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Dörries, Matthias

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Politics, Geological Past, and the Future of the Earth

Matthias Dörries[*]

Abstract: *»Politik, geologische Vergangenheit und die Zukunft der Erde«*. From the 1940s, new technologies, like carbon dating, ice- and sea-core drilling, and pollen analysis not only vastly expanded time horizons in geophysical and climatological research, but also pinpointed past events on a newly historical timescale. Using natural proxy indicators, these studies brought to light a series of globally disruptive events in geological time, for example, volcanic eruptions of previously unknown scale and types that had also an impact on the Earth's climate. The past became discrete. Knowing more about the past also meant knowing more about possible futures, given that some catastrophic events have occurred repeatedly or have become increasingly predictable with the help of computer modeling. This meant that scientists' claims about the future of the earth increasingly came to interfere with politics and with traditional economic planning. The paper argues that the "new" past has come to weigh in two ways on the present and the future. First, it dwarfed the human time scale, thus increasing the challenge of dealing with heterogeneous time scales. Second, prehistoric past events came to take on political significance. The deep past became part of political history, and thus of politics.

Keywords: Deep time, political history, history of paleoclimatology, climate change, volcanology, geoengineering.

1. Introduction

In 1923, the British economist John Maynard Keynes asserted: "The long run is a misleading guide to current affairs. In the long run we are all dead" (Keynes 1923, 80). Ever since, the quotation has served as an argument on behalf of government action to soften economic recessions. Leaving aside the argument about government intervention in free markets, what does "the long run" mean here? In 1923, at the age of 40, Keynes could expect to live another 30 years or so. Hence, for him, economic recovery should come quickly – within a few years or a decade at most – so that he and others then alive could still profit from it. The frame of Keynes' timescale was roughly a generation, thirty years at most.

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[*] Matthias Dörries, Institut de Recherches Interdisciplinaires sur les Sciences et la Technologie (IRIST), Strasbourg University, 7 rue de l'Université, 67000 Strasbourg, France; dorries@unistra.fr.

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How much does Keynes' statement apply in the light of current debates on climate change? The most recent reports by the Intergovernmental Panel on Climate Change (IPCC) point to severe long-term consequences of on-going anthropogenic climate change for future generations and casts its eye on the end of the twenty-first century (IPCC 2013, 2014). The long run may well be the only guide for responsible action here and now. So, one may ask, under what conditions might the long run (several decades, hundreds, thousands, or perhaps even millions of years) be a good guide to current affairs? What time horizons are, or should be, used for scientific, political and ethical reasoning? What to do with the heterogeneous time-scales with which various disciplines work? What is responsible political action, in light of events that may (or may not) occur within a few decades (or centuries)? Current scientific projections of the Earth's future climate present a conundrum for society. When scientists make claims about the future of the Earth, they interfere with politics and with traditional economic planning, whose time horizon has typically been restricted to five years or to a decade at most.

Part of this discussion has been carried out in the political realm under the heading of intergenerational justice, mostly in reference to John Rawls' seminal 1971 book *A Theory of Justice* (Rawls 1971). My paper, however, does not aim to contribute to this normative discussion, which has kept political scientists, economists and philosophers busy over the last forty years. It examines how scientists and politicians came to ask and reflect upon these questions that currently dominate the scientific-political debate. Over the last few decades, scientists have started to pose new challenges to politicians by usurping the future. They were enabled to do so by digging out a whole new deep past, of thousands and millions of years, and by providing not only a flood of unprecedented historical data, but also by adding whole new kinds of previously unknown events to the Earth's past. While research over the last two hundred years had already dramatically expanded time horizons, this more recent research made the deep past much more concrete, pinpointing past events and their unfolding and duration with evermore confidence.[1] I argue that this new past has come to weigh on the presence and the future in two quite different ways: first, by expanding the dimensions of Earth's timescale, it further dwarfed human's timescale, and thus increased the challenge of dealing with such heterogeneity. Second, as events in the deep past began to inform both the present and the future, past events started to take on political significance. The deep past became part of political history, and thus of politics.

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[1] I will use the term 'deep past' throughout this article to refer to periods where proxy indicators only can be used for exploring the Earth's history. The notion of 'deep time' usually refers to the time before the Quaternary (the last 2.58 Ma), or, alternatively, the time before the Holocene (the last 11,700 years) (Caseldine 2012).

