Mines Branch Technical Bulletin TB 56

MINERALOGY OF THE MOUNT PLEASANT TIN DEPOSIT IN NEW BRUNSWICK

by

William Petruk*

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SYNOPSIS

The Mount Pleasant tin deposit in New Brunswick is unusually complex and contains a wide variety of minerals. The tin-bearing minerals are cassiterite and stannite. Cassiterite is the chief tin mineral and it occurs as disseminations in mineralized rock, fluorite masses, and sulphide veins. The cassiterite in the mineralized rock and sulphide veins occurs as small grains, whereas that in the fluorite masses is present as relatively large grains. Stannite was found mainly as irregular grains and minute inclusions in sphalerite and arsenopyrite.

Sphalerite is the most abundant ore mineral. It is generally black and contains minute exsolution bodies of chalcopyrite, stannite and pyrrhotite. Analyses of sphalerite concentrates give Zn 45.0 to 48.90%, Fe 7.8 to 13.1%, Cu 1.3 to 5.2%, Sn 0.14 to 0.38%, In 0.03 to 0.30%, Cd 0.12 to 0.18%, and Mn 0.06 to 0.08%.

Other minerals in the deposit are: rutile, wolframite, scheelite, hematite, chalcocite, tennantite, covellite, galena, molybdenite, bismuthinite, wittichenite, arsenopyrite, glaucodot, pyrite, marcasite, pyrrhotite, native bismuth, native gold, quartz, feldspar, topaz, zircon, siderite, calcite, fluorite, biotite, sericite, chlorite, kaolinite, dickite, hydromica, goethite, scorodite, arseno-bismite, and malachite.

Sphalerite geothermometry indicates that the depositional temperatures of sphalerite fall between 335°C and 700°C, and arsenopyrite geothermometry gives depositional temperatures up to 500°C.

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*Senior Scientific Officer, Mineralogy Section, Mineral Sciences Division, Mines Branch, Department of Mines and Technical Surveys, Ottawa, Canada.
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Direction des mines

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MINÉRALOGIE DU GÎTE D'ÉTAIN DU MONT PLEASANT AU NOUVEAU-BRUNSWICK

par

William Petruk*

RÉSUMÉ

Le gîte d'étain du mont Pleasant au Nouveau-Brunswick est exceptionnellement complexe et contient une grande variété de minéraux. Les minéraux stannifères sont la cassitérite et la stannine. La cassitérite, principal minéral d'étain, se présente en disséminations dans la roche minéralisée, dans les amas de spath fluor et dans les veines de sulfures. La cassitérite se présente en petits grains dans la roche minéralisée ou dans les veines de sulfures, alors que ses grains sont relativement gros dans les amas de spath fluor. On trouve la stannine principalement sous forme de grains irréguliers et d'inclusions minuscules dans la blende et l'arsénopyrite.

La blende est le mineral le plus abondant. Elle est généralement noire et contient de minuscules parcelles de chalcopyrite, de stannine et de pyrrhotine en solution solide d'insertion. Les analyses des concentrés de blende indiquent de 45.0 à 48.90 p. 100 de Zn, de 7.8 à 13.1 p. 100 de Fe, de 1.3 à 5.2 p. 100 de Cu, de 0.14 à 0.38 p. 100 de Sn, de 0.03 à 0.30 p. 100 de In, de 0.12 à 0.18 p. 100 de Cd, et de 0.06 à 0.08 p. 100 de Mn.

Les autres minéraux présents dans le gîte sont: le rutile, la wolframite, la scheelite, l'hématite, la chalcocite, la tennantite, la covellite, la galène, la molybdénite, la bismuthinite, la wittichenite, l'arsénopyrite, le glaucodot, la pyrite, la marcassite, la pyrrhotine, le bismuth natif, l'or natif, le quartz, le feldspath, la topaze, le zircon, la sidérite, la calcite, la fluorine, la biotite, la séricite, la chlorite, la kaolinite, la dickite, l'hydromica, la goethite, la scorodite, l'arsenobismite et la malachite.

L'étude géothermométrique de la blende montre que les températures extremes de mise en place de la blende sont 335°C et 700°C, et l'étude géothermométrique de l'arsénopyrite indique une température maximale de mise en place de 500°C.

*Agent scientifique senior aux Mines, Section de la minéralogie, Division des sciences minérales, Direction des mines, ministère des Mines et des Relevés techniques, Ottawa, Canada.

Ce rapport, en fait, a été présenté par l'auteur comme mémoire au congrès annuel de la Mineralogical Association of Canada, à Toronto, Ontario, le 18 mai 1964.

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INTRODUCTION

The Mount Pleasant tin deposit, in Charlotte County, New Brunswick, is located about 37 miles southwest of Fredericton. It occurs on Mount Pleasant (elevation 1,175 ft), in the vicinity of a lookout tower. When the writer visited the property in October 1962, he examined two mineralized zones. These zones, located about 4,500 feet and 500 feet north of the lookout tower, are referred to as the North and Fire Tower Zones, respectively. Parts of the North Zone have been designated as "Lodes" by company officials and this designation will be followed in the paper. Lode No. 1 represents the main portion of the North Zone, and Lodes Nos. 2 and 4 are about 220 and 550 feet, respectively, to the north-northwest of Lode No. 1. Lode No. 3 is south of Lode No. 1.

Diamond drilling programs are presently being conducted on the North and Fire Tower Zones, and underground development is in progress to test the North Zone. An adit has been driven into the north-northwest face of Mount Pleasant to intersect Lode No. 1 about 300 feet below its surface exposure.

Some fifty samples were collected by the writer from the North Zone, and some from the Fire Tower Zone. This collection was subsequently augmented by hand specimens and drill core samples supplied by officials of Mount Pleasant Mines Limited. The present study is restricted to the mineralogy of this material.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the contributions made to this report by the supporting scientific facilities of the Mineral Sciences Division, Mines Branch.

Chemical analyses for 64 miscellaneous constituents were contributed by R.C. McAdam, D.J. Charette, R. Craig, F.W. Brethour H.H. Bart and R.W. Buckmaster, of the Analytical Chemistry Subdivision; and semiquantitative spectrographic analyses for 22 samples were provided by Miss E.M. Kranck and Dr. A.H. Gillieson, also of the Analytical Chemistry Subdivision.

X-ray powder identifications and cell parameter measurements were carried out by J.M. Stewart of the Mineralogy Section, and D.T.A. tracings for 4 samples were prepared by R.H.Lake of the Physical Chemistry Section.

The writer is grateful to officials of Mount Pleasant Mines Limited for many courtesies extended when he visited the property, and for providing samples and information about the deposit.

GENERAL GEOLOGY

The geology of the Mount Pleasant deposit has been described by Hosking (1). According to him, the Mount Pleasant ridge is underlain by a series of acid and intermediate volcanic rocks and several kaolinized dykes. The volcanic rocks are intensely fractured and have been silicified, chloritized, and kaolinized.

CHARACTER OF THE DEPOSIT

Ore minerals are found in the silicified, chloritized and kaolinized volcanic rocks and "kaolinized dykes" (1). Those in the volcanic rocks occur as disseminations and veins, and those in the "kaolinized dykes" occur in mineralized fluorite masses and sphalerite veins.

Spectrographic analyses of samples of the volcanic rock, "kaolinized dyke", mineralized fluorite, and sphalerite veins are given in Figure 1. Chemical analyses for tin in samples of volcanic rock, mineralized fluorite, and sphalerite veins are given in Table 1.

TABLE 1

Distribution of Tin in Samples from the Mount Pleasant Deposit

Sample	Weight % Sn
Volcanic rock	Trace to 3.3*
Mineralized fluorite	11.0**
Sphalerite veins	0.25 to 11.0**

* Company's assay results (personal communication).
** Chemical analyses by staff of the Analytical Chemistry Subdivision.

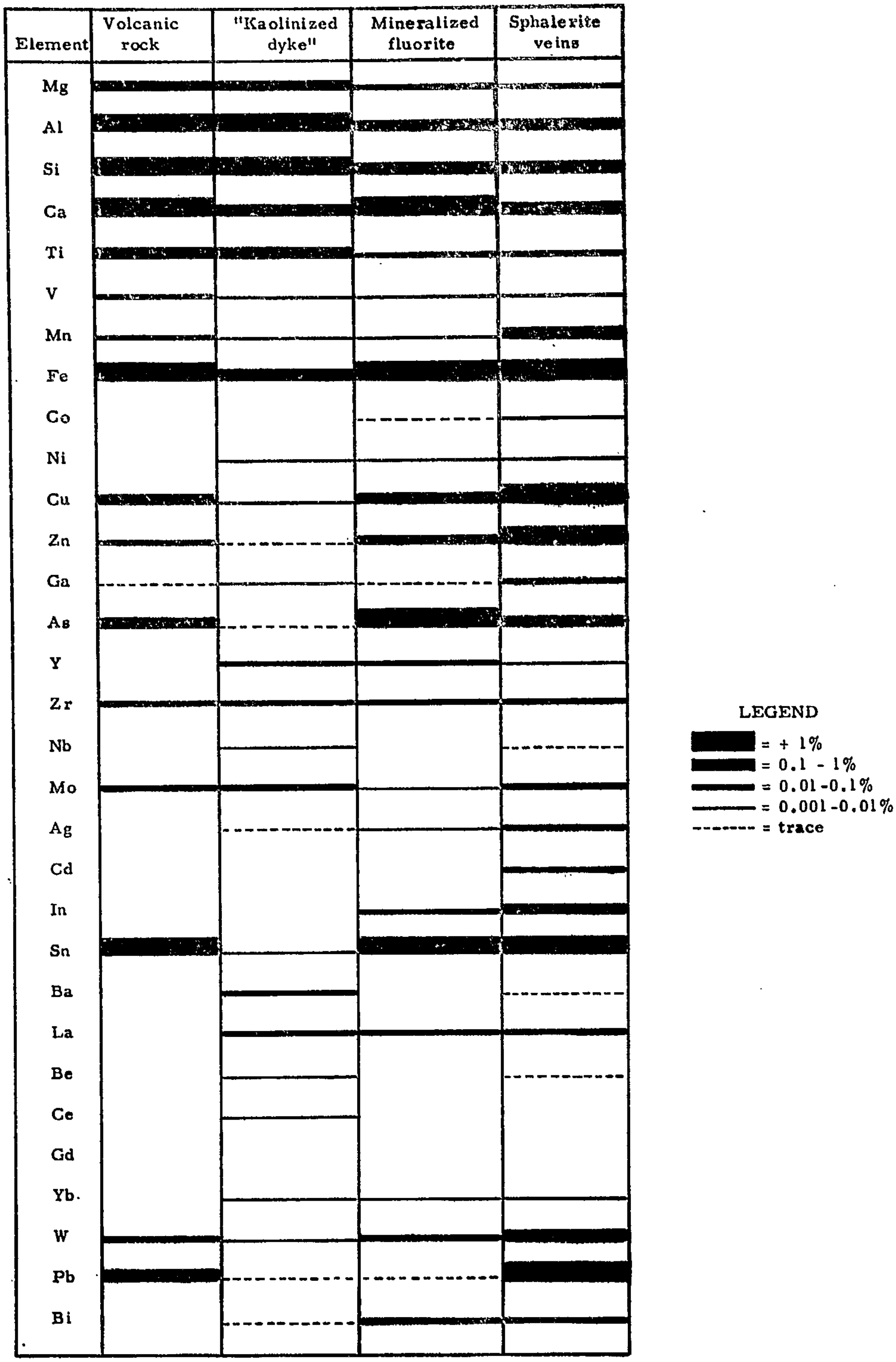

Figure 1. Results of spectrographic analyses of samples from the Mount Pleasant tin deposit.
(Analyses by E.M. Kranck and A.H. Gillieson, Analytical Chemistry Subdivision)

GENERAL MINERALOGY

The volcanic rock in the North and Fire Tower Zones is composed of the characteristic minerals of a greisen (2). This "greisen-type" rock contains numerous sphalerite veins and a few molybdenite, galena, fluorite, siderite, quartz, hydromica and kaolinite veins. The sphalerite veins range from a fraction of an inch to several inches in width (2), are generally black, and vary in mineralogy from simple to complex. The molybdenite, galena, fluorite, siderite, quartz, hydromica and kaolinite veins have a relatively simple mineralogy.

