

THE OCCURRENCE OF TIN AT THE
DICKSTONE NO. 2 OREBODY, NORTHERN MANITOBA

by

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Winnipeg, Manitoba

March, 1974

A Thesis

Submitted to the

Faculty of Graduate Studies and Research

The University of Manitoba

In Partial Fulfillment

of the Requirements for the Degree of

Master of Science

ABSTRACT

The Dickstone No. 2 Orebody, a small massive sulphide deposit situated in northern Manitoba, contains tin in amounts averaging 0.08% or 1.6 pounds per ton.

Most of the tin occurs as the oxide cassiterite. The cassiterite shows a considerable size range from $<.001$ mm. to 0.6 mm., with approximately 99% of all cassiterite present in grains larger than 0.1 mm. across. The larger cassiterite grains exhibit subhedral crystal forms, some of which show the effects of abrasion. Quartz, calcite and pyrite are most closely associated with the cassiterite.

A microprobe study of the cassiterites shows that the most common trace elements are indium, silver, neodymium, tungsten, iodine and lutetium. Calcium, antimony, and ytterbium occur moderately, while titanium, iron, zinc, tantalum and iridium occur infrequently.

Another tin-bearing mineral was encountered. Although not positively identified, this mineral is a calcium-titanium silicate, possibly sphene.

ACKNOWLEDGEMENTS

The writer would like to thank Dr. H. D. B. Wilson for his help and supervision during the preparation of this thesis. Acknowledgements are also extended to Mr. K. Ramlal whose guidance during the electron microprobe phase of this study proved invaluable. Mr. Ramlal also provided the atomic absorption data for all of the samples.

The assistance and co-operation of Dickstone Copper Mines Ltd. and Hudson Bay Mining and Smelting, the present mine operator, are deeply appreciated.

Special thanks are due to Mr. P. Martin, chief mine geologist of H. B. M. S., who provided the ore samples and information without which this study would not have been possible.

Dr. R. B. Ferguson provided valuable assistance in the preparation and interpretation of the X-ray powder photographs.

Dr. G. S. Clark of the University of Manitoba and G. D. Pollock of Selco Exploration Co. Ltd. offered constructive criticism during the preparation of the manuscript.

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Chapter 1

INTRODUCTION

Purpose of the Study

The Dickstone Mine of Northern Manitoba, a massive sulphide deposit, contains quantities of tin averaging 0.08% or 1.6 pounds per ton in the No. 2 ore zone.¹ The present study was undertaken in order to determine the mode of occurrence of the tin, the spatial distribution of tin through the mine, the size distribution of the tin mineral(s), the trace elements present within the tin mineral(s) and the factors influencing the tin concentration.

Location and Access

The Dickstone Mine, located in Northern Manitoba, is situated at approximately north latitude 54°50'; east longitude 100°30' (Figure 1). The deposits are located on the north side of Beaver Tail Lake, twenty miles west of Snow Lake, Manitoba. The mine is accessible by a road which joins the Flin Flon - Snow Lake railroad west of Snow Lake.

General Geology

The mine is located within a Precambrian "Amisk-type" volcanic belt (named after a type area west of Flin Flon), extending from Wekusko Lake in the east for more than 130 miles due west, past Flin Flon into

¹Personal Communication: P. Martin, Chief Mine Geologist, Hudson Bay Mining and Smelting.

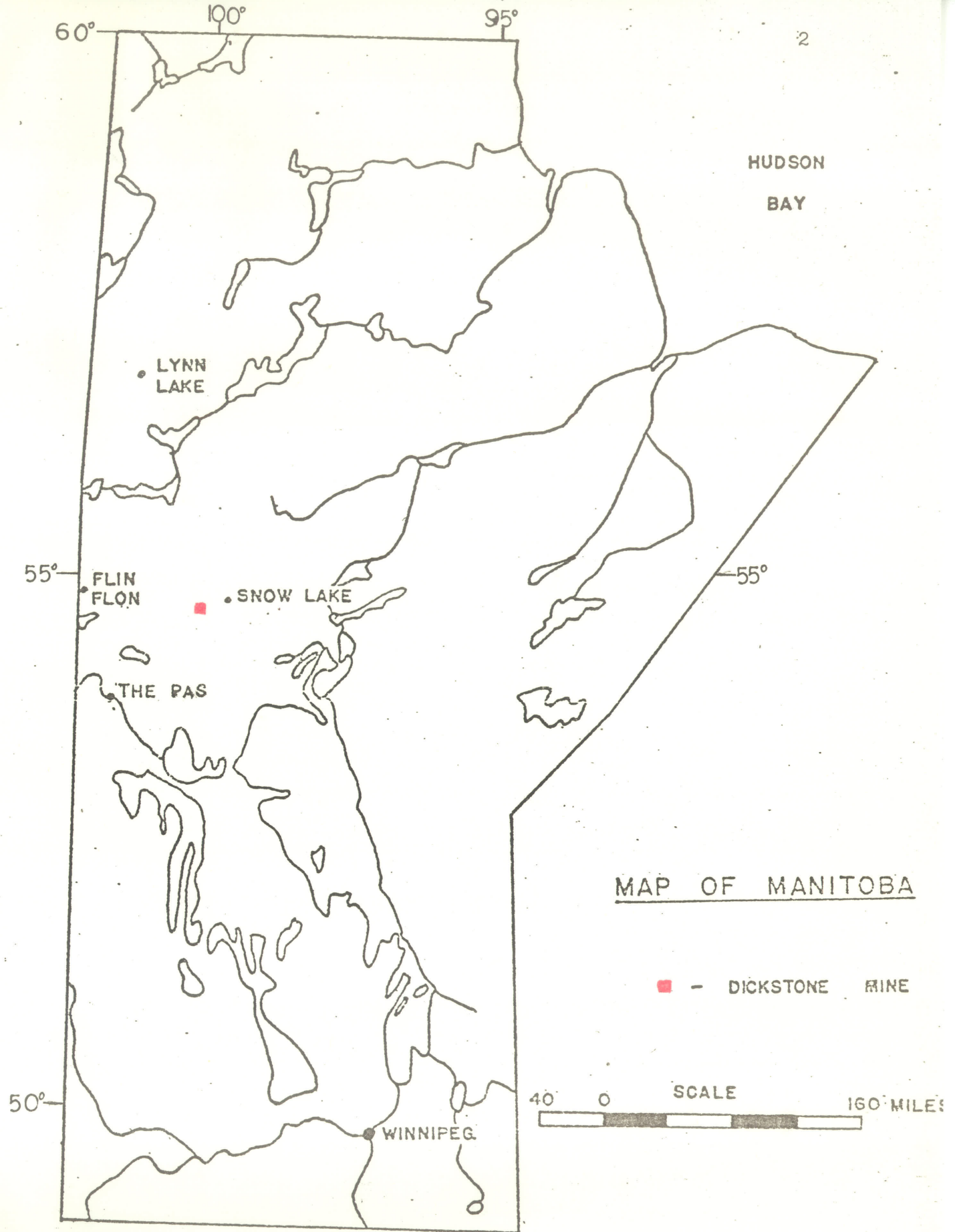


Figure 1: Location Map

Saskatchewan. The southern limit of this greenstone belt (which averages 30 miles in width) is covered by Paleozoic sedimentary rocks while the northern limit is bounded by the Kisseynew gneisses which represent highly metamorphosed equivalents of original sedimentary and minor volcanic rocks (Coates, et al., 1970).

The sulphide ore body is tabular, varies from 1 to 10 feet wide (average: 4 feet), strikes approximately north - south, dips near vertical and plunges 70° to the south.¹ The ore is composed primarily of pyrite, sphalerite, chalcopyrite, and pyrrhotite in a granoblastic intergrowth. Accessory minerals are quartz, arsenopyrite, and rarely calcite, scapolite and anhydrite. The sulphides vary from very fine grained chalcopyrite and sphalerite with rounded pyrite phenocrysts to coarsely crystalline bands of sphalerite, pyrite, and chalcopyrite and pyrite. Banding is usually encountered where there has been some folding of the footwall and likely represents plastic flow of the sulphides.²

The intrusive nature of the sulphides is evidenced by sharp contacts with the enclosing rock, inclusions of foliated footwall and hanging wall, and the penetration of sulphides into cracks in the country rock. These intrusive features may have been caused by remobilization of the sulphides after emplacement.³

¹Personal Communication: P. Martin, Chief Mine Geologist, Hudson Bay Mining and Smelting.

²Personal Communication: P. A. Cain, Vice-President, Mining, Sherritt Gordon Mines Ltd.

³Ibid.

History and Production

The property, situated on 15 claims in the Morton Lake - Herb Lake district of Manitoba, lay idle from 1948 to July, 1966 when Hudson Bay Mining and Smelting acquired a working option. The property was brought into production on November 2, 1970 with H. B. M. S. to receive 75% of the net profits from production. A strike resulted in the mine being shut down on January 27, 1971 after three months of production. Production was resumed in late June with the termination of the strike (Fielder, 1971).