The first part of the article will briefly sketch out a few elements of the historical development of how science came to expand time horizons over the last two hundred years, and then look at the development of new research techniques beginning in the 1950s, which led to a new past, with direct consequences for politics. The second part will provide a case study drawn from research in volcanology, and explore how research in this area took on significance in the political arena.

2. Confronting a New Past and Conceiving a New Future

In the course of the nineteenth century, geologists and naturalists redrew the Earth's past, vastly expanding time horizons. This new past evaded easy comprehension. In his studies in geology and evolution in *On the Origin of Species*, Charles Darwin discussed the lapse of time and marveled at an "infinite number of generations, which the mind cannot grasp" (Darwin 1976 [1859], 287). Darwin relied on a series of geological and paleontological works of the late eighteenth century and early nineteenth century, which within a few decades had expanded the Earth's past from 6000 years, then the dominant number in Christian theology, to hundreds of millions of years. The past had become an endlessly evolving sequence of change, happening on cosmic time scales, a "unique sequence of distinctive events in geohistory," which replaced previous conceptions of "repetitive patterns that might reveal underlying 'laws of nature,' unchanging and ahistorical" (Rudwick 2008, 558; see also Rudwick 2005). The discovery of deep time in geology and biology rattled long-established beliefs, and it put ultimately human beings (*homo sapiens*) only at the very end of a geological process whose length escapes human comprehension.

Historians of science have extensively covered these developments for the nineteenth century, but have so far paid scarce attention to subsequent research in these fields (Weart 2003, 2014; Webb 1986). However, especially, during the second half of the twentieth century, scientists not only expanded the time horizon to billions of years, but also started to fill the past with specific events, of which there was no knowledge before. Already during the nineteenth century, scientists had made first steps in this direction, when they identified specific periods, such as the ice ages (Imbrie and Imbrie 1986). However, from the late 1940s, new technologies, like carbon dating, ice- and sea-core drilling, and analysis of corals and pollen, provided scientists with a flood of new data and profoundly transformed geophysical and climatological research. In 1947 the American chemist Willard Libby, of the University of Chicago, introduced radiocarbon dating, for which he received a Nobel Prize in 1960 (Libby 1967). Measuring amounts of the isotope ^{14}C allowed scientists to attribute ages to objects going back as far as 50,000 years. In 1954, Willi Dansgaard, of the University of Copenhagen, suggested that ice cores and the fraction of oxygen isotopes in them could serve as proxy indicators and be used to reconstruct past climates. Using ice cores from US military drillings in Greenland, Dansgaard provided early climate reconstructions in the mid-1960s, now going back 100,000 years (Dansgaard 2005; Langway 2008; Martin-Nielsen 2013). Likewise from the late 1940s on, deep core drillings in the Indian and Pacific Oceans allowed scientists to draw conclusions about large volcanic eruptions during the last 65 million years. They also established a link between the ice ages and variations of the Earth's orbit around the sun (Imbrie and Imbrie 1986). Increasingly refined dating made it possible to determine cycles of ice ages of roughly 100,000 years length. All these techniques filled the Earth's past with events whose existence and duration had been previously unknown. These studies also brought to light a series of globally disruptive events in geological time, for example, volcanic eruptions of previously unknown scale and types or prolonged basaltic flood lava eruptions (on the paleohistorical timescale). In addition, these new techniques also provided clues to unknown more recent events not recorded directly in the human archives (in the form of, for example, grain prices, reports about crops, or death rates), such as a major volcanic eruption in 1257, for which researchers seem recently to have found the exact location (Lamb 1977; Lavigne et al. 2013).

One important consequence of this new research was that it made it possible to pinpoint specific events in the deep past, thus unlayering yet another qualitatively new kind of past of the Earth. Paleoscientists speak of event stratigraphy (Caseldine 2012, 331). Scientists were now able to portray a deep past that was increasingly textured and discrete. With this new research the past was no longer an incomprehensibly long time period far outside the human timescale, as it had been for Darwin. Rather, it became filled with specific events, on a scale that human reason could grasp. By becoming discrete and textured, the past took on a new quality: it started to make sense. Going beyond merely ordering past events on a timeline and establishing chronologies, researchers started to interpret these events, to write a history of the deep past. The deep past was no longer a largely unexplored area of cosmic dimensions, but had started – at least in parts – to acquire meaning for the researchers. Giving texture to past events, also meant saying more about their duration and impact. Here, for example, scientists were able to reduce the duration of some events from cosmic dimensions (100,000 years, as for the ice ages) to familiar human timescales of decades or even years (as for volcanic eruptions).

