

ORE MINERALOGY OF THE AGASSIZ (MacLELLAN) GOLD DEPOSIT IN THE LYNN LAKE REGION, MANITOBA*

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ABSTRACT

The Agassiz (or MacLellan) stratabound gold deposit is in a Proterozoic greenstone belt at Lynn Lake, Manitoba, and is unusual in its enrichment in Pb, Zn and Ag. A lesser, but significant, enrichment in Sb and Ni is evident from the presence of tetrahedrite-freibergite, polybasite, pyrrargyrite, geocronite, pentlandite, argentopentlandite, breithauptite and ullmannite in the ore. This is the third reported Canadian locality for argentopentlandite. Gold-silver alloy grains range widely in composition, from 93.1 wt. % Au and 4.9 wt. % Ag to 15.6 wt. % Au and 84.6 wt. % Ag. Tetrahedrite-freibergite also ranges widely in silver content, and an unusually high value of 44.5% was found in one grain. Iron contents of sphalerite grains are in the range 5.6 to 9.4 wt. %. The close association of the Ni and Sb minerals, and of native alloy grains, with galena may indicate that they formed by remobilization of Pb, Ag, Sb, Ni and, possibly, Au during metamorphism and deformation of the orebody. The complex mineralogical sites of silver in the ore may be important with regard to its recovery during milling.

Keywords: gold deposit, Lynn Lake, Manitoba, argentopentlandite, ullmannite, silver sulfosalts, alloys, nickel, antimony, microprobe analyses.

SOMMAIRE

Le gisement d'or stratiforme d'Agassiz (ou MacLellan), situé dans une ceinture de roches vertes Protérozoïque à Lynn Lake, au Manitoba, montre un enrichissement peu commun en Pb, Zn et Ag. Un enrichissement moindre, mais quand même significatif, en Sb et Ni résulte de la présence dans le minerai de tétraédrite-freibergite, polybasite, pyrrargyrite, géocronite, pentlandite, argentopentlandite, breithauptite et ullmannite. Lynn Lake est la troisième localité canadienne pour l'argentopentlandite. Les grains de l'alliage or-argent varient grandement en composition, de 93.1% Au et 4.9% Ag à 15.6% Au et 84.6% Ag (en poids).

La teneur en argent de la tétraédrite-freibergite varie beaucoup également, et une teneur exceptionnelle de plus de 44.5% a été déterminée dans un grain. La teneur en fer de la sphalérite varie de 5.6 à 9.4% (en poids). L'étroite association des minéraux de Ni et Sb, de même que des grains d'alliages natifs, avec la galène, fait supposer qu'ils se sont formés par remobilisation de Pb, Ag, Sb, Ni et, peut-être aussi, Au pendant une période de métamorphisme et de déformation du filon métallifère. On devra tenir compte de l'emplacement minéralogique complexe de l'argent dans le minerai lorsque l'on procédera à sa récupération lors du traitement du minerai.

Mots-clés: gisement d'or, Lynn Lake, Manitoba, argentopentlandite, ullmannite, sulfosels d'argent, alliages, nickel, antimoine, analyses à la microsonde électronique.

INTRODUCTION

The Agassiz gold deposit is located approximately 7 km northeast of Lynn Lake, Manitoba and is hosted by Proterozoic rocks of the Lynn Lake greenstone belt, Churchill Province (Fig. 1). The deposit is in the more northerly of two northeasterly trending belts of Wasekwan Group rocks (Milligan 1960, Emslie & Moore 1961, Gilbert *et al.* 1980). These rocks consist primarily of mafic volcanic rocks, intercalated felsic and intermediate units, and volcanoclastic sedimentary rocks. Rocks of the Wasekwan Group and of the overlying Sickle Group sedimentary sequence have been intruded by numerous plutons, including large mafic and felsic bodies such as the Lynn Lake Gabbro. Rocks of the greenstone belt now contain mineral assemblages of the upper greenschist to upper amphibolite facies.

The Agassiz deposit was briefly described by Stewart (1980), and a further account of its geology was given by Fedikow & Gale (1982). M.A.F. Fedikow is engaged in continuing studies of the deposit and its regional setting, and a detailed account is in preparation. Extensive diamond-drilling

