

Fe, O, and H Stable Isotope Signatures from Five Surficial Iron Oxide Deposits of the El Laco Volcano, Chile

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ABSTRACT

The 734 Mt (at 49.2% Fe) Plio-Pleistocene El Laco IOA deposit, hosted within a ~20-km² andesite stratovolcano complex located in northern Chile, remains one of the most enigmatic mineral deposits on Earth. Proposed genetic models include magnetite crystallization from an erupting immiscible Fe- and P-rich melt, metasomatic replacement of andesitic lava flows by a hypogene hydrothermal fluid, and iron oxide precipitation from a basinal brine. In this study, we fingerprint the source of the ore forming fluids responsible for mineralization at El Laco by measuring $\delta^{56}\text{Fe}$, $\delta^{18}\text{O}$, $\Delta^{17}\text{O}$, and $\delta^2\text{H}$ stable isotopes in bulk iron oxide (primarily magnetite with minor, secondary hematite and goethite) from five surficial ore bodies around the El Laco volcano. Values of $\delta^{56}\text{Fe}$ for iron oxides from all five ore bodies range from 0.04 to 0.70 ‰ (avg = 0.29, n = 26, SD = 0.15 ‰), with a narrow range of only 0.14 to 0.20 (n = 5) for magnetite from Rodados Negros. Iron oxides from Laco Sur, Cristales Grandes, and San Vicente Alto yielded $\delta^{18}\text{O}$ values that range from 4.4 to 4.5‰ (n = 5), 3.0 to 3.9‰ (n = 5), and -8.5 to -0.6‰ (n = 5) respectively. Magnetite from Rodados Negros yielded $\delta^{18}\text{O}$ values from 2.6 to 3.8 ‰ (n = 9), and $\Delta^{17}\text{O}$ values that range from -0.13 to 0.10 (n = 5). Bulk iron oxides from Laco Norte yielded $\delta^{18}\text{O}$ values that range from -10.2 to 4.4 ‰ (avg = 0.6 ‰, n = 24), with increasing value correlating to increasing magnetite content, and $\delta^2\text{H}$ ranges -189.4 to -61.1 (n = 10). The Fe isotope data indicate a magmatic source for Fe in all the El Laco ore bodies. The O isotope data from Laco Sur, Cristales Grandes, and Rodados Negros indicate a magma reservoir, whereas O and H data at Laco Norte and San Vicente Altos reveal a magmatic/magmatic-hydrothermal signature that has been altered to meteoric values consistent with goethite in equilibrium with local O and H meteoric isotopic values. The sum of the data unequivocally fingerprint a magmatic source for the ore bodies at El Laco and do not necessitate an isotopically specialized magma.