THE SHOCK OF THE ANTHROPOCENE

The Earth, History and Us

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CHAPTER 1

Welcome to the Anthropocene

In February 2000, a conference of the International Geosphere-Biosphere Programme held in Cuernavaca, Mexico, hosted a heated discussion about the age and intensity of human impacts on the planet. Paul Crutzen, an atmospheric chemist and Nobel Prize winner for his work on the ozone layer, stood up and exclaimed: 'No! We're no longer in the Holocene but in the Anthropocene!' This was the birth of a new word, and above all of a new geological epoch. Two years later, in an article in the scientific periodical *Nature*, Crutzen developed his assertion further: the stratigraphic scale had to be supplemented by a new age, to signal that mankind had become a force of telluric amplitude. After the Pleistocene, which opened the Quaternary 2.5 million years back, and the Holocene, which began 11,500 years ago, 'It seems appropriate to assign the term "Anthropocene" to the present, in many ways human-dominated, geological epoch.'[1]

The Nobel laureate proposed a starting date for this new era of 1784, the year that James Watt patented the steam engine, symbolic of the start of the industrial revolution and the 'carbonification' of our atmosphere by the burning of coal extracted from the lithosphere.

From the ancient Greek words *anthropos* meaning 'human being' and *kainos* meaning 'recent, new', the Anthropocene is then

1 Paul J. Crutzen, 'Geology of Mankind', *Nature*, 415, 3 January 2002: 23.

the new epoch of humans, the age of man. The Anthropocene is characterized by the fact that 'the human imprint on the global environment has now become so large and active that it rivals some of the great forces of Nature in its impact on the functioning of the Earth system'.[2] This is not the first time scientists have attested to or foreseen such human power over the fate of the planet, whether to celebrate it or as a cause for concern. As recently as 1778, in his *Epochs of Nature* volume of *Histoire naturelle générale et particulière*, Buffon explained that 'the entire face of the Earth today bears the imprint of human power'. This imprint would be particularly exerted on climate. By judiciously modifying its environment, humanity would be able to 'modify the influences of the climate it inhabits, and set the temperature to the level that suits it best'.[3] Following him, the Italian geologist Antonio Stoppani defined man in 1873 as a 'new telluric power', and in the 1920s Vladimir I. Vernadsky, who introduced the concept of the biosphere, emphasized the growing human effect on the globe's biogeochemical cycles.[4]

Nor was this the first time that scientists succumbed to anthropocentrism in making humanity a geological marker: the start of the Quaternary, in fact, was fixed to coincide with the appearance of the genus *Homo* 2.5 million years ago in Africa (*Homo habilis*), and the Holocene or 'recent epoch' was proposed by the geologist Charles Lyell on the basis of the end of the last glaciation but also on the then-believed coincident emergence of humans. The idea of adding the Holocene to the geologic time clock was put forward by Charles Lyell in 1833, but accepted only in 1885. Geologists, accustomed to working on the scale of the Earth's 4.5-billion-year history, have no reason to hurry in making our entry into the Anthropocene official. Besides, if the history of our planet is reduced to a day of

2 Will Steffen et al., 'The Anthropocene: Conceptual and Historical Perspectives', *Philosophical Transactions of the Royal Society* A, 369:1938, 2011: 842.

3 Georges-Louis Leclerc de Buffon, *Histoire naturelle générale et particulière*, Supplement 5: *Des époques de la nature*, Paris: Imprimerie royale, 1778, 237.

4 Steffen et al., 'The Anthropocene: Conceptual and Historical Perspectives'.

twenty-four hours, *Homo habilis* appeared only in the final minute, the Holocene began in the last quarter of a second, and the industrial revolution only in the two last thousandths of a second. With the Pleistocene counting in millions of years, and the Holocene in thousands, Crutzen's boldness in proclaiming a new Anthropocene dating back no more than a couple of centuries is readily understandable. His proposal will very likely continue to be debated for a while to come. At the 34th congress of the International Union of Geological Sciences, held in Brisbane in 2012, it was decided to establish a task group that would submit its report in 2016.

