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Mercury isotope cycling in meromictic ancient-Earth analog lakes and ponds

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Mercury (Hg) is a redox sensitive element with a rare "three-dimensional" isotope system, exhibiting mass-dependent (MDF) and mass-independent isotope fractionation for both odd mass number (odd-MIF, Δ^{199}Hg and Δ^{201}Hg) and even mass number (even-MIF, Δ^{200}Hg and Δ^{204}Hg) isotopes. Because unique Hg isotope signals are imparted during redox-related processes, Hg isotopes in sedimentary rocks can act as a novel proxy for paleo-environmental changes and have provided new insights into the co-evolution of environments and life on Earth. Reconstructing paleo-environmental changes using Hg isotopes remains challenging, however, due to an incomplete understanding of Hg isotope fractionation mechanisms, in particular within ancient marine environments that are rare today. For more than the first four-billion years of Earth history, dissolved free oxygen (O_2) was largely absent from deep marine environments. If Hg isotopes are to be effectively applied as a paleo-environmental tool, we must understand how they are cycled in environments with O_2-deficient 'anoxic' bottom waters.

In this presentation we will discuss the results of ongoing systematic Hg isotope and trace metal element studies of sediments formed under a variety of anoxic conditions today. The sediments were sampled at different water depths from three meromictic freshwater to brackish water bodies in the United States: Siders Pond in Massachusetts and Deming and Steel lakes in Minnesota. Anoxic conditions range from being accompanied by abundant sulfide ('euxinic' Siders Pond), abundant ferrous iron ('ferruginous' Deming Lake), and abundant dissolved manganese ('manganiferous' Steel Lake). Sedimentary Hg concentration are highest at the euxinic (average 101.47 ng/g) and ferruginous (average 99.69 ng/g) sites, and comparatively low at the manganiferous site (average 60.57 ng/g). Negative MDF and positive MIF values are observed in sediments at the ferruginous and manganiferous sites, with considerable variations with increasing water depth. The variations of Hg MIF below the oxycline at both sites are correlated with dissolved Fe and Mn contents. Analysis of sediments from the euxinic site is ongoing. Our study offers a unique opportunity to better understand Hg isotope cycling in the types of environments common on ancient Earth.