Designing an Integrated Theory of Earth's Biogeochemical Evolution

ARIEL D. ANBAR[1] AND THE DYNAMICS OF EARTH SYSTEM OXYGENATION TEAM

[1] School of Earth and Space Exploration and School of Molecular Sciences, Arizona State University (anbar@asu.edu)

The geosciences are poised for transformation. After ~ 250 years of investigation across an ever-increasing range of subdisciplines, we now know that the evolution of life and of Earth's biogeochemical cycles are inextricably linked to the evolution of the solid Earth. The emergence of life, the rise of an aerobic biosphere, biological radiations, mass extinctions, and even human evolution—these events and their placement in time are shaped by the trajectory of Earth's internal differentiation and dynamics, and their expression in surface tectonics and volcanism. From this vantage point, life emerged as an epiphenomenon of geophysics, and will remain tightly coupled to the workings of the solid Earth far into the Anthropocene. Hence some of the greatest questions in biogeosciences can only be answered through integration of our subdisciplines, considering the entire planet as a system.

Yet, despite tremendous advances in knowledge, we lack a quantitative, predictive "theory" of the Earth system that describes the mechanistic linkages between the interior and the surface, and how they have changed with time, let alone their relationships to life's emergence and evolution. The value of such a theory can be illustrated in efforts to understand the Great Oxidation Event (GOE) that transformed Earth's surface ~ 2.3 Ga, and made intelligent life possible. For example, even small changes in the balance between organisms' production and consumption of O_2 at the surface vs. consumption of O_2 by reactions with rocks, fluids and gases from the interior could have a big impact because the atmosphere is miniscule compared with the near-infinite O_2 sink represented by the bulk planet.

Superficially, at least the non-biological core of such a theory is straightforward: It would describe, with minimal parameterization, the physicochemical consequences of the planet's thermochemical evolution as it gradually cooled. In reality, to develop such a theory is an immense generational "grand challenge" requiring fundamental advances and vigorous collaboration across subdisciplines that rarely interact. The hurdles are both scientific and sociological.

This talk will present a possible framework for developing an integrated theory of Earth system evolution rooted in our GOE research, as well as insights into the sociological aspects of this challenge gleaned from scholars of communication and interdisciplinary dynamics.