Essay for ACM Sustainability workshop
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Geology and Sustainability

I think most geologists would say that sustainability is at the root of our discipline, though we certainly didn't invent the word or define the concept. Geology considers the earth as an open system of gases, liquids and solids, distributed from the outer limits of the atmosphere to the earth's center. We know that within this system are many interacting subsystems that involve the transfer of energy and materials from one area – and state – to another. Resources – minerals, fuels, water, soils and others – all exist within the earth system that geologists study. Geologists study how these resources are created, how they are altered, and how they move from place to place. Just tracing the routes of water on the globe, for instance, involves the atmosphere, the earth's land surface (sometimes called "the critical zone"), the oceans, the ice caps, and the crust and mantle of the solid earth. Humans alter many of the transfer processes and at the same time they alter the amounts of resources in storage. It may be true, as the physicists say, that matter can neither be created or destroyed, but matter can certainly be changed from an un-usable state to a usable one (think mining and smelting) or from a usable state to an un-usable one (think gasoline and carbon dioxide).

One of the unique dimensions geology brings to discussions of sustainability is "deep time." The earth is 4.5 billion years old and the geologic record of rocks contains all of its history, except for the last 5000 years or so when one of earth's species, *Homo sapiens*, developed writing. Want to know what the climate was like 100,000 years ago? Ask a geologist, who will consult the library of oceanic sediments, cave deposits, ice caps and other records. Want to know the probability of discovering more major petroleum reserves? Ask a geologist. Want to know when and how quickly those petroleum deposits formed? You get the idea.

The historical perspective geologists bring to discussions of sustainability also gives another context to the discussion. After spending a trimester studying earth processes and the record of volcanic eruptions, asteroid impacts, ocean openings and closings, glacial epochs, extinctions, and other highlights of earth history, one of my wise students commented that she was no longer worried about whether or not humans would destroy the earth, because the earth had already been around for 4.5 billion years and it surely would survive humans. The real question is whether or not HUMANS will survive unsustainable human practices of various types.

Geologists can also help compare the rates of human changes of the earth with the variety of rates that could be considered natural (at least, pre-human). Roger Hooke, now at the University of Arizona, has written several papers arguing that humans are the major agent now shaping the surface of the earth, at least in some regions (Hooke, 1999 is an example). The geologic records of atmospheric carbon dioxide support the conclusion of the IPCC and others that CO_2 content is now increasing more rapidly than at any time during the last 650,000 years (Chapman, 2010) and has reached a level in the atmosphere higher than at any time in the past 30 or so million years (c.f. Fletcher, et al., 2008). A reasonable geologic definition of "sustainability" might therefore be: the condition where historic rates of geologic processes (affected by humans) fall within the broad range of rates prior to humans on the planet. A definition like this one allows for the

occasional asteroid impact and the profound environmental change that follows it (an outlier), while putting rates of the last 5000 years (or 500 or 150 years) into proper geologic context.

Geologists divide the 4.5 billion years of continuous earth history into periods. The last 10,000 years, for instance, is called the Holocene. It is the period since most of the major ice sheets of the Northern Hemisphere retreated. Now, earth scientists suggest that the Holocene ended around 1800 AD and that a new period, the Anthropocene, has begun (Steffen, et al. 2007 and references, Zalasiewicz, et al., 2008). This proposal suggests that the planet has shifted fundamentally to a state of unsustainable human influence. The central feature of the Anthropocene is the rapid increase in fossil fuel consumption (and therefore in atmospheric carbon dioxide). In response to the Anthropocene, the mission of geologists has also changed. In addition to describing and measuring "natural" (read: non-human) change, geologists will necessarily turn to documenting unsustainability (cf. the American Quaternary Association vision statement http://www.amqua.org/publications/vision2000.html). Two hundred and ten years (1800-2010) is a short period of time, geologically speaking. Yet it is not clear to us geologists that sustainability (in our sense of the word) can be restored within a much longer – a geologically longer – time period.

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