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COEXISTING PRECIOUS METALS, SULFOSALTS AND SULFIDE MINERALS IN THE ROSS GOLD MINE, HOLTYRE, ONTARIO

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ABSTRACT

In the Ross mine, Holtyre, Ontario, native gold and electrum are associated with pearceite $(Ag_{0.89}Cu_{0.11}Fe_{0.002})_{17.02}As_{2.1}S_{11}$, tennantite $(Cu_{0.8}Zn_{0.13}Fe_{0.04}Ag_{0.03})_{12.06}As_{3.92}S_{13}$ and proustite Ag_3AsS_3. These minerals may occur together with pyrite, sphalerite, galena, chalcopyrite, bornite, nickeline and acanthite, in carbonate–quartz veins within lenticular carbonate bodies, andesite flows and tuffs, and intrusive syenitic bodies. Inclusions of electrum and native silver occur infrequently along well-defined cleavage planes of pearceite, and the highest gold and silver contents are associated with the arsenic-bearing sulfosalts and pyrite. Contact relationships of the carbonate-hosted veins and wall rocks in the mine suggest that the lenticular carbonate bodies were probably carbonate "exhalites" that had a syngenetic accumulation of base and precious metals. These metals are considered to have been remobilized and concentrated into the veins during synchronous metamorphism and intrusion.

Keywords: gold, silver, sulfosalts, sulfides, exhalite, metamorphism, remobilization, Holtyre mine, Ontario.

SOMMAIRE

Dans la mine Ross, à Holtyre (Ontario), l'or natif et l'électrum forment une association avec pearceite $(Ag_{0.89}Cu_{0.11}Fe_{0.002})_{17.02}As_{2.1}S_{11}$, tennantite $(Cu_{0.8}Zn_{0.13}Fe_{0.04}Ag_{0.03})_{12.06}As_{3.92}S_{13}$ et proustite Ag_3AsS_3. Ces minéraux peuvent se trouver associés à pyrite, sphalérite, galène, chalcopyrite, bornite, nickeline et acanthite dans des filons à carbonate–quartz dans des lentilles de carbonate, des coulées et tuffs andésitiques et des roches syénitiques intrusives. Des inclusions d'électrum et d'argent natif se trouvent occasionellement dans des plans de clivage bien définis de la pearceite; les teneurs les plus élevées en or et en argent sont celles des sulfosels à arsenic et de la pyrite. Les relations de contact entre les veines qui recoupent les zones à carbonates et les roches encaissantes dans la mine font penser que les lentilles de carbonate seraient des "exhalites" qui auraient connu une accumulation syngénétique de métaux tant précieux que vils. Ces métaux auraient été remobilisés et concentrés dans les filons pendant les événements simultanés de métamorphisme et d'intrusion.

(Traduit par la Rédaction)

Mots-clés: or, argent, sulfosels, sulfures, exhalite, métamorphisme, remobilisation, mine Holtyre (Ontario).

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INTRODUCTION

The Ross mine is a gold deposit located near Holtyre, Ontario, within the Archean Abitibi greenstone belt in the Superior structural province of the Canadian Shield. Mining at the Ross mine began in 1934 with an estimated reserve of 628,155 tonnes of ore averaging 5.88 g/tonne Au (Moore 1936). Reserves in 1975 were estimated at 518,00 tonnes averaging 4.64 g/tonne Au, 5.48 g/tonne Ag and 0.6% Cu (Fielder 1975). The mine is at present owned by Pamour Porcupine Mines Limited. There has been no production since 1980.

ORE MINERALOGY

This study focuses on the ore mineralogy in three principal systems of veins in the Ross deposit: the 14 veins within carbonate host, the 2B veins in andesite flows and tuffs, and the 18 veins in syenite. The carbonate veins represent about 15% of the total mineable ore. Veins in andesite tuff and flows constitute *ca.* 40% and veins in syenite represent an approximated average of 30% of the total ore.

Carbonate-hosted veins

Sulfosalts, native gold, electrum, native silver and minor sulfides together constitute 5 to 15% in both concordant and discordant veins in carbonate rock. The gangue consists of ankerite, dolomite, calcite and quartz, which together form 40 to 85% of the veins. Chlorite, sericite, epidote and albite average about 10 modal %. The main sulfosalt minerals, pearceite, tennantite and proustite, are mostly concentrated in ankerite, dolomite and calcite. The veins have a sulfosalt-to-sulfide ratio of approximately 2:1, an average grade of 5.26 g/tonne Au and a Ag/Au ratio of 2:1.