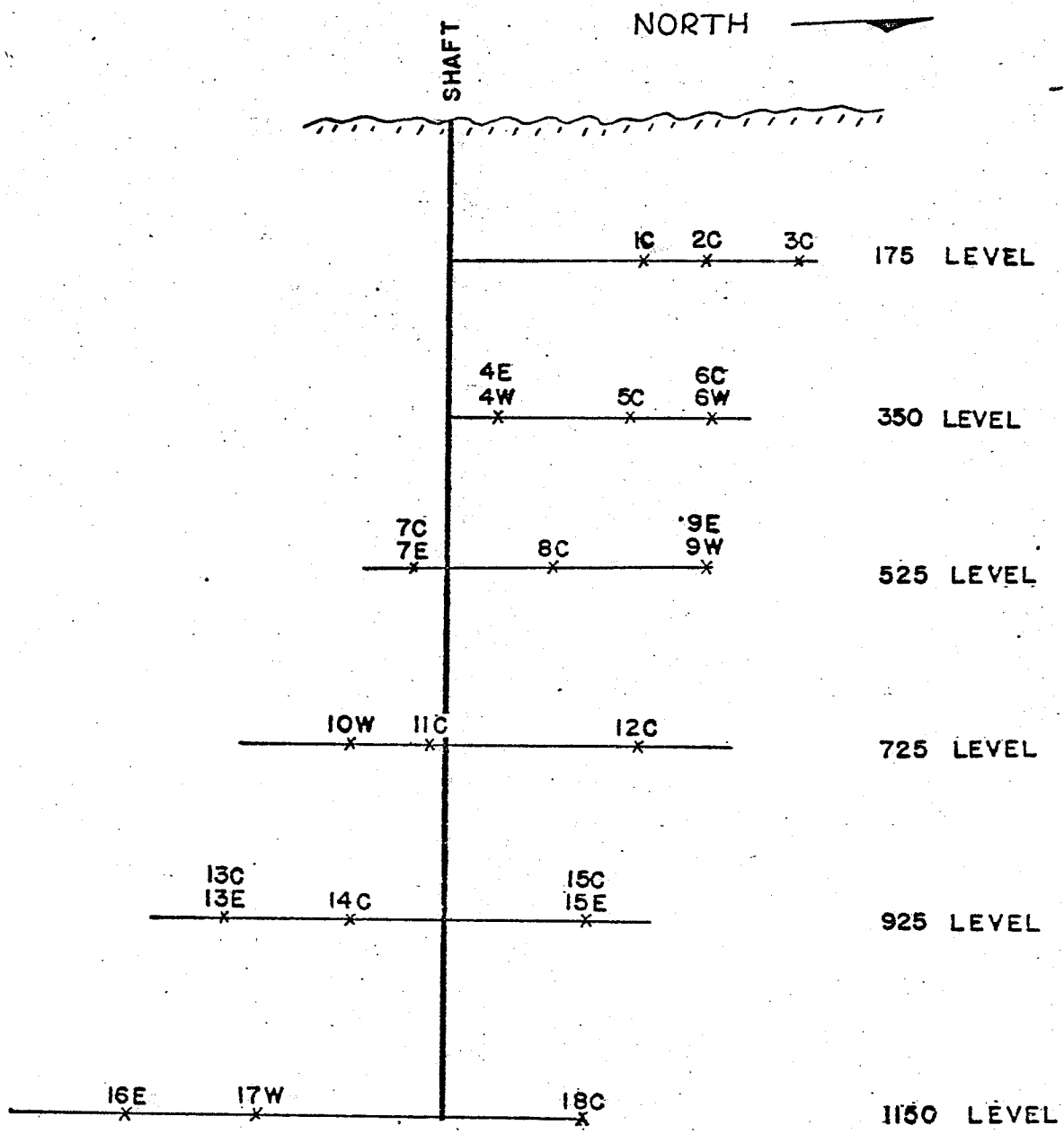
The No. 2 zone, containing cassiterite, has been mined at a rate of 350 tons per day since it went into production in the fall of 1970. The ore reserve (No. 2 zone) as of January 1, 1972, was 275,000 tons grading 2.04% Cu and 7.9% zinc.¹

The ore is shipped by rail to Flin Flon where it is treated in the H. B. M. S. concentrator and smelter.

Laboratory Methods

Twenty-four first-size grab samples were collected throughout the mine for use in the present study (Figure 2). In addition to these "representative" ore samples, two samples each of high grade copper (No. 19, 21) and zinc (No. 20, 22) ore were collected. These samples were analyzed by atomic absorption for copper, zinc, and tin. Ten samples were also analyzed for lead, but, because of the low concentrations encountered (20 - 70 ppm), these analyses were terminated (Table 2).

¹Personal Communication: P. A. Cain, Vice-President, Mining, Sherritt Gordon Mines Ltd.



DICKSTONE MINE
NO. 2 ZONE
LONGITUDINAL SECTION
1" = 200'

X SAMPLE LOCATIONS

Figure 2: Sample Locations

A polished section of $1\frac{1}{4}$ inch diameter was made from each of the samples. These sections were studied in the MAC-5 electron microprobe at the University of Manitoba. Each polished section was scanned for concentrations of tin with the electron beam of the microprobe. In addition, as this instrument provides for the simultaneous scanning of two elements, scanning was done for either zinc, sulphur or iron to facilitate the identification of sphalerite, pyrite and pyrrhotite.

When a grain with an appreciable tin count was encountered, the electron beam could be set on the grain and a chemical analysis run on that particular mineral. The results were only qualitative since the microprobe had not yet been standardized, and were useful in determining only which elements were present and not their concentrations. Electron photographs of many tin-bearing grains were also obtained from the microprobe.

The polished sections were also studied with a reflecting microscope, the identification of cassiterite and of calcite in the gangue were confirmed by X-ray powder photograph methods.

Chapter 2

WORLD TIN OCCURRENCES

The most important tin mineral, both in abundance and economic importance, is the oxide, cassiterite (SnO_2). Cassiterite, a member of the tetragonal system, may occur as short prismatic crystals, massive aggregates (radially fibrous botryoidal crusts or concretionary masses), brown rounded pebbles with a concretionary structure, or fine sand-like grains (Berry and Mason, 1959). Cassiterite is amenable to concentration in placer-type deposits because of its hardness of 6 - 7, specific gravity of 7, and chemical resistance. In fact, the major producing tin deposits of the world are the placers of Southeast Asia which account for 60% of the world's tin production (Sainsbury, 1969).

Almost all cassiterite-bearing lode deposits are closely associated, both spatially and genetically with granitic intrusive rocks (biotite or biotite-muscovite granite) or, as in Bolivia, with shallow-seated volcanic rocks such as quartz latite or dacite.

According to Sainsbury (1969); "Most of the major lode areas of the world fall into one of two distinct types: (1) long, narrow belts of tin-bearing granites in a wider intrusive complex (Southeast Asia), or (2) more diffuse belts of younger granites in extensive areas of Precambrian rocks (Nigeria). Most of the major linear belts lie near continental margins or along major orogenic belts inland in which granite magma was generated." Thus, most primary tin deposits are localized along tectonic belts in which granite has been intruded.

Economic tin deposits are unknown in Canada and the United States although tin is recovered as a by-product from mines which produce other metals. The Climax mine of Colorado produces tin from its molybdenum ores (Killeen and Newan, 1965). In Canada, tin is recovered, at the rate of 308 tons per annum, from the lead-zinc-silver-iron ores of the Sullivan mine of Southeastern British Columbia (Mulligan, 1966). This ore body contains an average of 0.06% tin, 90% of which occurs as cassiterite. The cassiterite occurs as small (.085 - 0.5 mm.) well-rounded grains surrounded by sulfide and/or gangue minerals (Mulligan, 1966). The tin content is highest along the outer margins of the central "barren" zone of pyrrhotite and pyrite, whereas the intermediate galena zone and the outer sphalerite zone contain very little tin ore. Other tin minerals present in minor amounts are the sulfides stannite, francheite, cylindrite, and teallite (Pentland, 1943).

Tin is also present at the Mount Pleasant Mine of New Brunswick. The tin occurs here as cassiterite and stannite in a greisen-type deposit associated with fluorite and base metal sulfide minerals near or in altered silicic dykes (Petruk, 1964).

Other occurrences of tin in Canada are in the lead-zinc-silver ores of Galena-Keno Hill, Yukon Territory, and the Snowflake Regal Silver deposit of British Columbia.

In the Precambrian Shield, tin is associated with lithium and beryllium minerals in muscovite-bearing granites and pegmatites and in fractional percentages in massive sulfide deposits in the Manitouwadge area of Ontario, the Noranda and Matagami areas of Quebec, the Normetal Mine of Quebec (Mulligan, 1966), and at South Bay and Kidd Creek, Ontario.

At Noranda and Matagami, copper-bearing sulfide deposits are characterized by high, but variable Co:Ni ratios, high tin contents (tin-rich pyrite), and appreciable amounts of arsenic, selenium and silver (Roscoe, 1965).

"Fractional percentages of tin in pyrite, pyrrhotite and chalcopyrite in the deposits at Manitouwadge, Ontario and Normetal, Quebec emphasize the possibility of important tin concentration in sulfide deposits" (Mulligan, 1966).

A study of the occurrence of tin at South Bay Mines, Confederation Lake, Ontario (Bridge, 1972), was done at the University of Manitoba in conjunction with the present study. Tin occurs in the South Bay massive sulphide zinc-copper orebody in amounts averaging 0.31%. The only tin mineral present is cassiterite, which occurs as minute (5 - 50 microns), well-rounded grains, commonly subspheroidal in shape. The amount of cassiterite is not in direct ratio with the amount of sphalerite although it is with sphalerite that cassiterite makes its most intimate association. Ag, La, Yb, and W have a high frequency of occurrence as trace constituents of cassiterite while In, As, Zn, and Cs occur moderately and Sc, Nb, Cd, Pd, Mo, Ni, Cr and Ca occur infrequently (Bridge, 1972).