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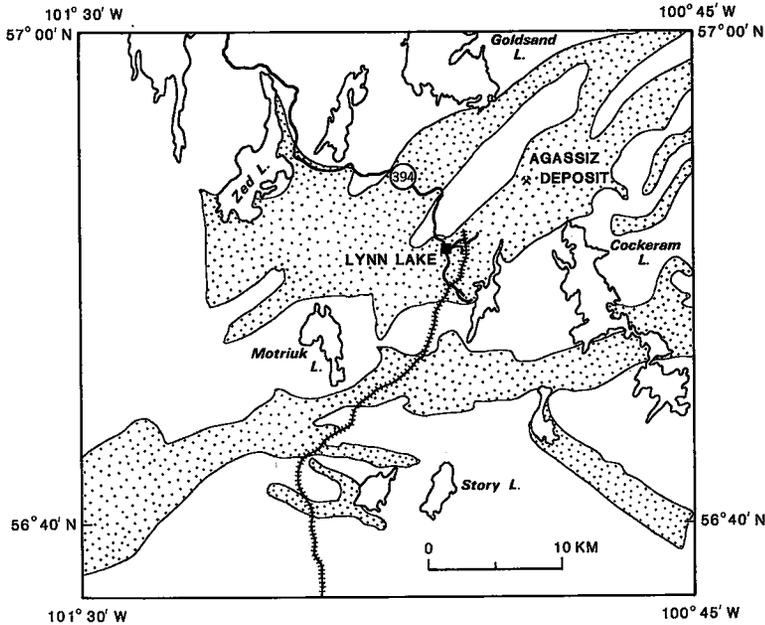


FIG. 1. Sketch map showing the location of the Agassiz deposit in relation to metavolcanic-metasedimentary belts (stippled) in the Lynn Lake area. These belts are from Fedikow & Gale (1982).

of the deposit by Sherritt Gordon Mines Ltd. has outlined 3,225,000 tonnes of probable, possible and inferred reserves at grades of 5.8 g/t Au and 13 g/t Ag. The company is co-ordinating the opening of the Agassiz (MacLellan) mine with the closing of their Fox mine, with production scheduled for May 1986 (Envers 1985). Because only preliminary mineralogical studies of the ore had been carried out, a study of the opaque minerals was undertaken to determine the Au- and Ag-bearing phases and the relationship, if any, between these and the known base-metal (principally Zn, Pb) contents of the ore zones.

THE AGASSIZ DEPOSIT

The Agassiz gold deposit is of interest because of its stratabound character and the contents of Pb and Zn, which are higher than in most gold deposits of the Canadian Shield. The supracrustal rocks in the area of the deposit consist of steeply inclined (about 77°N) intermediate and mafic volcanic flows and tuffs, greywacke and siltstone (Fedikow & Gale 1982, Fedikow 1983). The mineralized zone of the Agassiz deposit comprises interlayered normally and reversely graded siltstone, oxide-, sulfide- and silicate-facies iron formation, and basaltic flows and minor tuffs that are enriched in Mg, Ni and Cr (Fedikow *et al.* 1985). The siltstone, iron formation and mafic volcanic units have been cross-cut by a

series of gold- and silver-bearing carbonate-quartz-sulfide veins. The sulfides and altered host-rocks to the mineralization have been affected by a complex sequence of deformational events that ultimately produced a foliation (N65°E) that regionally is parallel to layering.

The footwall (stratigraphically underlying) rocks are composed of a soft, green, actinolite-chlorite schist. Fox & Johnston (1981) considered these rocks to be hydrothermally altered magnesian volcanic rocks; they named these tholeiitic picrites. The hanging-wall unit is characterized by amygdaloidal, porphyritic, fragment-bearing silicified and pyritized basalts, as well as polymodal mafic debris-flows.

A structure known as the North Shear terminates the mineralized zones, but is not thought to be significant with regard to genesis of the bulk of the sulfide mineralization. Nevertheless, it may have contributed to processes of secondary mobilization, including redistribution of gold and silver. Fedikow & Gale (1982) recognized four distinct types of alteration in the host rocks: carbonatization, silicification, chloritization and biotitization. Secondary biotite forms layers 2–3 cm thick in the sedimentary unit, and chlorite, except in a footwall actinolite-chlorite unit, is in general restricted to shear zones. The volcanic rocks that are enriched in Mg, Ni and Cr, as well as the siltstones, have been weakly to intensely carbonatized. Carbonate occurs as patches, veinlets

and disseminations with quartz. Silicification of the siltstones is interpreted to have taken place as diffuse fronts emanating from fractures, and to have been accompanied by the development of arsenopyrite "haloes" (Fedikow & Gale 1982).

ORE MINERALOGY

Polished sections were prepared from 103 short pieces of drill core from 11 holes in the main zone, 3 holes in the east zone and 4 holes in the west zone. Microscopic study of the specimens was supplemented, as necessary, by electron-microprobe analyses, obtained using a CAMEBAX instrument with a wavelength-dispersion spectrometer at an accelerating voltage of 20 kV.

Pyrite, pyrrhotite, arsenopyrite, sphalerite and galena are the most common sulfide minerals, and rutile and ilmenite the most common oxide minerals, in the ore. Chalcopyrite, magnetite and tetrahedrite-freibergite are minor constituents, and the rarer minerals are marcasite, titanite, gahnite, pyrrargyrite, polybasite, geocronite, pentlandite, argentopentlandite, breithauptite, ullmannite, native gold, electrum and auriferous silver.

