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COMMENTARY

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Key Points:
- Onset of the Anthropocene
- Redefining the Holocene

Supporting Information:
- Law_core.xlsx

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Hello Anthropocene, Goodbye Holocene

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The debate about the Anthropocene and the geologic boundary that, if approved, would mark its start is lively and extensive, and contentious. In a simple Google search, three quarter million hits and many hundreds of academic papers are returned, including perspectives in this journal, *Earth's Future* (e.g., Ellis and Trachtenberg, 2014). Since its informal introduction about 15 years ago (Crutzen and Stoermer, 2000), some reject a new epoch entirely, whereas others debate the position of its boundary in the geologic timescale. The thrust of this commentary is a correction to the recent geologic timescale, advancing the thesis that epoch status for the Holocene is unjustified and that, instead, we should define a Pleistocene-Anthropocene epoch boundary.

The Holocene is the youngest geologic epoch of the Quaternary. The official geologic timescale, managed by the *International Commission on Stratigraphy* (http://goo.gl/GFdeit), is based on identifiable markers, or "golden spikes," which, for the Holocene, is defined as:

> The base of the Holocene Series/Epoch is defined in the NGRIP ice-core record at a depth of 1492.45m at the horizon which shows the clearest signal of climatic warming, an event that marks the end of the last cold episode (Younger Dryas Stadial/Greenland Stadial 1) of the Pleistocene. [http://goo.gl/VYtCRT; *Walker et al*., 2009]

Thus, a moderate atmospheric signal characterizes the Pleistocene-Holocene boundary as currently defined, with the end of the latest (last?) glacial as its primary geologic signature (yet, the process of receding ice is similar among all Quaternary interglacials). The atmospheric/climatic trend of an interglacial that heralded the Holocene is continuing today, but the recent era of human influence on its environment, marking the Anthropocene, reflects multiple geologic changes of global proportions.

A particularly compelling perspective on the Anthropocene was produced by Will Steffen and others, sometimes referred to as "The Great Acceleration" [e.g., *Steffen et al*., 2004; http://goo.gl/W7akNv]. By tabulating dozens of change indicators over the past couple of decades and centuries, a picture emerges of rapid changes in recent times. Some of these changes are social constructs (such as McDonalds restaurants), but others represent lasting geologic signatures that are global in scope. Notably, our demands for resources and nourishment, which necessitate invasive mining and agricultural practices, have changed the surface of today's planet almost everywhere. These demands and associated waste products create a boundary that is readily recognizable in surface geology [e.g., *Wilkinson*, 2005] and by concentrations of chemical compounds [e.g., *Rockström et al*., 2009]. A recent class project at the University of Michigan revisited and updated the Steffen's analysis, confirming and extending the key patterns established earlier. For example, Figure 1 shows data from Law Dome ice core in Antarctica (see Supporting Information), which record rapid changes in chemical compounds that reflect modern agricultural and industrial practices. Selecting a boundary from these data would place the beginning of (accelerated) change in the window 1850–1950, which coincides with the onset of the mid-nineteenth century "Industrial Revolution" and the early twentieth century "Transportation Revolution."

The human influence has led others to define the Anthropocene boundary elsewhere. Agricultural practices underlie Bill Ruddiman's proposal for a boundary as long as 7000 years ago [*Ruddiman*, 2003]. Others, including the original advocate for the Anthropocene, Paul Crutzen, favor the chemical anomaly from atomic explosions since 1945 CE, although related isotopic tracers have a limited lifetime. Neither, however, reflects geologic change to the same degree since the Industrial Revolution in the