Chapter 3

MINERALOGY

Pyrite

Pyrite occurs at Dickstone as subhedral to euhedral cubes and dodecahedrons (Figure 3) and in massive aggregates. Most of the pyrite has been cut by later vein networks. These veins may be monomineralic (Figure 4) or polymineralic (Figure 5). Flow structure, evident in several locations within these veins (Figure 6), likely represents plastic flow of the sulphides under the effects of metamorphism.

The pyrite ranges from fine to very coarse grained and commonly shows the effects of corrosion by sphalerite and less commonly by chalcopyrite. The corrosion may occur along the vein borders which cut through the pyrite (Figure 7) or along the borders of individual pyrite crystals (Figure 8).

A close association between pyrite and the predominant tin-bearing mineral, cassiterite, is evident in many locations. The pyrite may completely enclose the cassiterite (Figure 10) or may just be adjacent to the cassiterite (Figures 10, 11, 13, 15, 17).

Sphalerite

Sphalerite, the zinc ore mineral at Dickstone, occurs primarily as massive aggregates (less than 1 mm. to several cm. across) which form a matrix for the pyrite crystals (Figure 3), but may also occur in veins

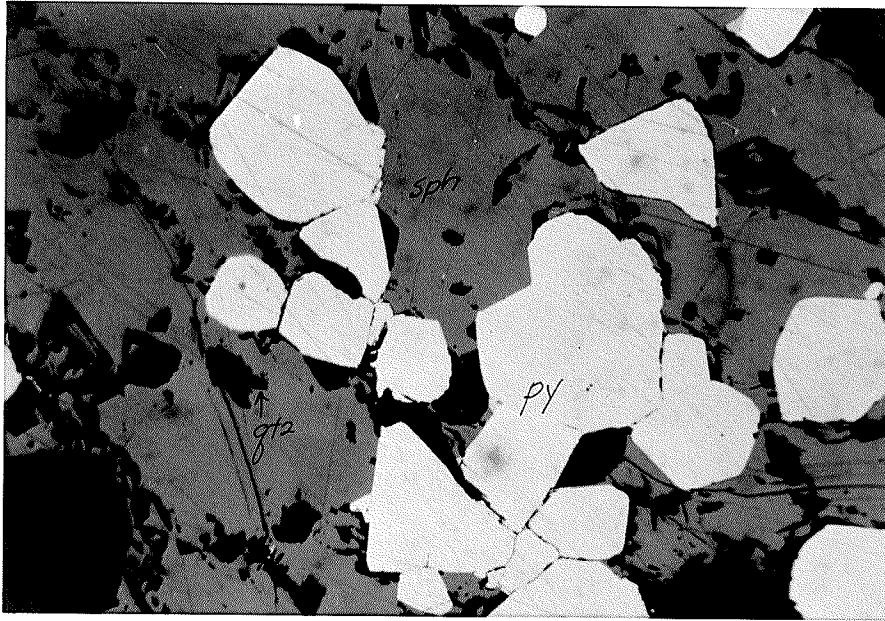


