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Contrasting marine and terrestrial metal sources in low temperature hydrothermal mineralization revealed by Mo, Fe and O stable isotopes

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The new metallic stable isotope systems have a powerful potential for tracing the environmental conditions, sources and transport in hydrothermal mineralization. We explore the ability of the Mo and Fe-isotopic systems to differentiate between marine and continental metal sources in low temperature mineralization associated with tectonic movement along the Dead Sea Transform (DST), which separates the Arabian plate from the Sinai sub-plate. The mineralization, mostly iron oxides and epigenetic dolomites replacing host-rock limestones, is studied at three key locations: (a) in the crests of anticlines (NE Negev Anticlines) adjacent to the present-day Dead Sea; (b) a shear fault (E Paran Fault) near its eastern termination at the DST and (c) the W Paran Fault, approximately 70 km west of the DST.

Iron oxide veins in the NE Negev Anticlines are enriched in molybdenum ([Mo] = 7ppm to 1.9wt%). Their Mo isotopic compositions show a remarkable variation from $\delta^{97/95}$Mo = -0.6‰ to +2.3‰ which positively correlates with Mo/Fe ratios. This range is interpreted to primarily reflect the mixing of an isotopic light 'continental' Mo end-member with an isotopically heavy Mo end member solution derived from concentrated evaporitic marine brines in the rift valley (Late Neogene Sedom Lagoon) that penetrated downward into the sedimentary rocks of the rift flanks before intermixing with Fe-bearing ground water in a sandstone aquifer containing molybdenum of clastic origin[1]. $\delta^{97/95}$Mo values higher than seawater (1.6‰) are attributed to Rayleigh isotopic fractionation during brine migration.

Fe isotopes express a terrestrial source and fluid-rock interaction. This is most clearly shown in the two Paran Fault sites where large iron oxide lenses occupy the fault zone and the dolomites are ferroan[2]. $\delta^{57/54}$Fe values show spatial variations: Fe-oxides (NE Negev Anticlines): -0.50 ± 0.50‰ (n=9); Fe oxides (E Paran Fault): -1.08 ± 0.40‰ (n=23) Fe-dolomites (E Paran Fault) = -0.87 ± 0.26‰ (n=15); Fe oxides (W Paran Fault) = -0.67 ± 0.47‰ (n=17); Fe-dolomites (W Paran Fault) = -0.61 ± 0.29‰ (n=13). These values reflect isotopically light Fe(II) source solutions formed by reductive dissolution of clastic iron minerals ($\delta^{57/54}$Fe = 0.34 ± 0.19‰ (n=8) in the sandstone aquifer. The mechanism by which the low $\delta^{57/54}$Fe(Fe(II) solutions formed could be abiogenic dissolution of clastic iron minerals, though recent studies have indicated bacterial iron reduction is a very effective mechanism for generating isotopically light Fe in silica-rich envronments[3].

Based on Mo isotopes we concluded that the Mg source for the epigenetic dolomitization in the NE Negev anticlines was the Sedom Lagoon. In contrast, the high [Mo] anomaly is not found in the Paran Fault dolomites and a major source of the solute metals was leaching of igneous and clastic rocks in the sub-surface[4]. At a regional scale, most dolomites are characterized by a simple petrographic zonation, together with a narrow range of O-isotope values (δ^{18}O = 29.1 ± 1.4‰; n=47), which reflect the interplay between temperatures ($\leq$ 50˚C) and variable δ^{18}O water values due to brine - groundwater mixing. However, petrographically complex zoned dolomites close to the DST in the E Paran Fault are characterized by low δ^{18}O values (21.9 ± 1.8‰; n= 25) and radiogenic strontium isotope ratios in the range of Sedom Formation evaporites that support the existence of a deeper hotter fluid that originated in the Mg-rich Dead Sea Rift brines[4].

[1] Ryb et al (2009) Geology 37, 463-466. [2] Grosz et al (2006) Geofluids 6, 137-153. [3] Johnson et al (2008) Ann. Rev. Earth Planet. Sci. 36, 457-493. [4] Erel et al (2006) Geochim. Cosmochim. *Acta* 70, 5552-5570.