Paper Number: 3225

Evaluating Uranium as a Tool to Infer Cryogenian Marine Oxygenation

Miles, C.M.[1], Lau, K.V.[1], Macdonald, F.A.[2], Maher, K.[1], and Payne, J. L.[1]

[1]Department of Geological Sciences, Stanford University, 450 Serra Mall, Bldg. 320, Stanford CA 94305

[2]Department of Earth and Planetary Science, Harvard University, 20 Oxford St., Cambridge MA 02138

The Cryogenian Period consists of the 717-660 Ma Sturtian glaciation, the 660-645 +/-5 Ma Cryogenian non-glacial interlude, and the 645 +/-5 -635 Ma Marinoan glaciation. It has been suggested that the origin and expansion of bilateria, inferred from biomarker and molecular clock data [1], occurred during the Cryogenian Period, and was related to a rise in atmospheric oxygen levels [2]. However, global changes in ocean oxygenation have been poorly constrained, partly due to the absence of a paleoredox proxy that is sensitive to the proposed changes in oxygenation. In this study, we estimate changes in oxygenation using uranium isotope ratios ($^{238}U/^{235}U$) and concentrations, both of which are sensitive to changes in redox conditions [3,4]. Because the residence time of uranium in the ocean surpasses the mixing time of the ocean itself, global seawater variations in uranium isotopes and concentrations can be recorded in carbonate sediments. However, diagenesis can make it difficult to rely on a single stratigraphic section for reliable interpretations. In this study, we measured the uranium isotope ($\delta^{238}U$) composition and concentration [U] of limestone samples collected from two stratigraphic sections separated by ~50 km in Mongolia to evaluate the extent and evolution of bottom water anoxia during the Cryogenian.

The $\delta^{238}U$ record from the more distal section shows a marked negative excursion from a mean of -0.45‰ to -0.80‰ at the stratigraphic height of 110 m. In comparison, [U] shifts from 2.1 ppm to 0.5 ppm at 40 m and back to 2.0 ppm at 100 m. In the more proximal stratigraphic section, $\delta^{238}U$ shifts from -0.4‰ to -0.8‰ at a stratigraphic height of 150 m. In contrast to the more distal section, [U] is substantially less variable, with a mean of 1.5 ppm. Our $\delta^{238}U$ data imply the occurrence of large fluctuations in oxygenation during the Cryogenian, but discrepancies between the negative excursions in [U] and positive excursions in $\delta^{238}U$ also indicate the additional influence of local controls. We suggest that local factors, such as diagenetic recrystallization and variation in primary mineralogy, may influence [U], complicating their use in reconstructing seawater chemistry. We also compare our uranium data to rare earth element anomalies to better evaluate the influence of local redox conditions. We hypothesize that $\delta^{238}U$ measurements in limestone, in comparison to [U], are more reliable proxies with which we can infer changes in ancient oceans. In particular, in the Cryogenian successions in Mongolia, our data suggest a transient oxygenation event in the aftermath of the Sturtian Snowball Earth glaciation.

References

[1] Erwin DH et al. (2012). The Cambrian Conundrum: Early Divergence and Later Ecological Success in the Early History of Animals. *Science* **334**: 1091-1097.

[2]Och LM and Shields-Zhou GA (2012). The Neoproterozoic oxygenation event: Environmental perturbations and biogeochemical cycling. *Earth-Science Reviews* **110**: 26-57.

[3] Stirling CH et al. (2007). Low-temperature isotopic fractionation of uranium. *Earth and Planetary Science Letters* **264**: 208-225.

[4] Weyer S et al. (2007). Natural fractionation of $^{238}U/^{235}U$. *Geochimica et Cosmochimica Acta* **72**: 345–359.