HOW LOW CAN YOU GO? A STORY OF MID-PROTEROZOIC OXYGEN AND THE POSSIBILITY OF TRANSIENT OXYGENATION EVENTS. C. W. Diamond[1,2] and T. W. Lyons[1,2], [1]University of California, Riverside; [2]NASA Astrobiology Institute, Alternative Earths Team

The composition of the mid-Proterozoic (1.8-0.8 billion-years-ago; Ga) atmosphere has been the topic of vigorous debate over the past decade or more—grabbing particular attention over the past few years. Our understanding has largely been shaped using redox-sensitive trace element concentrations and isotopes in shales and related mass-balance arguments along with soil-based estimates and atmospheric predictions grounded in assumptions about vast extents of deep marine anoxia. Most recently, chromium isotopes in iron-rich marine sediments and organic-rich shales have been at the center of the debate. A high-resolution dataset from Cole and others (2016, Geology) shows a lack of significant fractionation from crustal composition until ~800 million-years-ago, suggesting that atmospheric pO_2 remained well below 1% present atmospheric level (PAL) until that time. Not only does this estimate place O_2 at a level that could have inhibited the development of complex life, it also pushes it below the detectability limit of current generation telescopes—presenting the real possibility that if we were looking at the mid-Proterozoic Earth as a distant exoplanet, our efforts would render a false negative result if O_2 were being used a biosignature.

The notion of low mid-Proterozoic O_2 is not universally accepted, though. Recently, Zhang and others (2016, PNAS) presented a novel method of extrapolating atmospheric O_2 from marine sediments using an organic carbon export and oxidation model. Their model relied on data from the 1.4 Ga Xiamaling Formation of north China and produced O_2 estimates as high as 40% PAL. New, independent work on the Xiamaling Fm., however, reveals several fundamental problems with the interpretations made by Zhang and others. These differences will be included in the presentation.

Notwithstanding uncertainties centered on the Xiamaling story, transient spikes in O_2 beyond the Cr-isotope-based predictions are suggested in a growing base of geochemical and paleontological data and are consistent with redox-dependent nutrient models during this time period. In fact, we might expect such oscillations around the very low O_2 baseline estimated for the roughly billion years of the mid-Proterozoic—much like the whiffs of oxygen suggested for the latter portion of the Archean. The question then becomes the evidence for, duration of, and mechanisms behind possible transient rises in oxygenation against the dominantly low oxygen conditions suggested for the mid-Proterozoic ocean and atmosphere. Equally important are any relationships between possible oxygen variability and the early stages of eukaryotic development, including long intervals of stifled development under low O_2 conditions.

Many researchers believe that the initial rifting of Rodinia was responsible for the wholesale reorganization of Earth surface processes, including oxygenation, that took place later in the Neoproterozoic. However, the possible biospheric impact of incipient breakup of the supercontinent Nuna during the mid-Proterozoic also demands our attention, and the age of the Xiamaling Fm. makes it and contemporaneous formations ideal targets for fingerprinting possible transient shifts in oxygenation related to coeval tectonics. This study combines new and published data from the period spanning the breakup of Nuna to assess impacts it may have had on global weathering, nutrient delivery, biological diversity, productivity, and ultimately potential vacillations in atmospheric O_2 prior to indications of the more pronounced changes beginning at ~800 Ma.