While awaiting official validation by stratigraphers, however, the Anthropocene concept has already become a rallying point for geologists, ecologists, climate and Earth system specialists, historians, philosophers, social scientists, ordinary citizens and ecological movements, as a way of conceiving this age in which humanity has become a major geological force.

What humans are doing to the Earth

What are the arguments put forward? What imprints do humans make on the planet, albeit in a differentiated way that we shall explore below? For atmospheric chemists such as Paul Crutzen, or climatologists such as the Australian Will Steffen and the Frenchman Claude Lorius, the weapon that put an end to the Holocene is to be found in the air: 'The air trapped in ice is an abrupt indication that the hand of man, by inventing the steam engine, upset the world machine at the same time.'[5] Fingers point to the greenhouse gases emitted by human activity. In relation to 1750, as a result of these emissions, the atmosphere has been 'enriched' in methane (CH_4) to the tune of 150 per cent, nitrous oxide (N_2O) by 63 per cent and carbon dioxide (CO_2) by 43 per cent. As far as the last of these is concerned, its concentration has risen from 280 parts per million (ppm) on the eve of the industrial

5 Claude Lorius and Laurent Carpentier, *Voyage dans l'Anthropocène. Cette nouvelle ère dont nous sommes les héros*, Arles: Actes Sud, 2010, 11.

revolution to 400 ppm in 2013, a level unmatched for 3 million years. New ingredients have also entered the atmosphere since 1945: fluoride gases such as the CFCs and HCFCs particularly emitted by our refrigerators and air conditioners.

All these are 'greenhouse' gases inasmuch as they retain the heat that the Earth, warmed by the Sun, emits into space. And the accumulation of these gases in the atmosphere has not taken long to raise the planet's temperature. Since the mid nineteenth century, the thermometer has already risen by 0.8°C, and the scenarios of the UN Intergovernmental Panel on Climate Change (IPCC) foresee, depending on the political response they find, a total rise by the end of the present century of between 1.2°C and 6°C. A rise of 2°C in relation to the pre-industrial level, considered by the majority of climatologists as a danger threshold, will be very hard not to breach given the current lack of international political will, and, if the present tendency is not radically modified, climate experts predict a rise of 3.7°C to 4.5°C by 2100, with a whole train of meteorological disturbances and human miseries in its wake. The IPCC's latest report even envisions a rise of 8°C to 12°C by 2300, given a 'business as usual' scenario. The Andean ice cover in Peru has disappeared in twenty-five years, and the polar ice has been melting in the last few years much faster than experts had expected. While the climatologists of the 1980s and '90s conceived the relationship between concentration of greenhouse gases and climate change in a more or less global and linear fashion, systemic approaches and recent advances in modelling show that a small variation in the globe's average temperature can lead to sudden and disorderly changes.

The generalized degradation of Earth's living tissue (the biosphere) is the second element attesting to our swing into the Anthropocene. The collapse of biodiversity is bound up with the general movement of simplification (by anthropization through agriculture and urbanization), fragmentation and destruction of the globe's ecosystems, but it is also accelerated by climate change. An article published in *Nature* in June 2012 indicates that, even in an optimistic scenario, by the end of the twenty-first century, climate conditions on between 12 and 39 per cent of the Earth's surface will be such as present living organisms

