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Isotopic and Thermal Insights into the Fe Source of Handan-Xingtai Skarn Deposits, North China

WENBO WANG[1,2], XU CHU[2] AND SHANGGUO SU[1]

[1]China University of Geosciences (Beijing)
[2]University of Toronto
Presenting Author: wx.wang@mail.utoronto.ca

The source of Fe in magmatic-skarn deposits remains enigmatic in many magnetite deposits, especially these hosted in veins that intrude into carbonate country rocks. In this study, we focus on a typical Fushan iron deposit in the Handan-Xingtai metallogenic area in North China. The magnetite vein (Mt-I) sharply crosscut the contact aureole bordering a diorite intrusion. The meter-scale aureole shows zonation garnet skarn, epidote skarn, and weakly metamorphosed carbonate away from the intrusion. The magnetites are dendritic and skeletal, enclosing diopside, epidote calcite and silicate glass. In another locality, a magnetite vein (Mt-II) crosscuts marble, in which magnetite are euhedral-subhedral, granular, and rimed by white micas. Mt-II has higher contents of MgO and Al_2O_3, and a lower SiO_2 content compared to Mt-I, suggesting higher temperatures (up to 800 °C) of nucleation and growth than the skeletal ones (650 – 450 °C). The Mt-II magnetite grains with sharp compositional zones are veneered by a discontinuous rim that is depleted in Mg, Al, Si, indicating a general cooling trend (to 650 °C). Assuming equilibrium between Mt-I and garnet rim, the oxygen isotope thermometer yield ~550 °C, agreeing with the isochores of fluid inclusions in garnet (550 – 600 °C). Ensuing diffusion simulation, the sharp oscillatory zones indicate timescale as short as tens of years of supersolidus residence. The Fe isotopic characteristics of magnetite ores (-0.03 – +0.34‰) overlap the mafic enclaves (+0.12 – +0.30‰) within the diorite but differ significantly from the diorite (-0.56 – +0.20‰), indicating that the Fe is primarily sourced from the mafic magmatic endmember represented by these enclaves. As the mafic magma ascends to a shallow magma chamber and fractionates the hot oxide melt, euhedral magnetite crystals grow in the melt and deposit on the carbonate floor of magma chamber. The oxide melt also injects into the cold carbonate country rock, forming hopper or skeletal magnetite.