The "kaolinized dykes" consist of white earthy material, and are composed of kaolinite, quartz, fluorite, and hydromica. One "kaolinized dyke" contains a 6-inch-wide sphalerite vein and a number of fluorite crystals, and another contains masses of mineralized fluorite.

The minerals present in samples of the "greisen-type" rock, "kaolinized dyke", mineralized fluorite, and sphalerite veins are listed in Table 2.

DETAILED MINERALOGY

Metallic Minerals

The metallic minerals are present as veins, masses and disseminations in the "greisen-type" rock and mineralized fluorite.

Cassiterite

Cassiterite is the principal tin-bearing mineral in the ore. It is light brown in colour and has an adamantine lustre. Polished sections show that some of the grains are twinned and others have a very fine, zoned texture. The magnetic susceptibility of the cassiterite, determined with a calibrated Frantz isodynamic separator, is 0.1 to 2.5×10^{-6} e.m.u. A spectrographic analysis of a cassiterite concentrate* showed that it contains titanium, iron, tungsten, aluminum, calcium, nickel, indium, and gallium, and a chemical analysis reported 0.4% Ti and 0.3% Fe.

The cassiterite occurs in the "greisen-type" rock, fluorite veins and masses, and sphalerite veins (Figures 2, 3 and 4). The cassiterite in the "greisen-type" rock and fluorite occurs as euhedral crystals and irregular grains (Figures 2 and 3), whereas that in sphalerite veins occurs only as irregular grains (Figure 4). Some of the irregular grains in the "greisen-type" rock and fluorite are intergrown with rutile and chlorite and appear to have been replaced by these minerals.

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* See Appendix 1.

TABLE 2

Minerals Present in Samples from the Mount Pleasant Deposit

Minerals	"Greisen-type" Rock	"Kaolinized Dyke"	Mineralized Fluorite	Sphalerite Veins
Quartz	p	p	p	-
Chlorite	p	-	-	-
Fluorite	p	p	p	p
Topaz	p	-	-	-
Sericite	p	-	-	-
Zircon	p	p	p	-
Calcite	p	-	-	-
Siderite	?	-	-	-
Cassiterite	p	p	p	p
Rutile	p	p	p	p
Wolframite	p	-	p	p
Scheelite	-	p	-	-
Hematite	-	p	-	-
Stannite	p	-	p	p
Sphalerite	p	p	p	p
Chalcopyrite	p	p	p	p
Chalcocite	-	-	p	-
Tennantite	p	-	p	p
Covellite	p	-	-	p
Galena	p	p	p	p
Molybdenite	p	p	p	p
Bismuthinite	-	p	-	p
Wittichenite	-	-	-	p
Native bismuth	-	-	-	p
Native gold	p	-	-	-
Arsenopyrite	p	p	p	p
Glaucodot	-	-	p	-
Pyrite	p	-	p	p
Marcasite	-	-	-	p
Pyrrhotite	-	-	-	p
Goethite	p	-	-	p
Kaolinite	p	p	p	p
Hydromica	-	p	-	-
Scorodite	p	-	-	p
Arseno-bismite	p	-	-	p
Malachite	-	-	-	p

p = Mineral present.

\- = None found.

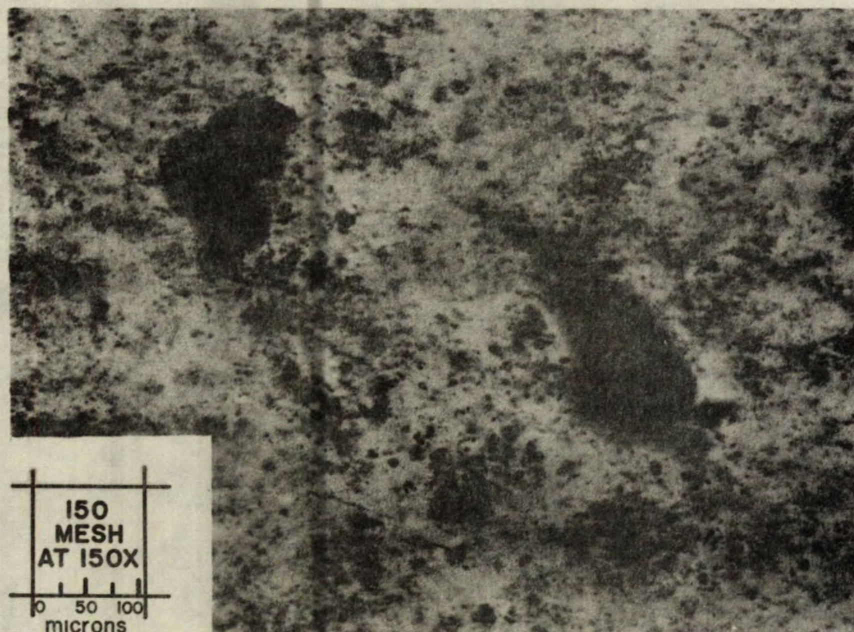

Figure 2. Photomicrograph of a thin section showing cassiterite grains in "greisen-type" rock.

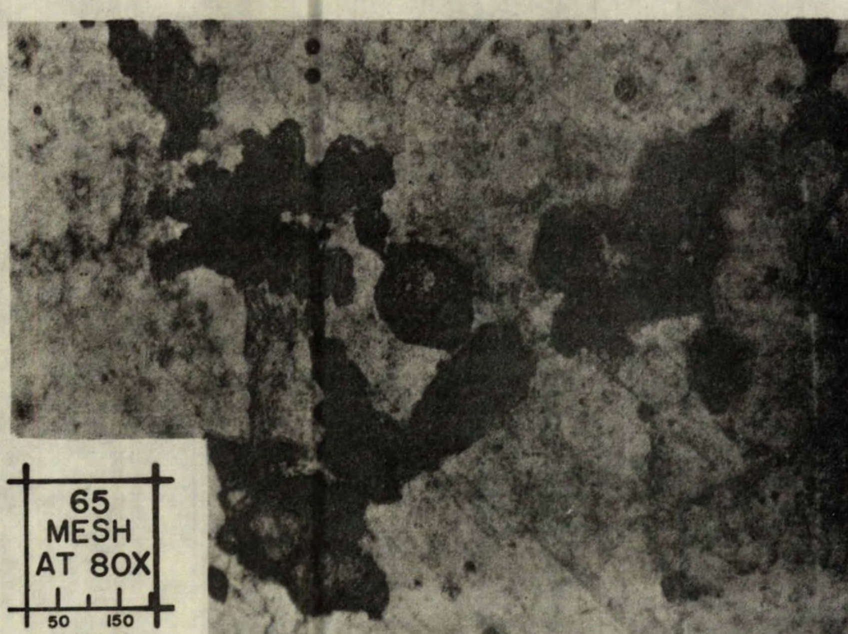

Figure 3. Photomicrograph of a thin section showing cassiterite in massive fluorite from a "kaolinized dyke".

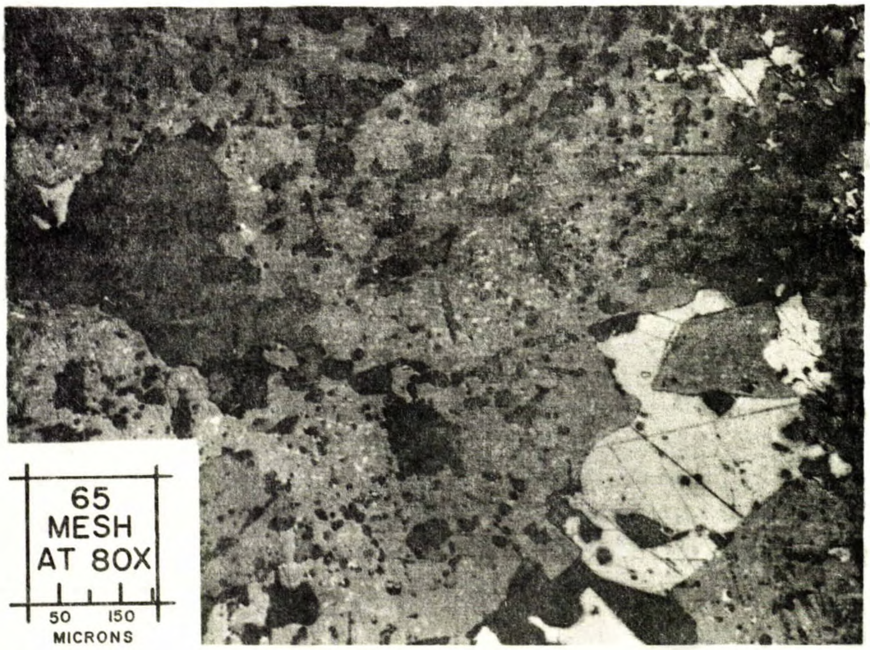

Figure 4. Photomicrograph of a polished section of Sample A, showing cassiterite (dark grey) in sphalerite (light grey). The small white dots in the sphalerite represent chalcopyrite inclusions and the large white area represents galena. The black areas represent voids in the sample.

The approximate size distribution of the cassiterite grains in the "greisen-type" rock, mineralized fluorite and sphalerite veins was determined from polished sections, both of the samples and of cassiterite concentrates prepared from these. This determination was done by examining 500 cassiterite grains in each polished section, estimating the surface area covered by each grain, and calculating the percentage of the total area covered by cassiterite grains of a particular size. The results, given in Table 3, show that most of the cassiterite grains in the massive fluorite are larger than those in the "greisen-type" rock and sphalerite veins.

TABLE 3

Grain Sizes of Cassiterite from the Mount Pleasant Deposit

(Determined by estimating surface areas)

Grain Size (microns)	Size Distribution of the Cassiterite in "Greisen-type" Rock	Size Distribution of the Cassiterite in Mineralized Fluorite	Size Distribution of the Cassiterite in a Sphalerite Vein
0- 10	7.8	0.1	1.1
10- 30	17.3	1.7	22.9
30- 50	23.9	2.8	20.5
50- 70	17.8	2.7	16.8
70-100	14.2	2.3	12.2
100-150	8.2	8.1	13.3
150-200	5.5	12.0	13.2
200-300	3.0	18.3	
+300	2.3	52.0	
Total	100.0	100.0	100.0

Stannite

Stannite is black in hand specimens and in this respect is similar to sphalerite. Its appearance in polished sections, however, is quite distinctive, and under the microscope it is clear that only a small amount of the mineral is present in the ore. Detailed microscopical studies combined with chemical analyses show that, in a sphalerite vein containing 10.98% tin, about 25% of the tin is in the form of stannite (3) and that, in a sphalerite vein containing 0.25% tin, all the tin is in the form of stannite.