This new past could also now be projected onto the present and future of the Earth. Having acquired relevance to the present, the past weighed on the future. The new knowledge brought with it a whole new set of social and political challenges, and marked the beginnings of a political history of the geological deep past. Events in the deep past began to matter in various ways: they put the current century into a larger perspective; they showed the continuities and discontinuities of the Earth's past; they pointed to potential threats and dangers lying ahead in the future; they provided a baseline from which to distinguish anthropogenic influence. The deep past has come to play a decisive role in framing political questions and decisions for our future, particularly concerning climate change. I turn now to one case study, drawn from my own research on volcanism and climate change (Dörries 2006, 2008), of how scientists and politicians make sense of this newly discovered past and how they frame these events for political purposes.

3. Volcanic Eruptions and Climate Change

The case study looks at a field of research that has attracted great attention in recent decades. Studying the effects of large explosive volcanic eruptions on global temperatures has been at the cutting edge of research beginning in the 1980s. Large explosive volcanic eruptions affect global temperatures for a period of one or two years, and thus provide excellent tools to calibrate and test existing climate models, which are central to the debate on anthropogenic climate change. But there was yet another reason why these studies figured so prominently in geophysical research in the 1990s: in 1991, Mt. Pinatubo, in the Philippines, erupted spectacularly. This eruption, one of the biggest in recent decades, was the most closely watched in history, and led to a flood of new data. Early results were discussed at an AGU conference in 1992. Ten years later, in 2002, researchers had calibrated their models and were able to present definitive and path-breaking studies at another AGU conference on "Volcanism and Climate Change" (Robock and Oppenheimer 2003) in Santorini, Greece.

However, at the 2002 conference it was already clear that the scientists were desperately waiting for new data. Now quite confident about modeling volcanic eruptions in the equatorial regions, they needed a large explosive eruption in the higher latitudes to test their models and hypotheses. They are still waiting to this day. Nature does not accommodate researchers, particularly those who work on natural events, such as volcanic eruptions that happen on an irregular schedule. Decades may pass before new data may flow, and some of the key researchers at the time are today approaching retirement. At a third AGU conference on "Volcanism and the Atmosphere," held in 2012 in Iceland (Robock 2013), researchers were still awaiting additional data (so marked time among other things with the issue of volcanism and air traffic, a concern that loomed large in the aftermath of the disruptive 2010 Icelandic Eyjafjallajökull eruption).

What I find intriguing here is how their object of study, large explosive eruptions with perturbing effects on the atmosphere, affects individual research careers, research methods and empirical approaches. Singular large natural events of a global scale attract researchers from many disciplines and focus their research. They dictate research patterns and strategies, not least because of the public attention and the funding that comes with them. But there is a vexing obstacle: the human lifetime does not fit the geological or geophysical timescale. Large geophysical events may happen only a few times (or never at all) during the lifetime of a researcher. This has an important consequence for how research in the field of volcanism and climate change is done: to make up for this deficit of contemporaneous data for calibrating their computer models, researchers have no alternative than to turn to historical data.

Many of the researchers began to work on reinterpretations of past volcanic eruptions and climatic changes, ranging from more recent human history to paleohistorical studies. For example, the spectacular eruption of Krakatau in the Netherlands East Indies in 1883, which had been thoroughly studied by Dutch and British researchers at the time, provided a valuable parallel to Pinatubo, comparable in size and also located in the equatorial region. Historical and more recent studies inform each other in an interesting back-and-forth. Krakatau provided data that were incorporated into modeling of future volcanic eruptions. Conversely, Pinatubo led scientists to revisit the past, including the eruption of Krakatau, and they reinterpreted the historical data in the light of the new data obtained from the Pinatubo eruption.