Common sulfides

The pyrite, arsenopyrite, and pyrrhotite contents of the ore are not unusual for gold deposits, but sphalerite and galena are more abundant than in most Precambrian gold deposits. The east zone has been reported to contain about 1.3% Zn and 0.8% Pb (Franklin & Thorpe 1982).

Pyrite occurs in the ore as disseminated grains and as monomineralic layers of subhedral to anhedral grains. These grains are on the order of 50 μm in diameter, although euhedral grains as large as 0.5 mm are also present. Some of these larger grains are embayed or corroded. Pyrite grains have been fractured in many cases, and the fractures were filled by pyrrhotite and sphalerite.

Arsenopyrite occurs in about 60% of the polished sections, generally as euhedral rhomb-shaped grains about 30–40 μm in diameter. It is similar to pyrite in general distribution, in some cases occurring in layers rich in both arsenopyrite and pyrite, or arsenopyrite alone. Arsenopyrite grains in general do not appear to have been fractured. Inclusions of pyrrhotite and chalcopyrite are present in some grains.

Pyrrhotite is abundant in most polished sections and is generally interstitial to pyrite and arsenopyrite. Both hexagonal and monoclinic phases may be present; a slightly more reflectant phase in the form of blades emanates orthogonally from fractures or submicroscopic linear features in a darker phase of pyrrhotite. Exsolution blades or flames of pentland-

TABLE 1. COMPOSITION OF SPHALERITE

Sample #	D.H. #	Zone	Zn	Fe	Mn	S
ASM-8	80-151	West	58.9	5.6	-	33.6
ASM-9	80-154	West	57.6	7.7	-	34.0
ASM-9	80-154	West	56.8	7.6	-	33.5
ASM-12	80-153	West	57.3	8.8	0.1	33.3
ASM-13	80-153	West	55.8	9.4	0.1	33.3
ASM-15	80-103	East	57.6	8.1	0.1	33.5
ASM-24	80-105	East	57.9	7.5	0.1	33.2
ASM-33	80-10	Main	58.7	7.0	0.3	33.4
ASM-42	80-11	Main	57.6	7.6	0.2	33.4
ASM-45	80-11	Main	55.9	9.3	0.1	33.3
ASM-72	80-19	Main	57.1	8.2	-	33.6
ASM-80	80-37	Main	57.2	8.3	0.2	33.3

Composition is expressed in weight %.

ite are evident in some sections. Some pyrrhotite grains have been partly replaced by a fine-grained mixture of pyrite and marcasite ("birds-eye" texture), generally interpreted as due to weathering or supergene processes.

Sphalerite, typically containing inclusions of chalcopyrite and pyrrhotite, forms anhedral masses and fracture fillings. Textures are compatible with formation of sphalerite, in part, by partial replacement of pyrite, pyrrhotite and arsenopyrite. In a few cases the chalcopyrite inclusions in sphalerite are regularly oriented, suggesting exsolution. Analyses were obtained for sphalerite in specimens containing significant amounts of the mineral from all three of the mineralized zones (Table 1), in order to test for compositional changes that might indicate zoning within the ore along strike. No significant compositional changes were detected. The iron content of 12 grains ranges from 5.6 to 9.4 wt.%, a restricted range that may be due to buffering of FeS activity by the commonly associated pyrrhotite.

Galena is predominantly coarse-grained, although less commonly it is in very small grains with irregular boundaries; these grains appear to be, in part, interstitial to silicate grains. Galena heals or cements microbreccia zones; in many cases, it fills fractures in and replaces sulfides such as pyrite, pyrrhotite and, to a lesser degree, arsenopyrite. More rarely, galena occurs as inclusions in pyrrhotite and chalcopyrite. As discussed later, breithauptite, ullmannite and the sulfosalt minerals, tetrahedrite-freibergite, pyrrargyrite, polybasite and geocronite are all intimately associated with galena. This is commonly also true for grains of native alloy in the ore; galena and electrum were seen as composite fracture-fillings in arsenopyrite.

Chalcopyrite is a minor constituent in the ore, yet it is evident in small amounts in most sections. It occurs as tiny veinlets and irregular grains in the silicate gangue, and as grains along pyrite-pyrrhotite grain contacts. It is also common as inclusions and exsolution blebs in sphalerite, and rarely forms inclusions in arsenopyrite and galena.

Oxides and associated titanite

Rutile is common and is present in about half of the polished sections. It occurs most commonly as disseminated subhedral to anhedral grains and as aggregates of these that form lensoidal layers. Average grain-size is about 20 μm in diameter. More rarely, grains have the prismatic habit characteristic of the mineral.

Ilmenite, in both anhedral and subhedral lath-like grains, is the most abundant oxide mineral. Large tabular ilmenite grains, on the order of 100 μm long, in many cases poikilitically enclose silicate grains. Ilmenite and rutile are commonly associated, and in a few cases form a symplectic intergrowth.

