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Cr and Fe behavior during hydrothermal alteration of chromitites in the Sabzevar ophiolite (NE Iran): chemical and nano-textural characterization

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In order to understand the geochemical behavior of Cr (and Fe) during hydrothermal alteration of Cr-spinel, several chromitite bodies of variable sizes hosted in dunite-harzburgite from the central sector of the Sabzevar ophiolite belt (NE Iran) were examined. Two main alteration features were distinguished in spinels from both chromitite and dunite aureoles around chromitite: (i) Partly altered chromite corresponding to homogeneous spinel cores (Cr-spinel-I) either rimmed by or locally replaced by patches of *porous chromite with* pores filled with magnetite, serpentine and chlorite*, or heterogeneous domain with little or no inclusions/pores (ii) Zoned chromite* grains with a homogeneous core rimmed by a homogeneous corona of secondary spinel. Two chemical trends related to sub-solidus equilibration and hydrothermal alteration were observed in spinels from the Sabzevar chromitite-dunite samples: (i) in the massive and semi-massive chromites, the trend consists in the progressive increase of Cr without Fe^{3+} incorporation; (ii) in disseminated chromite and dunite samples, the increase in Cr is smaller and associated with Fe^{3+} increase. TEM observation at the nanoscale shows that porous Cr-spinel poorer in Al and Mg and richer in Cr and Fe contains relicts of homogeneous Cr-spinel-I and intercalated platelets of magnetite and lizardite/chlorite. Automated crystal orientation mapping (ASTAR) reveals the epitaxial growth of porous Cr-spinel and magnetite from Cr-spinel-I. The (001) and (111) planes of lizardite/chlorite and Cr-spinel/magnetite, respectively, are parallel. This suggests that spinel alteration occurs through local replacement involving chlorite and serpentine formation. A sequence of alteration during cooling involving first chlorite at temperatures below ~700°C and then serpentine formation is also predicted with thermodynamic modelling. The two different trends in composition between massive and disseminated chromites are reproduced with mass balance calculations by considering water to rock ratio >1 and aqueous Mg formation. In this hydrothermal alteration process, chromium is found to be immobile even during serpentinization where fO_2 is expected to be very low. Aluminum is transferred from the chromitite body to its host dunite (chlorite formation) and, on the contrary, iron is transferred towards the chromitite to eventually form magnetite ores.