Textural and chemical evolution of magnetite from the Paleozoic Shuanglong Fe-Cu deposit: Implications for tracing ore-forming fluids

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Abstract

The Aqishan-Yamansu belt in Eastern Tianshan (NW China) hosts several important Fe and Fe-Cu deposits, the origin of which is the subject of considerable debate. The coexistence of various types of ore-forming fluids makes it difficult to distinguish the genesis of the Fe-Cu deposits. We present detailed textural and compositional data on magnetite from the Paleozoic Shuanglong Fe-Cu deposit to constrain the formation of iron oxides and the evolution of the ore-forming fluids and thus define the genesis of the Fe-Cu ores.

Based on the mineral assemblages and crosscutting relationships of veins, two mineralization stages were established, including the early Fe mineralization and late Cu mineralization stage. Three types of magnetite, i.e., platy (MA), massive (MB), and granular (MC) magnetite occur in the Fe mineralization. Backscattered electron (BSE) images identified display oscillatory zoning in an early hematite and transformational mushketovite phase (MA-I), characterized by abundant porosity and inclusions, as well as two later generations, including an early dark (MA-II, MB-I, and MC-I) and later light magnetite (MA-III, MB-II, and MC-II). The MA-I has extremely high W contents and mostly displays as micro- and invisible scheelite inclusions, which were probably caused by the W expulsion during mushketovitization. The texture and composition of magnetite suggest that the later light magnetite formed via dissolution and reprecipitation of the precursor dark magnetite, and the temperature and oxygen fugacity of fluids decreased over time. Our study also shows the MB-II magnetite and coexisting chlorite display synchronous oscillatory zoning, with the calculated temperature from 444 to 212 °C. Such variations could indicate the incursion of external low-temperature fluids with high salinity, which can dissolve the primary dark magnetite. This study provides a good example of using magnetite to trace the complex evolution and multiple sources of ore-forming fluids.

Keywords: Magnetite, texture and chemistry, ore-forming fluid, Fe-Cu deposit, Eastern Tianshan

Introduction

Magnetite is a common mineral in many types of ore deposits, including Kiruna-type, BIF (banded iron formation), magmatic Fe-Ti oxide, Fe-skarn, IOCG, and porphyry deposits, and also in many igneous, metamorphic, and sedimentary rocks (Dare et al. 2014; Dupuis and Beaudoin 2011; Hu et al. 2015, 2017; Huang and Beaudoin 2019a; Nadoll et al. 2012, 2014; Wu et al. 2019; Zhao et al. 2018a). It can accommodate a variety of trace elements into its inverse spinel structure by substitution with Fe3+ and Fe2+ in tetrahedral or octahedral sites (Nadoll et al. 2014), and its textures and chemical compositions vary in response to different mineralizing systems and physicochemical conditions (Dare et al. 2014; Dupuis and Beaudoin 2011; Huang et al. 2019a; Nadoll et al. 2012). Previous studies have developed a series of discriminant diagrams to fingerprint various deposit types or ore-forming processes based on the compositional variety in magnetite (Dupuis and Beaudoin 2011; Nadoll et al. 2012). However, recent studies have also shown that the textural and chemical composition of magnetite can be significantly modified or reequilibrated by hydrothermal fluid and supergene processes (Broughm et al. 2017; Bain et al. 2021; Hu et al. 2014, 2015; Huang and Beaudoin 2019; Huang et al. 2018; Wen et al. 2017; Zhang et al. 2020b), for instance, mixing with high-salinity, chlorine-rich fluids have been suggested as an important mechanism for inducing coupled dissolution-reprecipitation (DR) reactions in magnetite from hydrothermal deposits such as skarn deposits and iron oxide-copper-gold deposits (Hu et al. 2014, 2015; Huang and Beaudoin 2019; Liang et al. 2020; Yin et al. 2017).