Goldschmidt 2021 Abstract
https://doi.org/10.7185/gold2021.8148

Multi-stage Hydrothermal Alteration of Chromium Spinels from the Sabzevar Ophiolite (SE Iran)

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Magnetite deposits comprise a discontinuous trail of massive magnetite ore bodies in highly sheared serpentinites of the Late Cretaceous Sabzevar ophiolitic belt, northeastern of Iran. Spinel grains are observed within both magnetite ores and host serpentinite. Magmatic chromian spinels with compositions close to $(Mg_{0.6},Fe_{0.4})(Cr_{1.2},Al_{0.75},Fe^{3+}_{0.05})O_4$ are preserved as relics in the host serpentinite. They display a porous alteration rim composed of patches of Cr-chlorite, a spinel of composition $(Fe_{0.6},Mg_{0.4})(Cr_{1.4},Al_{0.4},Fe^{3+}_{0.2})O_4$ (Cr-spinel II), magnetite and ferritchromite ($FeCr_2O_4$). In the magnetite ore bodies, Cr-spinel II is surrounded by ferritchromite and magnetite. Two generations of magnetite are discernible. A first ~ 20 µm-wide magnetite rim displays a SiO_2 content < 1 wt.%. A second magnetite rim is larger (40 to 200 µm) and shows a higher SiO_2 content, ranging between 1.21 and 2.35 wt.%. A micrometer ferritchromite rim between Cr-spinel II and magnetite I was identified with TEM. Thermodynamic modeling indicates that Cr-spinel II and chlorite are first produced after magmatic spinel between 575 and 725 °C. Ferritchromite and magnetite are predicted to form at lower temperature (T < 400 °C) under a high H_2 fugacity, probably associated with serpentinization. We interpret this progressive alteration as the result of seaweater/mantle rock interaction during exhumation on the seafloor. Thermodynamic calculations also suggest that the magnetite ore is formed through Fe rather than Cr transfer. Iron has to be transported at a scale > 10 m to explain magnetite ore formation during serpentinization.