil fuel use has pushed Earth outside the environmental conditions that every human culture evolved within.

The fourth, and so far final, transition was driven by a further globe-spanning organizational change. After the Second World War a suite of new global institutions was created, resulting in major increases in the productivity of the global economy alongside improvements in human health and material prosperity. Environmental historians describe these changes and the resulting step-change in the size and variety of environmental impacts as the Great Acceleration. Since 1945 changes to the global cycling of elements and the energy balance of Earth have departed from the range of conditions of the past 10,000 years, with major consequences for societies globally. A dangerous experiment with the future of human civilization has begun.

Arriving at the present day, we turn to the third theme in the book: which of the four critical transitions constitutes the beginning of the Anthropocene? The chosen date matters because it will be used to shape political responses to living in the Anthropocene. For example, a very early date could be used to normalize and downplay today's global environmental change, while dating it to the Industrial Revolution might be used to assign historical responsibility for the impacts of today's environmental problems. Given the high stakes, who will make the monumental decision of arbitrating on when humans actions constitute a force of nature? The answer is a little-known network of committees,

who will decide whether the Anthropocene will become part of the official geological history of Earth, known as the Geologic Time Scale. So far, their deliberations have been fraught and without consensus, with an official decision not expected for many more years.

In response, we present a simple method to arrive at a start date for the Anthropocene. Having established that Earth is moving towards a new state, we look to geological sediments to define an epoch, just as past epochs in Earth's history have been defined. A specific chemical or biological change in a geological sediment needs to be chosen to signal the beginning of a new human-influenced layer of sediment. This marker must also be correlated with changes in other sediments worldwide. Called a 'golden spike', the marker says: *after this point Earth is moving towards a new state*.

We sift through the various golden spikes that have been proposed. Our analysis concludes that the earliest date when these geological criteria are met is the year 1610, marked by a short-lived but pronounced dip in atmospheric carbon dioxide captured in an Antarctic ice-core, reaching its lowest level in this year. Called the Orbis Spike, from the Latin for 'world', it marks when the Columbian Exchange can be seen in geological sediments. Much of the drop occurred because Europeans carried smallpox and other diseases to the Americas for the first time, leading to the deaths of more than 50 million people over a few decades. The collapse of these societies led to farmland returning to forest over such an extensive area that the growing trees sucked enough carbon dioxide out of the atmosphere to temporarily cool the planet – the last globally cool moment before the onset of the long-term warmth of the Anthropocene.

The 1610 Orbis Spike marks the beginning of today's globally interconnected economy and ecology, which set

Earth on a new evolutionary trajectory. It also points to the second transition we identify – from an agricultural to a profit-driven mode of living – being the decisive change in *Homo sapiens*' relationship with the environment. In narrative terms, the Anthropocene began with widespread colonialism and slavery: it is a story of how people treat the environment and how people treat each other.

This brings us to the final theme in the book, the future of humanity in the Anthropocene. Will there be a fifth transition to a new form of human society, perhaps one that lessens our environmental impacts and improves people's lives? Or are we akin to bacteria in a petri dish – which multiply until they have consumed the available resources and then nearly all die – are we heading for a collapse of human society? Again, the lens of Earth system science allows us to approach the question in a new way.

We view human societies as complex adaptive systems, noting that such systems change from one state to another when they are gripped by feedback loops where change reinforces further change. Analysing each of the four transitions we see these self-reinforcing loops and the emergence of new states, to agricultural, mercantile capitalist, industrial capitalist and consumer capitalist modes of living. The new form of human society that emerges is always reliant on greater energy use, greater information availability and an increase in collective human agency, and has greater environmental impacts. Understanding the non-linear history of human societies and the dynamics of additional energy and information availability begins to explain how *Homo sapiens* has become a force of nature like no other.

We make the case that since the early modern world of the sixteenth century two interlinked self-reinforcing feedback

loops – the investment of profits to generate more profits, and the production of ever-greater knowledge from the scientific method – have increasingly dominated the world's cultures. These forces have unleashed ever-increasing rates of change, including environmental change. At its root, this is an outcome of the exponential growth of the global economy, which, growing at 3 per cent per year, is expected to more than double in size every twenty-five years. When the economy was small, doubling its size had little impact – the change experienced over a human lifespan was typically modest. But as a very large economy doubles in size, and soon doubles again, ever-more dramatic changes to society and the Earth system become the norm. These rising social and environmental changes point towards either a new configuration of human society or its collapse.

A fifth transition to a new mode of living is a daunting prospect. Yet just as the post-war settlement improved lives, a new transition to a higher-energy, greater-information state could radically increase human freedoms and even undo much environmental damage. What a looming transition does mean is that the political choices made over the coming few decades may well set the course for much of humanity over a far longer time period. Our hope is to illuminate what is at stake in order to allow the crafting of humane and intelligent responses to living on our human-dominated planet.