Geophysicists compensated for the slow pace of geophysical events by turning towards the past. A large part of the conference was devoted to so-called proxy indicators, such as pollen analysis, tree ring records, corals, marine sediments and ice cores. Using physical or biophysical characteristics, proxy indicators provide a record of the past climate variations.[2] They were particularly helpful for those past events, for which researchers either did not or could not have human reports and data, because they lay outside human memory or written records. A whole series of past events was newly detected by using a variety of new methods.

Using natural proxy indicators, these studies brought to light a series of globally disruptive events in deep time, among them explosive volcanic eruptions of previously unknown scale – like the Quaternary eruption of Toba in Sumatra, which happened approximately 74,000 years ago and is currently the most widely studied historic case of a large-scale explosive eruption. Toba came at the beginning of a line of research that identified a whole series of previous "super-eruptions." The Earth's past in the 1980s had become quite different from its past in the early 1960s.

Already in the nineteenth century, geologists described a huge caldera lake in the middle of Sumatra. However, they were unable to provide a date for the

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[2] The Fifth Assessment Report of the IPCC defines proxy indicators as follows: "A proxy climate indicator is a record that is interpreted, using physical and biophysical principles, to represent some combination of climate-related variations back in time. Climate related data derived in this way are referred to as proxy data. Examples of proxies include pollen analysis, tree ring records, speleothems, characteristics of corals, and various data derived from marine sediments and ice cores. Proxy data can be calibrated to provide quantitative climate information." (IPCC 2013, Annex III, 23).

eruption that formed it. The new dating technologies of the 1960s and 1970s made this possible: they transformed a (timeless) geological formation into a past event. In 1976, Dragoslav Ninkovich and William L. Donn, of the Lamont-Doherty Geological Observatory, identified a very large eruption when they studied the climatic impact of explosive volcanic eruptions during the last 65 million years (the Cenozoic era), with the help of sea cores (Ninkovich and Donn 1976). Their results were published in a *Science* article stressing the "strong impetus in recent years" for "the study of climate dynamics." (Ninkovich and Donn 1976, 899). A comparative study of various sea cores in East and Southeast Asia allowed them to look into geologic time. They worked with piston cores of limited depth, and a few deep sea drilling cores from the DSDP (Deep Sea Drilling Project), that ranged back some 60 million years. The two authors identified Toba as the cause and proposed that Toba erupted some 70,000 years ago, leaving a caldera with dimensions of 30 km to 100 km, from an eruption volume of 2000 cubic kilometers (which they compared to the puny 70 cubic kilometers for Santorini), which might possibly have affected the Earth's climate during an already existing Cenozoic cooling trend. Ninkovich and Donn pointed to existing difficulties in establishing correlations on a global scale among deep-sea records, as well as in the analyses of the vertical record of the cores. However, they continued:

> It is true […] that some explosive volcanism in the geologic past greatly exceeded in magnitude that in the historic past. Such events, when occurring at critical times of climate evolution, might have strongly modulated the intensity of climate change (Ninkovich and Donn 1976, 906).

In all likelihood, Toba had had climatic and environmental consequences for the whole Earth. Two years later, Ninkovich et al. (1978) were able to provide more precise data for the Toba ash layer and its distribution over Asia, and to date Toba's eruption to some 75,000 years ago. Toba figured in the 1970s as the largest detected explosive volcanic eruption of the Quaternary, the last 1.8 million years. As it erupted after the evolutionary appearance of human beings, it came to stand for a threat to human civilization, and stimulated spirited debates in the 1990s. Was it responsible for a so-called genetic bottleneck in human evolution (Ambrose 1998)? Could genetic research be successfully linked to geological research? At the time of the Toba eruption, humans had migrated out of Africa, along the shores of the Asian continent, into the Indian continent. However, *homo sapiens* was not yet a global species. The argument was that the eruption, with its massive influence on climate and weather, led to mass deaths due to famine and almost extinguished the human species. This question is still under debate, and a resolution depends on what extent researchers will be able to provide an exact timeline of the events. The debate about the genetic bottleneck brought in the human dimension. Toba was no longer just a past geological event; it had now possibly been also a human catastrophe.

