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The Geologic Challenge of the Anthropocene

Over the past century global temperatures have steadily increased. This current warming trend is disconcerting because humans, rather than geologic forces, are driving the changing climate through the combustion of fossil fuels—becoming, as Chakrabarty argues, geophysical agents in their own right. Many have termed this human-induced planetary warming a new geologic epoch, the Anthropocene.[1] Barring a global catastrophe, such as a meteorite impact, Crutzen has suggested that humans will remain the dominant environmental force for many millennia. The concept of the Anthropocene has provided a powerful tool for discussing our role in changing the Earth's climate with nonscientists. However, from a geologic perspective, Crutzen's focus on atmospheric carbon emissions misses the deeper stratigraphic deposits that may provide the strongest evidence of our time in the Earth's future geologic record: the non-climate-related activities that fuel our postindustrial civilization and its myriad electronic media.

Traditionally, epochs in geologic time are defined by large-scale changes in Earth's environment. These changes can be magnetic, biological, or chemical, and occur so abruptly that they disturb most of life on Earth. One such dramatic and abrupt change in the rock record occurred at the Cretaceous-Paleogene boundary, 66 million years ago. Many readers will recognize this time as the period when not only the dinosaurs went extinct, but also nearly three-quarters of the plant and animal species on Earth.[2] This event was first discovered when a father and son team studying rocks in Italy identified a thin layer of clay that contained 30 times the typical levels of the rare-earth element iridium. While iridium is rare in Earth's crust, it is abundant in meteorites and asteroids. They therefore hypothesized that there was a catastrophic impact with an object from outer space.[3] Since then, this iridium-rich clay layer has been identified at more than 100 sites around the world, providing evidence that this was a worldwide event demarcating an abrupt shift between geologic epochs.

1 Paul J. Crutzen, "Geology of Mankind," *Nature* 415, no. 6867 (2002): 23.
2 David Jablonski and W. G. Chaloner, "Extinctions in the Fossil Record [and Discussion]," *Philosophical Transactions of the Royal Society B* 344, no. 1307 (1994): 11–17.
3 Luis W. Alvarez et al., "Extraterrestrial Cause for the Cretaceous-Tertiary Extinction," *Science* 208, no. 4448 (1980): 1095–108.

Further back in time, the boundary between the Permian and Triassic was one of Earth's most extensive known extinction events. This particular extinction, which occurred 250 million years ago, is thought to have resulted from a series of major events such as ocean anoxia,[4] volcanism,[5] and climate change of the order of 8°C.[6] At this geologic boundary, fossils of many marine and freshwater species sharply decline, while there appears to be a more a gradual decline in land-based species, indicating that the ocean was likely affected before the land. It took nearly ten million years for the Earth to recover to the same level of biodiversity,[7] which gives an indication of the severity of this event. This abrupt change in life on Earth was clearly demarcated by the number of fossils in the stratigraphic record indicating that there was a sharp and fundamental change in Earth's natural history.

While humans may think that they are disconnected from geologic epochs millions of years ago, this is far from the truth. When James Watt invented the steam engine in the 1700s, it was the beginning of the large-scale human impact on the planet. This invention allowed for ancient geologic carbon to be reintroduced into the contemporary carbon cycle through its conversion of coal to carbon dioxide. However, this technological progress came at an environmental cost. In the 800,000 years before the industrial revolution, atmospheric carbon dioxide concentrations typically ranged from 175 to 300 parts per million (ppm).[8] The atmospheric carbon dioxide concentration today is over 400 ppm. The rise in the atmospheric carbon dioxide concentration today is attributed to human activity based on a number of scientific approaches. First, carbon isotope measurements of today's atmosphere can only be explained by the incorporation of ancient carbon introduced during the combustion of fossil fuels.[9] Additionally, when sophisticated computer models that simulate the Earth system are used to reconstruct tempera-

4 P. B. Wignall and A. Hallam, "Anoxia as a Cause of the Permian/Triassic extinction: Facies Evidence from Northern Italy and the Western United States," *Palaeography, Palaeoclimatology, Palaeocology* 93 (1992): 21–46; Lee R. Kump, Alexander Pavlov, and Michael A. Arthur, "Massive Release of Hydrogen Sulfide to the Surface Ocean and Atmosphere during Intervals of Oceanic Anoxia," *Geology* 33 (2005): 397–400.