The Anthropocene is one of the most arresting ideas to emerge from science in recent years. It could radically change the world. To do so, it must withstand intellectual scrutiny and have the capacity to alter our collective behaviour in a sustained way. Given the increasing recognition of the global environmental crisis humanity faces, the Anthropocene may have that kind of rare power. Acknowledging the Anthropocene forces us to think about the long-term impacts

of the globally interconnected mega-civilization we have created, and what kind of world we will bequeath to future generations. Perhaps it can also help us change that future to one more aligned with the name we give ourselves: *Homo sapiens*, the wise humans. This might be possible, since the Anthropocene may become one of the few scientific discoveries that fundamentally alters our perception of ourselves.

Past scientific discoveries have tended to reduce the importance of humans. In 1543 Nicolaus Copernicus set out the proof that the Earth revolved around the Sun: we are not at the centre of our solar system. Later, Charles Darwin's 1859 book *On the Origin of Species* revealed that *Homo sapiens* are descended from ape-like ancestors: we have no special origin, and are simply part of the tree of life. More recently still, the Kepler satellite and telescope has shown us that we live on just one of many trillions of planets in one of billions of galaxies in the universe. Acknowledging the Anthropocene reverses this trend. The future of the only place in the universe where life is known to exist is increasingly being determined by human actions. After almost 500 years of ever-increasing cosmic insignificance, people are back at the centre of the universe.[3] One key scientific challenge of our time is to understand the power we have. Only then will we be able to answer the political question of our age more wisely: what should we do with this immense power?

CHAPTER 1

The Hidden History of the Anthropocene

> 'If only the Geologists would let me alone, I could do very well, but those dreadful Hammers! I hear the clink of them at the end of every cadence of the Bible verses.'
>
> JOHN RUSKIN, LETTER TO HENRY ACLAND, 1851

> 'He who controls the past controls the future. He who controls the present controls the past.'
>
> GEORGE ORWELL, *NINETEEN EIGHTY-FOUR*, 1949

Names are powerful. Early maps of Earth, first drawn in the sixteenth century, showed large areas without names. Swathes of nothing. When Europeans arrived in these places, they often named the mountains, rivers, and other geographical features. These landscapes were already inhabited, known and named, but as Europeans named them for themselves, they claimed them, filling the gaps on their maps and erasing the original names. The narratives of these places were changed, tilted to the narratives of the naming group. These actions resonate deeply. People today still casually say that Christopher Columbus 'discovered' America, despite the fact that more than 60 million people were

already living in the Americas when he and his fellow travellers arrived.

Religion and notions of the superiority of Europeans loomed large as justifiers of both the conquest of land and of the names themselves. The heyday of geologists naming vast portions of Earth's history was also the European colonial era. Similar societal preoccupations are likewise deeply entwined when it comes to naming the geological time that we humans live in. And of course these preoccupations change over time, as do the meanings of the names used. Peking, Bombay and Leopoldville have gone. Beijing, Mumbai and Kinshasa tell a different story.

Similar power struggles over meaning apply to contemporary Anthropocene debates, including whether to formally define the term as a new geological epoch. But where did the idea of the human epoch come from? Understanding this history is an essential step to make sense of how we think about, and ought to think about, the Anthropocene today.

The Standard Narrative

The modern history of the Anthropocene starts with a small meeting of the International Biosphere–Geosphere Programme (IGBP) in Cuernavaca, Mexico, in February 2000. The IGBP had been formed in 1987 to coordinate research into what scientists call 'global change'. The central idea is that Earth functions as an integrated system of interacting physical, chemical, biological and human components. To speak of 'global change' is therefore to speak of trends in this single complex Earth system that humans are a part of. Global change is more than climate change, and avoids treating 'the environment' as separate from human affairs. What people do

affects the world around them, and these effects feed back to the human component of the Earth system.

One key focus of the IGBP has been to assess past global changes, particularly change in the Holocene Epoch, the name geologists give to the warm interglacial period spanning the past 11,700 years. In the Cuernavaca discussion, Paul Crutzen, a Nobel Prize-winner for his work on the atmospheric chemistry of the hole in the ozone layer, was annoyed by this repeated mention of the Holocene when referring to very recent global change, often dominated by human actions. According to those in the meeting, Crutzen exclaimed that we were not in the Holocene anymore. Following a struggle to find words to express his disquiet, he declared, 'We are now in the, the Anthropocene!' As Crutzen recalled the meeting to a BBC journalist several years later: 'I was at a conference where someone said something about the Holocene. I suddenly thought this was wrong. The world has changed too much. No, we are in the Anthropocene. I just made up the word on the spur of the moment. Everyone was shocked.'[1]

