AN UNUSUAL GAHNITE-FORMING REACTION, GECO BASE-METAL DEPOSIT, MANITOUWADGE, ONTARIO

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ABSTRACT

Gahnite, together with nigerite and högbomite of unusual composition, is present in phlogopite-staurolite-cordierite schists within the Geco base-metal deposit, Manitouwadge, Ontario. These minerals are enclosed within cordierite and a vermicular cordierite-corundum intergrowth and are nowhere in contact with tin-bearing phlogopite. Högbomite and nigerite are rarely enclosed in zincian staurolite. Textural and chemical evidence suggests that gahnite was produced at upper amphibolite - lower granulite grade by the reaction: zincian staurolite + tin-bearing phlogopite - cordierite + corundum + gahnite + nigerite + högbomite + tin-poor phlogopite.

Keywords: gahnite, nigerite, högbomite, zincian staurolite, tin-bearing phlogopite, Geco deposit, Ontario, electron-microprobe analyses.

INTRODUCTION

Gahnite is believed to have formed by a variety of processes including (1) desulfidation of sphalerite during metamorphism (e.g., Frost 1973), (2) precipitation from a metamorphic-hydrothermal solution (Wall 1977), (3) derivation from a primary ZnO phase during metamorphism (e.g., Segnit 1961), (4) dehydration of zinc-enriched staurolite during metamorphism (Stoddard 1976, 1979, Atkin 1978), and (5) formation from residual ZnO that was produced during a silicate reaction (Dietvorst 1980). Gahnite at the Geco mine, an Archean Cu-Zn massive-sulfide deposit located at Manitouwadge, 200 km east of Thunder Bay, Ontario, was probably formed by more than one of the above mechanisms (Spry, in prep.). The present contribution concerns only that gahnite considered to have resulted from the breakdown of zincian staurolite and tin-bearing phlogopite. The pre-metamorphic origin of the Geco deposit was first recognized by Suffel et al. (1971). Metamorphic mineral assemblages suggest that Geco has been metamorphosed to upper amphibolite or lower granulite grade (Petersen & Friesen 1982).

PETROGRAPHY

The specimens containing gahnite were collected adjacent to the 4/2 ore zone on the 2850 level within a weakly foliated phlogopite-staurolite-cordierite schist. This particular rock-type is one of several that constitute the sericite schist group of the mine series (Bakker 1979). Gahnite, corundum, pyrrhotite, högbomite and nigerite are minor constituents of the rocks, which consist primarily of phlogopite, staurolite, cordierite, pyrite and chalcopyrite. Other minerals present in small amounts are sericite, zircon and chlorite.

In some specimens, staurolite occurs as embayed porphyroblasts surrounded by a rim of cordierite. Staurolite is never in contact with phlogopite, the most common mafic phase. Phlogopite is generally bladed, but where in contact with cordierite, phlogopite has a ragged appearance. Pyrite and chalcopyrite commonly occur within phlogopite and along grain boundaries. In other specimens, staurolite is extremely corroded and partly replaced by a vermicular intergrowth of cordierite and corundum.
Subhedral gahnite, up to 0.8 mm in length, occurs within cordierite, commonly in embayments within staurolite (Fig. 1b). Brown nigerite and brown högboinite, anhedral to euhedral and up to 0.6 mm across, are not only associated with the vermicular cordierite–corundum intergrowth (Fig. 1c), but also occur as inclusions within cordierite. Rare inclusions of högboinite and nigerite, some of which are associated with fractures, occur within staurolite. Nigerite commonly occurs as inclusions or overgrowths on gahnite (Fig. 1d).

**MINERAL CHEMISTRY**

Analyses of the major and minor oxides and silicates were carried out with a Jeol 733 Super-probe and an ARL electron microprobe (Table 1); the excitation potentials were 15 and 20 kV, respectively. The standards used were natural and synthetic spinels for Zn, Fe, Mg and Al, amphibole for Mg, Fe, Si and Al, biotite for K, Mg, Al, Si and Fe, wollastonite for Ca and Si, rhodonite for Mn, rutile for Ti and synthetic cassiterite for Sn.

The gahnite is enriched in MgAl₂O₄ and FeAl₂O₄ and depleted in ZnAl₂O₄ relative to zincian spinel found elsewhere in the Geco deposit (unpubl. data) and in other deposits that have been ascribed to formation via desulfidation mechanisms (Spry & Scott 1982).

