Berner Lecture: Sources of atmospheric CO_2 over geologic time

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One of Robert Berner's seminal scientific contributions was in developing a quantitative framework for understanding the dynamics of the geological carbon cycle. In the process of this work, he recognized that sources of CO_2 to the atmosphere are one of the least well understood components of the carbon cycle, despite the basic control that they exert on its long-term evolution. This puzzle challenged Berner during his career and still remains to be fully resolved today. Nonetheless, recent work is shedding new light on how CO_2 source terms operate, raising fresh questions about the drivers of long-term variations in the carbon cycle and global climate. In this talk, I will attempt to review some of these recent discoveries and the progress towards quantifying CO_2 sources over geologic time.

Release of CO_2 resulting from reactions during weathering of sedimentary rocks has long been identified, but some of the main controlling factors and the relevance to the carbon cycle are gaining renewed recognition. Sulfide oxidation can act as a transient CO_2 source, by changing the alkalinity balance of the oceans over millions to tens of millions of years. Meanwhile the oxidation of ancient "petrogenic" organic carbon in sedimentary rocks directly releases CO_2 to the atmosphere. Results from a study of rivers draining the Andes mountains of Peru confirm a strong erosional control on oxidation of both pyrite and petrogenic organic carbon. These findings, together with other similar recent studies, suggest that tectonically- and climatically-driven changes in erosion rates and lithological exposure may have played important roles in the evolution of the carbon cycle. While these roles have traditionally been viewed solely through the lens of CO_2 drawdown via silicate weathering, the competing effects of CO_2 release during oxidative weathering can now begin to be untangled.

At the same time, new approaches show promise for quantifying changes in solid Earth degassing over time: one tracking plate motions over the last ~100 Myrs in an effort to account for amount of carbonate delivered to subduction zones, and the other based on modeling first-order trends in mantle chemical evolution over 4 Byrs of Earth's history. Together, the results of these modeling efforts suggest that the planet's tectonic machinery has exerted a first-order influence on the evolution of atmospheric CO_2 and global climate, not only by changing erosional regime but also by regulating the flux of carbon released from the deep Earth.