Knowing more about Toba also meant knowing more about possible futures. Once work with proxy indicators became more routine and calibrated, other large explosive volcanic eruptions came into focus. Toba now stood in a line of some fifty or so so-called “super-eruptions,” extending into the deep past of the Earth (Mason, Pyle and Oppenheimer 2004). Given that these catastrophic events have occurred repeatedly, scientists felt increasingly confident in predicting that they will happen again in the future. I do not mean here predictions of a very short timescale, like those based on monitoring that allows scientists to predict imminent volcanic eruptions with a high degree of probability. I have in mind rather a qualitative prognostication, of the kind ‘This will happen again,’ made on the basis of certain eruption patterns in the Earth’s past. Toba’s newly discovered history weighed on the present: what to do with the fact that these super-eruptions have occurred repeatedly, though not regularly, over the course of the last millions of years? And further ahead: how to deal with the future threat of a super-eruption? What to do, practically, about an event that could happen any time in the next few decades, but generally happens, on average, let’s say, once in a hundred thousand years? What is reasonable to do? Is it worth spending time and money on this? Does it make sense to expand the catalogue of future apocalyptic scenarios?

In the aftermath of the 2004 tsunami in Asia, the British government formed an expert group, the Natural Hazards Working Group (NHWG) that looked at global risks of rare occurrence but high impact – among them volcanic super-eruptions. This gave some scientists a good reason to worry publicly about super-volcanoes. As part of this initiative, the British Geological Society of London published a report called *Super-eruptions: Global Effects and Future Threats*, a manifesto to convince the British government to take action in these matters.

The report begins with the ominous and worrisome observation: “It’s not a question of ‘if’ – it’s a question of ‘when’”, a question to which nobody has an answer. After introducing super-volcanoes and comparing their impact on the Earth with those of asteroids, the report insists on the statistically higher probability of super-eruptions, “five to ten times more likely to occur within the next few thousand years than an impact [of an asteroid]” (Sparks et al. 2005, 1). Noticeable is here the scale suggested in this line of reasoning: a few thousand years. The threat is neither presented as imminent, within the lifetime of the human beings currently existing on the Earth, nor as belonging to a very distant future (let us say one hundred thousand years). It is located rather in a future of thousands of years, thus, within the familiar time dimensions of human civilization. The future event is presented as one that may “threaten the fabric of civilization,” implicitly located in the Western world: “an area of the size of North America or Europe could be devastated.” In the light of such possible destruction from a super-eruption for the authors, “preparedness is the key to mitigation,” and they stress the need for the “world community” to come up with “preparation plans” (Sparks et al. 2005, 2, 20). The authors ask:

> What might happen if several billion people needed evacuation from most of Asia, and, simultaneously, three or four years of severe volcanic winter threatened agriculture throughout North America and Europe? This is not fanciful, but the kind of acute problem and inevitable consequence of the next super-eruption (Sparks et al. 2005, 20).

I leave aside the airily implausible scenario of evacuating "several billion people." Rather, I focus on the authors' reasoning, which shows a mixing of incompatible timescales.

When they talk about mitigation, they take the present (current human civilization) as the standard for reasoning. The text exemplifies the dilemma of heterogeneous timescales: although the likelihood that the event will strike in the next decades is slim, we should be ready here and now. On the other hand, they first present super-volcanoes as a problem that is reasonably discussed in timescales of a few thousand years. Within a perspective of thousands of years, the likelihood that humans, and human civilization, if not indeed the Earth, will be different is surely higher than not at the time of a postulated future super-eruption. The authors try to align human and natural timescales by talking, abstractly, on the one hand about a long-lasting civilization of a few thousand years, and, on the other, by reducing the natural geological timescales to thousands of years. Natural hazards are thus brought within familiar human time scales to make sense of them; they are domesticated. Moreover "civilization" apparently has no other meaning in this context than the simple long-term survival of human beings after a super-eruption. Here two different ways of reasoning within time scales stand juxtaposed: the individual human with a lifetime of decades, and the human species with a million-year history. In this line of reasoning, individual human beings play no role, striking, given that the difference between individual human beings, and humanity as an abstraction, figures prominently in political and philosophical debates over intergenerational justice.