Figure 3 PYRITE (py) CRYSTALS IN A SPHALERITE (sph)-
QUARTZ (qtz) MATRIX. POLISHED SECTION X100

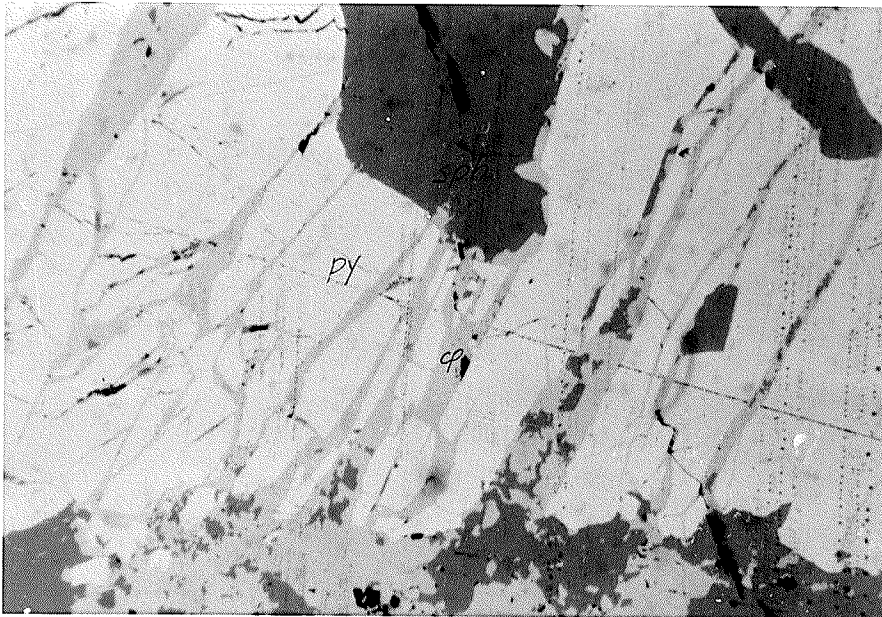


Figure 4 PYRITE CUT BY CHALCOPYRITE (cp) VEINS.
POLISHED SECTION X100

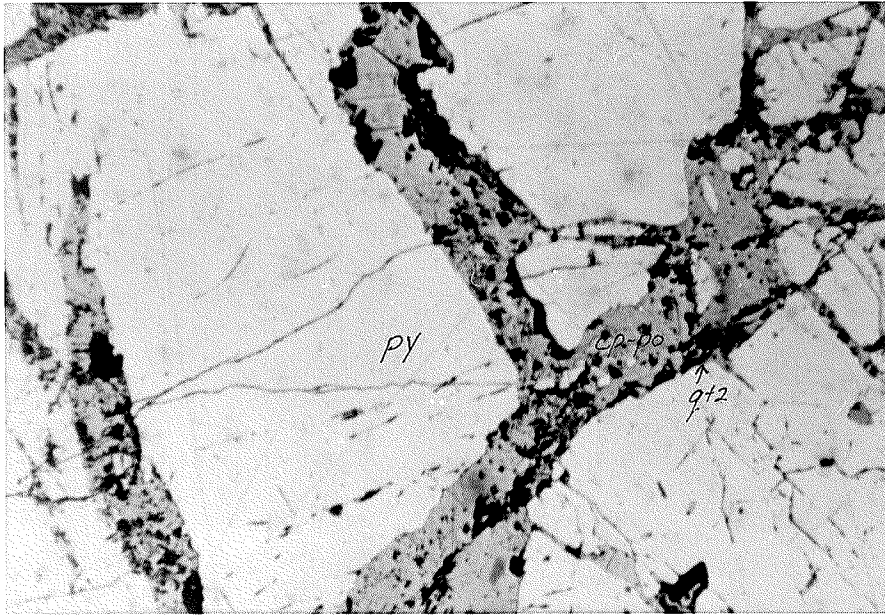


Figure 5 PYRITE CUT BY VEINS OF CHALCOPYRITE,
PYRRHOTITE (po) AND QUARTZ. POLISHED
SECTION X100

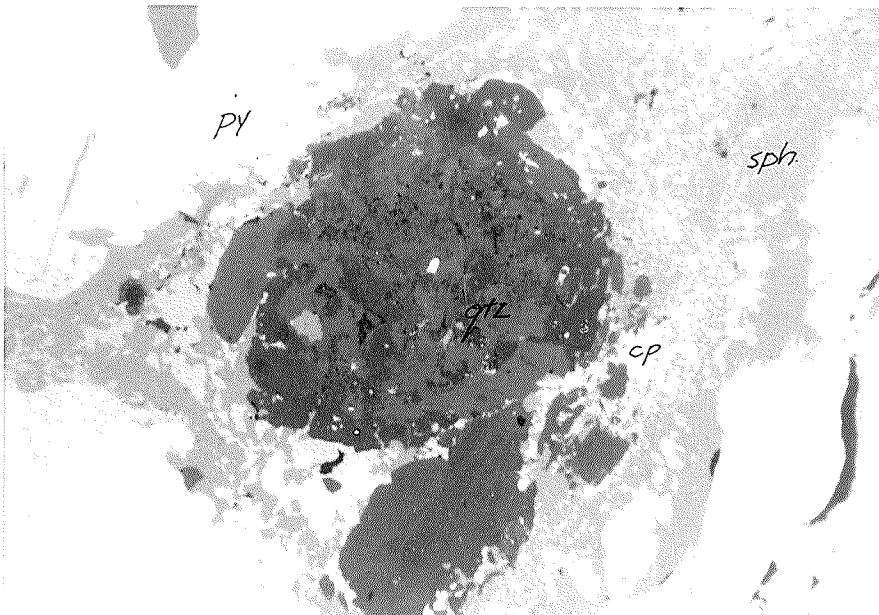


Figure 6 FLOW STRUCTURE IN A QUARTZ-SPHALERITE-
CHALCOPYRITE VEIN CUTTING THROUGH PYRITE.
POLISHED SECTION X100

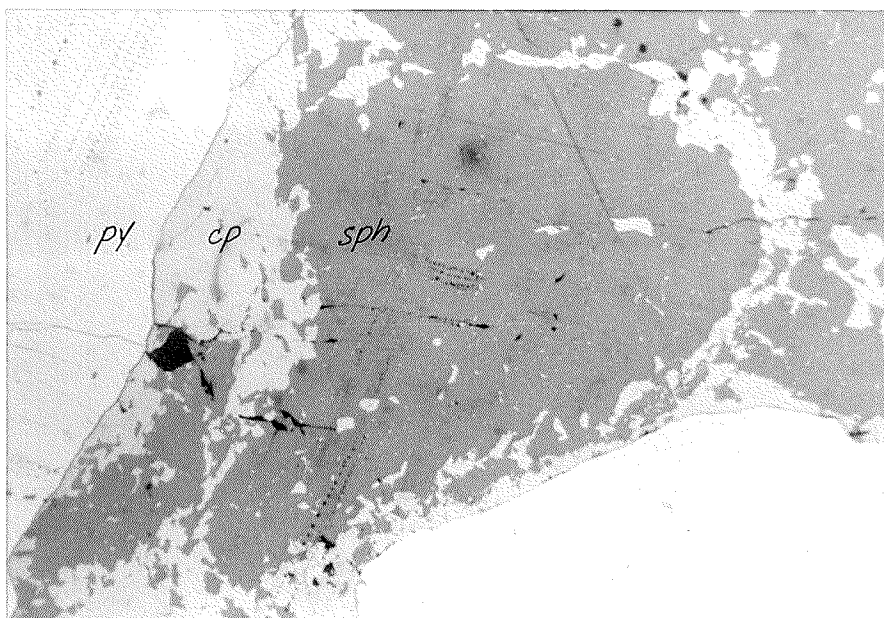


Figure 7 REPLACEMENT OF A SPHALERITE VEIN BY
CHALCOPYRITE. POLISHED SECTION X100

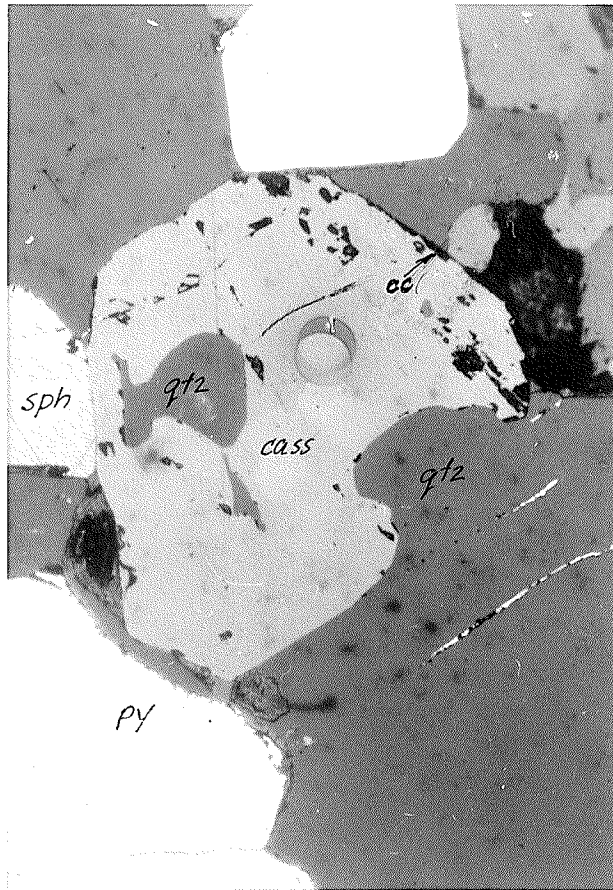


Figure 8 REPLACEMENT OF CASSITERITE BY
CALCITE (cc). POLISHED SECTION X250

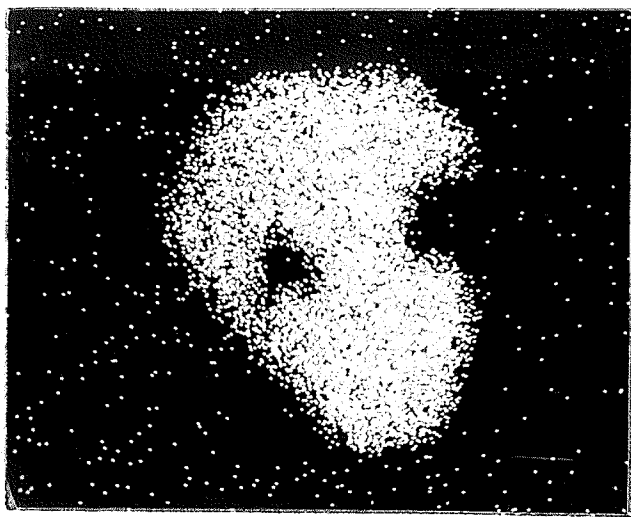


Figure 9 ELECTRON SCAN PHOTOGRAPH (TIN SCAN)
OF THE CASSITERITE CRYSTAL OF FIGURE 8
(X100)

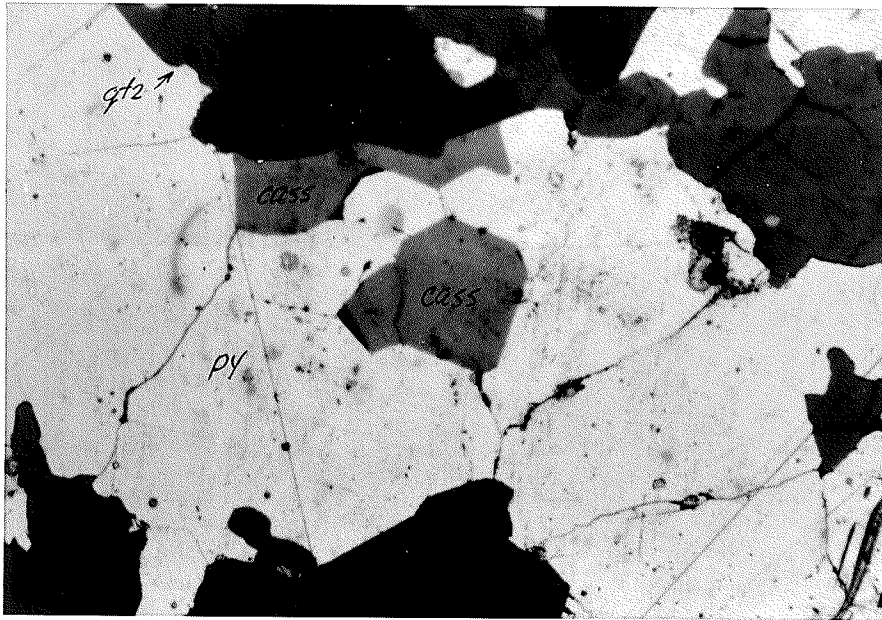


Figure 10 CASSITERITE TWIN IN A PYRITE MATRIX.
POLISHED SECTION X100

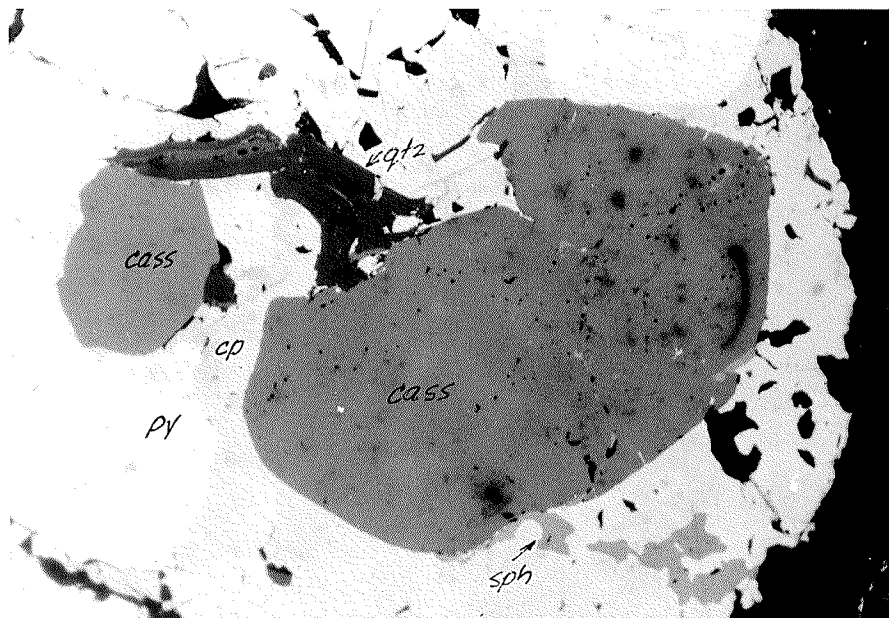


Figure 11 REPLACEMENT OF A CASSITERITE (cass) CRYSTAL BY CHALCOPYRITE. POLISHED SECTION X200

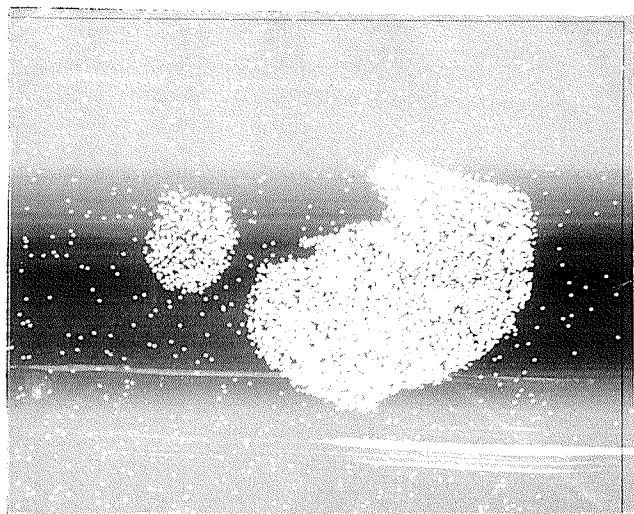


Figure 12 ELECTRON SCAN PHOTOGRAPH (TIN SCAN) OF THE CASSITERITE GRAINS OF FIGURE 11 (X100)