have never before faced.[6] On top of those extinctions directly caused by climate change, there is the damage to sea life caused by the acidification of the oceans (up 26 per cent in relation to the pre-industrial period), since these absorb a quarter of our CO_2 emissions.[7] In the last few decades, the rate of extinction of species has been from 100 to 1,000 times greater than the geological norm: biologists speak of a 'sixth extinction' since the appearance of life on Earth.[8] Since the Convention on Biological Diversity of 1992, the pace of extinction has in no way slowed down, for lack of action on the main forces of degradation, and it is estimated that the 100,000 currently protected areas in the world will save at best 5 per cent of all species. Three-quarters of the world's fishing zones are at maximum production or over-exploited. The mass of humans (32 per cent), along with that of their domestic animals (65 per cent), now makes up 97 per cent of the total biomass of land vertebrates, leaving only 3 per cent for the remaining 30,000 land-dwelling vertebrate species.[9] At the current rate, 20 per cent of the planet's species will have disappeared by 2030,[10] but many essential 'services' provided to humanity by the biosphere – pollination, carbon capture, protection from erosion, regulation of water quality and quantity, etc. – have already been greatly reduced.

As well as climate change and the collapse of biodiversity, scientists also note other major transformations that attest to our entry into the Anthropocene. These include in particular the biogeochemical cycles of water, nitrogen and phosphate, each as important as that of carbon, which have also come under human control in the course of the last

6 Anthony D. Barnosky et al., 'Approaching a State Shift in Earth's Biosphere', *Nature*, 485, 7 June 2012: 52–8.

7 For a recent study of this, see World Meteorological Organization, 'Record Greenhouse Gas Levels Impact Atmosphere and Oceans', Press Release No. 1002, 9 September 2014, wmo.int.

8 Stuart L. Pimm et al., 'The Biodiversity of Species and Their Rates of Extinction, Distribution, and Protection', *Science*, 344:6187, 30 May 2014, sciencemag.org.

9 Vaclav Smil, *The Earth's Biosphere: Evolution, Dynamics, and Change*, Cambridge, MA: MIT Press, 2002, 284.

10 Edward O. Wilson, *The Future of Life*, London: Vintage, 2003, 102.

two centuries. The modification of the continental water cycle is massive, with the draining of half the planet's wetlands and the construction of 45,000 dams with heights of more than fifteen metres, together retaining 6,500 cubic kilometres of water, some 15 per cent of the total flow of the world's rivers.[11] These transformations have substantially modified the processes of erosion and sedimentation, without however freeing the greater part of humanity from water insecurity.

The nitrogen cycle has been radically transformed with industrialization (the burning of fossil fuel releasing nitrous oxides) and the Haber-Bosch process (1913) that converts atmospheric nitrogen into nitrogen suitable for fertilizer. These two phenomena represent nitrogen flows twice as great as the 'natural' flow through the biosphere, basically bound up with biological fixing by bacterial symbiosis.[12] The nitric oxide released by fertilizers accentuates the greenhouse effect, and excess urea and nitrates enter water-tables, rivers and estuaries, causing eutrophication and hypoxia.

The global phosphorous cycle also bears the mark of human domination, with an anthropic flow eight times greater than the natural one. Some 20 million tonnes of phosphorous are extracted each year from phosphate mines in the lithosphere, chiefly to be used for fertilizer. It is estimated that 9 million of these 20 million tonnes end up in the oceans.[13] Scientists have shown that an increase in phosphate level of only 20 per cent in relation to the underlying natural flow was in the geological past one of the causes for the collapse of the oxygen level in the oceans, leading to the massive extinction of aquatic life.

Scientists and geographers have also attempted to estimate the extent to which terrestrial ecosystems have been turned into the

11 Christer Nilsson et al., 'Fragmentation and Flow Regulation of the World's Large River Systems', *Science*, 308, 15 April 2005: 405–6.

12 Johan Rockström et al., 'A Safe Operating Space for Humanity', *Nature*, 461, 24 September 2009: 472–5; James N. Galloway et al., 'Transformation of the Nitrogen Cycle: Recent Trends, Questions, and Potential Solutions', *Science*, 320:5878, 2008: 889–92.

