2000

The "Anthropocene"

PAUL J. CRUTZEN AND EUGENE F. STOERMER

The name Holocene ("Recent Whole") for the post-glacial geological epoch of the past ten to twelve thousand years seems to have been proposed for the first time by Sir Charles Lyell in 1833, and adopted by the International Geological Congress in Bologna in 1885 (1). During the Holocene mankind's activities gradually grew into a significant geological, morphological force, as recognised early on by a number of scientists. Thus, G. P. Marsh already in 1864 published a book with the title "Man and Nature," more recently reprinted as "The Earth as Modified by Human Action" (2). Stoppani in 1873 rated mankind's activities as a "new telluric force which in power and universality may be compared to the greater forces of earth" [quoted from Clark (3)]. Stoppani already spoke of the anthropozoic era. Mankind has now inhabited or visited almost all places on Earth; he has even set foot on the moon.

The great Russian geologist V. I. Vernadsky (4) in 1926 recognized the increasing power of mankind as part of the biosphere with the following excerpt ". . . the direction in which the processes of evolution must proceed, namely towards increasing consciousness and thought, and forms having greater and greater influence on their surroundings." He, the French Jesuit P. Teilhard de Chardin and E. Le Roy in 1924 coined the term "noösphere," the world of thought, to mark the growing role played by mankind's brainpower and technological talents in shaping its own future and environment.

The expansion of mankind, both in numbers and per capita exploitation of Earth's resources has been astounding (5). To give a few examples: During the past 3 centuries human population increased tenfold to 6000 million, accompanied e.g. by a growth in cattle population to 1400 million (6) (about one cow per average size family). Urbanisation has even increased tenfold in the past century. In a few generations mankind is exhausting the fossil fuels that were generated

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over several hundred million years. The release of SO_2, globally about 160 Tg/year to the atmosphere by coal and oil burning, is at least two times larger than the sum of all natural emissions, occurring mainly as marine dimethyl-sulfide from the oceans (7); from Vitousek et al. (8) we learn that 30–50% of the land surface has been transformed by human action; more nitrogen is now fixed synthetically and applied as fertilizers in agriculture than fixed naturally in all terrestrial ecosystems; the escape into the atmosphere of NO from fossil fuel and biomass combustion likewise is larger than the natural inputs, giving rise to photochemical ozone ("smog") formation in extensive regions of the world; more than half of all accessible fresh water is used by mankind; human activity has increased the species extinction rate by thousand to ten thousand fold in the tropical rain forests (9) and several climatically important "greenhouse" gases have substantially increased in the atmosphere: CO_2 by more than 30% and CH_4 by even more than 100%. Furthermore, mankind releases many toxic substances in the environment and even some, the chlorofluorocarbon gases, which are not toxic at all, but which nevertheless have led to the Antarctic "ozone hole" and which would have destroyed much of the ozone layer if no international regulatory measures to end their production had been taken. Coastal wetlands are also affected by humans, having resulted in the loss of 50% of the world's mangroves. Finally, mechanized human predation ("fisheries") removes more than 25% of the primary production of the oceans in the upwelling regions and 35% in the temperate continental shelf regions (10). Anthropogenic effects are also well illustrated by the history of biotic communities that leave remains in lake sediments. The effects documented include modification of the geochemical cycle in large freshwater systems and occur in systems remote from primary sources (11–13).

Considering these and many other major and still growing impacts of human activities on earth and atmosphere, and at all, including global, scales, 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. The impacts of current human activities will continue over long periods. According to a study by Berger and Loutre (14), because of the anthropogenic emissions of CO_2, climate may depart significantly from natural behaviour over the next 50,000 years.

To assign a more specific date to the onset of the "anthropocene" seems somewhat arbitrary, but we propose the latter part of the 18th century, although we are aware that alternative proposals can be made (some may even want to include the entire Holocene). However, we choose this date because, during the past two centuries, the global effects of human activities have become clearly noticeable. This is the period when data retrieved from glacial ice cores show the beginning of a growth in the atmospheric concentrations of several "greenhouse

gases," in particular CO_2 and CH_4 (7). Such a starting date also coincides with James Watt's invention of the steam engine in 1784. About at that time, biotic assemblages in most lakes began to show large changes (11–13). Without major catastrophes like an enormous volcanic eruption, an unexpected epidemic, a large-scale nuclear war, an asteroid impact, a new ice age, or continued plundering of Earth's resources by partially still primitive technology (the last four dangers can, however, be prevented in a real functioning noösphere) mankind will remain a major geological force for many millennia, maybe millions of years, to come. To develop a world-wide accepted strategy leading to sustainability of ecosystems against human induced stresses will be one of the great future tasks of mankind, requiring intensive research efforts and wise application of the knowledge thus acquired in the noösphere, better known as knowledge or information society. An exciting, but also difficult and daunting task lies ahead of the global research and engineering community to guide mankind towards global, sustainable, environmental management (15).