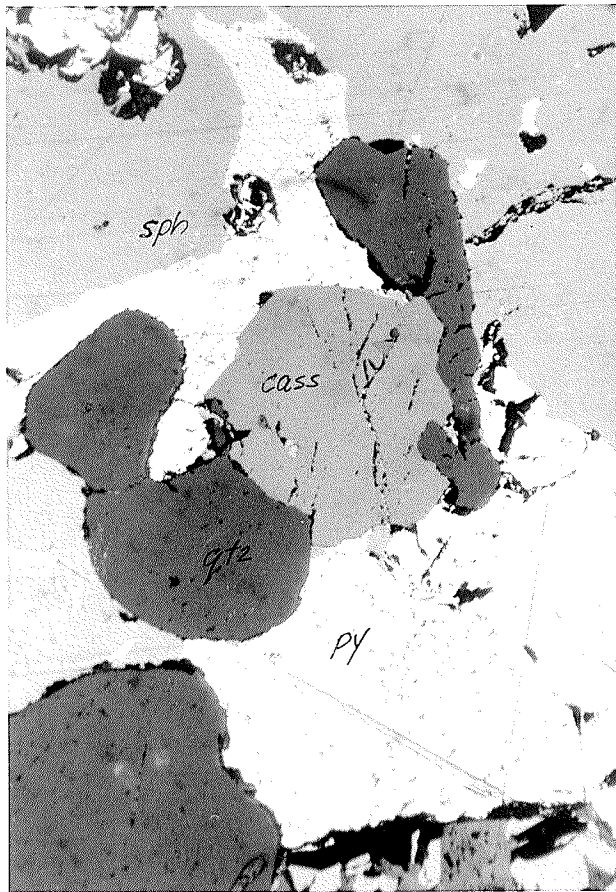


Figure 13 CASSITERITE CRYSTAL CUT BY VEINS OF SPHALERITE, PYRITE, CALCITE, QUARTZ. POLISHED SECTION X75

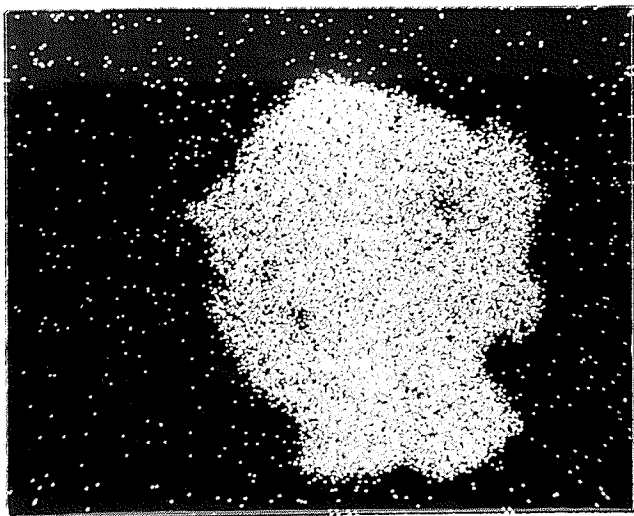


Figure 14. ELECTRON SCAN PHOTOGRAPH (TIN SCAN) OF THE CASSITERITE CRYSTAL OF FIGURE 13 (X100)

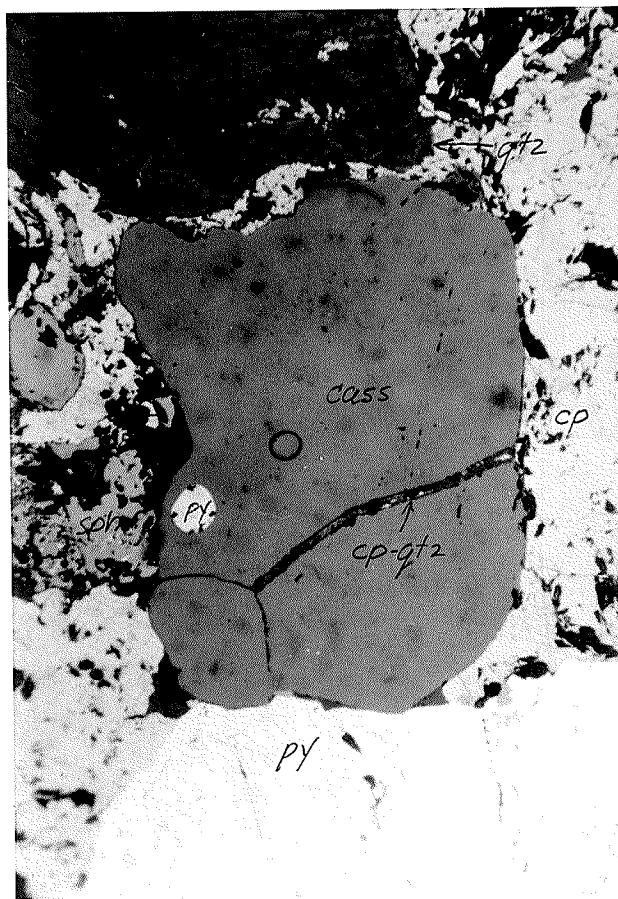


Figure 15 ABRADED CASSITERITE GRAIN CUT BY A CHALCOPYRITE-QUARTZ VEIN. ROUNDED PYRITE INCLUSION. POLISHED SECTION X200

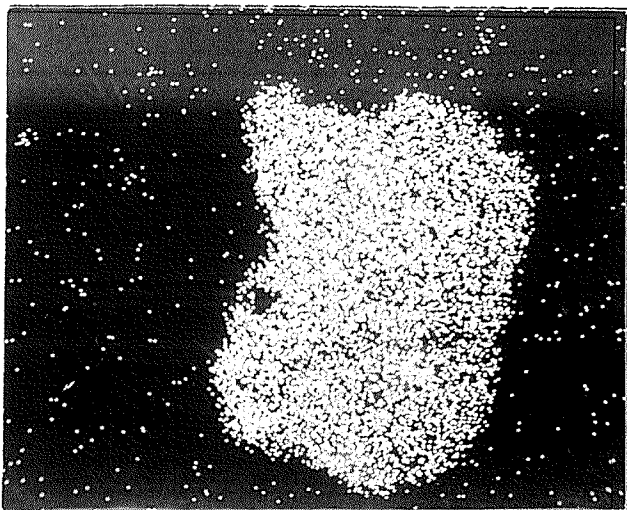


Figure 16 ELECTRON SCAN PHOTOGRAPH (TIN SCAN) OF THE CASSITERITE GRAIN OF FIGURE 15. (X100)