This reasoning correlates with another line of the authors' argumentation. As they focus on "long-term consequences for the global community," the authors compare natural events with anthropogenic events, such as climate change or nuclear waste disposal. In a section on public perception and risk, addressed to "modern politicians and decision-makers," the authors set out to compare the risk of nuclear waste disposal to the risk from super-eruptions, given that both imply geological time scales. They reason as follows: it is likely that tens of millions of people will die over the next 100,000 years from a super-volcanic eruption, whereas storage of nuclear waste may affect adversely only a few people. While they admit briefly that the "huge time periods involved make such comparisons difficult," they nevertheless hammer their argument for the study of super-eruptions home again:

> Enormous amounts of human effort and financial resources are allocated to the nuclear waste problem, which with existing technology is only likely to lead to a small number of deaths over a period 30 times longer than recorded human history. In contrast, natural events, which are inevitable and could even

> threaten civilisation, are currently not recognized as a problem (Sparks et al. 2005, 17).

For the sake of preserving civilization, they conclude, current resources should be invested in remote natural hazards. Some people already have been thinking about technological fixes for averting the consequences of supervolcanoes. The American scientist Michael Rampino, of New York University, suggested in 2002 a "repository for terrestrial civilization […] a backup system for the planet, fostering recovery of terrestrial civilization in the wake of global disasters," the survival of some abstract humanity being a synecdoche for the Earth's entire biosphere (Rampino 2002, 566).

4. The Environmental Movement and the Extension of Time Horizons

The rapidly changing practices and technologies in the field of volcanism and climate change were part of a larger development of the 1960s and 1970s that led first scientists and subsequently politicians to consider taking a longer view. Not only did this research provide new data of the deep past with relevance for politics, as shown above, but it also challenged the usual time framework of political reasoning. The rise of environmental sciences and environmental movement during the 1960s gave voice to new worries about the long-term consequences of unlimited growth and industrialization, the environmental degradation, and the exhaustion of resources that had been built up incrementally over millions of years. The emphasis on long-term consequences of human action led to clashes with standard political practices and beliefs of the time, as it extended the political time horizons from years to decades.

This point can be illustrated here with one example from the early 1970s – the polemical book *The Doomsday Syndrome* (Maddox 1972) by the British journalist John Maddox, editor of *Nature* at the time. Published in 1972, the book virulently attacked long-term "prophecies of calamity" by authors like Rachel Carson in *Silent Spring* (Carson 1962), Paul Ehrlich in *The Population Bomb* (Ehrlich 1968), and Barry Commoner in *The Closing Circle* (Commoner 1971). For Maddox, the rising ecological and environmental movements, particularly in their radical version, with their speculative assumptions, were irrational at the core. Thinking in long-term future worst-case scenarios meant underestimating human ingenuity in solving challenging problems of the future. In the best Enlightenment tradition, Maddox remained optimistic.

Maddox reasoned on timescales different from his opponents. Whereas Carson, Ehrlich and Commoner might have been thinking about decades, a century or more, Maddox reasoned in terms of years. Where the environmentalists saw the present as dangerously determining the long-term future of the Earth and human beings, he regarded the future as open, largely malleable to human purposes at any moment.

Maddox himself framed the problem as one of time-scale: “On what horizon should well intentioned people fix their gaze?” (Maddox 1972, 4). For him it was much more important to focus now on current “poverty, injustice and avoidable death,” instead of a “preoccupation with distant calamity” (Maddox 1972, 9). Addressing vague future problems was an unwelcome distraction from the truly urgent problems the world faced at the present. For Maddox, “doomsday science was politically irresponsible, economically damaging, and potentially authoritarian (though apparently liberal in disguise).” Prophets of doom advocated political and social change to avoid future problems, leading for Maddox, to a “strange affiliation between liberal ideas and authoritarian methods” (Maddox 1972, vi). Maddox believed “ecology” was no longer a scientific discipline, but a political slogan.

In a postscript to the book, Maddox reacted to the contemporary publication of *Limits of Growth* (Meadows et al. 1972) by the Club of Rome, which he dismissed as “pretentious nonsense.” While sympathetic in principle to a quantitative computer-based approach, Maddox deplored oversimplification due to the necessary aggregation in the description of the world. For example, non-renewable resources were represented by a single number. However, Maddox argued, “the history of the past few decades has shown clearly enough that relatively scarce materials are constantly being replaced by more common ones” (Maddox 1972, 285). Scientific research and innovation, together, with economic market mechanisms, had taken care of that during the past decades and would do so in the future. In short, the Club of Rome model did not correspond to what Maddox called the “real world.” When the Club of Rome presented its model as an “admonitory projection into the future,” it rather looked to Maddox like “a familiar academic escape from responsibility” (Maddox 1972, 287).