Högboinite has a generalized formula (proposed by Zakrzewski 1977) of $R^{3+2-3}Tl_{6}R^{3+4}O_{8}$, in which $R^{3+}$ represents Mg$^{3+}$, Zn$^{2+}$, Mn$^{2+}$ and Fe$^{3+}$, and $R^{3+}$ represents Al$^{3+}$ and Fe$^{3+}$. Tin and silicon may substitute for titanium. Högboinite was previously reported by Chew (1977) in a sample found in the Willroy base-metal deposit 2 km west of Geco. Except for Chew’s (1977) and Mancktelow’s (1981) analytical results, in which Fe/(Fe + Mg) = 0.72 (atomic ratio), other examples of högboinite reported in the literature show Fe/(Fe + Mg) in the range 0.02 to 0.62. Unlike the högboinite from Willroy,
which contains less than 1 wt. % ZnO, that from Geco contains, on average, 10.2 wt. % ZnO. Such unusually zinc-rich högbomite had previously been reported only by Moleva & Myasnikov (1952), who described högbomite that contains 11.1 wt. % ZnO from the U.S.S.R.

Nigerite, which has a formula analogous to högbomite, namely $R_2^{2+} + 2e^{2+}R_3^{2+}R_4^{3+}(O,OH)_3$, in which $R_2^{2+}$ represents Mg$^{2+}$, Zn$^{2+}$, Fe$^{3+}$ and Mn$^{2+}$, $R_3^{2+}$ represents Al$^{3+}$ and Fe$^{3+}$, and $R_4^{3+}$ represents Ti$^{4+}$, Sn$^{4+}$ and Si$^{4+}$, was recognized previously at Geco by Essene et al. (1982) and Petersen et al. (1982). Petersen et al. analyzed several samples of nigerite from Geco and found a wide range in their Sn content. Their revised abstract (E.U. Peterson, pers. comm. 1982) describes nigerite compositions having the highest Mg, Zn and Ti contents as well as the lowest Sn content ever recorded for this mineral. Nigerite samples reported here have compositions that are similar to these.

**DISCUSSION**

Bannerjee (1974) initially recorded the presence of cassiterite in the Geco deposit. Essene et al. (1982) noted that cassiterite occasionally coexists with nigerite and that rutile or ilmenite (or both) coexist with högbomite, suggesting that cassiterite may be a source for the tin in nigerite, and rutile or ilmenite (or both) may be a source for the titanium in högbomite. Cassiterite, ilmenite and rutile, however, are not present in the samples studied here. Although phlogopite does not appear to have been produced during the gahnite-forming reaction, phlogopite contains Ti and Sn, and probably constitutes the source of Ti and Sn for nigerite and högbomite in these samples.

At Geco, the common association of gahnite, nigerite and högbomite with cordierite or a cordierite-corundum intergrowth, together with the evidence that where gahnite (with or without nigerite) and staurolite are present, the staurolite is embayed or corroded, suggests that these minerals are genetically related. The presence of zinc in staurolite, gahnite, högbomite and nigerite, in addition to the textural evidence, suggests that the following prograde reaction has been involved in the formation of gahnite:

$$\text{zinccian staurolite} + \text{tin-bearing phlogopite} = \text{cordierite} + \text{corundum} + \text{gahnite} + \text{nigerite} + \text{högbomite} + \text{tin-poor phlogopite}.$$ 

Experimental work by Richardson (1968)
TABLE 1. CHEMICAL COMPOSITIONS OF MINERALS FROM PHLOGOPITE-
STAUROLITE-CORDIERITE SCHIST, GECO MINE

<table>
<thead>
<tr>
<th>Mineral</th>
<th>MgO</th>
<th>Al₂O₃</th>
<th>SiO₂</th>
<th>Fe₂O₃</th>
<th>FeO</th>
<th>MnO</th>
<th>K₂O</th>
<th>Na₂O</th>
<th>Total Fe as FeO</th>
<th>Zn</th>
<th>Zr</th>
<th>Sn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pyrite</td>
<td>4.50</td>
<td>0.20</td>
<td>0.20</td>
<td>0.50</td>
<td>0.10</td>
<td>0.10</td>
<td>0.05</td>
<td>0.05</td>
<td>7.45</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Chalcopyrite</td>
<td>4.50</td>
<td>0.20</td>
<td>0.20</td>
<td>0.50</td>
<td>0.10</td>
<td>0.10</td>
<td>0.05</td>
<td>0.05</td>
<td>7.45</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Pyrrhotite</td>
<td>4.50</td>
<td>0.20</td>
<td>0.20</td>
<td>0.50</td>
<td>0.10</td>
<td>0.10</td>
<td>0.05</td>
<td>0.05</td>
<td>7.45</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Biotite</td>
<td>12.00</td>
<td>1.00</td>
<td>1.00</td>
<td>2.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.05</td>
<td>0.05</td>
<td>15.00</td>
<td>0.5</td>
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<tr>
<td>Quartz</td>
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<td>2.00</td>
<td>5.00</td>
<td>2.00</td>
<td>2.00</td>
<td>0.05</td>
<td>0.05</td>
<td>30.00</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Total Fe as FeO</td>
<td>12.00</td>
<td>1.00</td>
<td>1.00</td>
<td>2.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.05</td>
<td>0.05</td>
<td>15.00</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>

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REFERENCES


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