13 Ibid.

artificial ones of pasture, crop-land and cities. It turns out that the human species, having increased from a population of 900 million in 1800 to 7 billion in 2012, takes nearly a third of the production of continental biomass for its own needs (in terms of food, clothing, housing and many less vital things),[14] and consumes each year one and a half times what the planet can annually produce on a sustainable basis. This means that 'we' – meaning above all the 500 million most well-off inhabitants of the globe – are not only consuming the fruits of the tree on which we sit but also sawing through its branches.[15]

The Anthropocene is characterized by an unprecedented upsurge in energy mobilization: first with coal, then with hydrocarbons and uranium, which increased energy consumption by a factor of forty between 1800 and 2000.[16] This leap in energy has served to transform the planet with multiplied power, to plough up, urbanize and domesticate ecosystems. Pasture, crop-land and cities, which represented 5 per cent of the Earth's land area in 1750 and 12 per cent in 1900, today cover close to a third. Including partially anthropized biomes, it is estimated today that 84 per cent of the ice-free land surface of the planet is under direct human influence.[17] Ninety per cent of photosynthesis on Earth occurs in 'anthropogenic biomes', that is, ecological ensembles modified by human beings. As the geographer Erle Ellis concludes, the new model of the biosphere 'moves us away from an outdated view of the world as "natural systems with humans disturbing them" and towards "human systems with natural ecosystems embedded within them"'.[18]

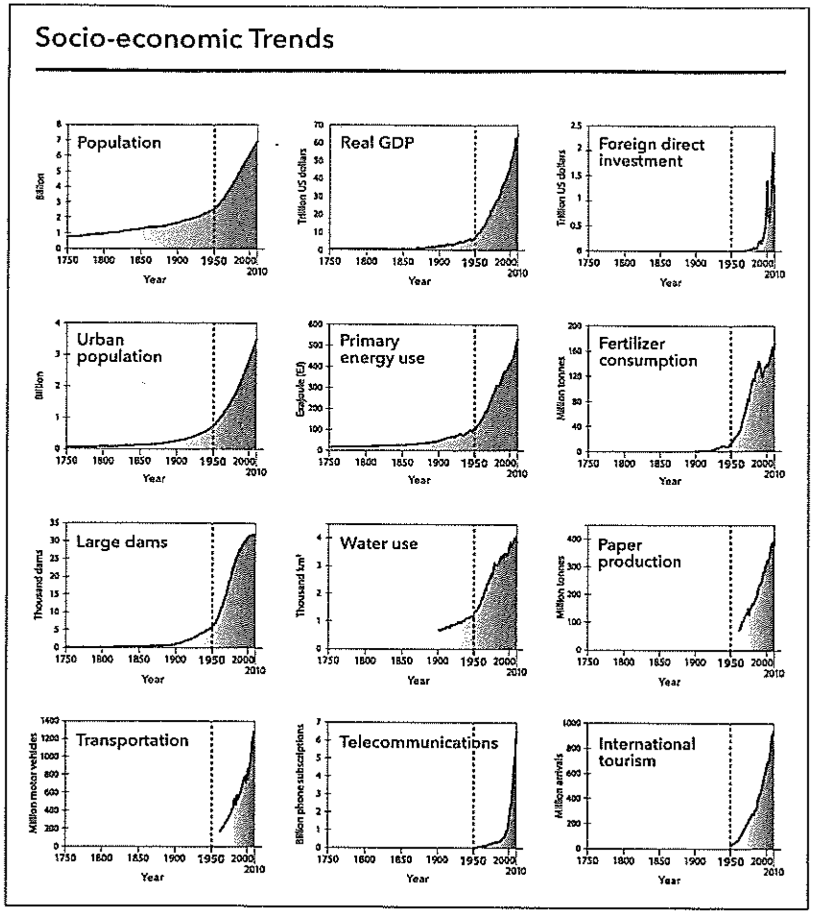
14 Helmut Haberl et al., 'Quantifying and Mapping the Human Appropriation of Net Primary Production in Earth's Terrestrial Ecosystems', *Proceedings of the National Academy of Science, USA*, 104, 2007: 12,942–7; Rockström et al., 'A Safe Operating Space for Humanity'.