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Commentary

Paul J. Crutzen and Eugene F. Stoermer, "The 'Anthropocene'" (2000)

WILL STEFFEN

It is entirely fitting that the first attempt to define the Anthropocene appeared in the newsletter of the global change research program IGBP (International Geosphere-Biosphere Programme) rather than in one of the mainstream scientific journals. The term was introduced in 2000 by Paul Crutzen and Eugene Stoermer in *IGBP Newsletter* 41.

This publication was a crystallization of Paul Crutzen's first use of the term Anthropocene during a discussion at a meeting of the IGBP Scientific Committee in Cuernavaca, Mexico, in February 2000. Scientists from IGBP's palaeoenvironment project were reporting on their latest research, often referring to the Holocene, the most recent geological epoch of earth history, to set the context for their work. Paul, a vice-chair of IGBP, was becoming visibly agitated at this usage, and after the term Holocene was mentioned yet again, he interrupted them: "Stop using the word Holocene. We're not in the Holocene any more. We're in the . . . the . . . the . . . (searching for the right word) . . . the Anthropocene!"

The newsletter article built on this impromptu comment and began to flesh out what he actually meant by it, but it was by no means the first suggestion that human activities were beginning to have global impacts. For example, George Perkins Marsh in 1864 published *Man and Nature* and in 1874, *The Earth as Modified by Human Action*, and Italian geologist Stoppani in 1873 compared human activities to the great forces of earth. Twentieth-century commentators on the rising human impact on the global environment included Eduard Suess, Pierre Teilhard de Chardin, and Vladimir Vernadsky (see Part 5). However, the Crutzen/Stoermer article in 2000 made two explicit points that greatly furthered usage of the Anthropocene both as a term and as a concept. First, they proposed "to use the term 'anthropocene' for the current geological epoch" and then later suggested that "to assign a more specific date to the onset of the 'anthropocene' seems somewhat arbitrary, but we propose the latter part of the 18th century." So even at this first usage they proposed that the term Anthropocene be formalized to replace the Holocene as the current geological epoch, and they even suggested a historical start date for the new epoch.

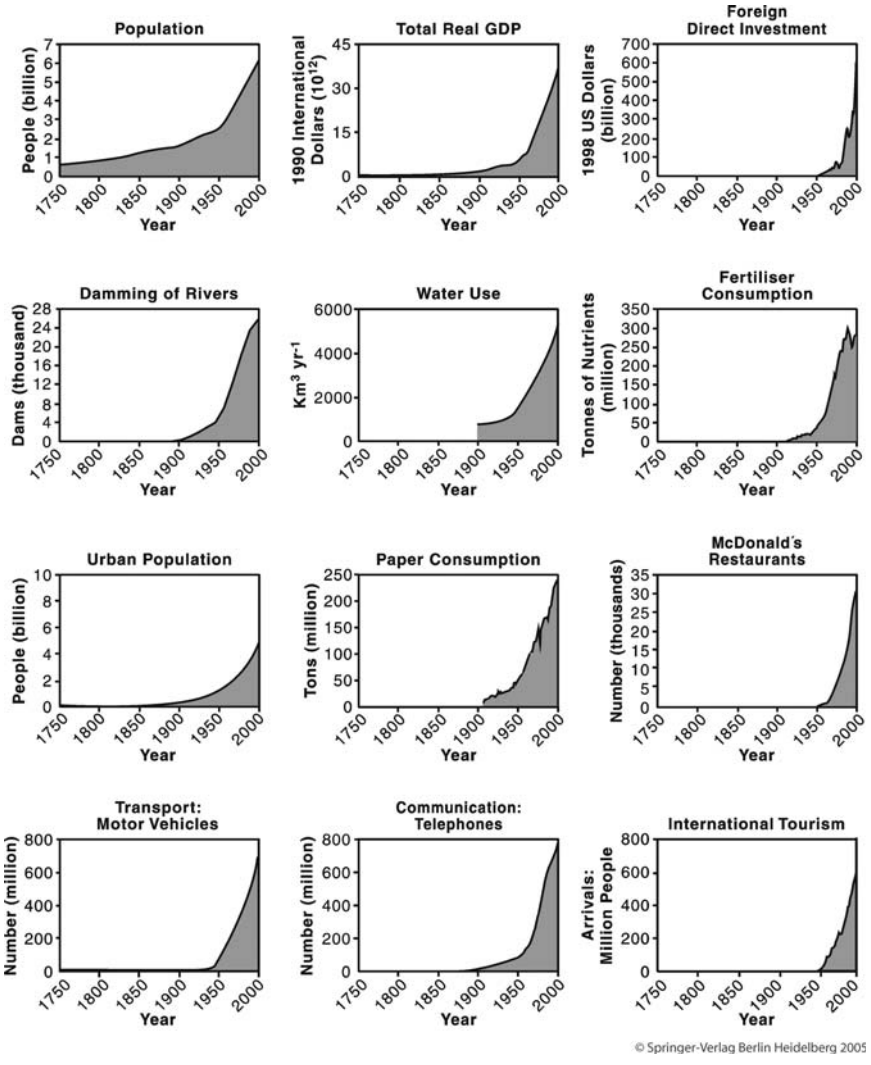
The introduction of the term Anthropocene coincided with the IGBP synthesis project, a synergy that benefited both. Given Paul Crutzen's senior leadership role in the Programme, the concept of the Anthropocene became rapidly and widely used throughout the IGBP as its projects pulled together their main findings. The Anthropocene thus became a powerful concept for framing the ul-

