Marking the Start of the Anthropocene

Is human impact on Earth sufficient to leave a permanent mark on the geological record? Should geologists formally recognize a new human-dominated geological epoch? If so, when did it begin?

Several articles in the March 12th issue of *Nature* examine these questions. Nearly all scientists agree that humans have indeed had impacts that will be detectable in the geological record millions of years into the future: use of fire, extinction of large mammals such as the woolly mammoth, clearing of land for farming, metal mining (for copper, lead mercury, etc.), coal burning and greenhouse gas increases beginning in the Industrial Revolution, deposition of long-lived plastics in the ocean, etc.

Although it has not been formally adopted by geologists, the term "Anthropocene" has already come into widespread use for our new human-dominated geological epoch.

According to geologists, our current epoch -- the Holocene (Greek for "entirely recent") -- began at the end of the Pleistocene Epoch only 11,650 years ago. At that time glacial retreat accelerated, allowing an influx of fresh water into the ocean, causing increased amounts of the hydrogen isotope deuterium in precipitation over Greenland and leaving a clear signal in Greenland ice cores.

The Holocene and Pleistocene Epochs are part of the Quaternary Period (coinciding with the 2.5-million year duration of the ice ages) which in turn is part of the Cenozoic Era (Greek for "recent life"). Geologists use the term "recent" somewhat differently than the rest of us. The Cenozoic Era began 66 million years ago when a giant asteroid crashed into the Earth in the area of the Yucatan Peninsula, wiped out the dinosaurs, and left worldwide deposits of the rare element iridium. We now officially live in the post-dinosaur era (even if some politicians seem bent on disproving this).

The question of when to mark the start of a new epoch can be a tricky one. We're not even 12,000 years into the Holocene, a very short time period in the multi-billion-year geologic history of the Earth. Some geologists feel it is much too soon for a new epoch, given that past epochs tended to last several millions of years.

Another argument against designating a new geological epoch is that the Holocene could already be considered as the age of humans (even if its start was marked by glacial retreat). In favour of this argument there is evidence the Earth was slipping back into a new ice age 6000 to 8000 years ago, coinciding with naturally declining atmospheric carbon dioxide levels. However, a massive increase in land clearing for agriculture released large amounts of carbon from decaying forests. This enhanced Earth's greenhouse effect, offset the natural decline in carbon dioxide and kept the glaciers in retreat.

On the other hand, in support of designating a new epoch, there are very clear signs that human impacts on a geological scale have accelerated over the most recent several hundred years. Most scientists therefore feel that there is a need for a geological epoch defined by humanity's footprint on the planet, with a well-defined starting point associated with a distinct human-caused event.

Geologists are very particular about starting points. The Anthropocene working group that reports to the International Commission on Stratigraphy and to the International Union of Geological Sciences is searching for a marker that can be defined by a narrow time range, with impacts that will be detectable in rock and/or ice layers around the world. An asteroid strike such as the one that initiated the current Cenozoic Era would be ideal from a geological perspective (but perhaps not from a human perspective).

The search for precision in a starting point probably rules out the Industrial Revolution, which gradually built up steam over more than a hundred years during the 18th and 19th centuries. But the authors of one of the papers in *Nature* ("Defining the Anthropocene") (http://www.nature.com/nature/journal/v519/n7542/full/nature14258.html) discuss the relative pros and cons of two alternative dates: 1610 and 1964.

Why 1610? According to the authors, Antarctic ice cores show a 7-10 ppm downward spike in atmospheric carbon dioxide that is centered on this date. They suggest that this downward spike was caused by massive reforestation in the New World, coinciding with a catastrophic decline in indigenous human populations triggered by the rapid spread of smallpox and other diseases introduced by European colonists. Various sources estimate that roughly 50 million Native Americans died at the end of the 16th and beginning of the 17th centuries. Their relatively advanced New World agricultural civilizations collapsed. Forests and shrub lands replaced their crop fields. This vegetation absorbed vast amounts of carbon dioxide, sending atmospheric levels into sharp decline.

Another advantage of the 1610 date from a geological perspective is that European colonization of the New World coincided with a great influx of non-native species, ranging from plants and earthworms to cows, pigs and horses. The authors note that "the transoceanic movement of species is a clear and permanent geological change to the Earth system." Traces of these species will be left behind in the fossil record. They further note the argument of many historians that colonization of the New World created the conditions required for the subsequent Industrial Revolution: access to cheap resources and profitable new markets for manufactured goods.

The alternative 1964 date coincides with the height of atmospheric nuclear weapons testing and peak levels of radionuclides such as carbon-14. The authors point out this carbon-14 spike represents "an unambiguous global change in a number of stratigraphic deposits," and can be supplemented by other isotopes of plutonium and radioiodine. But they also note that, compared to the transoceanic movement of humans, disease-causing organisms, and other species during colonization of the New World around 1610, radionuclide fallout may prove to have relatively limited long-term biological effects. Also, nuclear weapons testing could be seen as an event that occurred well after the start of marked human impacts on the geological record.

It is somewhat sobering to consider that the two leading candidates for the start of the Anthropocene coincide with the population crash of indigenous peoples in the Americas, and the testing of nuclear weapons. Yet, like other physical and biological scientists, geologists must search for the greatest possible precision and explanatory power in their classification systems. It will be interesting to follow their future discussions and debates concerning the creation of the Anthropocene.