Grains of pearceite are generally irregular in shape and range from 80 to 500 μm in diameter. Pearceite commonly shares its boundaries with tennantite and convex boundaries with coarse crystalline galena. Concentric fractures are present in pearceite grains in a few instances (Fig. 1). Proustite commonly forms a rim on subhedral grains of pearceite (Fig. 2). Where inward growth of proustite has persisted, it appears that pearceite has been completely replaced by proustite (Fig. 2).

Leafy, irregularly shaped grains of native gold up to 30 μm in diameter commonly occur along the

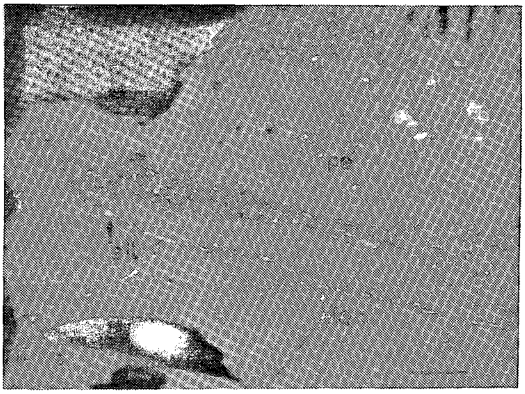

FIG. 1. Exsolution flames of electrum (elec) and native silver (sil) in pearceite (pe). Note the orientation of the exsolved material parallel to the cleavage of the pearceite crystal. Concentric fracture at the lower left is filled with carbonate matrix. P.S. 2607; scale bar 0.02 mm.

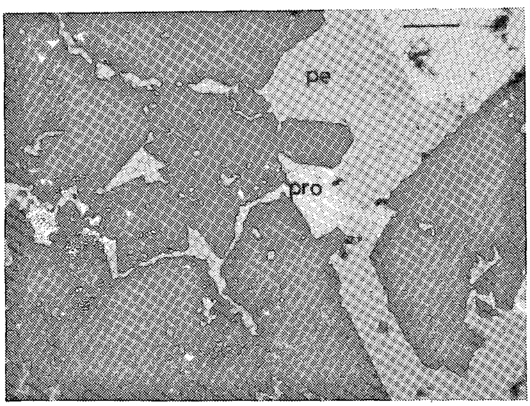

FIG. 2. Blebs and fingers of proustite (pro) growing into pearceite (pe). The margin of the pearceite grain appears to have been replaced by proustite. P.S. 2605; scale bar 0.08 mm.

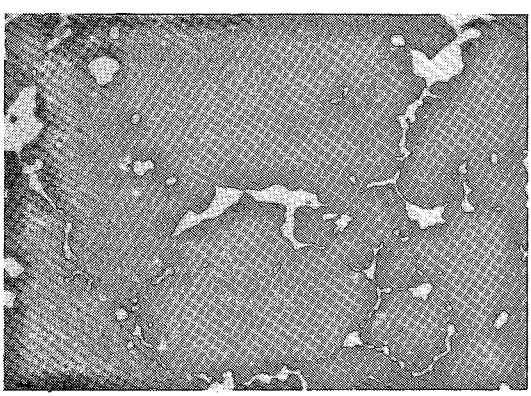

FIG. 3. Leafy and platy grains of native gold (au) dispersed in a carbonate matrix. Note the rimming of carbonate margins by leafy grains of gold. P.S. 2608; scale bar 0.08 mm.

