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The Role of Evaporitic Rocks in the Formation of the Xishimen Iron Skarn Deposits, Eastern North China Craton

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The Xishimen iron skarn deposit is one of numerous iron skarn deposits in the Handan-Xingtai area, North China Craton (NCC). This deposit contains 110 Mt million tons of Fe with an average grade of 43 wt. %. Mineralization mainly occurred along the contact between an early Cretaceous diorite stock and the Middle Ordovician Majiagou and Cixian Formations consisting of limestone and evaporate-bearing dolomitic limestone. Magnesian skarn assemblages are extremely developed in the contact zone whereas intensive albitization is widespread within the diorite stock.

Quartz and amphibole from the ore-related diorite and diopside from the skarn assemblages contain abundant fluid inclusions. Four types of fluid inclusions are distinguished at room temperature: two phase aqueous inclusions (type 1), opaque mineral-bearing fluid inclusions (type 2), transparent daughter mineral-bearing inclusions (type 3), and gas rich aqueous inclusions (type 4). Type 1 fluid inclusions in quartz are small (<5 μm) and present as trails penetrating crystal boundaries, thus are interpreted as secondary fluid inclusions. Type 2 inclusions are abundant in quartz, amphibole and diopside and show similar microthermometric behavior marked by halite dissolution after vapor bubble disappearance. Some inclusions decrepitated when heated above 500°C, without homogenization. The opaque phases did not dissolve even heated to 800 °C. The salinity values were calculated from the temperature of halite dissolution, ranging from 49.7 to 70.8 wt.% NaCl equiv. Type 3 inclusions hosted in diopside show a relatively narrow range in homogenization temperature and salinity values with a mode at 450-550 °C and 50-70 wt.% NaCl equiv., respectively. Most fluid inclusions were homogenized by halite dissolution. Some inclusions are characterized by total homogenization to liquid and halite disappearance

over a small temperature interval (10-20 °C).

A combination of SEM-EDS characterization and Laser Raman spectroscopic analysis indicate that the opaque phases in type 2 inclusions were dominated by pyrrhotite, indicating a Fe-rich reducing fluid liberated from the crystallizing dioritic magma. Apparently, cooling of this magmatic-hydrothermal fluid was unlikely to precipitate the contained ferrous iron as magnetite or hematite as the ore mineral at Xishimen. Rather, the ferrous iron would be incorporated into silicates or deposited as iron sulfides and/or siderite under the reducing conditions. This in turn indicates that the ferrous iron must have been transformed to ferric iron by some oxidants.

Pyrite from the Xishimen iron deposits have high $\delta^{34}\text{S}$ values ranging from 14.0 to 17.3 ‰ ($n = 5$), significantly different from a magmatic sulfur and thus indicating an external source for the sulfur. We suggest that such an external sulfur were most likely derived from the evaporate sequences mainly consisting of gypsum, anhydrite, and halite from the Majiagou and Cixian Formations in and around the mine. Sulfate from the evaporate beds could have acted as an important oxidant that led Fe^{2+} to be transformed to Fe^{3+} , forming magnetite and hematite. Interaction of the Fe-rich reducing magmatic fluid, as indicated by the abundance of pyrrhotite in the type 2 inclusions, with evaporates, or mixing between this fluid with the sulfate-bearing oxidizing fluids derived from the evaporate beds are considered as the key mechanism in the formation of magnetite ores of the Xishimen deposit. The extensive sodic alteration in the Xishimen iron deposit confirms the role of external saline fluids in the formation of the Xishimen iron deposit.

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