timate significance of global change. The overall IGBP synthesis volume, which was published in 2004 (Steffen et al. 2004), contained two figures, included here as Figures 1 and 2, which have become widely reproduced as a visual depiction of the Anthropocene. These figures show many shifts in the global environment over the past two centuries away from Holocene patterns and limits. These changes include changes in not only climate, but also in stratospheric ozone, biodiversity, land cover, structure of marine and coastal ecosystems, the water cycle, and the biogeochemical cycles of carbon, nitrogen, phosphorus, and sulfur. Coincident with these global changes in the environment are equally impressive changes in the human enterprise, including population, economic activity, resource use, and connectivity. The evidence for a connection between human activity and change in the global environment is strong. The period from 1950 to 2000 stands out as one of the most remarkable in all of human history for its rapidity and pervasiveness of change, and it is now often called "The Great Acceleration."

Beyond the synthesis project itself, the IGBP research networks and broader community, which numbers thousands of scientists in about seventy countries around the world, played a central role in the spread of the term Anthropocene throughout the global change research community and beyond. Primarily because of its usefulness as a concept in global change research, the term appeared more and more frequently in the scientific literature, albeit still informally, to refer to the post–Industrial Revolution period of intertwined human and environmental change. This rapid spread of the term is in contrast to the 1980s, when Eugene Stoermer began using "anthropocene," but it never caught on then in the wider research community.

