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Hydrothermal Precipitation of Chromites

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Chromite is a typical refractory igneous mineral, precipitated from mafic magmas at relatively high temperatures. Chromites commonly occur in sedimentary, metamorphic and metasomatic rocks, where they are interpreted as relics of an igneous phase and serve as the source of Cr for low-temperature Cr-bearing minerals. We present evidence for the dissolution and nucleation of chromite within hydrothermal solutions from the northern Oman ophiolite.

A crustal diopsidite dike replaces the layered gabbro about 70 m above the base of the lower crust section along Wadi Fizh, northern Oman ophiolite. The main mineral assemblage is diopside + anorthite + uvarovite + chromite + chlorite + titanite. Minute euhedral chromite grains are enclosed by uvarovite (Ca-Cr garnet). Coarser chromite grains are discrete and skeletal, and show oscillatory concentric zoning. The uvarovite shows oscillatory concentric zoning in terms of color, and the chromite is embedded only in the greenish (possibly high-Cr#) zones of the uvarovite. Another diopsidite dike (mantle diopsidite), found in dunite, located 20 m below the base of layered gabbro section, is comprised of diopside, grossular and chromite. The chromite sometimes forms thin seams and is of xenocrystic origin. The chromite seam is parallel with that in the surrounding dunite, suggesting a replacement origin of the diopsidite. Some of the xenocrystic chromite grains are partially resolved, and thin film-like chromites fill grain boundaries of nearby diopside grains.

The hydrothermal chromite is similar in chemistry to that commonly found in igneous rocks (e.g., Cr# = 0.8, Mg/(Mg + Fe²⁺) = 0.1-0.2, TiO₂ < 0.3 wt% and Fe³⁺/(Cr + Al + Fe³⁺), up to 0.3), but its Cr# is clearly different from that of mantle chromite (0.6–0.7) in peridotites and chromitites from the Oman ophiolite. The partially resolved chromite (xenocrystal) in the mantle diopsidite is similar in chemistry to ordinary mantle chromite from Oman. The diopside is overall Mg-rich, but its Mg# is lower in the crustal diopsidite (0.84–0.97) than in the mantle diopsidite (0.95–1.0). The greenish diopside in the

mantle diopsidite contains up to 2wt% of Cr₂O₃. The uvarovite shows a variation in Cr#, from 0.5 to 0.8 with an increase in greenish tint. The anorthite is Ca-rich, and its Ca/(Ca + Na) ratio is >0.93. The chlorite is Mg-rich Cr-bearing clinocllore.

Laser Raman spectrometry indicates the minute fluid inclusions in minerals (titanite and anorthite) from the crustal diopsidite are H₂O-rich. They also contain small amount of Cl, equivalent to 5–10 wt NaCl (Mernagh and Wilde, 1989). They contain fine composite grains of anhydrite and calcite as daughter minerals. Preliminary La-ICP-MS analysis on the fluid inclusions detected Na but not K.

Our results mentioned above suggest that a hydrothermal solution collected Cr by partial to total dissolution of chromite within the upper mantle and precipitated chromite, along with high-Cr# uvarovite, within the lower crust upsection. The temperature of formation of the crustal diopsidite is higher than 500–550°C (stability of anorthite + diopside + chlorite) and lower than 700–800°C (stability clinocllore) (Arai and Akizawa, 2014). The pressure condition is 0.2–0.3 GPa because of the stratigraphical position (just above the Moho) and the thickness of the crustal section, 6 km (Reuber, 1988).

The metasomatic agent involved was a CO₂- and SO₂-bearing hydrothermal solution containing appreciable silicate components that could carry Cr, possibly as a carbonate and/or sulfate complex (cf., Rai et al., 2007). The results from this study suggest that a hydrothermal origin is possible for chromites in ultramafic rocks that have experienced fluid activity. Experimental results (Nakamura and Kushiro, 1974; Mibe et al., 2002) suggest that olivine-oversaturated fluids (or supercritical fluids) are possibly formed in the mantle if hydrothermalism is available. This indicates a possibility of hydrothermal dunite formation in the mantle. Therefore, the formation of hydrothermal chromitite enveloped by hydrothermal dunite is possible if chromite is effectively concentrated in the peridotite-H₂O system.

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