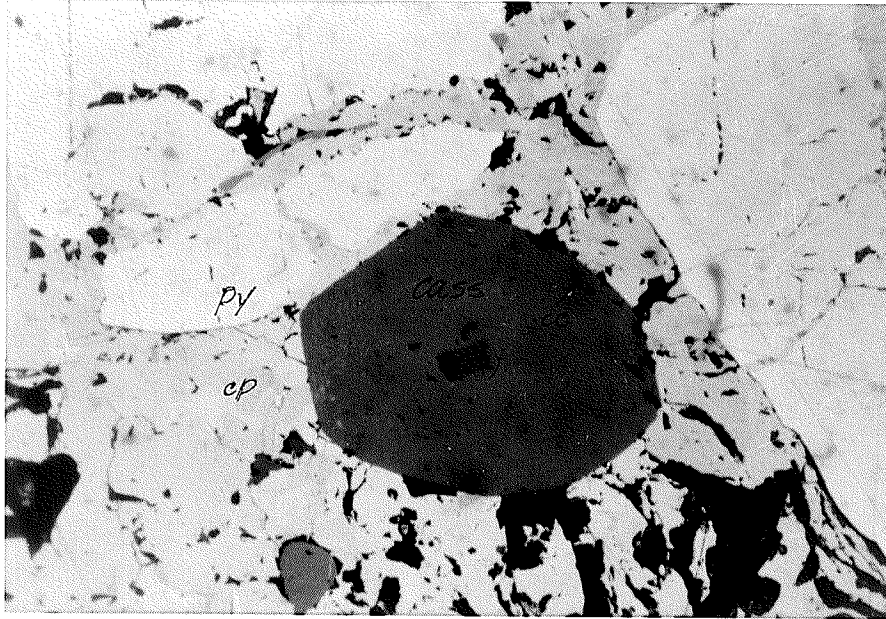


Figure 17 REPLACEMENT OF A CASSITERITE CRYSTAL BY
CALCITE. POLISHED SECTION X200

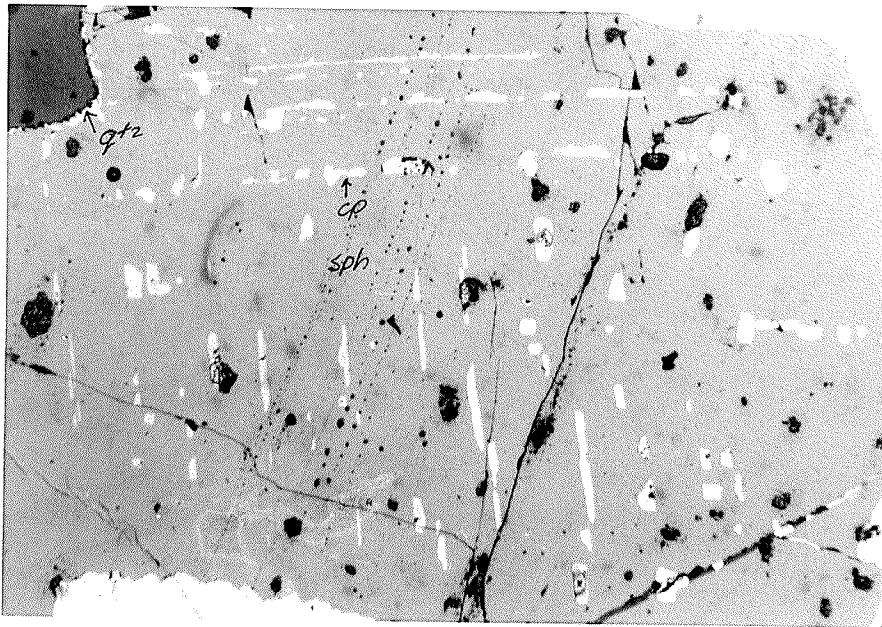


Figure 18 EXSOLUTION LAMELLAE OF CHALCOPYRITE IN
SPHALERITE. POLISHED SECTION X100

which cut the pyrite (Figures 6, 7). Most of the sphalerite contains exsolution lamellae of chalcopyrite (Figure 18) indicating co-crystallization of these two minerals. Replacement of sphalerite by chalcopyrite is illustrated by the encroachment of chalcopyrite into sphalerite in layers (Figure 19) or along grain boundaries (Figure 7).

Sphalerite contains trace amounts of tin while the other minerals are essentially devoid of tin.

Chalcopyrite

Chalcopyrite is the copper ore mineral at Dickstone. It occurs either as massive aggregates with a considerable size range (less than 1 mm. to several cm. across), in vein networks (Figures 4, 5, 6, 7) cutting the earlier pyrite where it is closely associated with pyrrhotite, or as exsolution blebs or lamellae in sphalerite (Figure 18). Replacement of sphalerite (Figures 7, 19), pyrite, and cassiterite (Figure 11) by chalcopyrite is indicative of the late genesis of this mineral.

Pyrrhotite

Pyrrhotite is present in heavily fractured massive aggregates or in vein networks associated with chalcopyrite (Figure 5).

Arsenopyrite

Arsenopyrite is a minor constituent of the ores at Dickstone. This mineral exhibits good columnar crystals (Figure 20) with rhombic cross-sections.

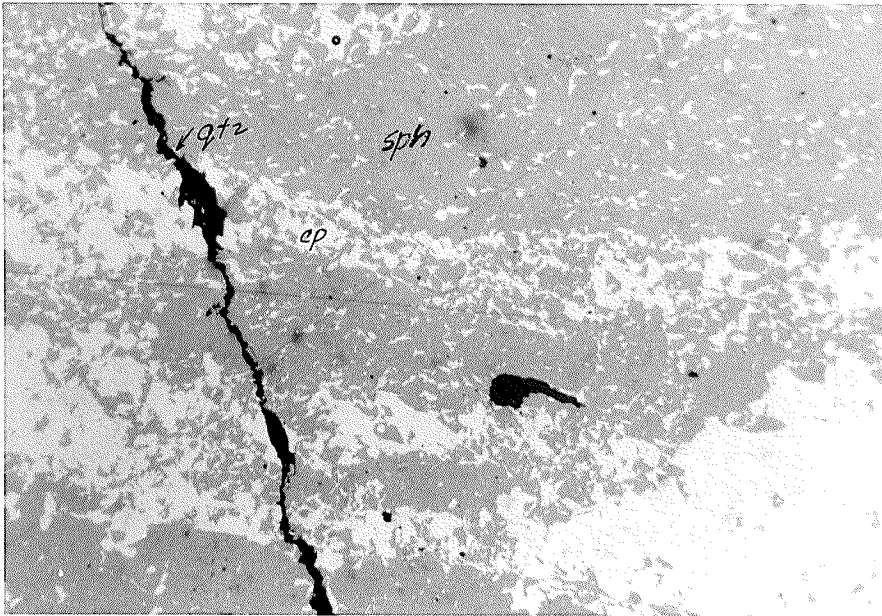


Figure 19 REPLACEMENT OF SPHALERITE BY CHALCOPYRITE.
POLISHED SECTION X100

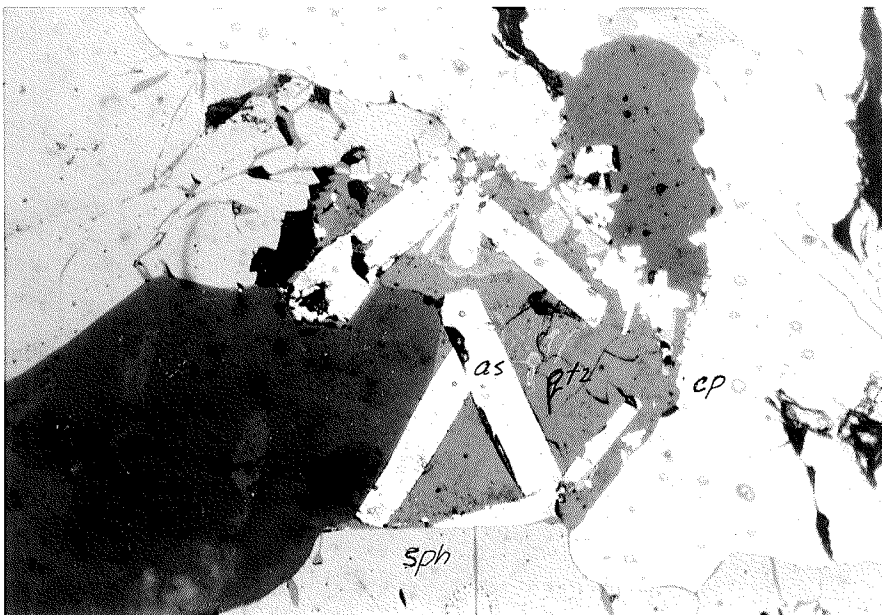


Figure 20 ARSENOPYRITE (as) CRYSTALS. POLISHED
SECTION X200

Quartz

The predominant silicate mineral in the Dickstone ore is quartz. White and clear varieties were observed ranging in size from <1 mm. to several cm. across. The quartz shows a definite association with cassiterite, often occupying an adjacent position and sometimes appearing to have caused corrosion of the cassiterite (Figure 15). The smaller cassiterite grains frequently occur within embayments along the quartz aggregate boundaries. The quartz, which occurs as irregular aggregates, replaces sphalerite, pyrrhotite, chalcopyrite and pyrite.

Calcite

The presence of calcite in the ores at Dickstone was confirmed by an X-ray powder photograph of a small area of sample 13c (Figure 21). The calcite replaces cassiterite at this location.

The author was unable to identify the dark mineral which replaces the cassiterite in Figures 8, 17 and 22.

Cassiterite

The most important tin mineral in the ores at the Dickstone Mine is cassiterite. The cassiterite occurs as discrete grains, ranging in size from less than 0.001 mm. to 0.6 mm. in diameter. The larger cassiterite grains frequently exhibit a short prismatic and pyramidal crystal habit (Figures 8, 10, 11, 13, 17, 21, 22). The crystal faces have been modified by abrasion (Figure 15) caused during either emplacement or metamorphism and by replacement by calcite (Figures 21, 8, 17, 22) and chalcopyrite (Figure 11).