15 Global Footprint Network, footprintnetwork.org.

16 Steffen et al., 'The Anthropocene: Conceptual and Historical Perspectives'.

17 Erle C. Ellis, 'Anthropogenic Transformation of the Terrestrial Biosphere', *Philosophical Transactions of the Royal Society A*, 369:1938, 2011: 1,010–35.

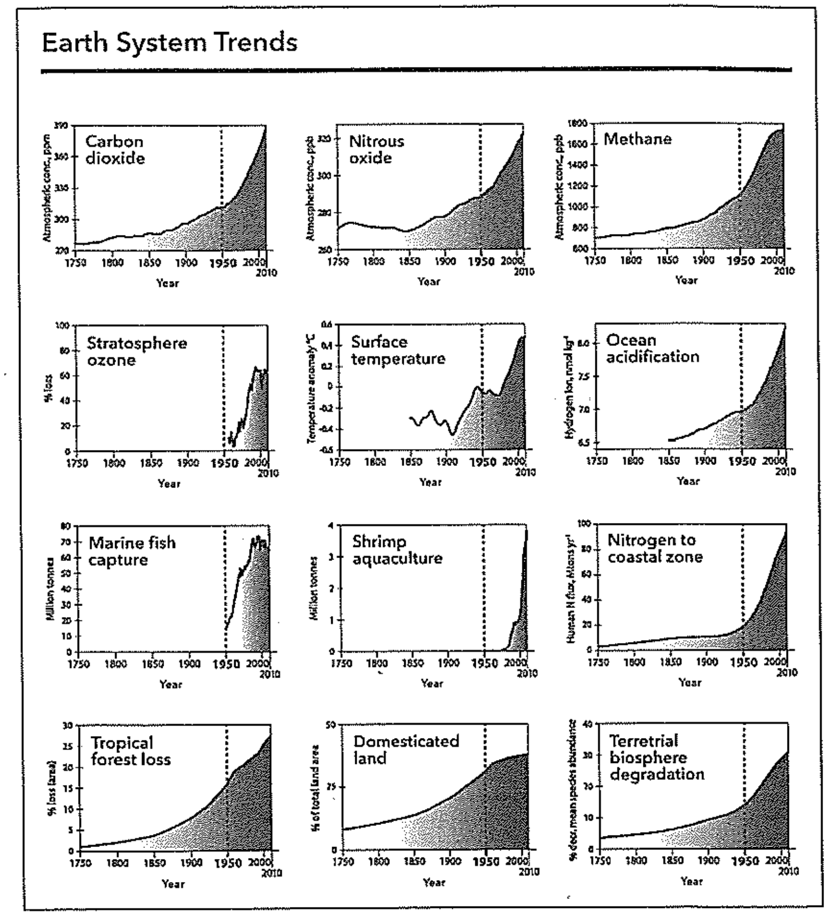
18 Erle Ellis and Navin Ramankutty, 'Anthropogenic Biomes', in *The Encyclopedia of Earth*, eoearth.org.



1a

Figure 1 (1a and 1b on facing page): *Dashboard display of the Anthropocene*
For these twenty-four parameters of the Earth system, a take-off can be observed around 1800, and a 'Great Acceleration' after 1945.[19]

19 Details on the source data for all figures are to be found as part of the Illustration Credits.



1b

Figure 1 gives a dashboard display of the Anthropocene, showing the evolution of twenty-four parameters of the Earth system since 1750. For the nine most important of these, a team of scientists from the Resilience Centre in Stockholm studied possible tipping points affecting biodiversity (the risk of collapse of certain 'services' that nature performs for us, such as pollination), air and atmosphere pollution, the intensification of biogeochemical cycles and the anthropization of land. They then set for each of these nine parameters a limit not to be crossed. For four of these, however, the limit (danger threshold of a sudden tipping of the Earth system into a catastrophic state) has already been approached (or passed): nitrogen cycle, greenhouse gas emissions, extinction of biodiversity and phosphate cycle.[20]

In order to agree to inscribe the Anthropocene in the series of geological epochs, however, stratigraphers are not content with models or predictions. What they need is something solid – sediment, a stratigraphic division that can be seen and measured here and now. Three arguments can be given here in support of the Anthropocene.

