Nanoinclusions in Magnetite, Ma On Shan Fe Skarn Deposit, Hong Kong

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Magnetite can contain a large number of elements which are popularly used to study its formation conditions. However, it is still unclear whether elevated concentrations of elements in magnetite are due to the presence of cryptic inclusions. Clear understanding of inclusions in magnetite and critical assessment of whether elements are contributed by inclusions are essential to rigorously define the chemistry of magnetite and interpret analytical results. Numerous microscopic studies are focused on igneous magnetite, but little study has focused on hydrothermal magnetite. In this preliminary study, we report nanoscale inclusions in skarn magnetite and their manifestation on analytical results.

Iron ore samples from the Ma On Shan Fe deposit in Hong Kong are used for this study. Mining at Ma On Shan commenced in 1906 and ended in 1976, extracting roughly 6 million tons of iron ore. It is a typical magnesian skarn deposit localized along the contact between Cretaceous biotite monogranite and Devonian carbonate. The skarns are mineralogically varied, but a common assemblage consists of magnetite, andradite, pyroxene, humite, and fluorite.

Magnetite was studied by SEM and TEM for microscopic observations, and EMPA and LA-ICP-MS for in situ chemical analysis. Under the electronic microscope, nanometer inclusions are abundant in magnetite of all samples. Silica-rich phases are typically enriched in Mg with variable amounts of Ca, Al, Sn, Mn, and Fe(?). These phases are elongated, rounded, or irregular in shape and are randomly distributed in the host magnetite. Aluminum-rich phases have significant concentrations of Mg, Zn, Mn, and Fe(?). Usually, Al-rich phases occur as exsolved planes, but some are also randomly distributed with irregular shapes. Tin-rich phases usually have minor Al, Mn, and Fe(?). Sometimes Sn-rich phases occur as grains surrounded by Al-rich phases, and sometimes they have small pores in their center. Most of these phases have varying compositions and shapes, unlike exsolutions, but outliers that could be relics of altered or crystallized minerals. In situ analytical results of magnetite are high in Mg, Al, Si, Mn, Zn, and Sn, plotted in the field of skarn magnetite. All magnetites have similar Si concentrations because Si-rich phases are widely distributed. The Si-rich phases also have clear effects on analytical concentrations of Mg, whereas Al-rich phases likely control analytical contents of Zn, Mn, and Mg to some degree. High concentrations of Sn are attributed to the Sn-rich inclusions.

Our results show that nanoinclusions have apparent effects on total analytical results of magnetite. Therefore, despite their advantages in discriminating magnetite populations, nanoinclusions should be thoroughly assessed before bulk isotopic and geochemical analyses.