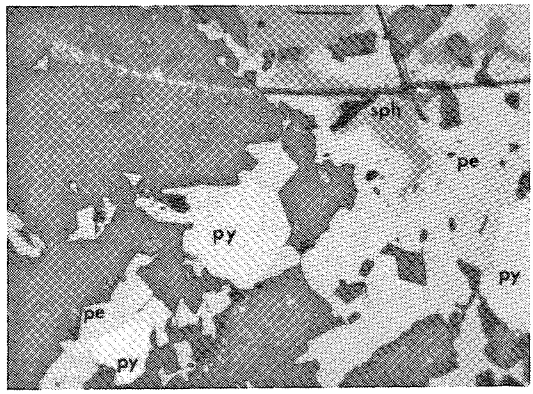

FIG. 4. Pearceite (pe) in association with sphalerite (sph) and pyrite (py) in a carbonate matrix. Sphalerite interfingers with grain of pearceite. Notice the pyrite grain overgrown by pearceite in the lower left corner. P.S. 2611; scale bar 0.08 mm.

boundaries of euhedral dolomite, calcite and quartz (Fig. 3) in association with pyrite. In other instances, electrum and native silver occur as exsolution intergrowths within platy crystals of pearceite (Fig. 1).

Pyrite, sphalerite, galena, chalcopyrite, bornite, nickeline and acanthite are intergrown with the sulfosalts and precious metals. Pyrite shows a great tendency to be idiomorphic (Fig. 4) except for late-stage pyrite, which is generally irregular and confined only to fractures and grain boundaries of the gangue minerals. Rims of pyrite are commonly overgrown by pearceite in a few instances (Fig. 4).

Veins in andesite tuffs and flows

Discordant veins in andesite contain 0.5 to 10% tennantite, pyrite, chalcopyrite and native gold. The gangue consists of 25% quartz and an average of approximately 2% dolomite in a matrix of chlorite, epidote, sericite and plagioclase. Tennantite and sulfide minerals have mutual boundaries, and the sulfosalts-to-sulfide ratio averages 2.4:1. Both tennantite and the less abundant sulfide minerals are commonly intergrown with grains of native gold 10 to 30 μm in diameter. Veins in the tuffs and flows average 4.3 g Au/tonne and have a Ag/Au ratio of approximately 1.3:1.

Veins in syenite

The veins in syenite form a stockwork-like network within and at the edge of syenite intrusive bodies that transect the carbonate rock, andesite flows and tuffs. Tennantite, pyrite, chalcopyrite, bornite and chalcocite constitute about 1 to 3% of these veins. The sulfosalt and sulfide minerals occur in a matrix of dolomite, quartz, sericite and kaolinite, and have an average sulfosalt-to-sulfide ratio of 3:1. No native gold was identified, but calaverite, a gold-silver tel-

TABLE 1. COMPARISON OF FEATURES IN THE THREE SYSTEMS OF VEINS, ROSS GOLD MINE

Features	Carbonate-hosted veins	Veins in andesite tuffs and flows	Veins in syenite
Geological setting	Stratabound carbonate rock within andesite; carbonate quartz veinlets in layers	Discordant stockworks of veins in andesite tuffs and flows	Discordant stockworks of veins within syenite bodies
% of total mineable ore	ca. 15%	ca. 40%	ca. 30%
Mineralogy	Ankerite, dolomite, calcite, quartz, sericite, chlorite, epidote, albite, pyrite, chalcopyrite, galena, sphalerite, tennantite, argentite, proustite, pearceite, native gold, electrum	Dolomite, quartz, calcite, chlorite, epidote, sericite, plagioclase, pyrite, chalcopyrite, tennantite, native gold	Dolomite, quartz, calcite, sericite, kaolinite, pyrite, chalcopyrite, bornite, chalcocite, tennantite, native gold and calaverite
Relative % of precious metals, sulfosalts and sulfides	5 to 15%	0.5 to 10%	1 to 3%
Sulfosalt/Sulfide ratio	2:1	2.4:1	3:1
Average grade	5.26 g Au/tonne	4.3 g Au/tonne	3.11 g Au/tonne
Ag/Au ratio	2:1	1.3:1	8:1

luride, is present as small inclusions in sulfosalt grains. Veins in the syenite have an average of 3.11 g Au/tonne and a Ag/Au ratio of approximately 8:1.

A summary and comparison of the features in the vein systems is presented in Table 1.

ANALYTICAL STUDIES

Pearceite and tennantite were confirmed by X-ray power-diffraction patterns. The composition of these minerals, as determined by the electron microprobe, is given in Tables 2 and 3. The two minerals are the arsenic-bearing varieties of the polybasite–pearceite and tennantite–tetrahedrite solid-solution series. These compositional series are stable within the temperature range of greenschist-facies metamorphism (Frondel 1963, Maske & Skinner 1971).