Titanite was tentatively identified in eleven polished sections, and was confirmed in several of these. In most cases it is closely associated with rutile and ilmenite, and in a few sections it is interstitial to aggregates of anhedral rutile grains.

Magnetite is less common in the ore than are the titanium oxide minerals. It occurs as equant anhedral grains that are, in some cases, greater than 200 μm in diameter. Some magnetite grains are intensely fractured and, in one instance, gold is a prominent fracture-filling constituent.

Gahnite was recognized in one specimen as comparatively large grains, >150 μm in diameter. These range from highly irregular to more or less equant poikilitic masses and include silicate minerals, tabular ilmenite grains and, more rarely, small arsenopyrite grains.

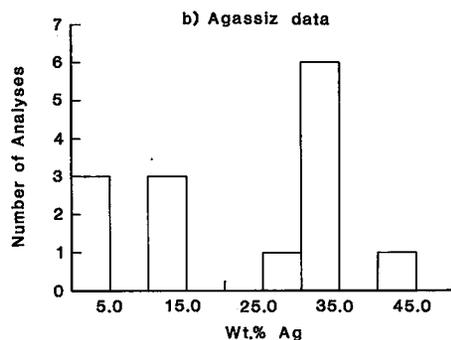
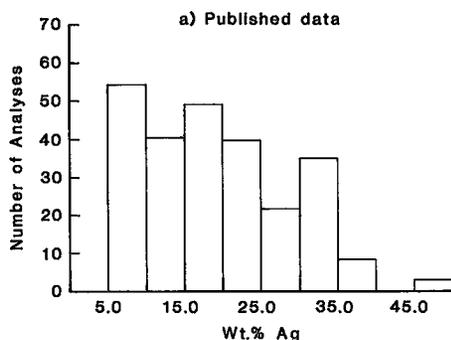


FIG. 2. Silver contents of tetrahedrite-freibergite specimens. a) Compositions for 250 specimens from the literature, with 493 values less than 5 wt.% Ag omitted. b) Compositions for 14 grains from the Agassiz gold deposit.

Sulfosalt minerals

The sulfosalt minerals present, tetrahedrite-freibergite, pyrrargyrite, geocronite and polybasite, are all antimony-bearing minerals. Three of the minerals are also silver-bearing; the exception is geocronite, although the latter mineral is not unexpected considering the presence of both antimony and arsenic in the ore. Pyrrargyrite and geocronite were identified by X-ray powder-diffraction studies by A.C. Roberts of the Geological Survey of Canada and R. Conlon of Carleton University, respectively. All of these sulfosalt minerals are intimately associated with galena.

Tetrahedrite and freibergite generally occur as small anhedral grains that range in size from less than 10 μm to about 150 μm , and average about 20-30 μm . These grains are in many cases at the contact between galena and the other common sulfide

TABLE 2. COMPOSITION OF GRAINS OF TETRAHEDRITE-FREIBERGITE

Sample #	D.H. #	Footage	Zone	Cu	Ag	Hg	Fe	Zn	Sb	As	S
ASM-2	80-8	153	Main	38.2	0.2	-	2.8	4.9	22.8	4.6	26.3
ASM-2	80-8	153	Main	37.3	0.1	-	2.3	5.9	28.2	0.8	25.4
ASM-2	80-8	153	Main	36.2	4.1	-	4.6	2.3	16.3	8.7	26.4
ASM-15	80-103	288	East	13.0	32.6	-	5.0	2.0	25.5	0.1	20.7
ASM-24	80-105	333	East	13.8	30.4	-	5.2	0.8	26.2	0.6	21.2
ASM-25	80-105	433	East	16.4	27.4	-	5.6	0.8	26.9	0.5	20.9
ASM-44	80-11	226	Main	14.5	30.7	-	5.5	1.3	26.2	0.6	21.4
ASM-55	80-15	87	Main	14.0	33.7	-	5.1	0.7	26.0	0.1	20.5
ASM-77	80-37	67	Main	28.6	12.9	-	5.2	1.2	27.9	0.2	24.1
ASM-77	80-37	67	Main	28.0	13.8	-	5.1	1.1	27.9	0.2	24.0
ASM-77	80-37	67	Main	28.4	13.1	-	4.8	1.6	28.3	0.1	23.8
ASM-81	80-34	52	Main	4.9	44.5	-	5.1	0.5	25.2	-	21.3
TQ 84 8(2)	80-103	?	East	13.8	32.2	0.1	5.7	0.9	26.6	-	20.6

Composition is expressed in weight %.

