Effect of thermal alteration on the preservation of molybdenum- and zinc-isotope palaeoproxies in organic-rich sediments

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The isotopic compositions of molybdenum (Mo) and zinc (Zn) can be used to reconstruct marine palaeo-redox and/or palaeonutrient conditions. Both of these elements undergo removal from seawater into organic-rich sediments, the isotopic composition of which can be used to trace past ocean chemistry. Reliable application of these proxies requires that post-depositional processes such as oxidative weathering and thermal maturation do not have a significant effect on the isotopic compositons of ancient sedimentary rocks. In this study, we present the results of two experiments designed to test whether thermal maturity exerts a control on the concentration and isotopic composition of Mo and Zn.

Firstly, a series of controlled laboratory pyrolysis experiments using samples of the Kimmeridge Clay (Upper-Jurassic) and Posidonia Shale (Lower Jurassic) demonstrates a lack of isotopic variation of Mo and Zn with increasing thermal maturity. However, Mo concentrations increase towards higher thermal maturities in both rocks.

The second experiment focuses on two intervals of the Posidonia Shale that, despite being separated by only 10's of kilometres within the Lower Saxony Basin, have undergone significantly different thermal histories since burial. This difference has allowed the organic matter in one of the successions to be relatively immature (vitrinite reflectance of ~0.54, early oil window) while the other is overmature, with no remaining hydrocarbons (vitrinite reflectance of ~3.5). Despite this significant difference in organic-matter composition, Mo-isotope compositions are identical in both successions, while Mo concentrations and Mo/TOC ratios are higher in the over-mature core.

The results of the Lower Saxony Basin study closely replicate the trends from the pyrolysis experiments. Mo and Zn isotopes are largely resistant to the thermal alteration of organic-rich sediments. The increase in Mo concentrations with increasing maturity may, however, have implications for the use of proxies such as Mo/TOC ratios to evaluate basin hydrography in ancient organic-rich sediments.

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