The abundance of gold was determined from digested samples (0.02 g/mL) of representative specimens of the veins by atomic-absorption spectrometry (as described by Fryer & Kerrich 1978). The veins in carbonate bodies contain 7 ppm, those in andesite tuffs and flows, 4 ppm, and those in syenite, 3 ppm. Gold abundances in pearceite and tennantite range from a minimum of 4000 ppm to 4% in 0.1 g/mL dissolved samples from the carbonate-hosted veins. The gold content ranges from 4000 ppm to 3.7% in 0.1 g/mL digested samples of the late-stage pyrite present in the vein systems.

SIGNIFICANCE

Gold-bearing carbonate–quartz veins in the Ross deposit are lenticular bodies interlayered with andesite flows, tuffs and argillites in the mine. Syenite bodies within this sequence have sharp to gradational contacts and host the 18-vein system. Gold, silver and base-metal concentrations in carbonate horizons interlayered with mafic to felsic volcanic rocks in the Abitibi greenstone belt have previously been interpreted as "exhalite" material (Ridler 1973, 1975, 1976) formed syngenetically with their enclosing volcanic rocks.

In the light of their shape and relationships with host rocks, the gold-bearing carbonate–quartz veins at the Ross mine are attributed to base-metal- and precious-metal-rich exhalations deposited during

TABLE 2. COMPOSITION OF PEARCEITE IN CARBONATE-HOSTED VEINS

	Pearceite Range	2607A Av. (5 grains)	Pearceite Range	2607B Av. (5 grains)
Ag wt.%	71.56-72.52	71.98	71.32-72.32	71.91
Cu	5.45- 5.72	5.58	5.10- 5.56	5.27
Fe	0.07- 0.11	0.096	0.09- 0.10	0.092
As	6.81- 7.01	6.94	6.70- 7.19	6.96
Sb	n.d.	n.d.	n.d.	n.d.
S	14.96-15.58	15.38	14.87-15.90	15.52
Total		99.98		99.75

Approximate chemical formulae based on 11 sulfur atoms.
2607A (mean values): $(Ag_{0.888}Cu_{0.11}Fe_{0.002})_{17.39}As_{2.1}S_{11}$

2607B (mean values): $(Ag_{0.888}Cu_{0.11}Fe_{0.002})_{17.02}As_{2.1}S_{11}$

TABLE 3. COMPOSITION OF TENNANTITE IN CARBONATE-HOSTED VEINS

	Tennantite Range	2607A Av. (4 grains)
Cu wt.%	40.98-41.37	41.19
Zn	6.40- 7.63	6.86
Fe	1.43- 1.71	1.64
Ag	2.95- 3.20	3.04
As	19.11-20.38	19.73
S	27.86-28.32	28.00
Total		100.46

Approximate chemical formula based on 13 sulfur atoms, using the mean values of 4 grains: $(Cu_{0.8}Zn_{0.13}Fe_{0.04}Ag_{0.03})_{12.06}As_{3.92}S_{13}$

quiescence following submarine volcanism. Some components of these primary, conformable exhalite deposits, notably gold, silver, arsenic, sulfur and minor base metals, could have been redistributed and concentrated into networks of discordant dilatant fractures to create veins in the carbonate rock, andesite tuffs and flows during regional metamorphism in the greenschist facies. Intrusion of syenitic magma that was probably contemporaneous with metamorphism appears to have created more veins within and around the bodies of syenite. The gold, silver, arsenic and sulfur appear to have combined preferentially with the base metals during metamorphism and emplacement of the syenite bodies. This is reflected in the high gold and silver contents of the sulfosalt minerals and high sulfosalt-to-sulfide ratios of the vein systems.

The relative decrease of gold values in the discordant veins of the andesite tuffs, flows and syenites compared with those in carbonate bodies corresponds to the lower concentration of sulfosalts and sulfide minerals in andesite- and syenite-hosted veins. Remobilization of gold, silver, arsenic and sulfur, induced by metamorphism and attendant intrusion of magma within the greenschist facies, may have been selective. Fluids generated during metamorphism and intrusion may have been more restricted in volume and of lower complexing ability than the massive volumes of fluid carrying stable metal-complexes from which the primary carbonate "exhalite" precipitated.

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