minerals. Analyses of 13 tetrahedrite–freibergite grains in 9 polished sections (Table 2, Fig. 2) indicate a wide range in silver content, and thus in values of the Ag:Cu ratio. Seven of the grains contain more than 25 wt. % Ag and are thus freibergite according to the 20 wt. % boundary suggested by Riley (1974). One of the freibergite grains was found to contain 44.5 wt. % Ag, an unusually high amount judging from a plot of published data for 250 specimens containing more than 5 wt. % Ag (Fig. 3). Riley (1974) found 42.5 wt. % Ag in a specimen from Mt. Isa, Australia, and Zakrzewski & Nugteren (1984) reported 48.2 and 45.3 wt. % for two grains from the Hällefors silver mine. These four compositions represent exceptional cases because the main compositional field terminates at about 38.5 wt. % Ag. The Agassiz tetrahedrite grains with the lowest silver contents are in a specimen that contains only very minor galena, and this suggests that there may be a correlation between the presence of Ag-rich tetrahedrite–freibergite and the presence of abundant galena.

Pyrrargyrite is rare in the ore and occurs as anhedral grains that range in size from 20–30 μm to greater than 100 μm. All the grains observed are closely associated with galena. In one section the pyrrargyrite appears to occupy a vug along with calcite. Results of three analyses (Table 3) indicate that the mineral is nearly stoichiometric, with only limited substitution of arsenic for antimony.

Polybasite was tentatively identified in one section, in which it occurs as a small anhedral grain about 10 μm in diameter. This grain is included in galena, an association that is shared with the other sulfosalt minerals.

Geocronite was also observed in only one polished section, again as anhedral grains intimately associated with galena. The grains are on the order of 75 μm in longest dimension. The identity of the mineral was established by qualitative (EDS) electron-microprobe and X-ray powder-diffraction methods.

Nickel and antimony minerals

Nickel in minor amounts is present in the ore in the minerals pentlandite, argentopentlandite (Fe,Ni)_{8-x}Ag_{1-x}S₈, breithauptite NiSb and ullmannite NiSbS. Antimony-bearing phases are the sulfosalt minerals described above, breithauptite and ullmannite. The latter minerals are apparently very rare in the Agassiz ore.

Pentlandite has been tentatively identified in 9 of the 103 specimens studied, and its identity has been confirmed in several cases. It occurs as small (less than 10 μm long) blades or exsolution flames in pyrrhotite grains. In some cases the blades occur in the middle of pyrrhotite grains, but in many cases they

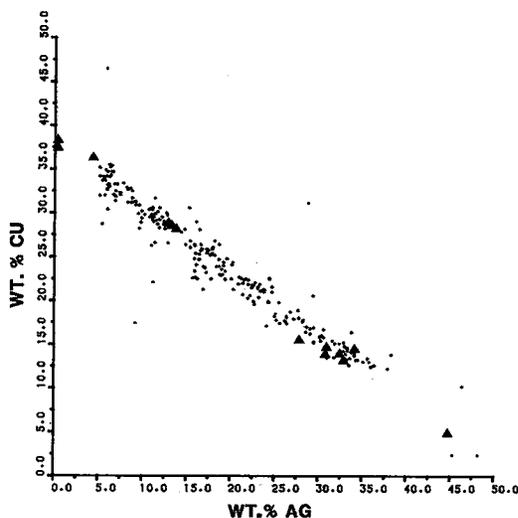


FIG. 3. The negative linear relationship between copper and silver contents of tetrahedrite–freibergite specimens on the basis of 250 published analyses (493 specimens containing less than 5 wt. % Ag have been omitted). The data for 13 specimens from the Agassiz deposit are shown by triangles.

extend inward from the pyrrhotite grain-boundaries. An analysis of one pentlandite grain indicated a significant content of cobalt (3.2 wt. %; Table 3). Some enrichment of cobalt in the ore may also be suggested by a content of 1.1 wt. % obtained in one analysis of pyrite (Table 3) associated with pentlandite-bearing pyrrhotite.

Argentopentlandite, in association with pyrrhotite and sphalerite, was recognized in only one specimen. This is the third known locality for argentopentlandite in Canada. Its occurrence was previously reported in Pb- and Zn-bearing base-metal zones along the contact of the Bird River Sill, Manitoba, and in the nickel ores of the Sudbury district (Scott & Gasparini 1973). The composition of two of the Agassiz grains is listed in Table 3.

Breithauptite occurs as very small blebs intergrown with chalcopyrite at galena–pyrrhotite grain contacts. In one case it was observed as finely intergrown grains in galena in close association with tetrahedrite.