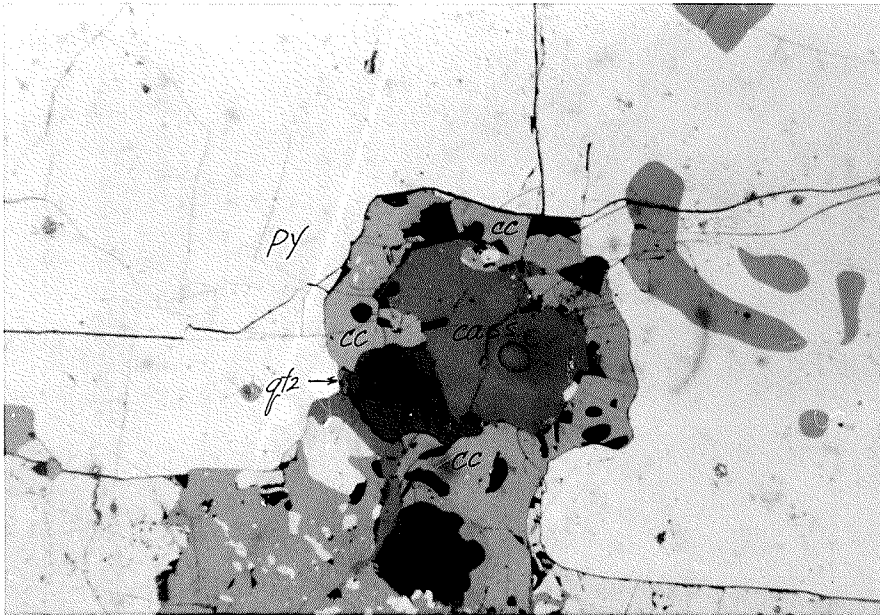


Figure 21 REPLACEMENT OF CASSITERITE BY CALCITE.
POLISHED SECTION X200

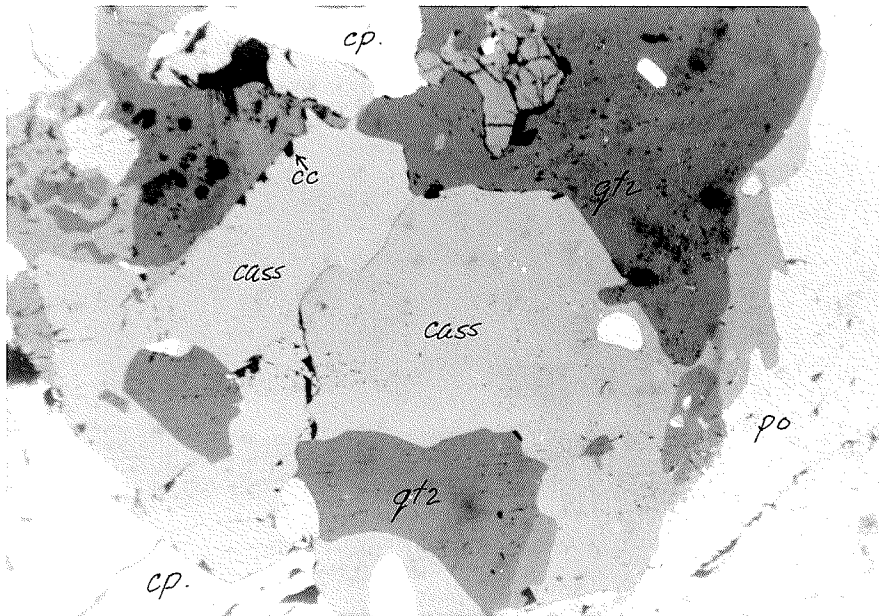


Figure 22 REPLACEMENT OF A CASSITERITE TWIN BY
CALCITE. POLISHED SECTION X75

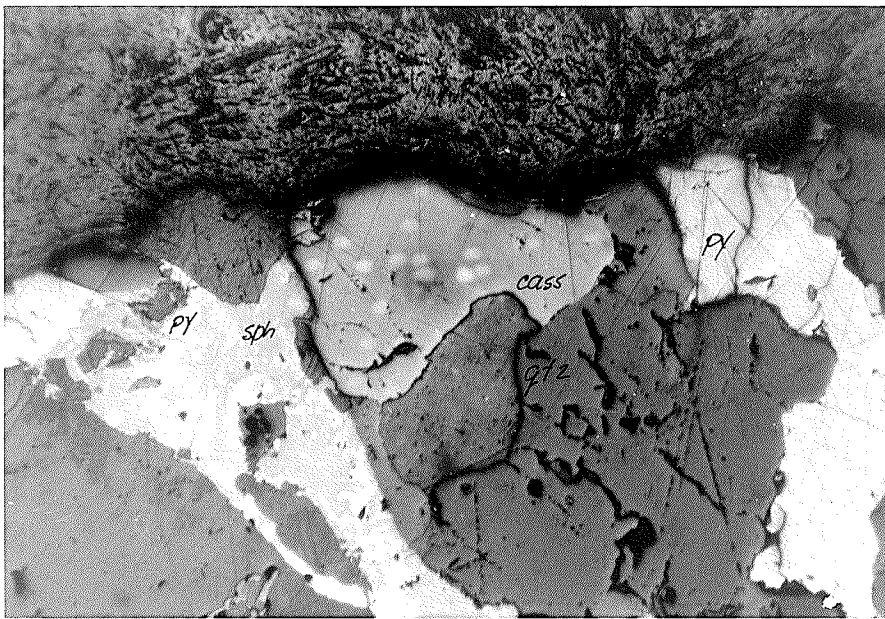


Figure 23 CASSITERITE GRAIN. NOTE THE CIRCULAR LIGHT COLOURED IMPRESSIONS MADE BY THE ELECTRON BEAM OF THE MICROPROBE. POLISHED SECTION X125

Possible cassiterite twins (Figures 10, 22) were observed in two locations. Except for tiny inclusions of sphalerite, chalcopyrite, pyrite, quartz and calcite (Figures 8, 15, 17, 22) and the cross-cutting veins of these same minerals (Figures 13, 15), the cassiterite grains are homogeneous. Electron beam traverses across several cassiterite grains (Figure 23) showed that the tin concentration did not vary within individual grains.

A more complete description of the tin-bearing minerals encountered in the Dickstone No. 2 orebody is presented in Chapter 5.

Chapter 4

PARAGENESIS

The general metamorphic paragenetic sequence at Dickstone, as ascertained from replacement textural evidence, is from early pyrite - cassiterite, to sphalerite - chalcopyrite, chalcopyrite - pyrrhotite, and later quartz.

Replacement of pyrite by sphalerite, chalcopyrite, pyrrhotite and quartz indicates an early genesis for the pyrite. Furthermore, the pyrite is cut by extensive vein networks of these same minerals (Figures 4, 5, 6). Textural evidence was not observed which could enable the author to ascertain the relationship between pyrite and cassiterite.

The cassiterite is replaced by calcite (Figure 21) and chalcopyrite (Figure 11), suggesting an early formation for the cassiterite.

The replacement of pyrite by sphalerite, chalcopyrite, and pyrrhotite suggests a late formation of these minerals. Exsolution lamellae of chalcopyrite in sphalerite (Figure 18) suggests co-crystallization of these two minerals. Replacement of sphalerite by chalcopyrite (Figures 7, 19) indicates that some chalcopyrite formed later than sphalerite. Pyrrhotite, which also replaces sphalerite, appears to have co-crystallized with chalcopyrite.

Quartz and calcite have formed late in the Dickstone ores. The quartz replaces sphalerite, chalcopyrite, pyrrhotite and pyrite while the calcite replaces cassiterite.

Chapter 5

TIN-BEARING MINERALS AT DICKSTONE

Concentrations of tin were encountered in two minerals at the Dickstone Mine through the use of the electron microprobe. The more common of these two was identified as cassiterite with the aid of X-ray powder photographs (Figures 24, 25). The other tin-bearing mineral is a calcium-titanium silicate, possibly sphene.

Sphene

The tin-bearing mineral denoted as sphene was not positively identified. Lack of standardization of the microprobe prevented a quantitative chemical analysis, however, a qualitative analysis indicated that this mineral is a calcium-titanium silicate.

Sphene, with the chemical formula CaTiSiO_5 , commonly occurs as an accessory mineral in intermediate and acid igneous rocks and in metamorphic rocks.

At Dickstone, sphene occurs as small (0.006 - 0.01 mm.), rounded to sub-rounded, elongate grains. These grains are brown and are most commonly associated with quartz. A total of approximately 10 - 15 grains was encountered in two polished sections.

The tin count, although not nearly as high as in the cassiterite, is several times higher than the background value, indicating a slight concentration of tin in this mineral. The similarity between the Sn^{4+} and Ti^{4+} ionic radii ($\text{Sn}^{4+} = 0.71\text{\AA}$, $\text{Ti}^{4+} = 0.68\text{\AA}$) and octahedral

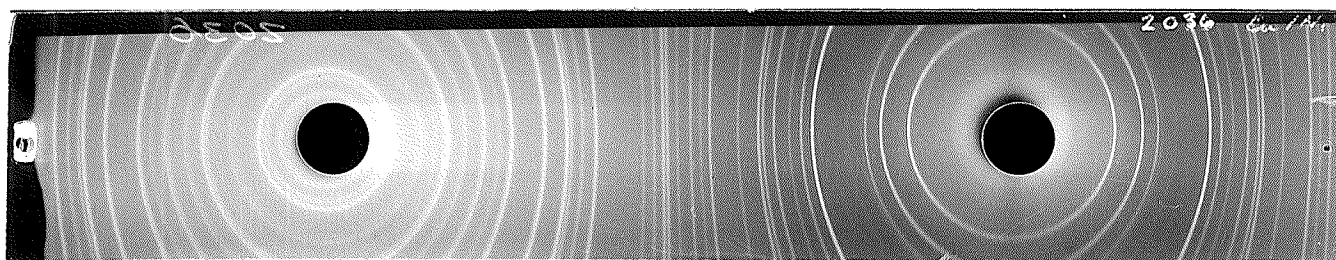


Figure 24 X-RAY POWDER PHOTOGRAPH: CASSITERITE CU/NI RADIATION. 57.54 MM. DIAMETER CAMERA. STANDARD (UNIVERSITY OF MANITOBA)

