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Identification of Cr-magnetite in Neoproterozoic serpentinites resulting of Cr-Spinel alteration in a past hydrothermal system: Aït Ahmane ultramafic unit (Bou Azzer ophiolite, Anti Atlas, Morocco)

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If magnetite is a common serpentinization product, centimetric, massive and almost pure magnetite veins are rarely observed in serpentinites. Unique examples of these, in the Aït Ahmane ultramafic unit (Bou Azzer Neoproterozoic ophiolite, Anti-Atlas, Morocco), offer the opportunity to assess the hydrothermal processes that prevailed at the end of the Precambrian.
Pseudomorphic lizardite/chrysotile texture of unaltered serpentinites suggests an oceanic-like first serpentinization stage, under static and low temperature conditions (T <350 °C). Nevertheless, abundance of magnetite (up to 7.86 wt. %) and absence of brucite, attest that serpentinization probably took place over 200 °C. Magnetic measurements reveal a lower magnetite content in hydrothermalized serpentinites hosting the magnetite veins, with lowest values (down to 0.58 wt. %) for bleached serpentinites constituting the wall rock of veins. Fresh serpentinites are characterized by relatively small sized magnetite grains, mainly pseudo-single domain magnetites. Hysteresis parameters and first order reversal curves (FORC) diagram denote a magnetic grains size that increases with the alteration. This well-marked tendency is also reveals by a shift of the isothermal remanent magnetization (IRM) components toward lower coercivities for altered serpentinites. This grain size increase is associated with the emergence of a new magnetic phase with the hydrothermal alteration, the Cr-magnetite, evidenced by thermomagnetic measurements with Tc around 540 °C. This ultimate Cr-spinel alteration product is associated with another Cr-spinel alteration mineral, the ferritchromite, also identifiable on thermomagnetic curves by a rapid increase of the magnetite susceptibility at 130 °C due to its transformation during heating. Thermomagnetic curves allow us to propose a proxy, the CrM/M ratio providing a quantification of the Cr-magnetite contribution to the magnetic susceptibility, relatively to the pure magnetite one. This CrM/M ratio increases drastically with the hydrothermal alteration of serpentinites and Cr-spinels, attesting of a change of the magnetic mineralogy.
Combined with petrography, mineral and bulk chemistry, these magnetic data allow us to propose that a Cl-rich acidic hydrothermal event, involving temperatures below 350 °C, appears to have been responsible of an intense magnetite leaching in host serpentinite and an advanced Cr-spinel alteration in ferritchromite and Cr-magnetite. Iron provided by this leaching may have conducted to the unique magnetite veins formation in the Aït Ahmane ultramafic unit. Two different settings are proposed concerning the nature of the hydrothermal event: (1) a continental hydrothermal system as advanced for the Co-Ni-As ores in the Bou Azzer inliers or (2) an oceanic black smoker type hydrothermal vent field on the Neoproterozoic sea-floor.