TABLE 3. COMPOSITION OF PYRRARGYRITE, ARGENTOPENTLANDITE, PENTLANDITE, ULLMANNITE AND ASSOCIATED PYRITE AND PYRRHOTITE

Mineral	Sample #	Fe	Ni	Co	As	Sb	Ag	S
Pyrrargyrite	ASM-46	0.2	-	-	0.1	25.1	58.1	18.3
Pyrrargyrite	ASM-15	-	-	-	0.4	23.1	58.7	17.9
Pyrrargyrite	ASM-15	-	-	-	-	22.8	59.1	20.3
Argentopentlandite	ASM-13	32.3	21.2	-	NA	NA	12.7	31.1
Argentopentlandite	ASM-13	34.0	21.0	-	NA	NA	11.5	32.1
Pyrrhotite	ASM-13	59.2	0.5	-	NA	NA	-	39.0
Pentlandite	ASM-74	28.6	34.3	3.2	NA	NA	-	32.2
Pyrite	ASM-76	45.2	-	1.1	NA	NA	-	52.0
Ullmannite	ASM-77	-	27.4	NA	NA	54.8	NA	15.3

NA: element was not sought.

Ullmannite is present in an intergrowth with chalcopyrite that is hosted by galena, and in one case occurs as a euhedral grain, containing pyrrhotite inclusions, enclosed in galena. The composition of the mineral is presented in Table 3. The association of ullmannite and galena in the Agassiz ore is not unique. Patrick & Hall (1984) identified euhedral ullmannite in galena in specimens from a boulder of mineralized breccia at Tyndrum, Scotland.

Breithauptite and ullmannite are rare minerals in gold deposits, although Safonov *et al.* (1984) recently reported their presence in the ore of the Kolar gold deposits, India. To the best of our knowledge, argentopentlandite has not previously been reported to occur in a gold deposit.

Native alloy phases

Native alloy phases in the ore span a wide range of compositions in the gold-silver system, and this is reflected in the pale yellow to bright golden-yellow colors of individual grains. The phases are here termed gold, electrum (>20% Ag; Bates & Jackson 1980), and aurian silver (Boyle 1979).

Native alloy grains in the Agassiz ore are associated with pyrrhotite, arsenopyrite, galena, pyrite, sphalerite, ilmenite and magnetite. The average grain-size is about 20–30 μm , although individual grains and veinlets greater than 150 μm were observed. The native alloys occur as: 1) small, irregularly shaped grains or tiny veinlets generally less than 10 μm in the gangue, 2) larger rims on, or fracture

fillings in, galena, arsenopyrite and pyrrhotite, 3) inclusions in arsenopyrite, pyrrhotite and galena, 4) larger anhedral grains associated primarily with arsenopyrite and galena, and 5) sutured grains associated with similarly textured galena. As is obvious from these modes of occurrence, there is a general association between galena and the native alloy phases.

The composition of 30 native alloy grains (Table 4) indicates that gold is universally a significant constituent. Of 14 specimens in which native alloy grains were analyzed, 3 contain grains with mercury contents on the order of 2 wt.%. There is a suggestion in the data that minor amounts of Sb and Hg are more common in grains with an atomic proportion of silver to gold of 1:4 or higher (fineness of 400 or less), although two gold-rich grains in one specimen contain about 2% Hg. Native alloy grains in some specimens are relatively uniform in composition, but an interesting aspect of the data is that in a number of specimens this is far from true. Specimens 8, 9, 25 and TQ 84–8 contain grains with a wide range of compositions. It is not known whether or not these different compositions could have been produced by low-temperature subsolidus exsolution of different phases, or from differential mobility of some elements (and addition or removal of different amounts of silver or gold, or both, in the case of different grains of native alloy) during metamorphism. Because the Au/Ag proportions are so variable (Table 4, Fig. 4), the latter explanation is preferred. The analytical results indicate that the compositions are skewed toward more silver-rich values, with the modal class representing atomic proportions of approximately 3 Ag to 1 Au.

The overall gold/silver ratio for the Agassiz deposit is about 0.45, on the basis of grades of 5.8 g/t Au and 13 g/t Ag (Northern Miner, Nov. 8, 1984). This ratio contrasts with an average fineness

