

Iron, O, and D/H stable isotopes from five El Laco iron oxide ore bodies indicate a magmatic/magmatic-hydrothermal genesis with variable alteration by meteoric water

TM Childress¹, AC Simon¹, M Reich², F Barra², I Bindeman³

¹Department of Earth and Environmental Sciences, University of Michigan, Ann Arbor, Michigan; ²Department of Geology and Andean Geothermal Center of Excellence, University of Chile, Santiago, Chile; ³Department of Geological Sciences, University of Oregon, Eugene, Oregon;

The 734 Mt (at 49.2% Fe) Plio-Pleistocene El Laco IOA deposit, hosted within a ~20-km² andesite stratovolcano complex located within the 1,300-km-long Central Volcanic Zone of Chile, remains one of the most enigmatic mineral deposits on Earth. Proposed genetic models for El Laco include magnetite crystallization from an erupting immiscible Fe- and P-rich melt, metasomatic replacement of andesitic lava flows by a hypogene hydrothermal fluid, and magnetite 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 D/H stable isotopes in bulk iron oxide (primarily magnetite with minor, secondary hematite and goethite) from five different surficial ore bodies around the El Laco volcano: Laco Norte, Laco Sur, Rodados Negros, Cristales Grandes, and San Vicente Altos. Values of $\delta^{56}\text{Fe}$ for magnetite from all five ore bodies range from 0.04 to 0.70 ‰ (avg = 0.29 ‰, n = 26, SD = 0.15 ‰), with a range of only 0.14 to 0.20 ‰ (n = 5) for magnetite from Rodados Negros. Magnetite from Laco Sur, Cristales Grandes, and San Vicente Altos 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 $\Delta^{17}\text{O}$ ranges from -0.13 to 0.10 ‰ (n = 5). Magnetite from Laco Norte yielded $\delta^{18}\text{O}$ values that range from -10.2 to 4.4 ‰ (avg = 0.7 ‰, n = 21, SD = 4.2 ‰), and D/H ranges -192.8 to -61.1 ‰ (n = 5). 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 source reservoir, whereas O and D/H data at Laco Norte and San Vicente Altos reveal an originally magmatic/magmatic-hydrothermal signature that has been altered to meteoric values. The sum of the data unequivocally fingerprint a magmatic source for the ore bodies at El Laco.