U isotope evidence for a common occurrence of extensive anoxia in the Cryogenian ocean

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Molecular clock estimates and sponge biomarkers suggest that animals may have diverged in the Cryogenian Period (~720-635 Myr ago). However, large and morphologically complex animals first appeared in the sedimentary record only in the Ediacaran Period (635–541 Ma). This early origin and their delayed diversification has been assumed to be due to low levels of O_2 in the Crygoenian ocean. The low trace metal abundances (e.g., U, Mo, V) and Fe-S-C systematics in Cryogenian euxinic organic-rich sediments (ORS) support this hyperthesis[1,2]. However, those prior studies were limited to local or indirect proxies of ocean oxygenation. Here, to obtain new constraints on the extent of global redox changes in the Cryogenian ocean, we measured U isotope compositions ($\delta^{238}U$) of ORS of Member I, basal Datangpo Formation (~663–654 Ma), South China, from two drillcores.

The average $\delta^{238}U$ of samples from the basal and the middle of the Member I is −0.39 ± 0.23 ‰ (2SD; relative to standard CRM145), and $\delta^{238}U$ of samples from the top of the Member I is −0.63 ± 0.17 ‰. Those $\delta^{238}U$ values are significantly lower than the average $\delta^{238}U$ of 0.02 ± 0.12 ‰ for restricted Black Sea (deep-water Unit I) euxinic sediments and a modeled $\delta^{238}U$ value of 0.2 ‰ for open ocean euxinic sediments in the modern well-oxygenated oceans. The U/Al ratios of those samples indicate that >40% of U are detrital, suggesting that the $\delta^{238}U$ of authigenic U in those samples are even lower. Because ^{238}U is preferentially removed to euxinic sediments compared to ^{235}U, expanded anoxia will deplete seawater of ^{238}U relative to ^{235}U, leading to deposition of ORS with low $\delta^{238}U$. Thus, these low $\delta^{238}U$ values suggest a common occurrence of extensive anoxia in the Cryogenian ocean. The stratigraphic variations of $\delta^{238}U$ from both records suggest the upper Member I have experienced more severe anoxic conditions than the lower Member I. This interpretation allows for a temporary and mild ocean oxygenation in the the wake of the Sturtian glaciation[2,3].

[1] Li et al. (2012) EPSL 331–332, 246–256. [2] Zhang et al. (2015) EPSL 429, 11–19. [3] Lau et al. (2017) EPSL 458, 282–292.