The stannite occurs in sphalerite veins, "greisen-type" rock, and mineralized fluorite. That in the sphalerite veins is present as irregular grains, and globules and lamellae (Figure 5), and that in "greisen-type" rock and mineralized fluorite is present as irregular grains and inclusions in arsenopyrite. The larger irregular grains contain globules and lamellae of chalcopyrite (Figure 6), and some of those in sphalerite surround cassiterite (Figure 7 and 8). It is possible that the stannite that surrounds cassiterite is a reaction product resulting from replacement of cassiterite by Fe-Cu-rich sphalerite. A similar feature was described by Novak et al. (4) for samples from the Kutna Hora area in Czechoslovakia, in which a reaction between cassiterite and pyrrhotite produced stannite.

Sphalerite

The sphalerite from the Mount Pleasant deposit is generally black, but crystals of a brown variety were found in kaolinite veins. Sphalerite is the most abundant ore mineral in the deposit and it occurs as veins and disseminations in the "greisen-type" rock and mineralized fluorite. That in the veins is present as masses and contains numerous inclusions, representing practically all the metallic minerals. Chalcopyrite is the most common inclusion and it characteristically occurs as globules and lamellae (Figure 9). In some places the chalcopyrite globules and lamellae are so numerous that in hand specimens the black sphalerite appears brown. Stannite and pyrrhotite occur in the same manner as chalcopyrite, but their quantities are small.

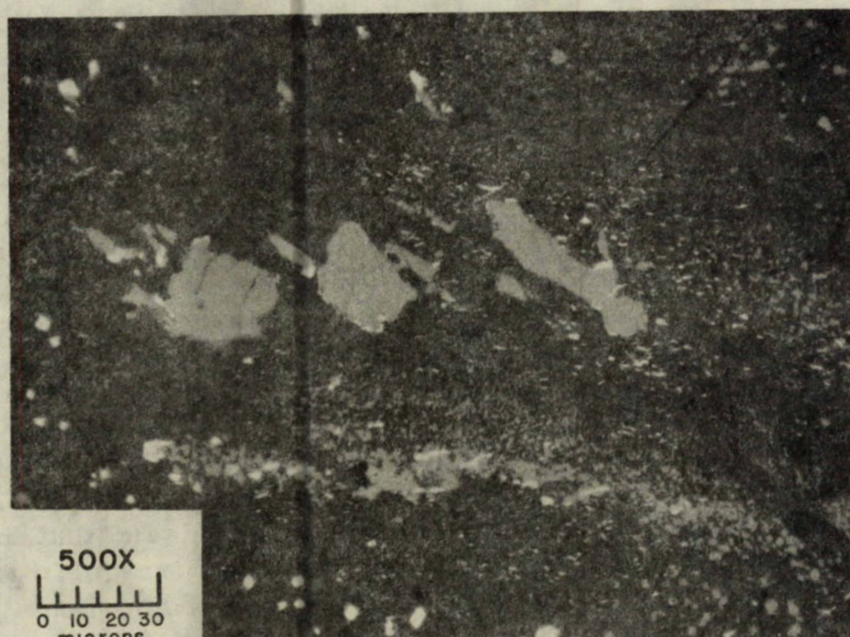

Figure 5. Photomicrograph of a polished section of Sample A, showing irregular grains and minute globules and lamellae of stannite (light grey) in sphalerite (dark grey). The white dots represent chalcopyrite.

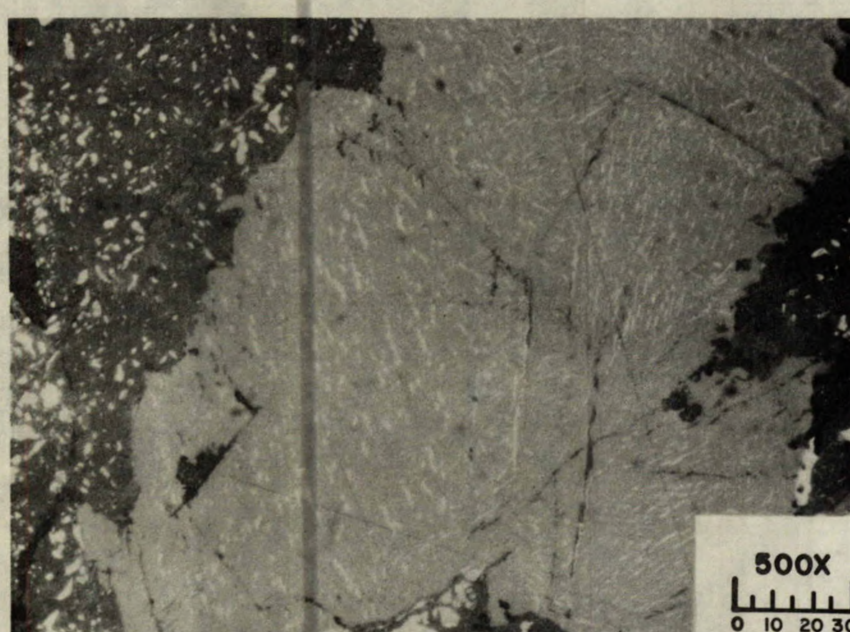

Figure 6. Photomicrograph of a polished section of Sample A, showing globules and lamellae of chalcopyrite (white) in stannite (light grey) and sphalerite (dark grey).

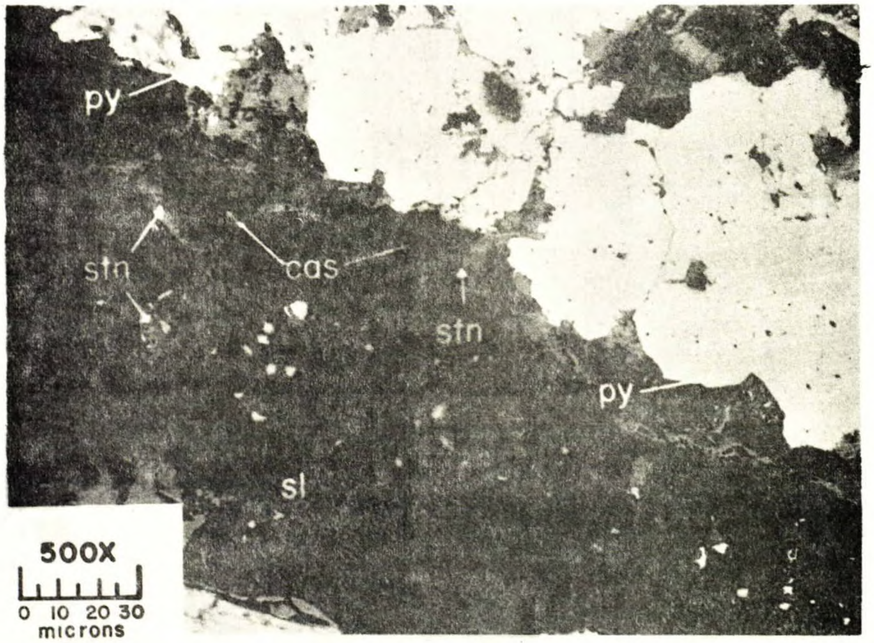

Figure 7. Photomicrograph of a polished section of Sample A, **showing** two grains of cassiterite (cas) bordered by stannite **(stn). Other** minerals in the photomicrograph are sphalerite **(sl) and pyrite (py).**

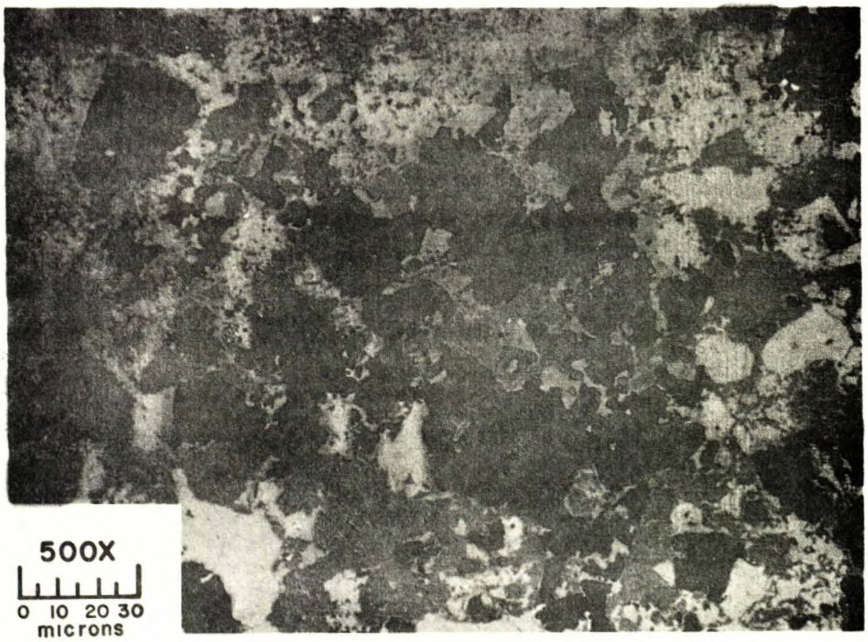

Figure 8. Photomicrograph of a polished section of Sample A, **showing** cassiterite (dark grey) in stannite (light grey) and **sphalerite** (medium grey). The black areas represent voids in the **sample.**

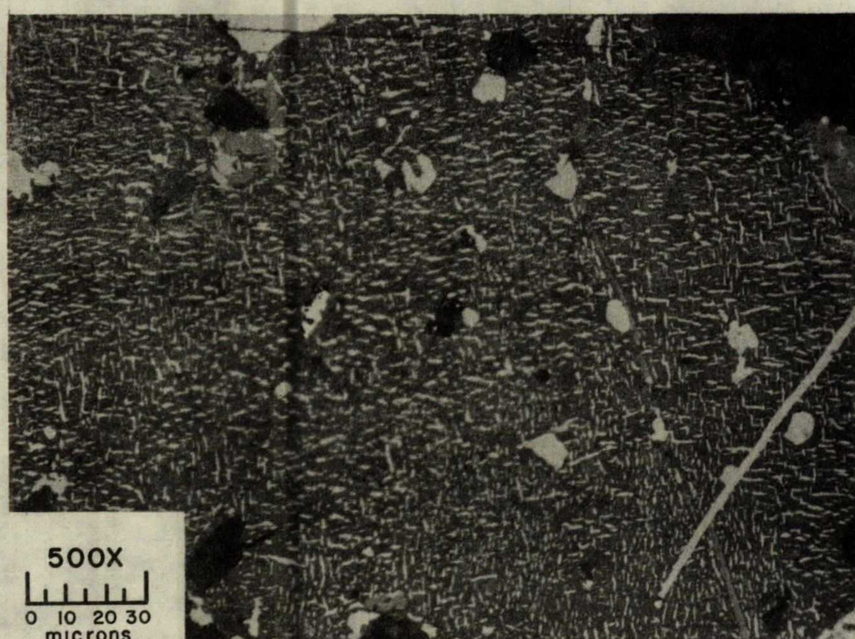

Figure 9. Photomicrograph of a polished section of Sample W, showing the numerous small chalcopyrite globules and lamellae (white) in sphalerite (grey). The light grey areas represent stannite.

Five sphalerite samples were prepared for analysis. One of these was prepared from a composite ore sample undergoing beneficiation tests in the Mines Branch (Sample B-3-14), and the other four were selected from hand specimens of sphalerite veins. The hand specimens were crushed and the sphalerite was cleaned by means of heavy liquids, a superpanner, and a Frantz isodynamic separator. Sufficient amounts for relatively complete analysis, however, were prepared only from Samples G and B-3-14. The results of the chemical analyses are given in Table 4.