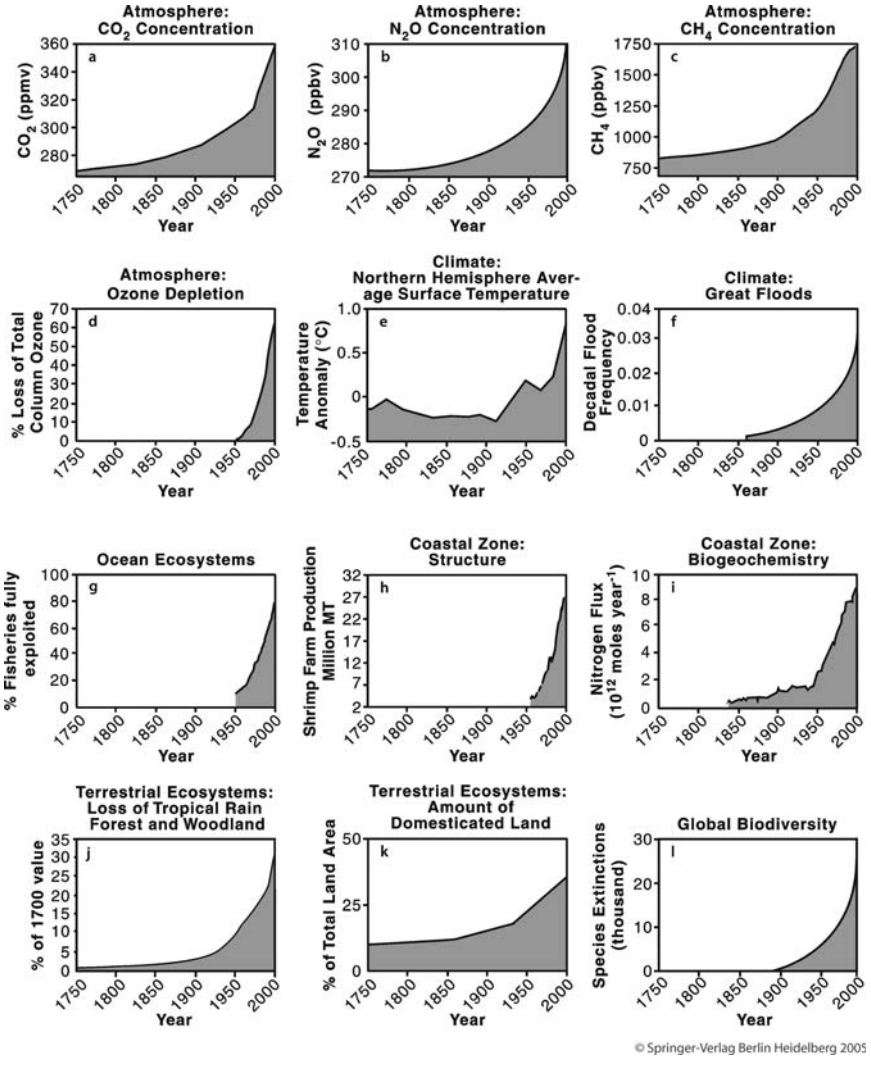
Later, in the first decade of the twenty-first century, the Anthropocene concept spread beyond the global change research community and into the mainstream geological community. In 2009 Jan Zalasiewicz and Mark Williams, both stratigraphers based at the University of Leicester, took the lead in the next step—the possible formalization of the term as the next geological epoch in earth history. They formed the Anthropocene Working Group of the Subcommission on Quaternary Stratigraphy (International Commission on Stratigraphy), whose task is to amass the geological (primarily stratigraphic) evidence that the earth has indeed been driven out of the Holocene by human activities and has entered a new geological epoch. The process of formalization is rather tortuous, and the case must be strong enough to convince a series of commissions and subcommissions in the international geological community.

A key event in the formalization process was a workshop in May 2011 at Burlington House in London, organized by the Geological Society of London. The focus of the workshop shifted the emphasis from global change science to the types of evidence in the geological record that would confirm the Anthropocene



The development of the human enterprise from 1750 to 2000. Further details and references for individual data sets are given in Steffen et al. 2004.

as a new epoch. The participants were mainly from the geological sciences, and the change in the mood of the group as the workshop unfolded was fascinating. Beginning from a position of skepticism, as good scientists should, the participants pointedly questioned whether human activities could really challenge the great forces of nature. As speaker after speaker demonstrated via observations that the



The growing human imprint on the Earth System from 1750 to 2000. Further details and references for individual data sets are given in Steffen et al. 2004.

imprint of the human enterprise was already clear in many stratigraphic features of earth, the mood changed to one of excitement. Participants began to put themselves into the position of geologists centuries or millennia in the future, looking back on this remarkably sharp and profound period of environmental change and speculating on what they would actually find in the stratigraphic record.

When did the Anthropocene start? There are two leading potential dates. The first was proposed by Paul Crutzen, who put the start at the beginning of the Industrial Revolution, near the end of the eighteenth century. In hindsight it is clear that the invention of the steam engine, the access to fossil fuels, and all of the associated developments put humanity on the pathway that has led to the Anthropocene. The other candidate is around 1950, or the end of World War II. This date marks the beginning of the Great Acceleration, when the global environment moved unequivocally out of the Holocene envelope. From a stratigraphic perspective, the end of World War II also produced an unmistakable geological marker, the radioactivity associated with the advent of the nuclear age.

Perhaps the most fascinating question surrounding the concept of the Anthropocene is how humanity will react if the new epoch is formally recognized by the geological community. The concept has already spilled over into the popular press. In 2011 the Anthropocene appeared on the cover of *Le Monde* magazine, was welcomed as the "Age of Man" in *National Geographic* magazine, and was even highlighted as a feature story in *The Economist*. Will humanity charge ahead more deeply and irreversibly into the Anthropocene, perhaps by attempting to geo-engineer its way out of the climate crisis, or will it have the humility (and good sense) to pull away from its present course, redefine its relationship with the rest of nature, and steer back toward a Holocene-like state of the Earth System?

Further Reading

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