Crutzen was onto something. Working with an ecologist, Eugene F. Stoermer, who had used the same term previously in talks and lectures, he quickly published a one-page paper in the March 2000 issue of the *IGBP Newsletter*. The pair wrote that several researchers since the nineteenth century had noted the increasing impact of human actions on the environment, that the impacts today are substantial, global, and long-lasting. They concluded by saying, '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.'[2]

Curtzen and Stoermer suggested that the current epoch began in the latter part of the eighteenth century, at the

beginning of the Industrial Revolution, since this can be seen in a rise in the greenhouse gas carbon dioxide captured in ice-cores from Antarctica. This, and a short follow-up report in the leading scientific journal *Nature,* launched the contemporary explosion in the use of the term the Anthropocene.[3]

This storyline was then cemented by geologists. Jan Zalasiewicz, a deep-time geologist at the University of Leicester in England, who led a group investigating the new idea of the Anthropocene under the auspices of the Geological Society of London, reiterated the same points as Crutzen. Writing for the *Observer* newspaper in 2008, Zalasiewicz noted that 'the idea was crystallized by Paul Crutzen', concluding that 'the Anthropocene does seem geologically real and could be judged to have begun in 1800.'[4]

Similar points were published in the scientific literature, with twenty-one geologists, again led by Zalasiewicz, stating:

> A case can be made for [the Anthropocene's] consideration as a formal epoch in that, since the start of the Industrial Revolution, Earth has endured changes sufficient to leave a global stratigraphic signature distinct from that of the Holocene or of previous Pleistocene interglacial phases, encompassing novel biotic, sedimentary, and geochemical change.[5]

There were some references to older mentions of human activity impacting the environment, just as Paul Crutzen had noted, but the Anthropocene, the human epoch, was presented as a new, 21st-century idea.

Superficially, this storyline makes sense. It says that contemporary Earth system scientists – a group both authors of this book belong to – revealed new evidence that human actions are substantially impacting the environment to an extent that humans have ushered in a new geological epoch. This narrative rests on two problematic assumptions. First,

the story subtly promotes a narrative that humans have rather unknowingly and unwittingly caused major global-scale environmental changes. Second, it implies that little was said about the environmental impacts of human actions until very recently (when scientists pointed it out at the turn of the twenty-first century).

But have people innocently caused ever-rising environmental changes? Two French historians, Christophe Bonneuil and Jean-Baptiste Fressoz, compellingly challenge the idea that humans accidentally damaged the environment and changed the Earth. Their detailed history of environmental problems shows that almost all individual major environmental changes have had some scientists and others warning of the consequences of business-as-usual.[6]

Back in 1661, polymath John Evelyn wrote of London air as

> a cloud of sea-coal, as if there is a resemblance of hell upon Earth ... This pestilent smoak, which corrodes the very yron and spoils all the movables, leaving a soot upon all things that it lights: & so fatally seizing on the lungs of the inhabitants, that the cough and the consumption spare no man.

His book was directly addressed to King Charles II, recommending tree planting to reduce air pollution.[7] Later, Stephen Hales demonstrated the links between plants and the atmosphere in his 1727 book *Vegetable Staticks*, showing that deforestation drives local climate change.[8]

Concerns about exhausted fish stocks and the loss of forests were common. As one of the giants of the Enlightenment, George-Louis Leclerc, better known as the Comte de Buffon, wrote in 1778,

> The most contemptible condition of the human species is not that of the savage, but that of those nations, a quarter civilized, that have always been the real plagues of nature ... They ravaged the land ... starve it without making it fertile,

> destroy without building, use everything up without renewing anything.[9]

While such sentiments were common devices used to justify imposing colonial farming practices, by the 1820s the desert ruins of past civilizations were used to warn that rampant resource use can cause irreversible climate change with devastating consequences. Indeed, utopian socialist Charles Fourier's 1821 text entitled *The Material Deterioration of the Planet* called for a new planetary medicine, analogous to human medicine for illness, to address planetary environmental threats.[10]

Writing in 1876, Friedrich Engels succinctly reported a central problem we still grapple with today:

> When individual capitalists are engaged in production and exchange for the sake of the immediate profit, only the nearest, most immediate results can be taken into account in the first place ... What cared the Spanish planters in Cuba, who burned down forests on the slopes of the mountains and obtained from the ashes sufficient fertilizer for one generation of very highly profitable coffee trees – what cared they that the heavy tropical rainfall afterwards washed away the now unprotected upper stratum of the soil, leaving behind only bare rock! In relation to nature, as to society, the present mode of production is predominantly concerned only about the first, the most tangible result; and then surprise is expressed that the more remote effects of actions directed to this end turn out to be of quite a different, mainly even of quite an opposite, character.[11]

This basic problem has existed in numerous guises, in terms of carbon dioxide emissions, species extinction, the ozone layer and much more, for many decades, and in some cases hundreds of years. At the very least, some people were aware of serious cumulative global environmental problems prior to the last couple of decades.