TABLE 4

Analyses of Sphalerite from the Mount Pleasant Deposit*

Element	Weight %				
	Sample G**	Sample K**	Sample L**	Sample O**	Sample B-3-14
Zn	48.90	nd	nd	nd	45.20
Fe	7.80	nd	nd	nd	13.12
S	32.23	nd	nd	nd	30.70
Mn	0.06	0.05	0.08	0.08	nd
Cd	0.18	0.18	0.16	0.12	nd
In	0.12	0.30	0.07	0.03	nd
Cu	5.20	5.15	1.28	1.93	2.07
Sn	0.38	0.38	0.25	0.25	0.14
Ca	2.62				2.21
F (Calc)	2.50				2.11
Insol.	nd				4.35
	99.99				99.90

* Analyses performed by the staff of the Analytical Chemistry Subdivision, Mineral Sciences Division, Mines Branch, Ottawa.
** For sample locations, see Appendix 2.
nd = Not determined.

The calcium and insoluble reported in the analyses can be attributed to fluorite and quartz, since these minerals were detected in the respective samples. The copper, the tin and some of the iron can be attributed to inclusions of chalcopyrite and stannite. On these assumptions the compositions of the sphalerite in Samples G and B-3-14 were calculated. The results are given in Table 5.

TABLE 5

Chemical Compositions of Sphalerite from the Mount Pleasant Tin Deposit
(Calculated to 100%)

Element	Sample G	Sample B-3-14
Zn	62.10	52.97
Fe	4.33	13.37
Mn	0.07	nd
Cd	0.23	nd
In	0.16	nd
S	33.11	33.66

nd = Not determined.

The cell parameters of the sphalerite in Samples X, G, K, W, L, O and B-3-14 were measured by X-ray diffraction, and the amounts of FeS in solid solution were determined by applying the measured values to the curve prepared by Skinner et al.(5) (Table 6). The determined FeS contents for the sphalerite in Samples G and B-3-14 are in general agreement with the chemically analysed values. It is, therefore, assumed that the FeS contents determined from cell dimension measurement for the sphalerite in the other samples are near the true ones.

TABLE 6

Unit Cell Parameters and FeS Contents of Sphalerite from the Mount Pleasant Deposit

Sample	Cell Parameter (measured), A	Mol per cent FeS	
		Determined from Cell Parameter	Determined from Chemical Analyses
X	5.4105	2.8	
G	5.4129	8.0	7.5
K	5.4135	9.3	
W	5.4147	12.0	
L	5.4178	18.5	
O	5.4180	19.0	
B-3-14	5.4209	25.6	22.8

Table 4 shows that the manganese and cadmium contents in the samples studied are low and relatively constant. The indium content, on the other hand, varies from 0.03% in Sample O to 0.30% in Sample K. A comparison of the indium contents in the sphalerite samples with the tin contents in the host veins and the locations of the veins suggests that these three factors may be related (Table 7).

TABLE 7

Relationship between Indium Content in Sphalerite, Tin Content in Sphalerite Veins, and Locations of the Veins in the Mount Pleasant Deposit

Sample	Indium in Sphalerite, wt. %	Tin in Vein, wt. %	Location of Vein
K	0.30	2.28	Lode No. 1
G	0.12	1.57	Lode No. 1
L	0.07	0.27	Lode No. 2
O	0.03	0.25	1,500 feet N-NW of Lode No. 1

Chalcopyrite

Chalcopyrite is present in sphalerite and galena veins, "greisen-type" rock, and mineralized fluorite. It occurs as masses, irregular inclusions and veinlets in sphalerite, arsenopyrite, galena and pyrite, and as the globules and lamellae noted in the descriptions of sphalerite and stannite. Textural relations suggest that the globules and lamellae are exsolutions and represent a different generation of chalcopyrite than the masses, inclusions, and veinlets.

Chalcocite

Chalcocite was found in massive fluorite from the "kaolinized dyke" and in chalcopyrite from a galena veinlet in Lode No. 4. The chalcocite in the massive fluorite is intergrown with stannite (Figure 10), and that in the chalcopyrite occurs as veinlets and inclusions (Figure 11).

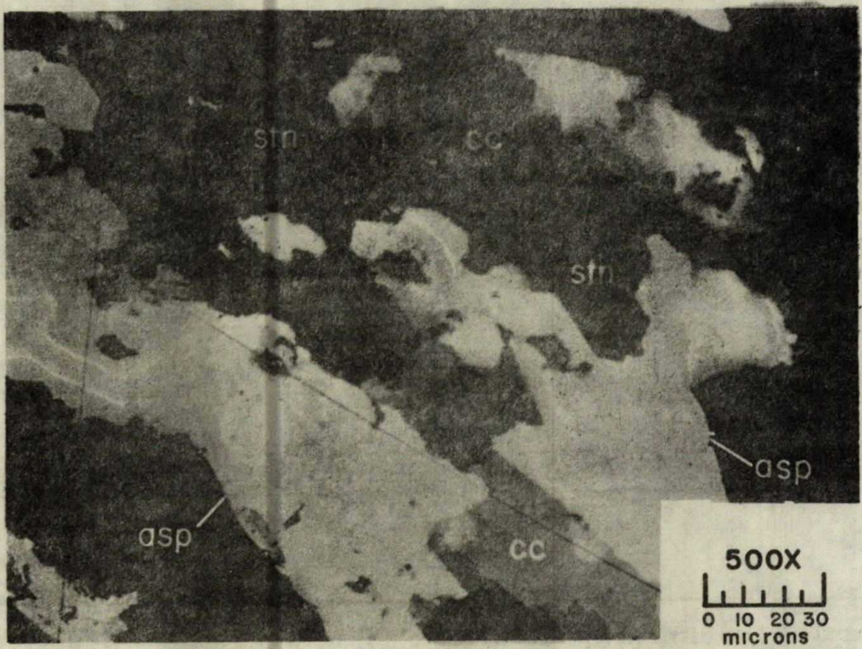

Figure 10. Photomicrograph of a polished section of a sample of massive fluorite from the "kaolinized dyke", showing chalcocite (cc), stannite (stn), and arsenopyrite (asp).

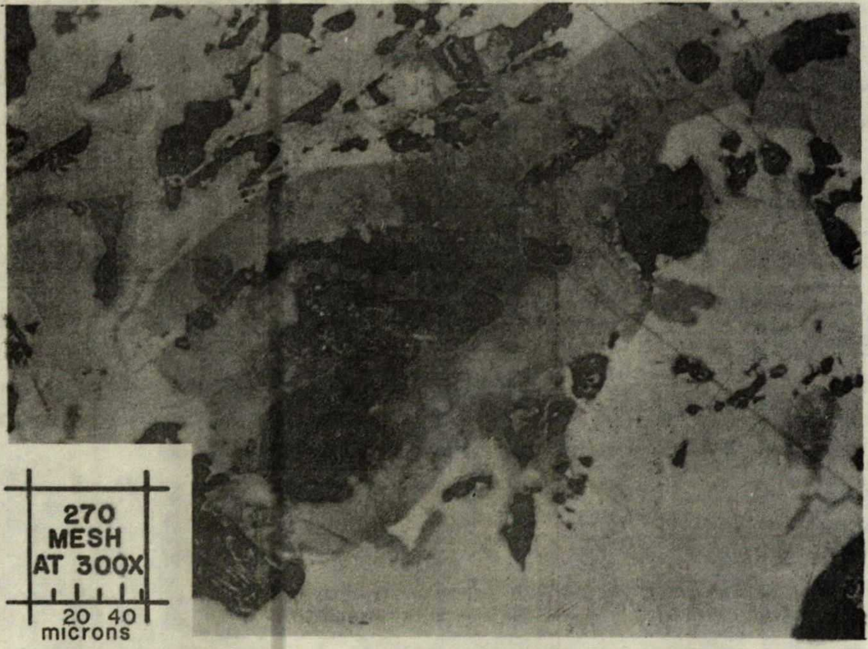

Figure 11. Photomicrograph of a polished section of a sample from the galena veinlet in Lode No. 4, showing chalcocite (grey) in chalcopyrite (light grey). The small grey featherlike areas in chalcopyrite represent sphalerite and the black areas represent pits and voids in the sample.

Tennantite

Tennantite was found in the "greisen-type" rock from the North Zone and in sphalerite veins from the Fire Tower Zone. That in the "greisen-type" rock occurs as irregular grains and as intergrowths with stannite. Its unit cell parameter was measured as 10.22, which is near that of normal tennantite (10.19 A) and appreciably lower than that of tetrahedrite (10.32 A) (6). This low unit cell parameter indicates that the tennantite can carry only small amounts of silver.

The tennantite in the sphalerite vein occurs as masses and intergrowths with sphalerite, and occasionally contains inclusions of cassiterite and goethite (Figure 12). Its unit cell parameter was measured as 10.29 A. This value is extraordinarily large, which indicates that the tennantite may either contain significant amounts of silver or have a composition near that of normal tetrahedrite.

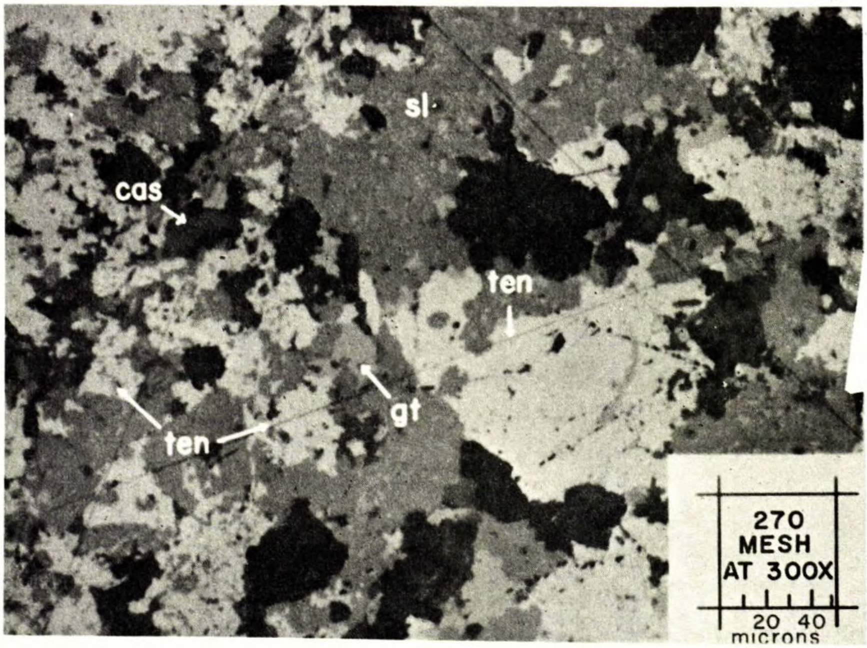

Figure 12. Photomicrograph of a polished section of a sphalerite-tennantite veinlet from the Fire Tower Zone (DH 135-107), showing tennantite (ten), sphalerite (sl), cassiterite (cas), and goethite (gt).

Covellite

Covellite was found only in a drill core sample from the Fire Tower Zone. It occurs as hair-like veinlets and borders in and around chalcopyrite (Figure 13), and is undoubtedly an alteration product.

Figure 13. Photomicrograph of a polished section of drill core from the Fire Tower Zone (DH 143-90), showing chalcopyrite (white) with hair-like veinlets and a border of covellite (grey).

