Iron and oxygen isotope signatures of the Pea Ridge and Pilot Knob magnetite-apatite deposits, southeast Missouri, USA

TM Childress[1], AC Simon[1], W Day[2], CC Lundstrom[3], I Bindeman[4]

[1]Department of Earth and Environmental Sciences, University of Michigan, Ann Arbor, Michigan, USA; [2]United States Geological Survey, Denver Federal Center, Lakewood, Colorado, USA; [3]Department of Geology, University of Illinois, Champaign, Illinois, USA; [4]Department of Geological Sciences, Eugene, Oregon, USA

The Pea Ridge (PR) and Pilot Knob (PK) magnetite–apatite deposits of southeast Missouri, USA, are part of an iron oxide-apatite (IOA) deposit district wherein all deposits are spatially and temporally related to host volcanic rocks. The dike-like (PR) and sill-like (PK) massive magnetite ore bodies in the Missouri deposits contain magnetite with individual mineral cores that contain polymineralic inclusions, and mineral rims that are relatively free of inclusions. Individual magnetite grains exhibit textural similarities to both igneous phenocrysts and secondary hydrothermal overgrowth. Quartz grains within the magnetite ore zone contain primary high salinity fluid inclusions (54 to 60 wt. % NaCleq.) that were trapped at 480 to >530 °C, and cross-cutting relationships between the ore bodies and igneous host rocks have been interpreted to indicate a magmatic origin for the deposits. The presence of both igneous and hydrothermal features has stimulated vigorous debate as to whether primary ore magnetite crystallized from a melt, precipitated from a magmatic-hydrothermal fluid, precipitated from a fluid of meteoric origin, or a combination of both magmatic crystallization and hydrothermal precipitation. Here, we will present new O and Fe stable isotope ratios for magnetite from the massive magnetite ore of PR and PK. The O isotope compositions ($\delta^{18}O$) of magnetite from PR and PK range from 1.0 to 7.0 ‰ (n=12) and 3.3 to 6.7 ‰ (n=3) respectively. The stable Fe isotope compositions ($\delta^{56}Fe$) of magnetite from PR and PK samples are 0.20 ±0.09 ‰ (n=11) and 0.19 ±0.06 ‰ (n=7) respectively. These new data are consistent with magnetite that crystallized from a silicate melt and magnetite that precipitated from a magmatic-hydrothermal aqueous fluid (typical igneous $\delta^{56}Fe$ ranges 0.06 to 0.49 ‰). We suggest a new model for the formation of these IOA deposits that invokes flotation of a magmatic magnetite-fluid suspension that offers a plausible explanation that combines the igneous and hydrothermal geochemical characteristics of the deposits. In this model, igneous magnetite would have an O-isotope signature consistent with the upper range of $\delta^{18}O$ values (i.e., 4.5 to 7 ‰) measured in the current study, and the magnetite rims that grew from a magmatic-hydrothermal aqueous fluid at lower temperature and/or lower evolved $\delta^{18}O$ would have O-isotope signatures consistent with our lower range of $\delta^{18}O$ values (i.e., 1 to 4 ‰).