Whole rock-rare earth element and magnetite chemistry as guides to exploration for metamorphosed base metal sulfide deposits in the Stollberg ore field, Bergslagen, Sweden*

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The Stollberg ore field (~12 Mt), 50 km W of the giant Garpenberg Zn-Pb-Ag-(Cu-Au) district (> 100 Mt) occurs in the regional Stollberg F2 syncline within 1.9 Ga bimodal felsic and mafic rocks metamorphosed to the amphibolite facies. Sulfide mineralization is hosted by volcanic rocks and skarn and consists of massive to semi-massive sphalerite-galena and pyrrhotite (with subordinate pyrite, chalcopyrite, arsenopyrite, and magnetite). The trace element composition of magnetite, which locally forms ore-grade masses and occurs as a common accessory in most rocks types at Stollberg, has previously proven to be a pathfinder in the exploration for ore deposits elsewhere and is evaluated here along with the rare earth element (REE) chemistry of altered rocks.

At Stollberg, the dominant country rocks are metamorphosed rhyolitic pumice breccia and rhyolitic ash-silt-sandstone with minor amphibolite sills. On the eastern side of the Stollberg syncline, mineralization at Stollberg and Dammberget occurs as stratabound replacement of limestone/skarn that grades into iron formation spatially related to garnet-biotite and gedrite-albite alteration. At Gränsgruvan on the western side of the syncline, sulfides occur in a silicified zone along with garnet-biotite and quartz-garnet-pyroxene alteration. Although the Tvistbo and Norrgruvan deposits along the north end of the syncline are small, they show geological characteristics that are transitional to deposits found on the western and eastern side of the syncline in that the ore is hosted by skarn rock and associated with quartz-garnet-pyroxene alteration. The Gränsgruvan deposit more closely resembles deposits found at Garpenberg than those located on the eastern limb of the Stollberg syncline. Whole-rock analyses of altered and unaltered rocks suggest that most components were derived from a felsic volcanioclastic component and that elements were immobile during alteration. These rocks (including altered rocks in the stratigraphic footwall) are light REE enriched, heavy REE depleted, and show negative Eu anomalies, whereas mineralized rocks (Fe- and base metal-rich) and altered rocks in the ore zone show the same REE pattern but with positive Eu anomalies.

Trace element compositions (using LA-ICP-MS techniques) of magnetite in high-grade ore, limestone/skarn, massive magnetite, and garnet-biotite, gedrite-albite, garnet-pyroxene alteration show a range of compositions. Such ranges in composition are inconsistent with previous studies in other ore fields that suggest the composition of magnetite can be used to define compositional fields characteristic of ore deposit type (e.g., Al+Mn vs. Ti+V wt. %) or approximate temperature of the ore-forming fluid. Magnetite in garnet-biotite and gedrite-albite alteration spatially associated with Dammberget typically contains > 200 ppm Ga, > 10 ppm Sn, and Ti/V ratios of > 10 whereas magnetite in garnet-biotite alteration associated the smaller Cederkreutz
deposit contains < 25 ppm Ga, < 2 ppm Sn, and Ti/V ratios < 0.1. Magnetite in garnet-biotite alteration associated with the Gränsgruvan deposit contains > 10 ppm Sn, 20 to 180 ppm Ga, and Ti/V ratios of 0.1 to 2. These and other trace element compositions of magnetite as well as REE patterns of altered host rocks show potential as exploration guides to ore in the Stollberg district.