Galena

The galena occurs as veins, small masses, and irregular inclusions in sphalerite and arsenopyrite. It is frequently intergrown with arsenopyrite, and occasionally contains minute inclusions of wittichenite, bismuthinite and native bismuth.

The cell parameter of the galena in a sample from a galena vein in Lode No. 4 was determined as 5.925 A. This value is slightly lower than normal (5.929 to 5.936 A) (7), which indicates that only small amounts of silver and bismuth are present in solid solution in galena (7). A spectrographic analysis* shows that the galena does contain small amounts of silver and bismuth, and a chemical analysis reported Bi 0.09%. The galena was not analysed chemically for silver, but, since silver and bismuth in galena are generally present as $AgBiS_2$ (7), the equivalent amount of silver was calculated as 0.04%, which is in agreement with the spectrographic analysis.

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* See Appendix 1.

Bismuthinite, Wittichenite, and Native Bismuth

Small amounts of bismuthinite, wittichenite and native bismuth were found in samples of sphalerite veins from both the North and Fire Tower Zones. The bismuthinite and wittichenite are present as irregular grains frequently intergrown with each other (Figure 14) and these generally occur as inclusions in arsenopyrite, galena and sphalerite. The native bismuth is present as inclusions in bismuthinite, arsenopyrite, galena and stannite.

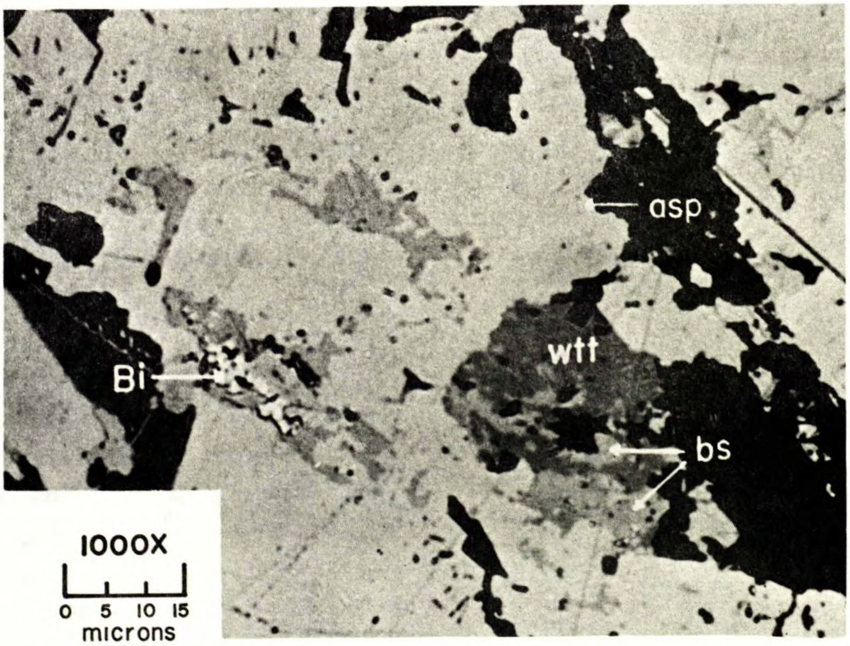

Figure 14. Photomicrograph of a polished section of Sample W, showing native bismuth (Bi), bismuthinite (bs) and wittichenite **(wtt)** in arsenopyrite.

Native Gold

One grain of native gold, about 20 microns in size, **was found** in a sample of the "greisen-type" rock from the Fire Tower Zone **(Sample** DH-137-80).

Molybdenite

Molybdenite occurs as veinlets, masses and minute inclusions in the "greisen-type" rock and in the sphalerite veins (Figures 15 and 16). That in the "greisen-type" rock is most abundant in the Fire Tower Zone and contains inclusions of pyrrhotite and native bismuth. Its X-ray diffraction pattern corresponds to that of rhombohedral molybdenite described by Traill (8), whereas the X-ray diffraction pattern of the molybdenite in sphalerite veins corresponds to that of normal hexagonal molybdenite (9). The significance of the molybdenite polytypes is not known; however, it is possible that each has a different origin.

Wolframite

The wolframite from the Mount Pleasant deposit is dark-brown and its X-ray diffraction pattern corresponds more closely to that of ferberite ($FeWO_4$) than to that of huebnerite ($MnWO_4$). It is most abundant in the Fire Tower Zone, and occurs as small masses and euhedral to anhedral grains in the "greisen-type" rock and the sphalerite veins (Figure 17).

Scheelite

Scheelite was found only in concentrates prepared from samples of the "kaolinized dyke" in Lode No. 1. The quantities were exceedingly small.

Rutile

Small amounts of rutile were found as irregular grains and prismatic crystals in the "greisen-type" rock, sphalerite veins, and mineralized fluorite. Some of the grains in the "greisen-type" rock and mineralized fluorite are intergrown with cassiterite (Figure 18).

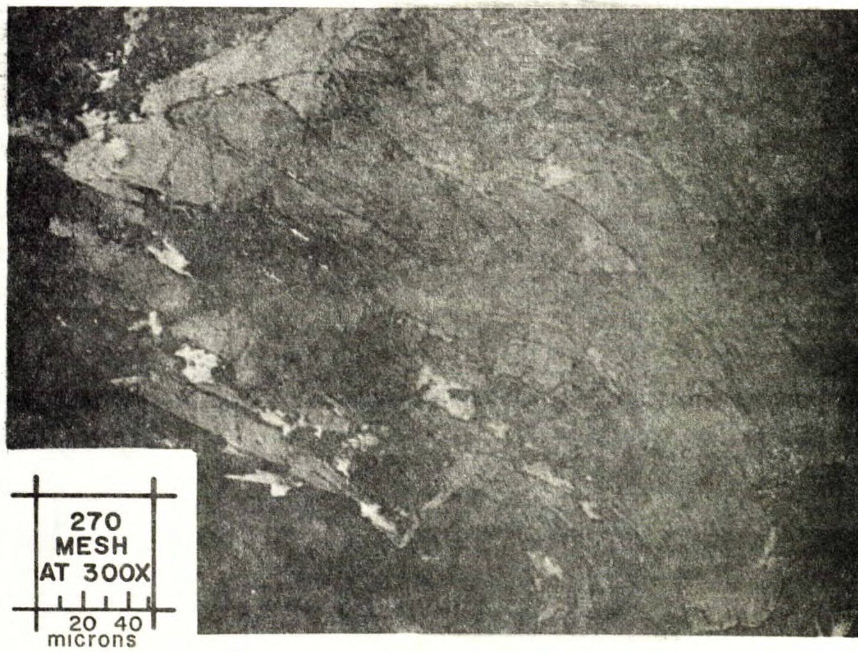

Figure 15. Photomicrograph of a polished section of a sample from the Fire Tower Zone, showing massive molybdenite (grey) with a few small inclusions of pyrrhotite (white).

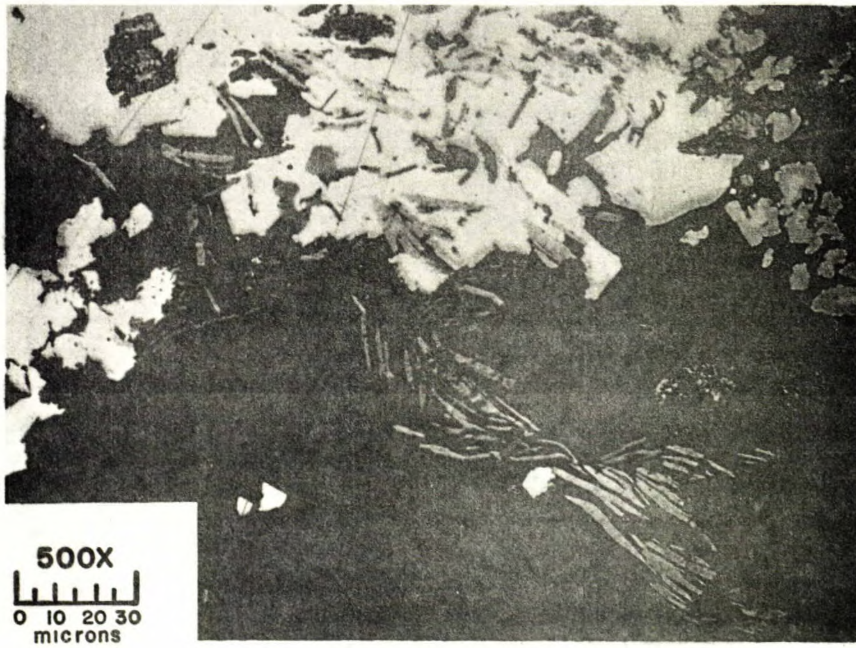

Figure 16. Photomicrograph of a polished section of Sample W, showing molybdenite (elongated grey grains) in gangue (black) and arsenopyrite (white).

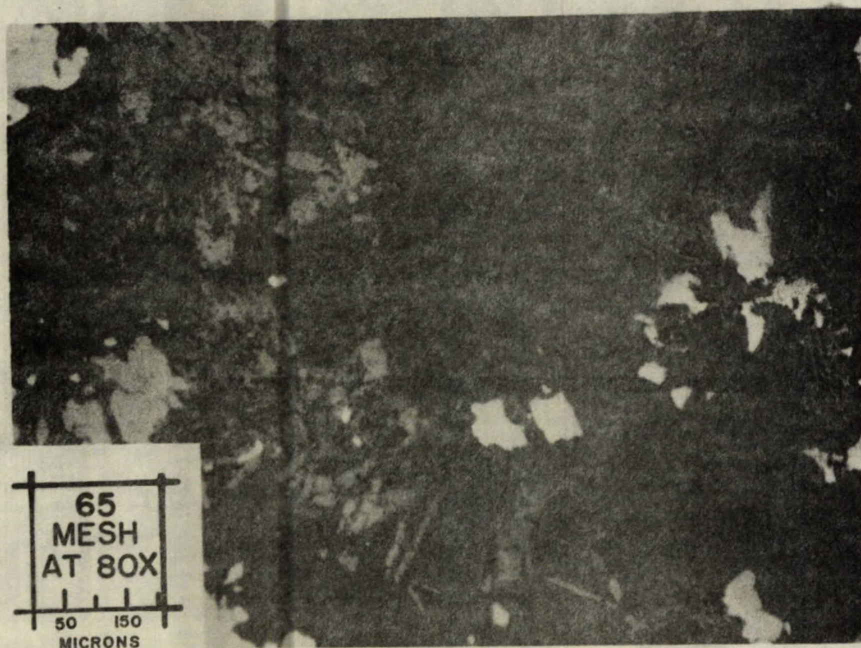

Figure 17. Photomicrograph of a polished section of Sample W, showing wolframite crystals (light grey) in gangue (grey). The white areas represent arsenopyrite.

