Nano-geochemistry of trace elements in magnetite from the Los Colorados IOA deposit in Chile

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The geochemical association and distribution of trace elements (TE) in magnetite help to elucidate the origin, formation processes, and alteration of Fe-ore deposits. This work reports TE nanogeochemical data in zoned hydrothermal magnetite samples from diorite of the Kiruna-type, Los Colorados, iron-oxide apatite (IOA) deposit, Chilean Iron Belt.

EMPA elemental maps of magnetite revealed two alternating zone types, <50 μm in width: zone-(i) is rich in Ti, Al, Si, Ca, Mg, Na, Si, Mn, contained in solid solution; and zone-(ii) contains TE accumulated in nanoparticles (NPs). The maximum concentrations of TE in zone-(i) (in ppm) are: Al (8300), Si (8000), Mg (5100), Ca (3400), Ti (3000), Mn (2700), Na (1000), respectively. On the ther hand, the maximum concentrations of TE in zones-(ii) (in ppm) are: Al (4800), Si (3400), Mg (2600), Ca (1700), Ti (1700), Mn (600), Na (400), respectively. The V content is relatively constant across zoning, and varies between 2000-2300 ppm.

TEM observations of magnetite samples prepared using focused ion beam (FIB) revealed a sharp contact between zones-(i) and -(ii) in single crystals of magnetite. Three types of NPs were identified in zone-(ii): (a) crystallographically oriented, euhedral, needle-like Ca-Mg-Si NPs, 50x500 nm in size, in magnetite, (b) isometric NPs of rutile, ~100x200 nm in size, associated with (c) anhedral (Al,Mg,Si,Ca)-rich NPs. The alternate zoning in TE incorporated in solid solution vs. forming TE NPs in magnetite are indicative of significant fluctuations in the content of TE in the mineralizing fluid and suggest changes from equilibrium conditions to kinetically-induced precipitation, respectively.