First of all, the level of atmospheric carbon dioxide has not been equalled for 4 million years (Pliocene), and future warming will lead the Earth to states unknown for 15 million years. The extinction of biodiversity is taking place with a suddenness matched only by five other episodes in the entire 4.5 billion years of life on Earth. The last extinction, which did away with the dinosaurs among others, goes back 65 million years and has left stratigraphic markers of the clearest kind. These phenomena, therefore, have the dual property of being caused by humans and being of a scale rarely noted in the geological past.

Secondly, the anthropic changes in the composition of the atmosphere have left traces even in the Antarctic ice cores. Extinctions and modified distributions of species (explosive invasions in the last few centuries, migrations bound up with climate change or the anthropization of biomes) cannot fail to leave fossil traces in the sediments. The transformations of lake-side and coastal fauna and flora caused by the human forcing of nitrogen and phosphorus cycles have also left a specific mark. As for the biomass of the 7 billion humans and their domestic animals, this makes up the predominant share of the overall

20 Anthony D. Barnosky, 'Approaching a State Shift in Earth's Biosphere'; Will Steffen et al., 'Planetary Boundaries: Guiding Human Development on a Changing Planet', *Science*, 347:6223, 13 February 2015.

biomass of terrestrial vertebrates, which will certainly appear remarkable to future palaeontologists.[21] Finally, the stratigraphic indication left by urbanization, dams, industrial production (the world automobile stock has reached 1,000 billion tonnes)[22] and mining and agricultural activity is notable and unique in the history of the Earth. It has even been recently shown that global warming, by modifying the volumes of glaciers, has an effect on volcanic and tectonic activity.[23]

Finally, entirely new substances deposited in the planet's ecosystems over the last 150 years (synthetic organic chemistry, hydrocarbons, plastics, some of which form a new type of rock,[24] endocrine disturbants, pesticides, radionuclides dispersed by nuclear tests, fluoride gases) constitute a typical signature of the Anthropocene in the sediments and fossils in the course of formation.

In a few million years from now, therefore, it is probable that geologists (if this profession typical of the Anthropocene survives), examining the rock deposits left by our epoch, will detect a transition as sudden as certain past somersaults in the Earth's billion-year history, such as the famous transition between the Cretaceous and the Tertiary 65 million years ago, when a meteor that hit what is now Central America led to the disappearance of three-quarters of the planet's species, including the dinosaurs. Yet today's geologists do not possess the strictly stratigraphic proof carved in the rock that they generally seek. Nonetheless, even if stratigraphers leave until later its validation in the official series of geological epochs, the Anthropocene thesis remains more robust in its wider geological definition, in terms of the sciences of the Earth system, than those of stratigraphy alone. This interdisciplinary field views the Earth as a complex system, from its core up to the high atmosphere, with subsystems (atmosphere, biosphere, hydrosphere, pedosphere, etc.) that are pervaded and connected by constant flows of matter and energy, in immense

21 Smil, *The Earth's Biosphere*, 186, 283–4.

22 Ibid., 269.

23 Bill McGuire, *Waking the Giant: How a Changing Climate Triggers Earthquakes, Tsunamis, and Volcanoes*, Oxford: Oxford University Press, 2012.

24 Patricia L. Korkoran, 'An Anthropogenic Marker Horizon in the Future Rock Record', *GSA Today*, 24:6, June 2014: 4–8.

feedback loops. In this perspective, as Jan Zalasiewicz, head of the Anthropocene Working Group of the International Commission on Stratigraphy explains, 'The Anthropocene is not about being able to detect human influence in stratigraphy, but reflects a change in the Earth system.'[25]

When did the Anthropocene begin?