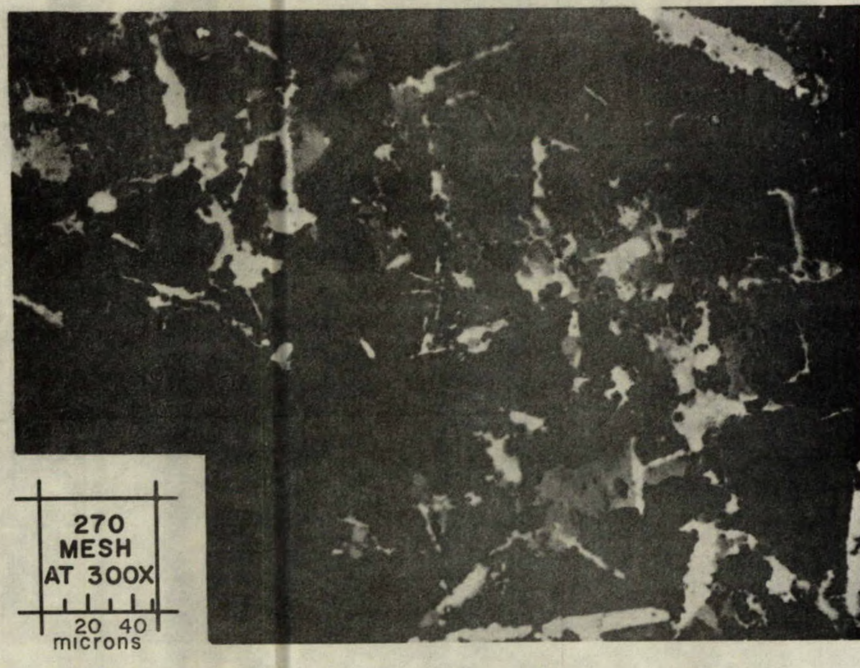

Figure 18. Photomicrograph of a polished section of massive fluorite from a "kaolinized dyke", showing rutile (white) and cassiterite (grey).

Arsenopyrite

Arsenopyrite occurs as masses, veins and euhedral to subhedral grains in "greisen-type" rock, in mineralized fluorite and in sphalerite veins. That in the sphalerite veins is frequently intergrown with pyrite and contains inclusions of galena, pyrite, sphalerite, chalcopyrite, stannite, native bismuth and bismuthinite, and that in the mineralized fluorite contains inclusions of glaucodot and stannite. A chemical analysis of an arsenopyrite concentrate prepared from a sample of a sphalerite vein reported 0.09% Co and a trace of nickel (less than 0.05%).

Glaucodot

Small amounts of glaucodot were found as minute rounded inclusions in the arsenopyrite in mineralized fluorite.

Pyrite

The pyrite occurs as masses, veinlets, and euhedral to subhedral grains in the "greisen-type" rock and sphalerite veins. It is intergrown with arsenopyrite and marcasite and contains inclusions of arsenopyrite, marcasite and pyrrhotite. A chemical analyses shows that it contains a trace of nickel (less than 0.05%).

Marcasite

Marcasite was found only as irregular grains intergrown with pyrite and arsenopyrite, and as inclusions in pyrite. The quantity is small.

Pyrrhotite

Pyrrhotite was found as minute globules and lamellae in sphalerite and as minute inclusions in pyrite and molybdenite. The quantity is small.

Hematite

Hematite was found only as a red stain on the kaolinite in the "kaolinized dyke".

Siderite

Siderite is present as the principal constituent of a 4-inch-wide siderite-fluorite vein in Lode No. 4. It is buff coloured and occurs as well-developed rhombohedral crystals. Its molecular composition, calculated from a chemical analysis, is $Fe_{0.86}Mn_{0.14}Co_3$. A spectrographic analysis of it is given in Appendix 1.

Goethite

Goethite occurs as irregular inclusions in sphalerite (Figure 12) and as a border around pyrite, arsenopyrite, sphalerite and chalcopyrite.

Scorodite, Arseno-bismite and Malachite

Encrustations of pale green scorodite and arseno-bismite were found along fracture surfaces in the fresh underground workings, and encrustations of brilliant green malachite were found on surface samples. These are secondary minerals, presumably formed from the oxidation of the ore.

Non-metallic Minerals

The non-metallic minerals in the North and Fire Tower Zones occur largely as constituents of the "greisen-type" rock and as veins and masses. The constituents of the "greisen-type" rock are quartz, chlorite, fluorite, topaz, sericite, zircon, apatite and calcite, and the minerals occurring as veins and masses are fluorite, hydromica, kaolinite and dickite.

Quartz

Quartz is the main constituent of the matrix of the rock, but some is also present as larger grains. These larger grains are composed of one or more crystals and are up to several millimetres in size. A few of them contain inclusions of topaz (Figure 19) and sericite, and some are bordered by narrow zones of fine-grained material that has the appearance of overgrowths or reaction rims (Figure 20). A similar feature was found by the writer in samples of Bolivian tin ore (10).

Chlorite

Chlorite occurs as irregular masses and small grains (Figure 21) and occasionally is intergrown with cassiterite. It is light green, and has a magnetic susceptibility of 75×10^{-6} e.m.u. Its X-ray diffraction pattern, part of which is given in Table 8, differs from that of normal iron-rich chlorite, but is similar to that reported for a chlorite from Cornwall, England (11). The Cornwall chlorite has been interpreted as having a mixed-layer kaolin-chlorite structure.

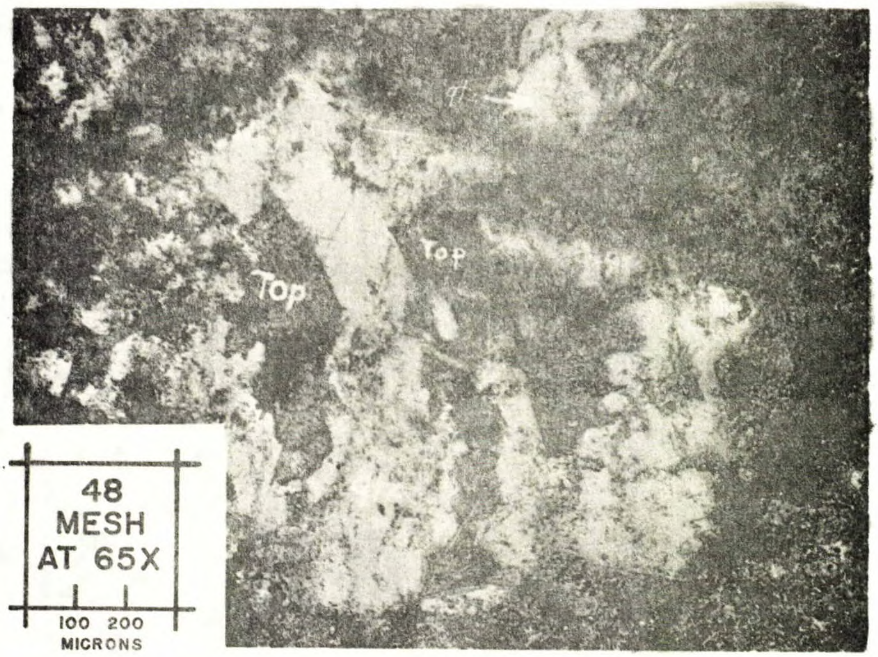

Figure 19. Photomicrograph of a thin section of Sample H-42-285, showing inclusions of topaz (top) in large quartz grains **(qtz).**

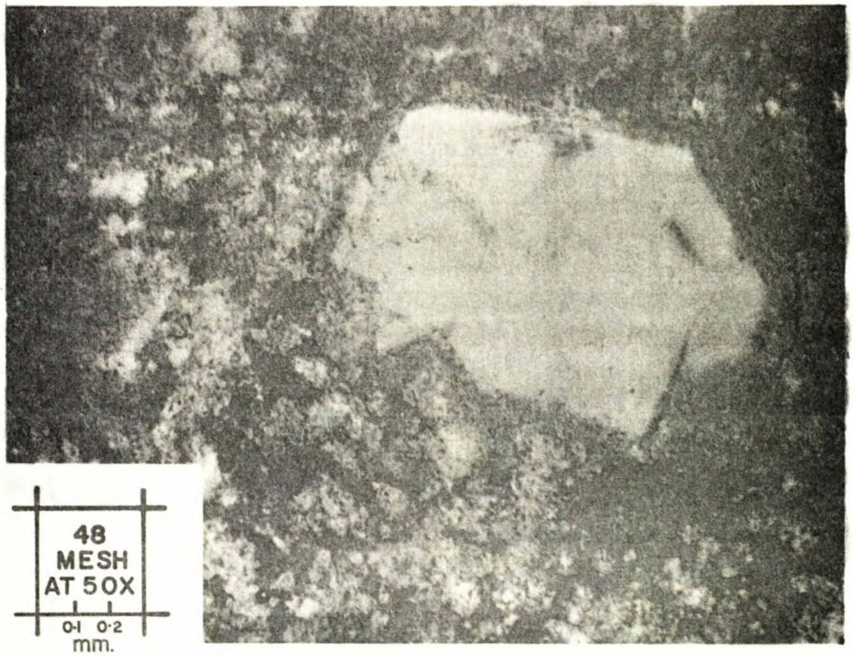

Figure 20. Photomicrograph of a thin section of Sample H-42-285, showing a quartz grain with an overgrowth or a **reaction rim.**

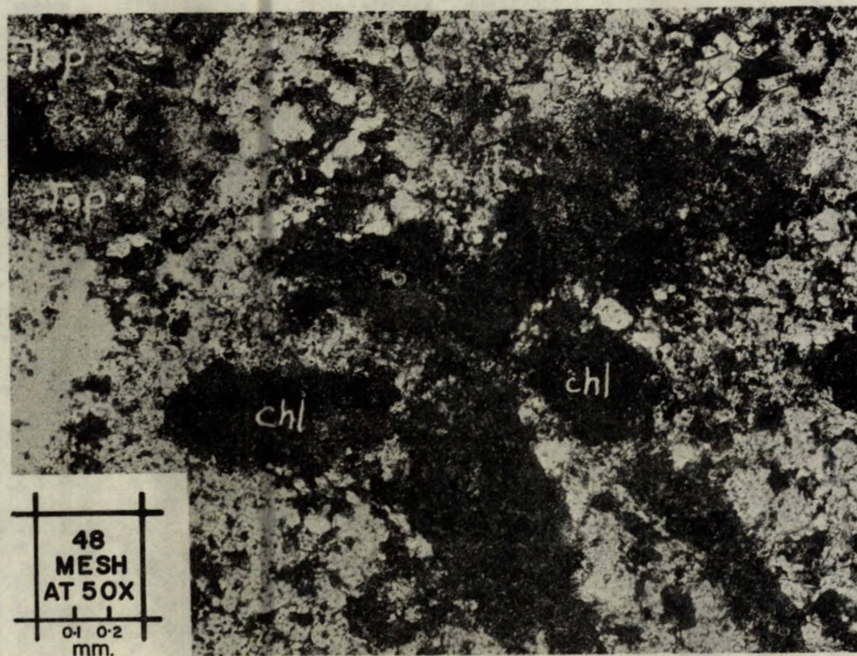

Figure 21. Photomicrograph of a thin section of Sample U-62-67, showing chlorite masses (Chl) and topaz (Top) in the "greisen-type" rock.

TABLE 8

Intensities of Some Basal X-Ray Diffractions from the Mount Pleasant Chlorite, the Cornwall Chlorite and Normal Chlorite

hkl	Mount Pleasant Chlorite	Cornwall Chlorite	Normal Iron-rich Chlorite
001	3	1.1	16
002	100	100.0	100
003	3	1.0	17
004	36	26.0	57
005	1	0.4	5

The chemical composition of the Mount Pleasant chlorite, given in Table 9, shows that it is an iron-rich variety, and in this respect is also similar to the Cornwall chlorite.

TABLE 9

Chemical Compositions of the Mount Pleasant and Cornwall Chlorites

	Mount Pleasant Chlorite, weight % *	Cornwall Chlorite, weight % (from Brindley and Gillery (11))
SiO_2	22.2	22.0
Al_2O_3	27.0	27.6
FeO	32.5	30.2
Fe_2O_3	3.7	4.7
MgO	1.0	4.7
MnO	0.4	
CaO	1.3	
TiO_2	1.0	
H_2O	9.8	10.6
Total	98.9	99.8

* Analyses performed by the staff of the Analytical Chemistry Subdivision.

