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Why Primary Copper Enrichment Could Be Expected at the Moho Transition Zone?

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Highly increased chalcophile element concentrations in harzburgites which underwent interaction with MORB melts in comparison to normal abyssal harzburgites have been observed from the Kane Megamullian oceanic core complex (OCC; Mid-Atlantic Ridge, 23°30' N; Ciazela et al. 2014). Ciazela et al. 2015 quantified the Cu enrichment based on the bulk rock analyses of plagioclase peridotites and a contact zone between mafic vein and hosting mantle, obtaining a four times higher concentration in the former and a nine times higher concentration in the latter with respect to unaffected spinel harzburgites (36 ppm Cu). Here, we provide a hypothesis for this enrichment, based on the S determination of bulk samples, and the in situ microscopy and electron microprobe (EMPA) analyses of two contact zones between mafic veins and host peridotites.

We determined the S concentrations in six mantle samples from the Kane Megamullion oceanic core complex that interacted with mafic melt. The Cu and S concentrations correlate well (r=0.95) for this set of the samples. This implies that sulfides are the main phases concentrating Cu and probably other chalcophile elements. Moreover, we investigated by in-situ methods two thin sections containing peridotites that exhibit distinct contact zones (8 and 15 mm wide) adjacent to gabbroic veins. By using reflected light microscopy, we have estimated the density of large (>40 µm) sulfides in the contact zones that is ~3.3 grains/cm2, whereas it is only ~0.3 grains/cm2 in the background peridotite. No large sulfide occurs in the gabbro vein. A similar analysis for the medium (10-40 µm) sulfides shows they are more common but similarly distributed, with densities of ~6.0 grains/cm2, ~1.5 grains/cm2 and ~0.7 grains/cm2, respectively. Subsequently, we performed the EMPA mapping of selected areas (1 cm2) crossing the contact zones in both thin sections. Based on S distribution in the given areas, we have discovered that the density of small (<10 µm) sulfides overcomes the density of large and medium sulfides, and the main crystallization front of the sulfides is ~ 3 mm wide, and is located on the margins of the contact zones adjacent to the mafic veins. A similar pattern of sulfide distribution was observed in an experiment performed under high pressure (2 kbar) and high temperature (1150 °C) in an internally heated pressure vessel, using a sulfur-saturated basaltic melt which was filled in an capsule of olivine (olivine from San Carlos; Fo. 90). Most of sulfides (~90%) in the experimental product crystallized at the contact of the basaltic glass adjacent to olivine capsule material.

The narrow sulfide crystallization fronts observed in the two thin section represent an example of a small-scale melt/rock interaction at the margins of local melt channels transporting MORB-type melt during its ascent through the lithospheric mantle. However, we suppose that this process may also operate on a broader scale, considering that the Cu concentration in 14 dunites from the Kane Megamullion area is 118 ± 17 ppm Cu (1σ; Ciazela et al. 2014), which is four times higher than that found in the associated spinel harzburgites. Dunites are usually formed due to reaction of mantle and MORB melts during their ascent through the lithosphere. That this processes may be of broader significance is indicated from observations in the Samail ophiolite in the Sultanate Oman. Here, some dunites, preferentially found in the up to several hundred meter thick Moho transitions zone, are associated with ancient copper deposits. At least 12 sites of ancient Cu excavations have been found throughout this zone (Boudier, personal communication). Although Cu has partially been redeposited in secondary processes, the data from our study and the characteristic distribution of the ancient mining sites imply that the first stage of Cu enrichment could be a primary magmatic process. The upcoming SlowMo project gives us a unique opportunity to verify this hypothesis.

Ciazela, J., Dick, H., Koepke, J., Kuhn, T., Muszynski, A., & Kubiak., M., 2014. Mantle-crust differentiation of chalcophile elements in the oceanic lithosphere. Abstract V31B-4756 presented at AGU Fall Meeting, San Francisco, Calif., 15-19 Dec.

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