If it is not the end of the world, it is certainly the end of an epoch: that of the Holocene, in which we have been living for the last 11,500 years. But at what time by the geological clock was the crime committed? Do we have to incriminate *Homo sapiens*, who appeared in Africa 200,000 years ago and went on to colonize Eurasia, the Americas and the Pacific islands? Did this species not bring about the disappearance of the megafauna (reptiles, birds and giant marsupials, the sabre-toothed tiger, the American lion, the European mammoth) by fire and hunting, everywhere that it settled? These transformations have left traces detected by geologists and archaeologists. Or should we locate the beginning of the Anthropocene just a few thousand years after that of the Holocene, as proposed by William Ruddiman, paleoclimatologist at the University of Virginia? Ruddiman argues that some 5,000 years ago humans had already emitted sufficient greenhouse gases – by deforestation, rice cultivation and stock-raising – to modify the Earth's climatic trajectory. These emissions and the warming they produced delayed the moment of entry into a new glacial episode. So, according to this controversial hypothesis, human action would already have contributed from the Neolithic age (as Buffon boasted in 1778!) to make the Holocene the longest interval of climate stability for 400,000 years (Figure 2). It was even this stabilization of the climate by human action in the Neolithic age that permitted the development of civilizations.

The problem with Ruddiman's thesis is that by focusing on the (slow) rise in CO_2 and methane emissions, on the deforestation and

25 Jan Zalasiewicz, response to Adrian J. Ivakhiv's 'Against the Anthropocene' blog post, *Immanence*, 7 July 2014, blog.uvm.edu.

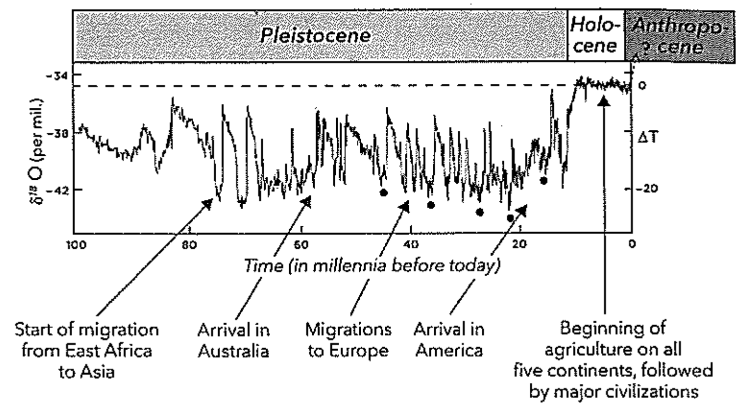


Figure 2: *Temperature and human history over 100,000 years. Note the remarkable stability of climate during the Holocene.*

agricultural practices of the Neolithic age, it does not take into account the changes of scale brought about by the industrial revolution. For Erle Ellis, who at one time supported this argument before rejecting it, it is only since the nineteenth century that humans have transformed the majority of biomes on the planet.[26]

At the end of the day, Ruddiman's evidence does not contradict that of an Anthropocene beginning with the industrial revolution. After having stabilized the Holocene climate in the Neolithic age (if this hypothesis is confirmed), since the nineteenth century humanity has started to bring the Earth out of the Holocene, entering an Anthropocene marked by sudden swings.

The British geographers Simon Lewis and Mark Maslin have recently proposed starting the Anthropocene with the European conquest of America. This major historical event, so fateful for the Amerindian people and foundational for a capitalist world-economy, did indeed leave its mark in our planet's geology. The unification of the flora and fauna of the Old and New Worlds caused an upheaval in the agricultural, botanical and zoological map of the globe, newly mingling in a biological globalization forms of life separated 200 million years earlier with the break-up of Pangaea and

26 Ellis, 'Anthropogenic Transformation of the Terrestrial Biosphere'.

the opening of the Atlantic Ocean. The demographic collapse of the Amerindian population (from between 54 and 61 million in 1492 to just 6 million in 1650, following the wars of conquest, infectious diseases brought by the Europeans, and forced labour) also had the effect of an urban and agricultural retreat and the reforestation of more than 60 million hectares of the American continent, which, by capturing CO_2, reduced the carbon concentration in the atmosphere from around 279 to 272 ppm between the start of the sixteenth century and 1610.[27] But if this low tide of atmospheric carbon is an ominous stratigraphic marker of one of the most terrible events in human history, the variation does not lie outside the general Holocene range of 260 to 284 ppm.