TABLE 4. COMPOSITION OF NATIVE ALLOY GRAINS

Sample #	D.H. #	Zone	Fineness	Au	Ag	Sb	Hg
ASM-8	80-151	West	482	47.8	51.4	-	-
ASM-8	80-151	West	653	64.1	34.0	-	-
ASM-8	80-151	West	573	56.1	41.8	-	-
ASM-9	80-154	West	870	86.7	12.9	-	-
ASM-9	80-154	West	344	33.0	63.0	2.0	-
ASM-11	80-153	West	878	87.0	12.1	-	-
ASM-16	80-103	East	385	36.9	59.0	-	2.1
ASM-16	80-103	East	402	39.0	57.9	-	2.3
ASM-16	80-103	East	391	37.6	58.6	-	2.5
ASM-25	80-105	East	632	62.1	36.1	-	-
ASM-25	80-105	East	495	49.6	50.7	0.1	-
ASM-25	80-105	East	519	51.5	47.8	-	-
ASM-25	80-105	East	471	46.7	52.4	0.2	-
ASM-25	80-105	East	781	76.5	21.4	-	-
ASM-37	80-11	Main	959	92.0	3.9	0.1	2.0
ASM-37	90-11	Main	950	93.1	4.9	-	1.8
ASM-45	80-11	Main	333	33.7	67.5	-	0.1
ASM-45	80-11	Main	393	39.1	60.4	-	-
ASM-45	80-11	Main	385	38.1	60.9	0.1	0.1
ASM-61	80-16	Main	812	78.8	18.2	-	-
ASM-72	80-19	Main	156	15.6	84.6	0.3	0.6
ASM-80	80-37	Main	190	19.4	82.7	1.0	-
ASM-81	80-34	Main	300	29.7	69.4	0.8	-
ASM-81	80-34	Main	320	31.6	67.1	0.8	-
ASM-87	80-34	Main	466	46.1	52.9	-	-
ASM-96	80-35	Main	443	43.6	54.9	-	-
ASM-96	80-35	Main	424	42.5	57.8	-	-
TQ 84 8(1)			333	32.5	65.1	1.6	1.3
TQ 84 8(1)			330	32.1	65.2	1.7	2.0
TQ 84 8(2)			628	61.6	36.5	0.2	-

Composition is expressed in weight %.

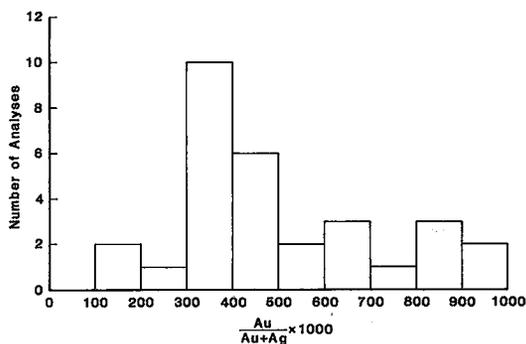


FIG. 4. Electron-microprobe data for native alloy grains from the Agassiz deposit, expressed in terms of their fineness.

of 509 for the native alloy grains analyzed. The difference reflects the presence of freibergite, pyrrhotite and other rarer silver-bearing phases. Although not established in this study, some silver may also be present in solid solution in galena.

The Au/Ag ratio at Agassiz is unusually low in relation to most gold deposits in the Canadian Shield. For example, Archean gold-quartz vein deposits average about 4.2 (Boyle 1979). However, values equal to or less than 1 were reported by Boyle for the gold deposits at Yellowknife, N.W.T., and he related these to the anomalous level of antimony enrichment in the veins. In the Agassiz case the presence of both antimony and lead may have favored the transport and deposition of silver.

The number of analyses of native alloy grains (Table 4), as indicated by a statistical assessment of the data, is not sufficient to determine whether or not the fineness of the grains in the three zones of mineralization is significantly different. An apparent gap in fineness values between 500 and 800 in grains from the Main Zone is not evident in the case of the East and West zones. No correlation was found to exist between the fineness of native alloy grains and depth as measured from the surface.

DISCUSSION

The Agassiz gold deposit is unusual in its enrichment in lead and zinc. The east zone, which contains approximately 800,000 tonnes, averages 11.7 g/tonne Au, 1.3% Zn and 0.8% Pb (Franklin & Thorpe 1982). Most gold deposits in the Canadian Shield are extremely low in base-metal contents, but the Berens River (Shklanka 1969), Ross (Jones 1948, Akande 1985) and Montauban deposits share the enrichment in Pb and Zn. The Montauban deposit, Grenville Province, is of interest for purposes of comparison because it consists of two conformable gold zones that contain disseminated sphalerite, chalcopyrite, galena, pyrite and pyrrhotite (McAdam & Flanagan 1976, Gauthier *et al.* 1985) and is spatially associated with conformable Zn-Pb deposits. Production commenced from the gold deposit during the summer of 1983. The south gold zone is apparently continuous with the main Zn-Pb deposit, is mainly hosted by diopside-tremolite rock associated with a calc-silicate unit, is richest in gold in its northern part where the gold is associated with sphalerite and lesser chalcopyrite, and contains an estimated 88,970 tonnes grading 6.48 g/t Au and 68 g/t Ag to a depth of 75 m. The north gold zone is hosted by biotite-quartz-cordierite-anthophyllite gneiss and, for a length of 488 m and to a depth of 75 m, was found to average 8.74 g/t Au, 15.8 g/t Ag, 0.43% Cu and 0.48% Zn across a width of 4.66 m (McAdam & Flanagan 1976). Overall reserves for the Montauban deposit were estimated in 1983 to be 923,000 tonnes at grades

of 3.8 g/t Au, 13 g/t Ag, 0.3% Zn, 0.2% Pb and 0.3% Cu. The gold zones have been interpreted to be of volcanic exhalative origin (Gauthier *et al.* 1985).