5 Paul R. Renne et al., "Synchrony and Causal Relations between Permian-Triassic Boundary Crises and Siberian Flood Volcanism," *Science* 269, no. 5229 (1995): 1413–16.

6 Michael M. Joachimski et al., "Climate Warming in the Latest Permian and the Permian–Triassic Mass Extinction," *Geology* 40, no. 3 (2012): 195–98.

7 Zhong-Qiang Chen and Michael J. Benton, "The Timing and Pattern of Biotic Recovery following the End-Permian Mass Extinction," *Nature Geoscience* 5, no. 6 (2012): 375–83.

8 Jean-Robert Petit et al., "Climate and Atmospheric History of the Past 420,000 Years from the Vostok Ice Core, Antarctica," *Nature* 399, no. 6735 (1999): 429–36; Dieter Lüthi et al., "High-Resolution Carbon Dioxide Concentration Record 650,000–800,000 Years before Present," *Nature* 453 (2008): 379–82.

9 P. P. Tans, A. F. M. De Jong, and W. G. Mook, "Natural Atmospheric 14C Variation and the Suess Effect," *Nature* 280 (1979): 826–28.

tures over the twentieth century, they cannot predict the observed rising temperatures unless the rise in atmospheric carbon dioxide due to fossil-fuel burning is included in their model projections.[10] Therefore, from a scientific perspective, the warming we are experiencing today is due to human activities.

In keeping with geologic tradition, for the Anthropocene to be classified as a new period in geologic time the changes we are currently imposing on the planet need to be preserved in the rock record a million years from now. Yet the primary pieces of evidence for the source of the warming today, such as the isotopic composition of atmospheric carbon dioxide, will not be preserved in the rock record. The isotope that clearly identifies the million-year-old carbon as the culprit for today's warming, radiocarbon or ^{14}C, decays over time and consequently is only present in material younger than 50,000 years old, much shorter than geologic time. Carbon that originates from million-year-old fossil fuel does not contain any radiocarbon and thus "dilutes" today's radiocarbon signal. Therefore, a million years from now, the rock record will not record how we have changed the carbon cycle through the use of fossil fuels. To meet the stratigraphic test for a new geologic epoch, advocates of the Anthropocene must be able identify a more enduring signature in the Earth's crust—one that scientists a million years from now can identify as a definitive marker of our presence.

Even though climate scientists agree that humans had an impact on the climate long before the industrial revolution,[11] geologists have yet to agree on when the Anthropocene began in the geologic record. Recently, a group of scientists have identified the Trinity Test of July 1945, which ushered in the era of nuclear weapons testing in the 1950s and 1960s, as the most compelling start date for the Anthropocene.[12] Just as iridium traces helped to identify the Cretaceous-Paleogene boundary 66 million years ago, these scientists have proposed that the rare isotopes formed in nuclear weapon detonations, such as plutonium 239, dispersed over large parts of the globe and demarcated the beginning of the Anthropocene. While these rare isotopes have been incorporated into

10 Gerald A. Meehl et al., "Combinations of Natural and Anthropogenic Forcings in Twentieth-Century Climate," *Journal of Climate* 17, no. 19 (2004): 3721–27.
11 William F. Ruddiman, "The Anthropogenic Greenhouse Era Began Thousands of Years Ago," *Climatic Change* 61, no 3 (2003): 261–93.
12 Colin N. Waters et al., "Can Nuclear Weapons Fallout Mark the Beginning of the Anthropocene Epoch?" *Bulletin of Atomic Scientists* 71, no. 3 (2015): 46–57; Jan Zalasiewicz et al., "When Did the Anthropocene Begin? A Mid-Twentieth Century Boundary Level Is Stratigraphically Optimal," *Quaternary International* (2015): in press.

soil and sediments that will eventually become part of the rock record, these chemical compounds are unlikely to be detected millions of years from now. All of the isotopes formed during nuclear weapons testing are unstable isotopes and decay in abundance over time. The longest-lived isotope is plutonium 239, which has a half-life of 24,110 years. This means that after 24,000 years half of the plutonium-239 has decayed into its daughter product. Therefore, after 100,000 years, or five half-lives, only a very small fraction of this isotope level survives in the rock record. While 100,000 years may seem like an infinite amount of time on a human timescale, from the geologic perspective 100,000 years is akin to one second over the course of one day. The chemical signal of nuclear weapons testing will fade over geologic time, and consequently will not leave an abrupt record in the rocks demarcating the birth of the Anthropocene. This means that another marker of human civilization, which *will* survive geologic time, is needed to pass the stratigraphic test for a new geologic epoch.

