Molybdenum and iron isotope evidence for anoxic Ediacaran deep ocean conditions

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The Ediacaran (635 to 541 Ma) was a period of major environmental perturbations including tectonic reorganisation, biologic evolution and environmental oxygenation. Thereby, the exact timing and the extent of deep ocean oxygenation within this time period remains debated.

We present Mo and Fe isotopic data of organic-rich black shales from the Teplá-Barrandian unit, Czech Republic, which were deposited in a hydrothermal vent site environment of a back-arc basin. New U-Pb age constrains provide a maximum depositional age of <560 Ma. By combining the Mo and Fe isotopic data with the main element composition of our black shales, we can distinguish between metal enrichment from seawater or from hydrothermal sources, respectively. Metal-rich samples with high Fe/Al ratios show negative δ^{56}Fe values around -0.4 ‰ and constant δ^{98}Mo values around +0.7 ‰. Both values are similar to the Mo and Fe isotopic composition of modern hydrothermal fluids and suggest metal enrichment predominantly from a hydrothermal source.

Our best estimate for the Ediacaran seawater δ^{98}Mo value is +1.2 ‰. This value is similar to the inferred seawater Mo isotopic composition from mid-Proterozoic and also most early Paleozoic black shales, but in stark contrast to a maximum value of +2.3 ‰ in contemporaneous Ediacaran black shales from the Doushantuo Formation, China [1]. We argue that the peak δ^{98}Mo values observed by [1] represent a local and transient signal, rather than global ocean δ^{98}Mo. We further suggest that continuously low global seawater δ^{98}Mo values during the Ediacaran indicate the lack of Mn oxides, which would preferentially remove isotopically light Mo from seawater leaving behind an isotopically heavy ocean. This in turn means that the deep ocean was largely decoupled from oxygenation and remained anoxic during the Ediacaran. First non-transient and modern-like high δ^{98}Mo values in Devonian black shales might indicate that complete deep ocean oxygenation occurred during Paleozoic times [2].

[1] Kendall et al. (2015) GCA **156**, 173-193. [2] Dahl et al. (2010) *PNAS* **107**, 17911-17915.