Nevertheless, the 'accidental Anthropocene' story is seductive. And people love stories. Like planetary environmental doctors, today's scientists can be saviours of the world, noting the symptoms of a sick Earth. People in power also find the accidental Anthropocene the least discomforting narrative, since it conveniently says: 'We didn't know the problem – we will try harder to deal with the environmental crisis from now on.' While this might be the story that is easiest to tell, it is not consistent with the historical facts. Scientists and the wider public were discussing the Anthropocene more than a century ago.

The Human Epoch is as Old as Geology

In order to think through the relationship between humans and geological time we need to understand: how old Earth is; when humans emerged on Earth; and when we started making an impact. In most cultures, for nearly all of human existence, the concept of time stretched far back to a cosmological beginning: Earth was understood to be very old, perhaps infinitely so. More recently, Christian scholars imposed a very short timescale on Earth's history. They analysed the chronology of events in the Old Testament to calculate that the Earth, according to the Bible, was about 6,000 years old – not very old at all. Then by the mid-eighteenth century some leading natural philosophers were coming to the conclusion that Earth was considerably older than popular religious commentaries implied. And so a third possibility was increasingly considered: that Earth was old compared to human history, and had a knowable date of birth. Hard evidence, however, was difficult to produce.

In 1778 the Comte de Buffon breached the impasse with his popular book *Epochs of Nature*. Buffon's goal was nothing less than to organize everything known about nature at the time.

changing, forming and re-forming, so that finding rocks that we are sure are as old as Earth is very difficult.

Radiometric dating of meteorites, which are parts of asteroids and some of the oldest material in the solar system, provided a solution. Because both the meteorites and the Earth formed at the same time, and the Earth must have existed for the meteorites to have collided with its surface, the oldest fragments of them provide a minimum age for the Earth. Today, following the dating of seventy different meteorites, the scientific community is agreed that Earth is 4.54 billion years old.[12]

From Buffon's early experiments to the first dating of ancient meteorites in the 1950s the age of Earth was being pushed ever further back. At the same time more and more fossils from deep in Earth's history were discovered. Notably, they did not contain traces of humans. From the time of the early geologists onwards it was increasingly clear that Earth had existed for a long time before humans existed. This led geologists, from Buffon onwards, to consider whether the last portion of geological time should be a human epoch.

Earth, according to Buffon's *Epochs of Nature*, has seven epochs, the final one being the Epoch of Man, named because of the transformation of Earth by human actions. He wrote, almost 240 years ago, that 'the entire face of the Earth today bears the imprint of human power.' And if that sounds eerily modern to today's ears, Buffon also suggested a kind of geoengineering. He thought that Earth was inexorably cooling and that this was detrimental to life, and so suggested that the climate could be altered via intentional deforestation or the planting of forests to 'set the temperature' to a level beneficial for human civilization.

Buffon's seven-epoch history of Earth rather too neatly mirrors the seven-day creation story. Indeed, in the

penultimate draft of Buffon's book there were only six epochs, with no special Epoch of Man. The reason why the human epoch was added to his thesis remains elusive. Perhaps challenging the establishment by stating that Earth was old, and making the case that there was a time before humans roamed the Earth, was enough for one book. Perhaps the designation of a human epoch was a self-protective concession to common religious views of the time. A human epoch usefully denotes people as 'special' and separate from the other animals. However, these concerns seem less likely as reasons for the inclusion of a human epoch in Buffon's case, as he was not known to bend to the views of others.

More than thirty years earlier, in 1749, Buffon first became famous after publishing the initial three volumes of his attempt at organizing and synthesizing the world's knowledge, *Natural History*. They were quickly translated into English, Dutch and German, and widely criticized for contradicting the biblical story. French religious authorities began censuring his work. He agreed to change some passages, and wrote that his views were 'only pure philosophical supposition'. One might think he caved in, but he performed an extremely clever manoeuvre: he published the entire correspondence of the proposed changes to the text in volume four of his *Natural History* series for everyone to see. More scandal ensued, but few would try to interfere with his ideas and writing again. So by the time *Epochs of Nature* was published, Buffon was very firmly in the upper echelons of the French establishment and heavily protected from religious criticism. We cannot know for certain, but his human epoch may not have been a religious choice at all; more likely it was based on an early understanding of the emerging fossil record, showing humans to be a recent addition to Earth that had begun to fundamentally alter it.

The final epoch was clearly, even at the time of the earliest geological investigations, as much about the future as it was about the past. It was about the power of human actions. Buffon's political hopes coincided with his history of Earth ending with a human epoch: as he notes in *Epochs of Nature*, he expected civilized humans to transform their home planet for their own betterment. Whatever the underlying reason, whether fossils, religion or political ideals, the classification of the present day as the human epoch was widely discussed in Europe in the late eighteenth century.