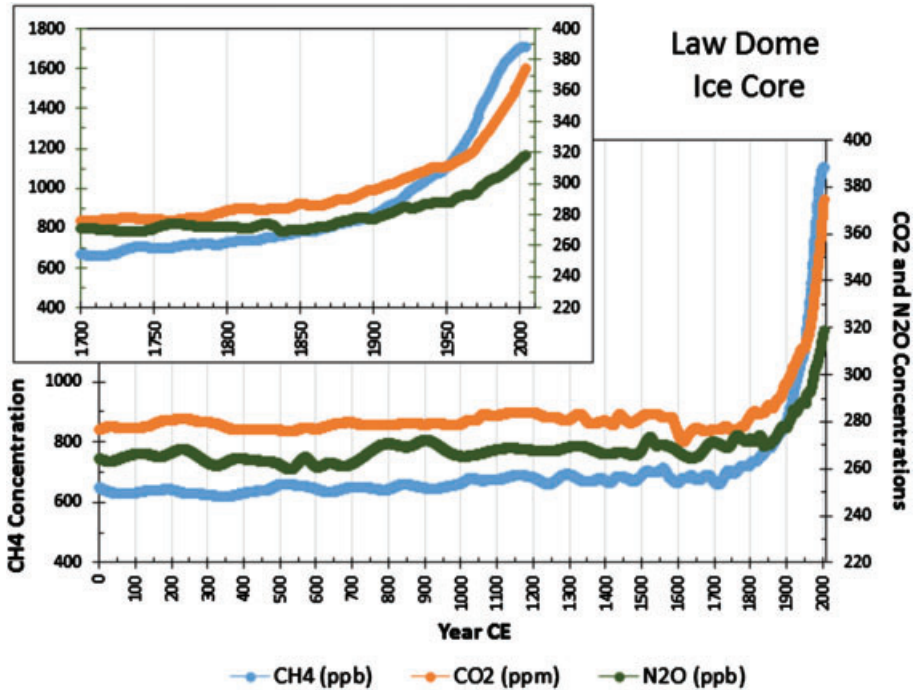

Figure 1. Atmospheric concentration of CH_4, CO_2, and N_2O from Law Dome ice core (Antarctica) since 0 CE; inset shows data after 1700 CE. After *MacFarling Meure et al.* [2006] and Supporting Information.

nineteenth century (Note: Crutzen originally supported an early nineteenth-century boundary for the Anthropocene [*Crutzen and Steffen*, 2003]). Finally, there is growing evidence for a modern species extinction episode (e.g., *Kolbert*, 2014; *The Sixth Extinction*). Species extinctions have traditionally defined the boundaries between geologic eras that contain complex life, i.e., the Paleozoic-Mesozoic and the Mesozoic-Cenozoic boundaries, as well as lower-level timescale boundaries. The nature of today's species extinction, however, does not allow one to draw a decadal scale boundary.

As the official timescale keepers deliberate the introduction of the Anthropocene and a Holocene-Anthropocene boundary [*Anthropocene Working Group of the Subcommission on Quaternary Stratigraphy*; *Zalasiewicz et al*., 2010; http://goo.gl/wIm6X0], they should consider the alternative: Remove the Holocene Epoch from the geologic timescale. While any timescale change is a contentious issue, let alone changes to an existing epoch, modern human society's interactions with its planet and ecosystems, embodied by the Anthropocene, are sufficiently large to produce a lasting geologic marker that supports such modification. This new boundary would remain visible in the geologic record of oceans and continents [see also *Corcoran et al*., 2014 on plastics], meeting the stratigraphic requirements that ultimately underlie the timescale and marking a shift from the Pleistocene's Milankovitch forcing to the Anthropocene's human forcing.

The Holocene is a climate-centric placeholder for change after the latest Quaternary glaciation, but does not, as defined, match the accelerated changes in land, ocean, and atmosphere that mark modern times. So, I suggest that (a) we remove the Holocene altogether in favor of a (young) Anthropocene Epoch that reflects planet-wide geologic changes since c. 1900 CE, or (b) we demote the Holocene to Stage/Age status, marking the end of the Pleistocene Epoch. The latter, perhaps more palatable compromise, would recognize historical precedent and allow continued use of Holocene in the literature as a temporal (Age) marker. Regardless, slicing the Quaternary Period in ever thinner epochs has no geologic merit. Instead, given the degree and impact of modern, human-induced changes on our planet, a young Pleistocene-Anthropocene boundary seems justified.

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