In the case of the Montauban deposit, the McAdam-Flanagan figures for the shallow part of the north gold zone indicate that the Ag:Au ratio is very comparable to that (~ 2.2) for the Agassiz deposit, but the figures for the south zone and for the overall reserves indicate a much greater proportion of silver. Base metals in the ore of the Ross mine are concentrated only in a specific set of veins (Akande 1985), apparently hosted by anhydrite-rich metasomatic bodies that have a flattened pipe-like shape, and these may be much more enriched in silver than the other sets of veins. Nevertheless, overall Ag/Au values for the deposit are apparently in the range 1 to 1.5 (Jones 1948), much higher than for Canadian Shield gold deposits in general. These data appear to establish a pattern whereby gold deposits enriched in Pb and Zn also have significantly higher Ag/Au ratios.

An interesting aspect of the Agassiz ore is the generally intimate association of the sulfosalt minerals and native alloy phases with galena. This suggests that Pb, Sb, Ag and Au, in particular, may have been partially mobilized during a postdepositional episode of metamorphism or deformation (or both). The extent to which such remobilization takes place during metamorphism is not well documented. However, in a detailed mineralogical investigation of the Izok Lake massive sulfide deposit, Northwest Territories, by one of the authors (D.C.H.), Pb, Ag, Sb, Bi and Cu were found to be dispersed into the footwall and hanging-wall rocks for as much as 3 metres from the massive ore, apparently during the regional metamorphism.

The minerals pentlandite, argentopentlandite, breithauptite and ullmannite all reflect an enrichment of nickel in the gold ore. Although breithauptite and ullmannite have recently been reported in ore of the Kolar district, India (Safonov *et al.* 1984) and nickeline has been noted in the Fred deposit, Filabusi district, Zimbabwe (Foster *et al.*, in press), such an enrichment is rare in gold deposits, even in those hosted in ultramafic rocks and their altered equivalents. Nevertheless, the nickel probably indicates that the metals were derived, at least in part, from the leaching of Mg-rich basalts or ultramafic rocks. In this regard, further investigation of the character of thin Mg-rich and Cr-rich units that occur along the ore horizon might be informative. These could represent komatiitic tuffs and are currently being studied petrogenetically.

On the basis of the general characteristics of the Agassiz deposit, Koo (1977) and Fedikow & Gale (1982) proposed an exhalative origin. The presence of magnetite-chert iron formation and of cross-cutting footwall alteration at the deposit (Fox &

Johnston 1981) are features favoring this interpretation. However, Fedikow *et al.* (1985) have suggested that the deposit may consist of an originally stratiform deposit that was cross-cut by a series of epigenetic carbonate-sulfide-quartz veins (with everything subsequently deformed?). A third possibility is that replacement of favorable units has taken place in association with cross-cutting veins, but this is not considered likely because other gold deposits occur along the same stratigraphic horizon (Envers 1985). As the deposit is unusual in terms of its base-metal contents, the enrichment of Ni in the ore, and the presence of thin associated Mg-rich and Cr-rich lithologic units, further petrochemical and other studies are recommended to elucidate its genesis.

CONCLUSIONS

The opaque and semi-opaque minerals identified in the Agassiz deposit are pyrite, pyrrhotite, arsenopyrite, sphalerite, galena, chalcopyrite, ilmenite, rutile, magnetite, tetrahedrite-freibergite, polybasite, pyrrargyrite, geocronite, native gold, electrum, aurian silver, pentlandite, argentopentlandite, breithauptite, ullmannite, titanite and gahnite. This is the third reported Canadian locality for argentopentlandite, and the first known occurrence of this mineral in a gold deposit.

Gold is present in the ore in native gold, electrum, and aurian silver. Silver is present in the same minerals, as well as in tetrahedrite-freibergite, pyrrargyrite, polybasite and argentopentlandite. The complex mineralogical sites of these elements, particularly of silver, could be important in attempting to maximize their recovery during milling.

Sphalerite was found to have an iron content in the restricted range of 5.6 to 9.4 wt.%, perhaps owing to buffering of FeS activity by pyrrhotite. Small tetrahedrite-freibergite grains associated with galena have a wide range of silver contents, and in one case an unusually high value of 44.5 wt.%.

Our mineralogical study indicates that the ore is enriched in nickel as well as in antimony and arsenic. Whole-rock geochemical profiles across the ore zones undertaken at the Manitoba Department of Energy and Mines have resulted in identification of these same patterns of enrichment. The enrichment of nickel in a gold ore is unusual and most likely indicates that the metals were in part leached from ultramafic source-rocks.

In spite of its stratiform nature, some aspects of the genesis of the deposit remain in question. Because of the unusual contents of Zn, Pb and Ni for a gold deposit, and the reported presence of both chemical sediments and unusual thin Mg-rich and Cr-rich tuffaceous (?) units along the ore horizon, further study of the deposit from a genetic point of view appears warranted.

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