Moving on to the nineteenth century, geologists were still regularly debating and publishing a final geological time-unit to denote the impacts of human activity. Religion also continued to exert a strong influence on geology. To the best of our knowledge the very first publication to use the 'anthropos' Greek prefix to denote a human epoch was in 1854 by Welsh Professor of Theology and geologist Thomas Jenkyn in a series of lessons on geology in the journal *Popular Educator*. This was no obscure specialist periodical. It came with the strapline 'a complete encyclopaedia of elementary, advanced and technical education', and carried lessons for the public on a wide range of subjects, from the physics of steam power to Latin to geology. Known as a 'national institution' it was praised across British society, with an estimated 100,000 weekly readers.[13]

In an early lecture Jenkyn gives a brief synopsis of the impact of human actions, first as hunter-gatherers, then as farmers, and finally as modern society. After discussing species extinction, and what he calls 'changing animal characters' via domestication and habitat destruction, he notes that humans are 'burning large forests, for agricultural purposes, upon a gigantic scale in North America, in Brazil, in Java, and most tropical countries where vast areas have been

extirpated'.[14] Again, he is sounding surprisingly modern. Jenkyn then discusses the influence of draining marshes, changing water courses, and building dykes to hold back the ocean, noting the major human impacts on soils and geology. On the importance of these changes he notes:

> It is not likely that the human race, living amid the geological changes which its civilization produces on the surface of the earth, will be able to form an adequate conception either of their physical importance, or of their scientific value. If you imagine that the continents of our globe were once more, as they have been frequently, before, submerged under the waves of the ocean, and that the geologist of some future millennium would be investigating these very complicated phenomena, then, *to him*, the particulars recorded in the geological works of the present age would be of incalculable value. They would give him new light in his inquiries and new power in his proofs, as he descanted upon the fossil flora and fossil fauna of the rocks which were deposited in, what would then be called, the human epoch.[15]

In his final lecture, a discussion of the present day, Jenkyn writes, 'All the recent rocks, called in our last lesson Post-Pleistocene, might have been called Anthropozoic, that is, human-life rocks.'[16] Observing the human impacts on Earth in the middle of the nineteenth century, Jenkyn gets his class to undertake a rather simple thought experiment. Imagining the future fossil record of human bones, domesticated animals, rapid species extinctions, and the impacts of directly altering Earth's surface, he concludes that it will clearly record the strong influence of humans on the Earth at this time. He names the then present day as the Anthropozoic ('human-life') epoch, based on the obvious influence of human actions on the fossils that will be found in the future. Jenkyn's thought experiment shows that the idea of a human epoch was self-evident in the nineteenth century.

Jenkyn was no maverick. Such ideas were common currency at the time. In Britain, the Reverend Samuel Haughton's popular *Manual of Geology*, published in 1865, uses the term Anthropozoic for the 'epoch in which we live'. In the United States, Professor of Geology James Dwight Dana's influential 1863 book, also titled *Manual of Geology*, extensively refers to the Age of Mind and Era of Man for the most recent geological period.

Italian priest and geologist Antonio Stoppani published similar ideas a decade later. In his 1873 book *Corso di Geologia*, under the chapter heading 'The First Period of the Anthropozoic Era', he notes the power humans have in comparison to other natural forces:

> I do not hesitate in proclaiming the Anthropozoic era. The creation of man constitutes the introduction into nature of a new element with a strength by no means known to ancient worlds. And, mind this, that I am talking about physical worlds, since geology is the history of the planet and not, indeed, of intellect and morality. But the new being [humans] installed on the old planet, the new being that not only, like the ancient inhabitants of the globe, unites the inorganic and the organic world, but with a new and quite mysterious marriage unites physical nature to intellectual principle; this creature, absolutely new in itself, is, to the physical world, a new element, a new telluric force that for its strength and universality does not pale in the face of the greatest forces of the globe.[17]

Somewhat surprisingly, given today's discussion of the Anthropocene, it seems to have been forgotten that the most recent geological time being the human epoch was widely discussed amongst geologists and students of geology back in the nineteenth century. There also appeared to be little controversy associated with the idea, suggesting that the human epoch was broadly agreed on at that time.

actions of humans appeared to be an important force and it was uncontroversial to consider the contemporary geological epoch as the human epoch.

In the twentieth century geologists in the West increasingly moved towards the consistent use of the term Holocene for the epoch that encompasses the present day. In terms of its age, the definition stayed the same as the older idea of human epoch: the time elapsed since the end of the last glaciation when farming, cities and civilization flourished; but its meaning began to shift. The current epoch became less and less associated with humans and their impacts. Increasingly, 'Holocene' only signified the current warm interglacial that we live in, even though Earth had been through many glacial–interglacial cycles in the past and none were classified individually as geological epochs.

