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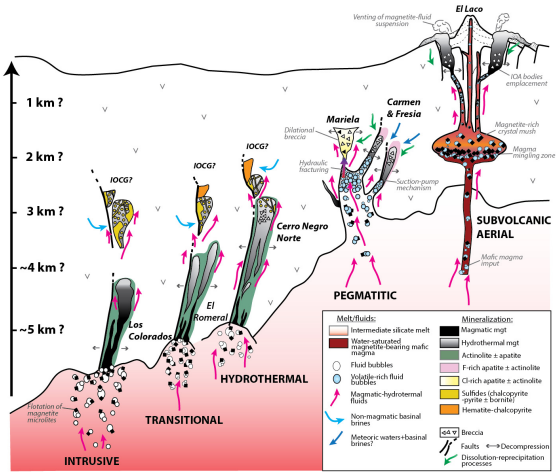
Magmatic-hydrothermal ore-forming processes revealed by magnetite geochemistry of Chilean iron oxide-apatite (IOA) deposits

MS. GISELLA PALMA LIRA, PHD[1], FERNANDO BARRA[2], MARTIN REICH[3], ADAM SIMON[4] AND RURIK ROMERO NÚÑEZ[2]

[1]Vergara 726
[2]Universidad de Chile
[3]University of Chile
[4]University of Michigan

Presenting Author: gipalma@ing.uchile.cl



Magnetite (Fe_3O_4) is the main iron ore of iron oxide-apatite (IOA) which represent the Cu-deficient end-member of the known "iron oxide-copper-gold (IOCG) clan". Magnetite chemistry has been used as a petrogenetic indicator to identify the geological environment of ore formation and as a fingerprint of the source reservoir of iron. Here we present new textural and microanalytical EPMA and LA-ICP-MS data of magnetite from Carmen, Fresia, Mariela and El Romeral IOA deposits located in the Cretaceous Chilean Iron Belt. We also provide a comprehensive summary and discussion of magnetite geochemistry from Andean IOAs including Los Colorados, Cerro Negro Norte, El Romeral (Chilean Iron Belt) and the Pliocene El Laco (Chilean Altiplano). The contrasting magmatic (high Ti, V, Ga) and hydrothermal (low Ti, V, Ga) signatures of magnetite, combined with a variety of microtextures (e.g., oscillatory zoning, colloform banding, reequilibration textures, mineral inclusions, exsolution lamellae and symplectites) revealed that these deposits formed by a combination of igneous and hydrothermal processes which involve multiple origin of ore-forming fluids (e.g., magmatic, meteoric, basinal brines). Moreover, dissolution-reprecipitation processes are important in the formation of hydrothermal magnetite and could modify the primary trace element distribution and textural. Chilean IOA deposits formed under a wide spectrum of P-T-X-fO_2 conditions. Each deposit describes a unique T-fO_2 path ranging from high-T, low-fO_2, purely magmatic (> 600 °C) conditions; to intermediate-T and -fO_2 magmatic-hydrothermal (300–600 °C) to low-T, high-fO_2 hydrothermal (< 200–300 °C) conditions at different levels of the crust. The *flotation model* provides the general framework to plausibly explains such features, the "magmatic-hydrothermal" origin of IOA deposits in arc-settings, and allows variation and definition of different subtypes of IOA mineralization, e.g., deep, *intrusive-like* (Los Colorados), *transitional* (El Romeral), *hydrothermal-like* (Cerro Negro Norte), apatite-rich, *pegmatitic-like* (Carmen, Fresia and Mariela) and shallow, *subvolcanic/aerial* (El Laco), that are fundamentally controlled by the depth of formation, cooling, decompression related to faults/structures, the composition of the host rocks, and the source and flux rate of hydrothermal fluids.