The similarity between the Mount Pleasant and Cornwall chlorites suggests that they may represent a distinctive type of chlorite found in "greisen-type" rocks.

Topaz

A significant amount of topaz is present in the "greisen-type" rocks, especially near fluorite and sulphide veins. It is white in hand specimens and occurs as euhedral to anhedral crystals (Figure 22), and as inclusions in quartz (Figure 19) and fluorite (Figure 23). The inclusions in the quartz are present as irregular and prismatic crystals, and those in fluorite occur as minute prismatic crystals and have a radial texture. It is possible that the topaz in fluorite was formed by a reaction between fluorite and the surrounding silicate minerals.

Sericite, Calcite, Zircon and Apatite

Sericite, calcite, zircon and apatite are present as minute grains in the "greisen-type" rock, and, as noted above, sericite is present in the large quartz crystals.

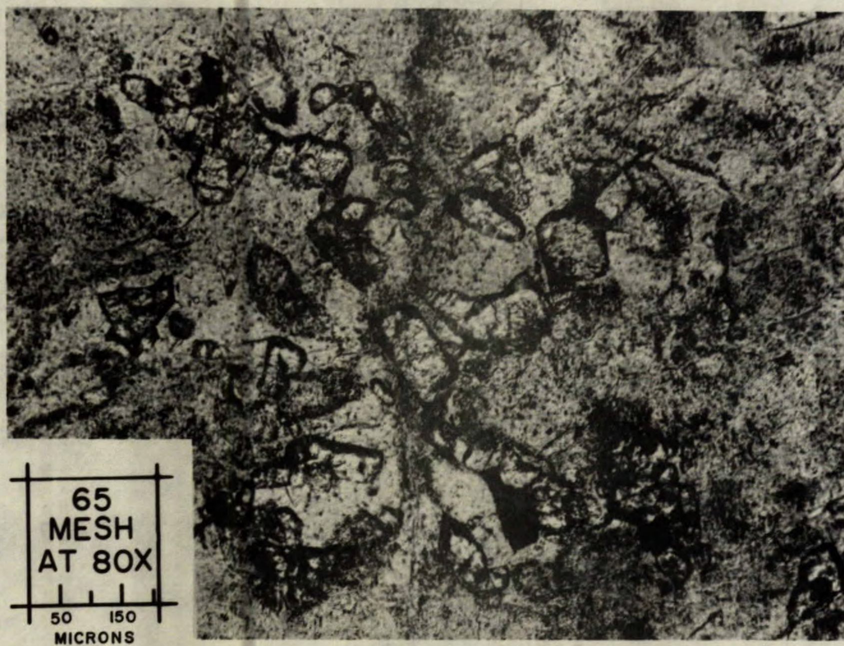

Figure 22. Photomicrograph of a thin section showing topaz grains in the "greisen-type" rock.

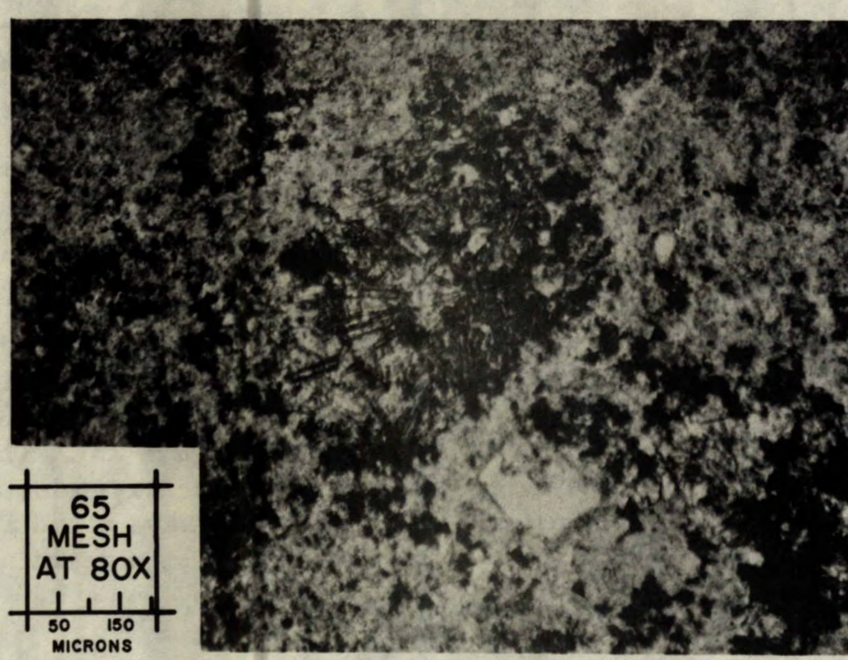

Figure 23. Photomicrograph of a thin section showing prismatic topaz crystals in a fluorite grain in the "greisen-type" rock.

Fluorite

Fluorite is abundant in the Mount Pleasant deposit. It occurs as a constituent of the "greisen-type" rock, as veins and masses, and as well-developed crystals in the "kaolinized dyke". That in the "greisen-type" rock is mauve and is present as discrete grains. That occurring as veins and masses ranges in colour from mauve through brownish-mauve to black. The brownish-mauve variety is mineralized, and contains a wide variety of elements, including a number of rare earth elements*. The black variety occurs as narrow veinlets along sphalerite veins, and contains minute inclusions of sphalerite which imparts the black colour to it. It also contains a wide variety of elements*.

The fluorite occurring as crystals in the "kaolinized dykes" ranges from colourless through light green to light mauve. Spectrographic analyses of these three types are also given in Appendix 1*.

Hydromica

The hydromica is whitish grey to brilliant yellow in colour. It is soft, has a soapy feel, and breaks into small particles when wetted. It occurs as veinlets and occasionally as encrustations on fluorite and the wall rock. Its D.T.A. tracing shows weak endothermal peaks at 114°C and 195°C and strong endothermal peaks at 650°C and 1050°C which are generally similar to those of muscovite. Its X-ray diffraction pattern is also similar to that of a 1M variety of muscovite (12). Spectrographic analyses show that the hydromica from a fluorite veinlet in Lode No. 1 contains more elements than that from a hydromica veinlet in the wall rock*.

Kaolinite and Dickite

The kaolinite at the Mount Pleasant deposit occurs as veins and masses and as the main constituent of the "kaolinized dykes". Its X-ray diffraction pattern shows typical kaolinite reflections and its D.T.A. tracing shows the typical endothermal kaolinite peak at 591°C and the exothermal peak at 969°C (13).

The dickite is a white, coarsely crystalline mineral that occurs as narrow veinlets near a "kaolinized dyke". Its X-ray diffraction pattern shows typical dickite reflections (14), and its D.T.A. tracing shows the typical endothermal dickite peak at 697°C and the exothermal peak at 990°C.

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* See Appendix 1.

GEOTHERMOMETRY

Sphalerite Geothermometry

Sphalerite geothermometry is based on the relationship between the FeS content in sphalerite and the depositional temperatures of sphalerite (15)(16)(17). Its application, however, is limited to sphalerite that was deposited in equilibrium with pyrrhotite and/or a pyrite surface. Equilibrium conditions are assumed to have been met when either the pyrrhotite is present in the mineral assemblage or pyrite inclusions are present in sphalerite. When pyrrhotite is present, a definite depositional temperature can be obtained for sphalerite that was deposited below 600°C, but when pyrite inclusions are present, only a maximum and a minimum temperature can be established (15).

The sphalerite from the Mount Pleasant deposit does not contain pyrrhotite in the mineral assemblage, and pyrite inclusions were found only in samples from Lode No. 1. The FeS contents in sphalerite from three locations in Lode No. 1 were determined by chemical or X-ray diffraction analyses, and minimum and maximum temperatures were established by applying the determined values to the equilibrium diagram given by Sims and Barton (15). The results are given in Table 10.

TABLE 10

Deposition Temperatures of Sphalerite from the Mount Pleasant Deposit

Sample	FeS Content in Sphalerite, %	Minimum Deposition Temperature, °C	Maximum Deposition Temperature, °C
G	7.5 (chem)	335	675
K	9.3 (X-ray)	380	700
W	12.0 (X-ray)	430	720

The Mount Pleasant sphalerite contains large amounts of copper, tin, and indium (Table 4). The effect of these elements on the depositional temperatures of sphalerite is not known. Application of sphalerite geothermometry to the Mount Pleasant deposit, therefore, is doubtful at the present state of knowledge.

Arsenopyrite Geothermometry

Arsenopyrite geothermometry, recently established by Clark (17), is based on the relationship between the arsenic content in arsenopyrite and its depositional temperature. Clark relates the arsenic content to the d_{131} X-ray diffraction spacing of arsenopyrite and expresses the depositional temperatures as a function of d_{131}.

The d_{131} spacings of arsenopyrite in 5 different samples from the Mount Pleasant deposit were measured and the equivalent depositional temperatures were determined by use of Clark's data. The results are given in Table 11.

TABLE 11

Values for the d_{131} Spacing of Arsenopyrite in Different Samples from the Mount Pleasant Deposit

Sample	Sample Location and Host	d_{131}, in A	Approx. Deposition Temperature
D	Fluorite mass, Sta. 26+00, Lode No. 1	1.634	500°C
G	Sphalerite vein, Sta. 26+50 Lode No. 1	1.633	450°C
W	Sphalerite vein, end of 101 drift, Lode No. 1	1.630	300 to 400°C
L	Sphalerite vein, 135 from adit, 102 W drift, Lode No. 2	1.626	
13	"Greisen-type" rock containing 2.80% Sn	1.626	

The d_{131} values obtained for arsenopyrite from Samples L and 13 fall below the range investigated by Clark (17). This indicates that the arsenopyrite is sulphur-rich and was deposited at either at low temperature or a high sulphur pressure (17), and both cases are considered possible for the Mount Pleasant deposit.

Clark has also shown that when arsenopyrite coexists with pyrite it was deposited at some temperature below 491°C, and when it does not coexist with pyrite it could have been deposited at some temperature above 491°C. Polished sections show that the arsenopyrite in Samples G and W coexists with pyrite and thus was deposited at some temperature below 491°C. They also show that the arsenopyrite in fluorite veins and masses (Sample D) does not coexist with pyrite, and thus could have been deposited at some temperature above 491°C. This is in agreement with the results obtained by the X-ray diffraction method (Table 11).

The temperatures indicated by arsenopyrite geothermometry fall close to the range obtained by sphalerite geothermometry, and are in general agreement with those obtained by Sainsberg (18) for the Lost River cassiterite deposit in Alaska. Sainsberg concluded that the Lost River cassiterite was deposited at temperatures of at least 500°C and the sphalerite was deposited at temperatures of at least 425 °C.

CONCLUSIONS

The mineral assemblage in the Mount Pleasant deposit is characteristic of mineral assemblages described for Cornwall-type tin deposits throughout the world (18) (19) (20) (21) (22) (23) (24) (25). The following similarities between the Mount Pleasant tin deposit and other tin deposits are noted:

(1) The mineralogy of the siliceous "greisen-type" rock at Mount Pleasant is similar to the mineralogy of rocks associated with the Cornwall, Bolivian, and Transvaal tin deposits.

(2) Kaolinite is present in the Mount Pleasant, Cornwall, and Lost River tin deposits.

