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Cr-rich olivine in deserpentinized peridotite and its implication

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Formation of Cr-rich olivine (Cr_2O_3 >0.1 wt %) in the presence of Cr-spinel ± pyroxene has been thought to require extremely reducing and/or high-temperature conditions. Indeed, terrestrial olivine is Cr-free except for some high-T occurrences from Archaean komatiites, inclusions in diamonds, and ultrabasic pseudotachylytes. Deserpentinization is an important fluid release process in subduction zones. One of the best studied examples of this process occurs in Cerro del Almirez (SE Spain), where the antigorite-out reaction front (Atg = Ol + Opx + Chl + H_2O) at eclogite facies conditions is well preserved. Large elongate olivine crystals (similar to spinifex textures in komatiites) at the reaction front contain abundant exsolution lamellae of Cr-magnetite, and estimated primary compositions of the elongate olivine show high Cr content (0.1-0.4 wt% Cr_2O_3), leading to a proposal of the spinifex-like textured peridotite being pseudotachylyte (>1600 ℃, Evans & Cowan, 2012), in contrast to the generally held view that the elongate olivine crystalized under ambient subduction-zone T (~680 ℃ at 1.9 GPa) but high supersaturation conditions.

To better understand the dehydration process of serpentinite in subduction zones, this study focuses on a deserpentinized peridotite from the Eclogite unit of the Sanbagawa belt (SW Japan). It consists of porphyroblastic olivine (~70 vol %, Mg#=0.952±0.004, NiO=0.37±0.04 wt%), antigorite (Al_2O_3=0.3-0.5 wt%), brucite, zoned Cr-spinel and Ni sulfides. Olivine porphyroblasts contain inclusions of antigorite, brucite, magnetite and Ni sulfides, suggesting that the olivine-forming reaction Atg + Brc = Ol + H_2O took place after serpentinization of a dunitic protolith. Sporadic occurrences of Ni-rich olivine (up to 8.1 wt% NiO) within the olivine porphyroblasts suggest prograde breakdown of Ni-rich sulfides. Zoned Cr-spinel grains are composed of a chromite core, a ferritchromite mantle, and an irregular-shaped overgrowth of Cr-magnetite. The chromite core, being the only primary mineral preserved, shows Cr-rich/Ti-poor compositions [Cr/(Cr+Al)=0.74-0.76, TiO_2 <0.14 wt%] indicative of a forearc wedge mantle origin. The Cr-magnetite rim contains inclusions of Cr-rich olivine (Cr_2O_3 = 0.12-0.70 wt %, Mg#=0.950±0.004, NiO=0.37±0.04 wt%), in addition to Cr-rich antigorite (Al_2O_3=0.5-3.1 wt%, Cr_2O_3=0.3-3.9 wt%), diopside and brucite.

Formation of the Cr-rich olivine inclusions can be explained by dehydration of Cr-rich antigorite that developed around Cr-spinel grains. Slow diffusivity of Cr^{3+} compared to the olivine growth rate may have caused disequilibrium Cr incorporation into olivine under low-T conditions just above the Atg + Brc breakdown equilibrium (~460-500 ℃). Alternatively, a distinct Cr substitution mechanism (Cr^{3+} + Fe^{3+} = Mg + Si) than that proposed for high-T olivine (Cr^{2+} = Mg or $2Cr^{3+}$ + vacancy = 3Mg) could explain the low-T formation of Cr-rich olivine. In any case, the local uptake of Cr in olivine from the Sanbagawa metaserpentinite does not imply very high-T conditions, and this weakens the main basis of the pseudotachylyte hypothesis for the spinifex-like textured peridotite in Cerro del Almirez. The geological record on the causal link between deserpentinization and deep earthquake nucleation remains elusive.

Keywords: Cr-rich olivine, antigorite, dehydration, subduction zone