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Metal migration through an oceanic crust-mantle transition zone (ICDP OmanDP holes CM1A and CM2B)

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The drillholes CM1A and CM2B of the ICDP Oman Drilling Project provide an unprecedented opportunity to study the behavior of metals Crust-Mantle boundary of an ancient fast-spreading mid-ocean ridge system (Oman ophiolite), where arriving primitive MORB melts extensively react with the mantle. The layered gabbro sequence (#Mg=58–68) is underlain by a sequence of massive dunites (#Mg=75–82), sometimes intercalated with gabbro (here called Moho Transition Zone, MTZ), followed by mantle harzburgites (#Mg=82–85).

The S concentration, like sulfide contents, increase downwards the gabbros (from 341 to 832 ppm), is high in dunites (~ 480 ppm) and then decrease down to ~ 63 ppm downwards the mantle harburgites. At least half of the sulfides are secondary, especially in serpentinized rocks, but magmatic pyrrhotite-pentlandite-chalcopyrite are well-preserved at gabbro-dunite contacts. Pyrrhotite shows a metal/sulfur (M/S) ratio of 0.90–1.02, wherein ~1.0 may indicate the presence of low-temperature troilite exsolutions. EPMA and LA-ICPMS measurements show that Zn, Co, and Cu reach maximum concentrations in the MTZ magmatic sulfides. This is confirmed with elevated bulk Cu contents (110–280 ppm) in the dunites intercalated with gabbros where $\delta^{34}S_{whole-rock}$ supports a predominantly mantle signature with minor seawater addition (+1.9 to +2.3‰, +3.6 to +5.5‰).

In situ $\delta^{34}S$ for pyrrhotites (+0.14‰ to +1.46‰), chalcopyrites (–0.78 to 0.73‰) and pentlandites (–0.27 to +2.35‰) provide a bulk $\delta^{34}S_{in-situ}$ (+0.4 to +1.4‰) similar to $\delta^{34}S_{whole-rock}$ (+0.6 to +0.9‰) in the respective samples. Calculated bulk $\delta^{56}Fe$ for a magmatic sulfide grain –0.12‰), is also close to mantle values (+0.025±0.025‰) [1]. As expected [2] $\delta^{65}Cu$ of magmatic chalcopyrites is higher (0.15–0.44‰), compared to secondary chalcopyrite and associated chalcocite (–1.02‰ to –0.56‰).

The enrichment in sulfides and selected metals (Cu, Zn, Co) in the MTZ seems to be originally magmatic, possibly through melt-mantle reaction between gabbroic veins and serpentinized mantle as we proposed previously for the slow-spreading oceanic lithosphere [2].

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[1] Craddock et al., 2013. Earth Planet. Sci. Lett. 365, 63–76

[2] CiÄ…Å¼ela et al., 2018. Geoch. et Cosm. Acta 230. pp. 155-189