Controls on gahnite formation: insights from the Lalor metamorphosed volcanogenic massive sulphide deposit, Snow Lake (Manitoba)

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Abstract

Rocks at Lalor, a zinc-rich volcanogenic massive sulphide deposit hosted in bimodal volcanic and volcaniclastic rocks of Paleoproterozoic age have been metamorphosed to lower amphibolite conditions. The footwall rocks comprise a large zoned alteration envelope that immediately underlies the sulphide lenses. Petrographic and electron-microprobe investigation of selected drill core samples has shown that gahnite occurrence is restricted to the deposit footwall. Gahnite was identified in samples of various bulk-rock compositions, all of which have been moderately to highly altered by syn-volcanic hydrothermal processes. Companion mineral assemblages for gahnite at Lalor vary from calcite-diopside-sphalerite, to anthophyllite-cordierite-quartz-sphalerite, cordierite-garnet-staurolite, chlorite-garnet-hornblende, and kyanite-anthophyllite-quartz-biotite. These observations suggest that bulk rock composition was not the main factor controlling gahnite formation at Lalor. Several textural and mineralogical settings for gahnite have been recognized. In most cases, textural relationships suggest that sphalerite was the precursor to gahnite. However, the rare occurrence of small gahnite overgrowths on partly corroded staurolite porphyroblasts indicates that locally gahnite formed from the breakdown of zincian-staurolite. Although it commonly occurs in association with sphalerite, gahnite is typically found peripheral to the main sulphide lens; it generally is associated with thinner sulphide bands/veins (<15 cm in thickness) or zones of disseminated sulphide mineralization. Where associated with thicker sphalerite horizons, it generally displays textures suggesting late formation. One of the salient features of gahnite occurrence at Lalor is its prevalence in anthophyllite-rich layers. Petrographic observations combined with EMP analyses indicate that gahnite formed along with anthophyllite as the result of a reaction between tschermakitic amphibole, sphalerite and quartz. This contrasts with its mode of formation in most documented examples of VMS-associated gahnite, where it has been interpreted to have been the product of reaction between sphalerite and either garnet or an aluminosilicate (kyanite or sillimanite) phase. Textural relationships indicate that gahnite formation generally postdated regional peak metamorphic conditions and was associated with late-metamorphic/hydrothermal fluids circulation. Thermodynamic modeling of the physicochemical conditions ($fO2$, $fS2$, $a Al_2O_3$, pH) of formation of the various gahnite-bearing assemblages documented at Lalor has been combined with textural analysis, whole-rock geochemistry, and mineral chemistry to provide new insights into the factors controlling gahnite-genesis in metamorphosed volcanic massive sulphide deposits.