The major-trace element chemistry of garnet in metamorphosed hydrothermal alteration
zones in the Proterozoic Stollberg Zn-Pb-Ag-(Cu-Au) ore field, Bergslagen district, Sweden: Implications for exploration*

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Altered and exhalative rocks are used as exploration guides to ore deposits since they are generally more extensive than the massive sulfide target. Major and trace element compositions of silicates (e.g., garnet) and oxides (e.g., gahnite and magnetite) in meta-exhalites have recently been used as a vectoring tool in the search for metamorphosed massive sulfide deposits. Here, we evaluate the major-trace element chemistry of garnet in altered (i.e., gedrite-albite, garnet-biotite, and garnet-pyroxene-carbonate alteration) and unaltered (i.e. rhyolitic ash-siltstone) rocks spatially associated with volcanogenic massive sulfide Zn-Pb-Ag-(Cu-Au) and magnetite deposits in the Stollberg ore field (metamorphosed to the amphibolite facies), to determine the spatial distribution of major/trace element compositions of garnet and the potential of garnet chemistry as a guide to ore.

Garnet in garnet-biotite alteration (extends intermittently for ~8 km along strike) and high-grade sulfides is Fe-rich (almandine) whereas garnet in skarn and garnet-pyroxene alteration contains significantly higher amounts of Ca (grossular), and Mn (spessartine). Concentrations (425 analyses) of trace elements in garnet were obtained from 38 samples in the Dammberget (n = 14), Gränsgruvan (n = 17), and Tvistbo (n = 7) deposits. Garnet contains elevated concentrations of Sc, Ti, V, Cr, Co, Zn, Ga, Ge, Y, and rare earth elements (REEs). Chondrite-normalized rare earth element patterns of garnet are depleted in light REEs (LREEs) and enriched in heavy REEs (HREEs). Garnet in sulfide-bearing altered rocks (i.e., garnet-biotite and garnet-pyroxene alteration) show a strong positive Eu anomaly, regardless of its major element composition, and contains elevated Zn (> 100 ppm) and Ga (> 15 ppm) contents, and low concentrations of Ti (< 200 ppm). Garnet-biotite alteration adjacent to unaltered rhyolitic ash-siltstone contains garnet which is LREE depleted, HREE enriched, and typically shows no Eu anomaly, or in some cases, minor negative Eu anomalies. In sulfide-free quartz-garnet-pyroxene rocks, garnet possesses no Eu anomaly and contains elevated concentrations of Ga (> 10 ppm), Sc (> 5 ppm), and Ti (> 100 ppm), but low concentrations of Co (< 1 ppm), Cr (< 5 ppm), and V (< 20 ppm). Garnet in gedrite-albite alteration exhibits a relatively flat chondrite-normalized REE profile, and contains elevated (> 10 ppm) Sc content, and low concentrations of V (< 2 ppm), Cr (< 3 ppm), and Zn (< 30 ppm). Garnet in mafic dikes and marbles contain the highest Cr (> 10 ppm), Co (> 5 ppm), V (25-250 ppm) and Ti contents, whereas garnet in rhyolitic ash-siltstone typically shows no Eu anomaly, and low concentrations of Zn (< 100 ppm), Ga (< 15 ppm), Cr (< 5 ppm), and V (< 3 ppm). Garnet in massive sulfides and sulfide-bearing alteration assemblages can be distinguished from sulfide-poor or sulfide-free rocks of the same alteration type on the basis of their positive Eu anomaly,
and Zn, Ga, and Ti content, which suggests garnet chemistry may be used as a vectoring tool to ore in the Stollberg ore field, and elsewhere in the Bergslagen district.