Meanwhile, scientists in the Soviet Union and Eastern Europe, largely operating separately from Western scientists due to the Cold War, were using differing terminology. *The Great Russian Encyclopaedia* described the present day as part of an 'Anthropogenic system (period) or Anthropocene', citing its first use by Russian geologist Aleskei Pavlov in 1922. Then in 1925 Ukrainian geochemist Vladimir Vernadsky published *The Biosphere*, in which he makes the point that life is a geological force that shapes the Earth. Later, in 1945, he brought to popular attention the idea that the biosphere combined with human cognition had created the Noösphere (from the Greek for mind), and therefore that humans were a geological force. This idea of the Age of Mind had been discussed since the mid-nineteenth century, and the French Jesuit priest and geologist Pierre Teilhard de Chardin had coined the term Noösphere in 1922. Noösphere, an idea which Vernadsky then developed further, was not commonly used, but non-Western scientists did often choose to employ

anthropogenic geological time-units, translated into English as both Anthropogene and Anthropocene, which sometimes created confusion.

Why did the West select the term Holocene, which doesn't name-check humans as an important cause of environmental change, when such alternatives were common in the nineteenth century? Why were the nineteenth-century ideas accepted or independently generated by scientists of the Soviet bloc? The difference may be due to differing dominant political ideologies. Downplaying and marginalizing environmental concerns has been a staple of Western societies throughout the twentieth century, thus the Holocene would be more obvious, and much less controversial, than the Anthropocene as a geological name for the present time. The Holocene would be the word one would select for a quiet life as an academic, training future geologists for life in the petroleum or mining industries. It is unthreatening to both the business of geology and the businesses geology enables.

The use of the term Anthropocene by Russian geologists soon after the October Revolution in 1917 is more obvious when it is placed in context. The post-revolution Marxist view of global collective human agency transforming the world politically and economically requires only a modest conceptual leap to arrive at a view that the same agency is a driver of increasingly global ecological and environmental change. The world, its environment included, would be transformed for the betterment of all. Of course, in the early days of the Soviet Union idea proclaiming revolutionary change were not merely accepted, but welcomed, unlike in the West.

The Holocene became the term used by Western scientists, usually defined as starting in 10,000 BP, which stands for

'Before Present', where present is defined by geologists as 1 January 1950. However, it was never formally defined, and was therefore technically not an official geological term. This changed in May 2008 when the International Union of Geological Sciences finally formally ratified the official definition of the Holocene Epoch as beginning in 11,650 BP and continuing to the present day. This separated the end of the last glaciation and the beginning of the current warm interglacial conditions, and marks the epoch within which we live.[20] Human actions are briefly mentioned, but merely as a side note: they do not feature as part of the definition. It is this shift in meaning that prompted atmospheric chemist Paul Crutzen, in the year 2000, to exclaim that a new human-time was needed, the Anthropocene. To him, the Holocene did not mean 'human impacts' or a 'human epoch', it meant 'current warm interglacial conditions'. And no geologist quickly corrected him.

The geological community, first under the auspices of the Geological Society of London, agreed with Crutzen, as we saw at the beginning of the chapter. Then in 2009, the International Commission on Stratigraphy created a formal committee to investigate this issue, the Anthropocene Working Group, led by Jan Zalasiewicz. This further erased the original human-centred definition of the Holocene and the history of the early-scientific understanding of human impacts on the environment in a geological context.[21] The history of the role of human actions in defining the official geological time we live in had been forgotten, meaning the Anthropocene appears to be a newer idea than it really is.

This brief 250-year history of the ways people have described the present day in geological terms illustrates two important points. Firstly, that people have known about widespread environmental changes, and that some of these would have

geological-scale impacts, for at least 150 years, and in some cases a century longer than that. From Buffon's very first attempt at a science-based history of Earth, the collective power of human actions on Earth have been a regular focus of the last phase of our home planet's history. We can only imagine what the world would look like today if the warnings of important changes to the environment had been taken seriously in the past.

Secondly, the geological arguments and narratives articulated at any one point in time are often tilted towards positions that more easily fit with the dominant concerns of the day, be they religious, political or philosophical. In the nineteenth century, discussion of the human epoch, the Holocene included, separated humans out as very recent additions to the Earth, special and different from the other animals. This retained the unique status of people that the societies of the day expected. The twentieth-century East and West naming conventions each sat most comfortably with the political traditions the scientists were part of. It seems that today's 21st-century Anthropocene debates have fallen into similar patterns of thinking. Whether today's geologists discussing the Anthropocene consciously downplay, do not know, or have forgotten the history of these debates and concerns over human impacts causing geologically important changes, the outcome is the same. The view is that the Anthropocene is new and we humans stumbled into it. The idea that the Anthropocene is an 'accidental' occurrence – people just did not know what they were doing – is, again, the least discomforting to the status quo, allowing those in positions of power to avoid responsibility for today's environmental problems.

