American Mineralogist, Volume 105, pages 397–408, 2020

Textural and compositional evolution of iron oxides at Mina Justa (Peru): Implications for mushketovite and formation of IOCG deposits

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Abstract

Magnetite is a common mineral in many ore deposits and their host rocks. It contains a wide range of trace elements that can be used to fingerprint deposit types and hydrothermal processes. In this study, we present detailed textural and compositional data on magnetite of the Mina Justa deposit in southern Perú to constrain the formation of iron oxides in the iron oxide Cu-Au (IOCG) deposit type.

Two types of magnetite, i.e., mushketovite (T_{M1}) and granular (T_{M2}) magnetite, are identified based on their morphology. Mushketovite shows three different zones (central bright, dark, and outer bright) in backscattered electron (BSE) images. The central bright part (T_{M1}-1), characterized by abundant porosity and inclusions, was intensively replaced by dark magnetite of the median rim (T_{M1}-2). The outer rim (T_{M1}-3) is also bright but lacks porosity and inclusions. Granular magnetite (T_{M2}) is anhedral and shows two different brightness levels (dark and bright) in BSE images. The dark (T_{M2}-1) and bright (T_{M2}-2) domains are intergrown, with irregular boundaries. In general, the dark zones of both magnetite types (T_{M1}-2 and T_{M2}-1) are characterized by higher Si, Ca, Al, and lower Fe contents than the bright zones. Additionally, the lattice parameters of the two types of magnetite are similar and slightly lower than that of pure magnetite, indicating that some cations (e.g., Si^{4+}, Al^{3+}) whose ionic radii are smaller than Fe^{2+} or Fe^{3+} may have entered into the magnetite structure by simple or coupled substitutions.

Our study shows that oxygen fugacity and temperature change are the dominant mechanisms leading to the formation of different types of magnetite at Mina Justa. Primary hematite, identified by Raman spectroscopy, was transformed into magnetite (T_{M1}-1) due to a sharp decline of f_{O_2} and then replaced by T_{M1}-2 magnetite during temperature increase, followed by the formation of T_{M1}-3 due to decreasing temperature, eventually forming the mushketovite with different zones. The granular magnetite may have originally precipitated from hydrothermal fluid that crystallized T_{M2}-1 and also T_{M1}-2 magnetite and was then modified by changing temperature and f_{O_2} to form T_{M2}-2. Even though the iron oxides in IOCG deposits may have formed in the same alteration stage, they could undergo a very complicate evolution process. Therefore, it is important to combine texture and mineral chemistry to investigate the origin and evolution history of iron oxides.

Keywords: Iron oxides, mushketovite, texture, mineral chemistry, hydrothermal fluids, IOCG deposit