While much of the debate on the Anthropocene surrounds how human civilization has impacted the climate through fossil fuel combustion, it is likely that the rock will record a different marker of our existence: the seemingly inexhaustible search for natural and mineral resources across the globe over the past 50 years. In the oceans, overfishing has put such pressure on natural fish populations that some predict that many marine fish species will be extinct by 2050. Due to the increasing human footprint, many terrestrial species are also facing extinction, as Carol Boggs reminds us in her contribution to this volume. As a warming climate is shifting, more extinctions are expected. These changes in animal and plant diversity are likely going to be recorded in the geologic record. However, it is likely that the recent technological boom associated with telecommunications and the internet will be the most distinctive marker of our time. Through the advent of new mobile technologies, we are mining the Earth for rare elements that allow our handheld devices to be sensitive to touch and our computer chips to process data faster, and replacing these devices with new models each year—producing what Jared Farmer has characterized as "future fossils."[13] The exponential production of computers of all shapes and sizes requires rare minerals that we have mined from previous geologic times. Is it not ironic that our conveniences of modern life, such as smartphones, will probably be what leave a permanent record in geologic time, rather than the inconvenient truth of climate change?

13 Jared Farmer, "Future Fossils" (paper presented at "Anthropocene Objects and Environmental Futures" workshop, Rachel Carson Center, Munich, Germany, 5–7 July 2015). See also a more recent reference to "technofossils" by Colin Waters et al., "The Anthropocene is Functionally and Stratigraphically Distinct from the Holocene," *Science* 351, 6269 (2016): 207–310.

"While much of the debate on the Anthropocene surrounds how human civilization has impacted the climate through fossil fuel combustion, it is likely that the rock will record a different marker of our existence."

In a few million years, the rock record of Earth will indeed record changes stemming from postindustrial human civilization. What remains unknown is how this record will play out. Will there be evidence of mass extinction and compositional changes of the Earth, or a recovery of life on Earth as civilization adapted to a less resource-driven economy? Only (geological) time will tell.

Selected Sources

Alvarez, Luis W., Walter Alvarez, Frank Asaro, and Helen V. Michel. "Extraterrestrial Cause for the Cretaceous-Tertiary Extinction." *Science* 208, no. 4448 (1980): 1095–108.

Jablonski, David, and W. G. Chaloner. "Extinctions in the Fossil Record [and discussion]." *Philosophical Transactions of the Royal Society B: Biological Sciences* 344, no. 1307 (1994): 11–17.

Petit, Jean-Robert, Jean Jouzel, Dominique Raynaud, Narcisse I. Barkov, J-M. Barnola, Isabelle Basile, Michael Bender, J. Chappellaz, M. David, G. Delaygue, M. Delmotte, V. M. Kotlyakov, M. Legrand, V. Y. Lipenkove, C. Lorius, L. Peplin, C. Ritz, E. Saltzman, and M. Stievenard. "Climate and Atmospheric History of the Past 420,000 Years from the Vostok Ice Core, Antarctica." *Nature* 399, no. 6735 (1999): 429–36.

Ruddiman, William F. "The Anthropogenic Greenhouse Era Began Thousands of Years Ago." *Climatic Change* 61, no. 3 (2003): 261–93.

Tans, P. P., A. F. M. De Jong, and W. G. Mook. "Natural Atmospheric 14C Variation and the Suess Effect." *Nature* 280 (1979): 826–28.

Waters, Colin N., James P. M. Syvitski, Agnieszka Galuszka, Gary J. Hancock, Jan Zalasiewicz, Alejandro Cearreta, Jacques Grinevald, C. Jaendel, John R. McNeill, C. Summerhayes, and A. Branosky. "Can Nuclear Weapons Fallout Mark the Beginning of the Anthropocene Epoch?" *Bulletin of Atomic Scientists* 71, no. 3 (2015): 46–57.