It was around 1809, under the effect of emissions caused by the growing use of coal, that the concentration of CO_2 reached the Holocene maximum (284 ppm), going on to reach 290 ppm by the mid nineteenth century. This time the break was of geological amplitude and not simply historical: the terrestrial atmosphere emerged from the Holocene in the early nineteenth century, and it was with the power of fossil fuels that human activities so profoundly transformed the Earth system's biology and geology (Figure 1), thus supporting Paul Crutzen's proposal of beginning the Anthropocene with the industrial revolution.

Other authors, such as the geologist Jan Zalasiewicz, chair of the Anthropocene Working Group, see unambiguous traces of a change of geological epoch in the mid twentieth century. The new radionuclides emitted into the atmosphere from 16 July 1945, when the first atom bomb was exploded in the Nevada desert, the novelty of petrochemical products and the sudden expansion in the use of synthetic nitrate fertilisers, all present very clear stratigraphic signals. The exponential acceleration of human impacts since the Second World War reinforces this hypothesis. The advantage of having the Anthropocene start at this time is that the type of proof sought by stratigraphers can be adduced right away (for example,

27 Simon L. Lewis and Mark A. Maslin, 'Defining the Anthropocene', *Nature*, 519, 12 March 2015: 171–80, nature.com.

the presence even at the poles of radioactive isotopes non-existent in nature).[28]

Other members of the community of Earth system scientists, as well as that of the human and social sciences, stand by Paul Crutzen's initial proposal to begin the Anthropocene at the end of the eighteenth century. For if 1945 presents an appropriate stratigraphic signal and indicates a destructive intensification of the Anthropocene, this belated date masks deeper causes and processes, and obscures the major rupture, both environmental and civilizational, of the entry into thermo-industrial society based on fossil fuels. In the present book, while discussing the importance of the conquest of America (Chapter 10) and the 'Great Acceleration' after 1945, our focus will be on the last quarter of a millennium.

Let us sum up. Succeeding the Holocene, a period of 11,500 years marked by a rare climatic stability (apart from the 'little ice ages', significant only on the scale of human history), a period of blossoming agriculture, cities and civilizations, the swing into the Anthropocene represents a new age of the Earth. As Paul Crutzen and Will Steffen have emphasized, under the sway of human action, 'The Earth currently operates in a state without previous analogy.'[29]

The advances in Earth system sciences presented in this chapter offer a new and fundamental regard on the Earth as a complex and fragile system, non-linear and ultimately highly unpredictable. By demonstrating the telescoping of the short timescale of human action and the long timescale of the Earth, these sciences have also opened a new field of investigation that is absolutely fundamental, at the intersection of the natural sciences and the humanities.

Contrary to the end of the Cretaceous period, or Lars von Trier's film *Melancholia*, the Anthropocene shock is not the result of a foreign

28 Jan Zalasiewicz et al., 'When Did the Anthropocene Begin? A Mid-Twentieth Century Boundary Level Is Stratigraphically Optimal', *Quaternary International*, 2015 (early online edition available at ib.berkeley.edu/labs/barnosky).

29 Paul Crutzen and Will Steffen, 'How Long Have We Been in the Anthropocene Era?' *Climatic Change*, 61, 2003: 251–7, 253.

body that strikes the Earth from outside and derails its geological trajectory. It is our own model of development, our own industrial modernity, which, having claimed to free itself from the limits of the planet, is striking Earth like a boomerang.