

TRACE ELEMENTS IN MAGNETITE AS INDICATORS OF PETROGENESIS AND PROVENANCE: APPLICATIONS TO MINERAL EXPLORATION

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There is growing interest in using detrital magnetite, from sediments and/or glacial till, as an indicator mineral in the exploration of mineral deposits because magnetite from different ore-forming environments appear to have distinct trace element signatures [1-2]. Magnetite forms under a wide variety of conditions, crystallizing at high temperature from silicate and sulfide liquids or precipitating at lower temperatures from a wide variety of hydrothermal fluids. A full suite of trace elements (25-30) can now be readily determined in situ in magnetite using laser ablation ICP-MS. However, in order to use magnetite chemistry as an indicator of petrogenesis and provenance it is necessary to understand 1) which trace elements are diagnostic, and 2) which parameters and processes control the trace element distribution in magnetite (such as partition coefficients, magma/fluid composition, redox and temperature). In this presentation I review magnetite chemistry from a variety of ore-forming environments [2-4], which include magmatic deposits (Fe-Ti-V-P and Ni-Cu-PGE), high-temperature (T) hydrothermal deposits (iron-oxide-copper-gold and porphyry-Cu) and low-T hydrothermal deposits (retrograde skarn, volcanogenic massive sulfides and banded iron formation). Magnetite records the changes in composition of magmatic melts, driven by crystal fractionation, in both silicate and sulfide systems. The composition of magnetite is also sensitive to co-crystallizing phases, with marked depletion in Ti when ilmenite crystallizes before magnetite and in Cu when a sulfide liquid segregates. Relative depletions of Cu and Ni in magnetite (and ilmenite) also have the potential to evaluate the fertility of mafic intrusions for Ni-Cu-sulfide mineralization hidden at depth [5]. Compared to magmatic magnetite, the chemical signature of hydrothermal magnetite is distinct, being depleted in elements that are immobile during alteration. Magnetite formed from low-T fluids has the lowest overall abundance of trace elements, probably due to reduced solubility at lower temperatures.

This technique has been applied to the enigmatic massive magnetite “lava flows” from El Laco, Chile, whose origin is still highly debated. The chemical signature of magnetite from the El Laco massive ore, compared with that from andesitic host rocks (both fresh and altered), provides new constraints to support the hydrothermal model of alteration of andesite lava flows rather than a magmatic origin from an Fe-oxide melt [6]. The trace element ‘fingerprinting’ of magnetite can also be applied successfully to provenance of sedimentary rocks [7].

References

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