Put another way, it seems like periods of revolutionary change that look set to engulf the globe, whether the

Industrial Revolution, the spread of Communism, or today's rapid technological changes, lead scientists of the day to declare a human epoch. But what about the evidence? The earliest geologists may, or may not, have had the evidence to define a geological epoch caused by human actions. The same can also be said for the case put forward by Paul Crutzen and contemporary geologists in the twenty-first century, that politics as much as evidence may have been the defining factor.[22] If we are to understand whether the scientific evidence does show that human actions have changed the Earth to such an extent that we now live in a new epoch, we will need to follow that evidence closely, rather than a pathway to a more politically or ideologically comforting place. To do this, we first need to take a step back to briefly examine the history of Earth and understand how geologists define epochs and time more generally.

the country. He named this the 'principle of faunal succession'. Quite simply, this consistent ordering of different types of fossils, even in very distant places, meant that rock layers could be matched no matter where they came from. This orderly succession showed that important changes to the abundance of different life-forms had happened at the same time in different places. There was a correlation between the rock layers in different areas of the country, which showed that these changes had happened at a large scale. Indeed, they seemed to have occurred everywhere. This ordering of rock strata using fossils began to allow these important events in Earth's history, and therefore their relative timing, to be pieced together.

There are three main types of rock. Igneous rocks are formed by the cooling and solidification of hot magma as it approaches the Earth's surface, including basal and granite. Some of these rocks are eroded by wind, water, ice and living organisms. Combined with occasional plant and animal remains these create loose sediments which are then compacted under enormous pressure from sediment material piling on top of them, becoming sedimentary rocks containing fossils. These include limestone, sandstone, shale, chalk and clay. The third type are metamorphic rocks – that are sedimentary rocks which have undergone extreme pressure and heating: marble, for example, is pressure-cooked limestone.

Most of Earth's crust is made of igneous rocks. Sedimentary rocks only make up about 9 per cent of it, but cover 73 per cent of today's land surface. The layering of sedimentary rocks, with younger rock on top of older rock, means that travelling down a geological sequence is akin to travelling backwards in time, with plant and animal types appearing and disappearing as we delve further into Earth's history.

This focus on layers and on matching rocks in different locations is why this branch of science is called stratigraphy – literally 'writing about layers'.

William Smith knew where his layers of rock were, and began to paint a picture of history around him. Armed with his idea of the 'principle of faunal succession', in 1799 he coloured a map of rock types in a five-mile area around the city of Bath, using the same colour for the same stratum across the region. It was the world's first geological map. Enthused, he then planned to produce a geological map of Britain. Smith took up survey work around the country, since he had been dismissed from his Bath-based canal job. This work allowed him to collect critical data, but the money he needed to finance national data collection did not materialize. In the end he crowd-funded the project, with 400 people pledging small sums to support his work. His geological map of England, Wales and Scotland was published in 1815. Although ignored by the scientific community, the map became well used by mine prospectors, canal builders and others. The next year he published *Delineation of the Strata of England*, followed by other books, but his social class and relative poverty meant he did not mix with leading scientists in high-society circles. His work and ideas went unacknowledged.

Smith's debts grew while he languished in relative obscurity. He sold his fossil collection to the British Museum for £700, but it was not enough. In 1819 he landed in the King's Bench debtors' prison. On his release, bailiffs took his home. He had nothing, and was back to travelling the country finding work as an itinerant surveyor. It took a decade, and a patron – Sir John Johnstone, a Member of Parliament – for Smith to receive widespread acknowledgement of his work. He is now recognized as the father of English geology.[3] His

approach, later expanded beyond fossils to include chemical and other signatures, is still used today to quickly assess new finds of rocks and where they fit within the history of the Earth.

Using these correlations amongst fossils, alongside modern techniques to accurately date rocks, geologists divide Earth's 4.5 billion-year history into portions, in a hierarchical series of ever-finer slices. There are five nested levels: Eons, Eras, Periods, Epochs, and finally Ages.[4] Each time-slice is based on the comings and goings of fossilized life: the higher up the hierarchy the bigger the changes. Like Russian dolls, four Eons, each spanning at least half a billion years, contain within them ten Eras, each spanning several hundred million years. Within these Eras sit a total of twenty-two Periods, each typically spanning 50 to 200 million years. Then, additionally, and just for Earth's most recent Eon, when many more fossils are available, time is sliced into a fourth level of 34 Epochs, each typically lasting 5 to 35 million years, and a fifth division of 99 Stages, each typically lasting 2 to 10 million years. This Geologic Time Scale (GTS) both divides time and summarizes the major events in Earth's history.[5] Figure 2.1 shows the grand sweep of Earth's history. Figure 2.2 depicts the final Eon, the past 541 million years, showing the nesting of the categories.

This system means that anyone can pinpoint any time in Earth's history, guided by changes to life, which are themselves responses to environmental changes, including the major events in Earth's history. The Geologic Time Scale is regularly updated as new scientific evidence accumulates: since the year 2000 there have been forty-three changes. To add, subtract, or in any way change the official chart, new scientific evidence must be presented and the International Commission on Stratigraphy must approve the change, which

is then ratified by the International Union of Geological Sciences.