Maddox’s time scales remained within the political framework of election cycles, roughly four or five years. The longer-lasting future environmental challenges and past disasters newly identified by scientists during the 1960s and 1970s did not fit this frame. He did not deny possible long-term environmental problems, but he put his hope into new discoveries and innovations, which would guide a way out of existing dilemmas. Maddox’s outlook is therefore politically conservative: the current political and economic system is capable of dealing with future problems thanks to its responsiveness, flexibility and dynamism. There is no need for political change; only for scientific and technological change, and innovation.

5. Conclusion: Geoengineering, the Past and the Future

Maddox's book presaged subsequent environmental debates, including climate change. Over recent decades, climatologists have increasingly made long-term predictions about the future of the Earth's climate. They have done so by reconstructing climates of the past and, with the help of models, using these data to identify anthropogenic climate change. This research had immediate political significance.

I will limit myself here to just one aspect of this debate, which again picks up the research on volcanism and climate change. For scientists, this line of research has not only served over the last decades to discover a past history of the climate and to calibrate climate models (as large-scale explosive eruptions have a short-term effect of one or two years on global surface temperatures), but it has also become, by way of analogy, a potential technical solution to the problem of anthropogenic climate change.

In a 2006 article, "Albedo enhancement," the atmospheric scientist and Nobel Prize winner Paul Crutzen suggested artificially injecting SO_2 into the stratosphere to reflect sunlight (like the volcanic eruptions of Pinatubo or Toba) and thus contribute to reducing the Earth's surface temperatures. Crutzen firmly put geoengineering, the deliberate modification of the Earth's global climate, on the scientific and political table. By directly addressing the delicate issue of massive deliberate human intervention on the whole Earth, Crutzen transgressed the limits of his own community; his colleagues refrained from addressing this topic. Crutzen justified his radical step by pointing to a "policy dilemma," to politicians' supposed incapacity to reduce CO_2 emissions. Given the "grossly disappointing international political response to the required greenhouse gas emissions," he painted possible catastrophic scenarios of global temperature rises of up to 5 °C within a few decades (Crutzen 2006, 214). Such exceptional circumstances, Crutzen argued, might require exceptional means.

Crutzen developed his arguments in two ways. First, like Maddox's environmentalists, he began with the assumption of worst-case scenarios. He then, unlike Maddox's environmentalists, he refrained from proposing political or social change and focused on a technological fix. Geoengineering was presented as an ad-hoc solution to a sudden potential catastrophic climate switch.

For Crutzen the deep past had become scientifically and politically relevant in a different way from Toba above: the deep past served not as a warning of recurring catastrophic events, but now rather as a reference point, by which to recognize the uniqueness of the current situation, which in turn required a unique solution, geoengineering. Crutzen coined a new term, the Anthropocene, which highlighted this uniqueness and served as a warning signal that showed how rapidly human beings were changing the face of the Earth in comparison to previous slow geological change. The Anthropocene stands for something radically new, a rupture with the Earth's previous history, its recent and deep past. Humans' increasing influence on the global environment had started for Crutzen two hundred years ago, with industrialization and the steam engine. Crutzen explained this divergence from the (geo)historical path with alarm: "Earth system is increasingly in the non-analogue condition of the Anthropocene" (Crutzen 2006, 217). Within a few decades, human beings have brought about changes to the Earth of magnitude that usually have taken place over hundreds of thousands or millions of years. The concept of the Anthropocene is provocative, in that it introduces as a geological era a period that so far has lasted only two hundred years. Confronted with this disturbing new heterogeneity of geological periods, the community of geologists still debates whether to officially adopt the Anthropocene.

The non-analogue, unique condition of the Anthropocene, revealed by the study of the deep past, ultimately prompted Crutzen to make his daring proposition of global geoengineering as a solution to rapid anthropogenic climate change (Crutzen and Stroemer 2000; Crutzen 2002). The Earth's new deep past serves as an argument for political and scientific action.

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