(3) Cassiterite, wolframite, molybdenite, bismuth minerals, silver-bearing copper minerals, arsenopyrite, and marcasite are present in the Mount Pleasant, Cornwall, Bolivian, and Transvaal tin deposits.

(4) Appreciable amounts of indium and gallium occur in the Mount Pleasant deposit, and these have also been reported from a number of Russian tin deposits of the Cornwall type.

(5) The indicated deposition temperature of the Mount Pleasant tin deposit is similar to that suggested by Sainsberg (17) for the Lost River tin deposit in Alaska.

REFERENCES

1. H.F.G. Hosking, "Geology, Mineralogy and Paragenesis of the Mount Pleasant Tin Deposits", Canadian Mining Jour. 84, No. 4, 95-102 (1963).

2. A.A. Ruitenberg, "Tin Mineralization and Associated Rock Alterations at Mount Pleasant, Charlotte County, New Brunswick", M.Sc. thesis, University of New Brunswick, Fredericton, New Brunswick (1963).

3. W. Petruk, "Mineralogical Investigation of Samples from the Mount Pleasant Tin Deposit in New Brunswick", Investigation Report IR 63-15, Mineral Sciences Division, Mines Branch, Dept. of Mines and Tech. Surveys, Ottawa (1963).

4. F. Novak, A. Bluml and A. Tacl, "The Origin of Stannite by Replacement of Cassiterite in the Turkank Zone of the Kutna Hora Ore Deposit", Min. Mag. 33, 339-342 (1962).

5. B.J. Skinner, P.B. Barton, Jr. and Gunnar Kullerud, "Effect of FeS on the Unit Cell of Sphalerite, A Revision", Econ. Geol. 54, 1040-1046 (1959).

6. L. Pauling and E.W. Neuman, "The Crystal Structure of Binnite, $(Cu,Fe)_{12}As_4S_{13}$, and the Chemical Composition and Structure of Minerals of the Tetrahedrite Group", Zeitschrift für Kristallographie 88 (Heft 1), 54-62 (1934).

7. D.O. Onteov, P.N. Nissenbaum and N.I. Organova, "The Nature of High Bismuth and Silver Contents in Galena of the Bukukinsk Deposit and some Problems of Isomorphism in the System $PbS\text{-}AgS_2\text{-}Bi_2S_3$", Geochemistry (1960), No. 5, pp. 494-510.

8. R.J. Traill, "A Rhombohedral Polytype of Molybdenite". Can. Mineral. 7, Pt. 3, 524-526 (1963).

9. R.G. Dickenson and L. Pauling, "The Crystal Structure of Molybdenite", Jour. Am. Chem. Soc. 45, 1466-1471 (1923).

10. W. Petruk, "Mineralogy of a Sulphide Tin-Silver Ore from Bolivia for Prospection Limited", Investigation Report IR 63-15, Mineral Sciences Division, Mines Branch, Dept. of Mines and Tech. Surveys, Ottawa (1963).

11. G.W. Brindley and F.H. Gillery, "A Mixed-Layer Kaolin-Chlorite Structure", in Clays and Clay Minerals: Proc. 2nd Nat. Conf. on Clays and Clay Minerals, Nat. Acad. Sciences Pub. 327, pp. 349-353 (1954).

12. J.V. Smith and H.S. Yoder, "Experimental and Theoretical Studies of the Mica Polymorphs", Min. Mag. 31, No. 234, 209-235 (1956).

13. R.C. MacKenzie, "The Differential Thermal Investigation of Clays", Min. Soc. London, London, pp. 98-139 (1957).

14. R.S. Dean, "Mineralogical Examination of Two Samples of Kaolin Minerals from Mount Pleasant Mines Limited, Charlotte County, N.B.", Test Report MPT-64-15, Mineral Processing Division, Mines Branch, Dept. of Mines and Tech. Surveys, Ottawa (1964).

15. P.K. Sims and P.B. Barton, "Some Aspects of the Geochemistry of Sphalerite, Central City District, Colorado", Econ. Geol. 56, 1211-2137 (1961).

16. Gunnar Kullerud, "The FeS-ZnS System, A Geological Thermometer", Norsk. Geol. Tids. 32, 61-147 (1953).

17. L.A. Clark, "FeS-AsS-S System: Phase Relations and Applications", Econ. Geol. 55, 1345-1381 and 1631-1652 (1960).

18. C.L. Sainsberg, "Metallization and Post Mineral Hypogene Alteration, Lost River Tin Mine, Alaska", Econ. Geol. 55, 1478-1506 (1960).

19. F.S. Turneare, "A Comparative Study of Major Ore Deposits in Central Bolivia", Econ. Geol. 55, 217-254 and 574-606 (1960).

20. A. Leube and E.F. Stumpfl, "The Roolberg and LeeuwPoort Tin Mines, Transvaal, South Africa. Part 2: Petrology, Mineralogy and Geochemistry", Econ. Geol. 58, 527-557 (1963).

21. K.F.H. Hosking, "Primary Ore Deposition in Cornwall", Trans. Royal Geol. Soc. Cornwall, 18, Pt. 3, 309-356 (1951).

22. V.V. Ivanov and A.A. Rozbianskaya, "Geochemistry of Indium in Cassiterite-Silicate-Sulphide Ores", Geochemistry (1961), No. 1, pp. 71-83.

23. T.V. Zabarina, V.V. Lapina and N.A. Minayeva, "The Distribution of Indium in Cassiterite, Sphalerite and Chalcopyrite at the Lifudzin Tin Deposit", Geochemistry (1961), No. 2, pp. 175-181.

24. Yu. P. Troshin, " Gallium-Indium in Sphalerites of Tranbaikaliya", Geochemistry (1962), No. 4,pp. 378-385.

25. I.G. Ganiov, D.N. Packadzhanov and L.A. Borisenok, "Geochemistry of Gallium, Tin, and some other Elements in the Process of Greisenization", Geochemistry (1961), No. 9, pp. 830-839.

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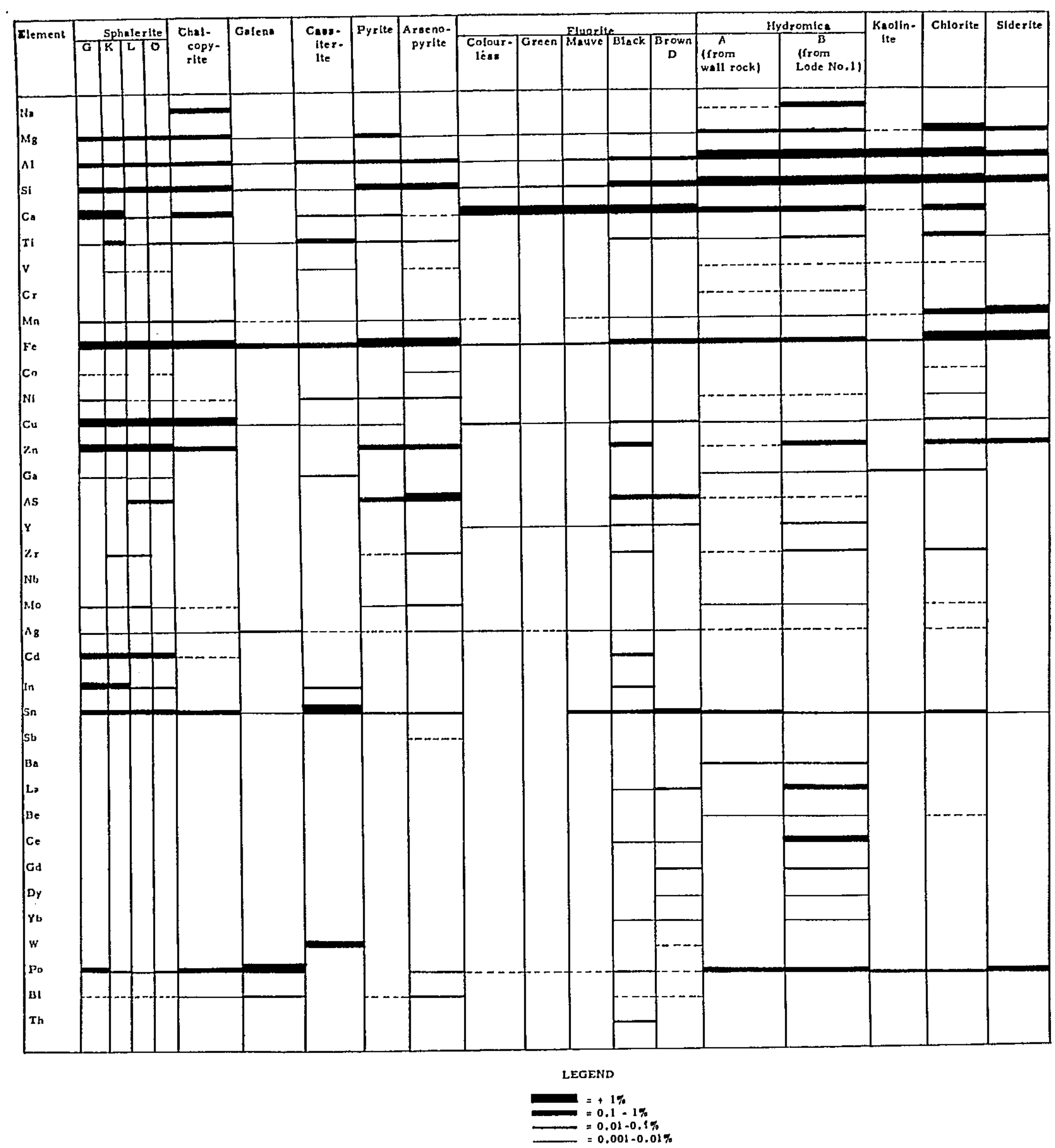
APPENDIX 1

Results of Spectrographic Analyses of Concentrates of Minerals from Mount Pleasant Tin Deposit*

(Not corrected for trace amounts of impurities)



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* Spectrographic analyses by E.M. Kranck and A.H. Gillieson, Analytical Chemistry Subdivision, Mineral Sciences Division, Mines Branch, Ottawa.

APPENDIX 2

Locations of Samples Studied to Obtain Data for Figures 1, Tables 1 and 4, Appendix 1

Sample	Location			Other Information
	Lode No.	Station	Drift	
Kaolinized dyke	1		Adit	"Kaolinized dyke"
Mineralized fluorite	1	26+00	101E	Massive fluorite in "kaolinized dyke"
A	1		Adit	Sphalerite vein in "kaolinized dyke"
G	1	26+50	101E	Sphalerite vein
H	1	26+70	101E	Sphalerite vein
K	1	26+60	101E	Sphalerite vein
W	1		101E	Sphalerite vein at end of drift
L	2		202W	Sphalerite vein 135 feet from adit
M	2		202W	Sphalerite vein 140 feet from adit
O		2-04	Adit	Sphalerite vein (1,500 feet N-NW of Lode No. 1)
X				Sphalerite-tennantite vein, DH-135-107, Fire Tower Zone
Chalcopyrite	4	2-11	Adit	Galena vein
Galena	4	2-11	Adit	Galena vein
Pyrite	2		202W	Pyrite vein 140 feet from adit
Arsenopyrite	2		202W	Pyrite vein 140 feet from adit
Colourless and green fluorite	1		Adit and 101E	Fluorite in "kaolinized dyke"
Brown fluorite	1	26+00	101E	Massive fluorite in "kaolinized dyke"
Hydromica A		9+00	Adit	Hydromica veinlet
Hydromica B	1	26+00	101E	Veinlet in massive fluorite in the "kaolinized dyke"
Siderite	4		Adit	Siderite vein

= = =