

## The Magmatic-Hydrothermal Evolution of the El Laco Recent Iron Oxide Deposit

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The El Laco iron oxide deposit is one of the largest and the most recent (<3 Ma) of the magnetite-apatite deposits of South America. It is located in the current volcanic arc of the Central volcanic zone of the Atacama Desert region of northern Chile, in the flanks of the Pleistocene El Laco volcano; the orebodies are found as large stratabound lenses of magnetite interbedded with flows of calc-alkaline andesite. These orebodies are rooted in subvertical pipes and dikes of massive magnetite hosted by large zones of alkali-calcic alteration, dominated by diopside, scapolite, K-feldspar, anhydrite, and magnetite hosting stockworks and breccias supported by magnetite as well as large veins with zoned unidirectional growth of diopside, magnetite, and anhydrite. The uppermost host andesite shows a pervasive steam-heated acid-sulfate alteration dominated by alunite and gypsum that is coeval with the replacement of the magnetite by hematite.

The magnetite orebodies are interpreted as having crystallized from unusual iron oxide melts at or close to the surface. Major arguments for a magmatic origin include (1) the presence of widespread volcanic structures that are not found in the host andesite; (2) the presence in the andesite of abundant melt inclusions with evidence for the separation of an iron oxide melt; and (3) the  $\delta^{18}\text{O}_{\text{magnetite}}$  signatures, which are similar to those of the magnetite in the unaltered andesite;  $\Delta_{\text{andesite-magnetite}}$  values indicate temperatures of formation always above 650°C. The related alkali-calcic alteration and associated veins also formed at unusually high temperatures (>850°C), as indicated by the  $\Delta^{18}\text{O}$  fractionation between diopside and magnetite and the presence of inclusions of hydrosaline melts that do not homogenize even at 800°C.

The suggested model involves the separation of an iron oxide melt from a parental silicate melt of andesitic composition due to contrasting viscosities and ascent to (sub)volcanic depths. This ascent and further crystallization was accompanied by the exsolution of a hydrosaline melt, which reacted with the host andesite forming the alkali-calcic alteration, and of large amounts of vapor that carried large amounts of F, P, and  $\text{SO}_4$ ; it reacted with the local water or snow to form the steam-heated alteration zone. This evolution is consistent with the  $\text{H}_2\text{O-NaCl}$  phase diagram at low pressures, which predicts the absence of liquid water at temperatures between approximately 800° and 350°C.

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