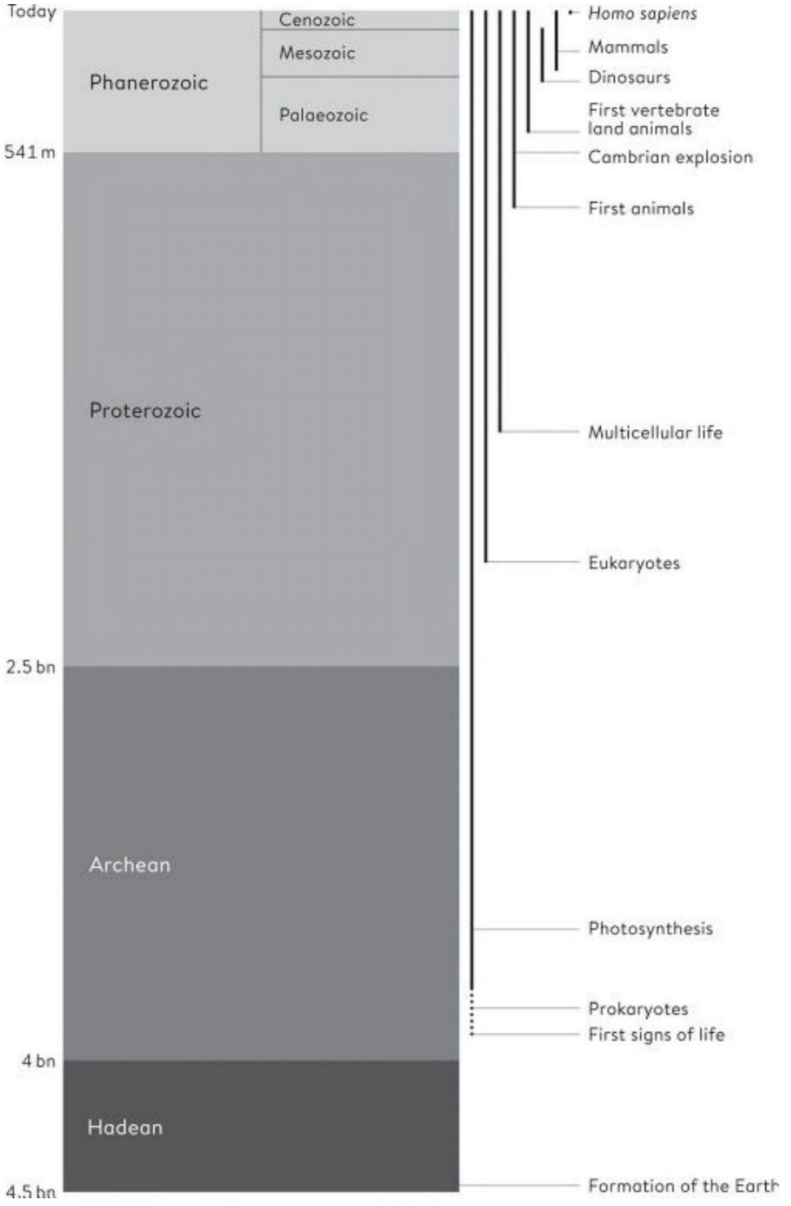

Figure 2.1 — The major biological and geological events in the 4.54 billion-year history of the Earth. The current Eon, the Phanerozoic, is shown with its three nested Eras.[6]

Eon	Era	Period	Epoch	Stage	GSSP	Age (millions)
Phanerozoic	Cenozoic	Quaternary	Holocene		✓	Present
			Pleistocene	Upper		0.0117
				Middle		0.126
				Calabrian	✓	0.781
				Gelasian	✓	1.80
		Neogene	Pliocene	Piacenzian	✓	2.58
				Zanclean	✓	3.60
			Miocene	Messinian	✓	5.333
				Tortonian	✓	7.246
				Serravallian	✓	11.63
				Langhian		13.82
				Burdigalian		15.97
				Aquitanian	✓	20.44
		Palaeogene	Oligocene	Chattian		23.03
				Rupelian	✓	28.10
			Eocene	Priabonian		33.90
				Bartonian		37.80
				Lutetian	✓	41.20
				Ypresian	✓	47.80
			Palaeocene	Thanetian	✓	56.00
				Selandian	✓	59.20
				Danian	✓	61.60
	Mesozoic	Cretaceous	Upper	Maastrichtian	✓	66.00
				Campanian		72.1
				Santonian	✓	83.6
				Coniacian	✓	86.3
				Turonian	✓	89.8
				Cenomanian	✓	93.9
			Lower	Albian		100.5
				Aptian		c. 113
				Barremian		c. 125
						c. 129.4