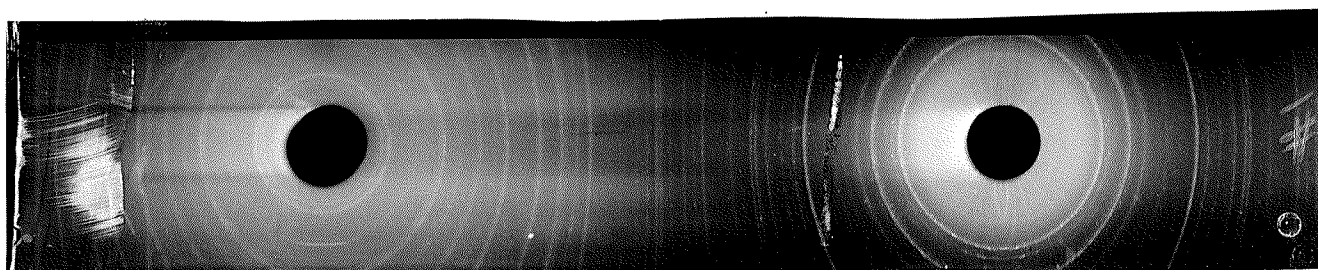


Figure 25 X-RAY POWDER PHOTOGRAPH: CASSITERITE CU/NI RADIATION. 57.54 MM. DIAMETER CAMERA. SAMPLE FROM DICKSTONE NO. 2 OREBODY (NO. 4e)

covalent radii ($\text{Sn}^{\text{iv}} = 1.45$, $\text{Ti}^{\text{iv}} = 1.36\text{\AA}$; Cotton and Wilkinson, 1962), accounts for the ability of tin to substitute for titanium in sphene.

The trace element content is similar to that of cassiterite except for the presence of rubidium (Rb) and manganese (Mn) in the sphene and the absence of silver (Ag) and neodymium (Nd) in one sphene sample (Table 3).

Cassiterite

Size Distribution:

Cassiterite occurs at Dickstone as discrete anhedral to sub-hedral grains. The grains range in size from less than 0.001 mm. to about 0.6 mm. as measured along the longest dimension of the grain. The cassiterite is brown and is distinguished by its characteristic internal reflection.

Table 1 shows that although many small grains occur, 99.8% of the cassiterite is in grains ranging from 0.1 to 0.7 mm. in longest dimension.

Spatial Distribution:

An attempt was made to contour tin values on a longitudinal section of the Dickstone No. 2 Orebody. The random occurrence of tin throughout the mine made this effort impractical. It is concluded that the tin has not concentrated in any recognizable pattern in the orebody down to the 1150' level. Perhaps more detailed sampling would reveal concentration patterns but that is beyond the scope of the present paper.

Table 1 SIZE DISTRIBUTION OF CASSITERITE GRAINS

Sample No.	No. of Cassiterite Grains	Size Range*(mm.)					
		.001	.001-.01	.01-.1	.1-.5	.5-.7	
1c	4	0	0	3	1	0	
2c	3	0	0	0	3	0	
3c	7	0	6	0	1	0	
4e	7	5	0	1	0	1	
4w	9	0	1	2	6	0	
5c	4	0	2	1	1	0	
6c	2	0	1	0	1	0	
7e	8	0	7	0	1	0	
7w	2	0	0	2	0	0	
8c	3	0	0	3	0	0	
13c	7	0	0	1	4	2	
15c	6	0	3	2	0	1	
Total	62	5	20	15	18	4	
Frequency of Occurrence (%)		8.1	32.3	24.2	29.0	6.4	100.0
Approximate Volume **(mm.) ³		(.001) ³	(.006) ³	(.06) ³	(.3) ³	(.6) ³	
Total Volume *** (mm.) ³		5x10 ⁻⁹	4.32x10 ⁻⁶	3.24x10 ⁻³	.486	.864	
Distribution of Cassiterite (%)		trace	trace	0.2	35.9	63.9	100.0
<p>* As measured across the longest dimension of the grain</p> <p>** Calculated by cubing the mean of the Size Range</p> <p>*** Equal to Approximate Volume x the number of grains in that size range</p>							

Influences on Tin Concentration:

The relationship between zinc and tin is shown in Figure 26. The data points show a broad scatter except at the two highest zinc concentrations where tin contents were correspondingly high. A broad scatter of data points is also indicated between copper and tin in Figure 27. In addition, Figure 28 indicates that no correlation exists between zinc and copper concentrations. Similarly, log - log and semi-log plots of the data failed to indicate any relationship between these three elements.

The data for Figures 26, 27 and 28 was obtained from Table 2.

Trace Elements:

A total of twenty-six trace elements was detected in the cassiterite of the Dickstone Mine, through the use of the microprobe analyzer. These elements were documented only qualitatively so their concentrations are not known. Table 3 shows the frequency of occurrence of each trace element.

The most abundant trace elements on a frequency of occurrence basis, are indium (In), silver (Ag), neodymium (Nd), tungsten (W), lutetium (Lu), and iodine (I). Calcium (Ca), antimony (Sb), and ytterbium (Yb) occur moderately, while titanium (Ti), iron (Fe), zinc (Zn), tantalum (Ta), and iridium (Ir) occur infrequently. Germanium, gallium, erbium, lead, bromine, copper, radium, vanadium, sulphur, osmium, lanthanum, and barium are present in only minimal amounts.

The fourteen most common of these trace elements have all been described in the literature as constituents of cassiterite except for Nd, Lu, I, Yb, and Ir. The often documented trace elements niobium,

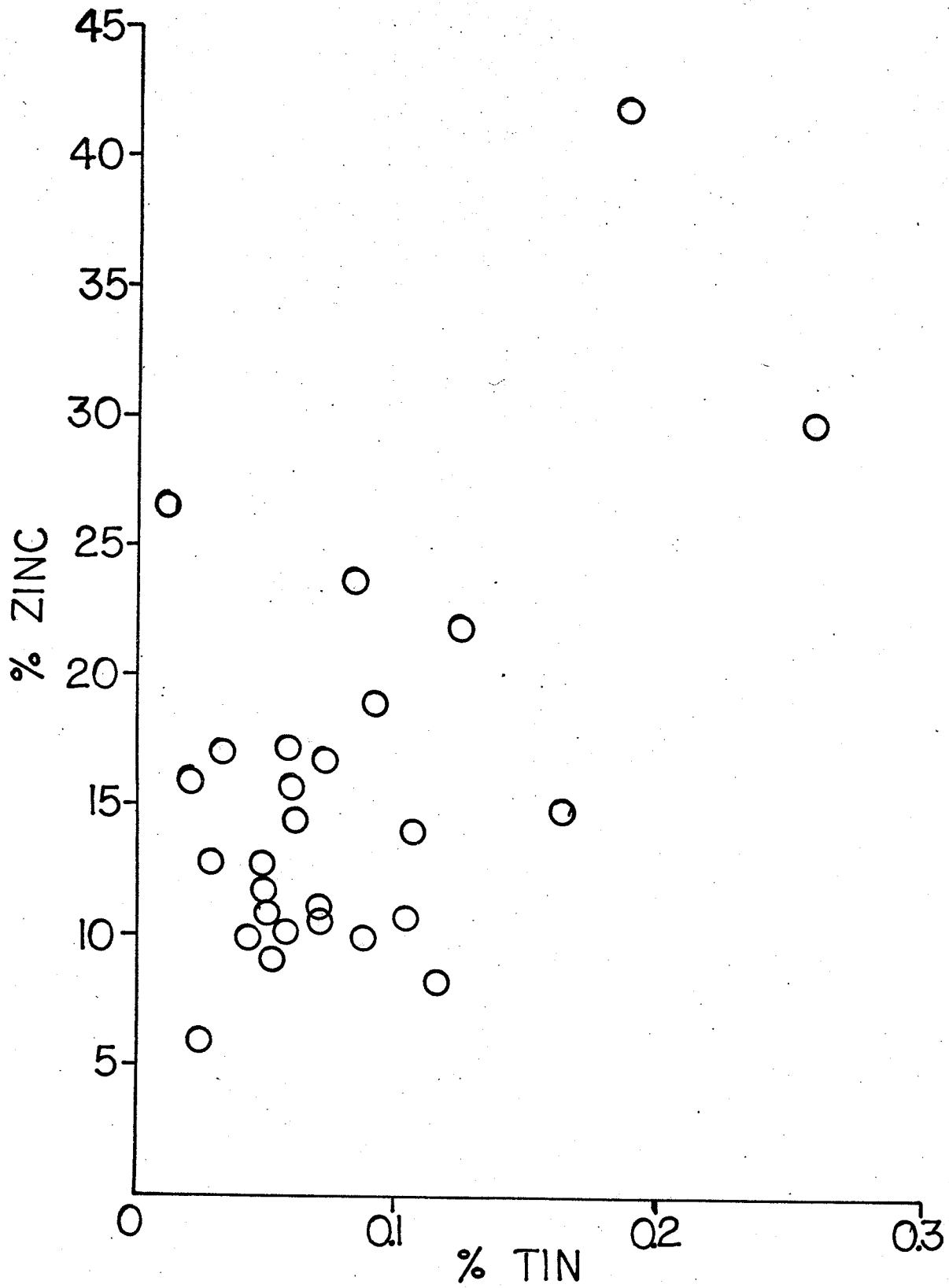


Figure 26: % Zinc vs % Tin

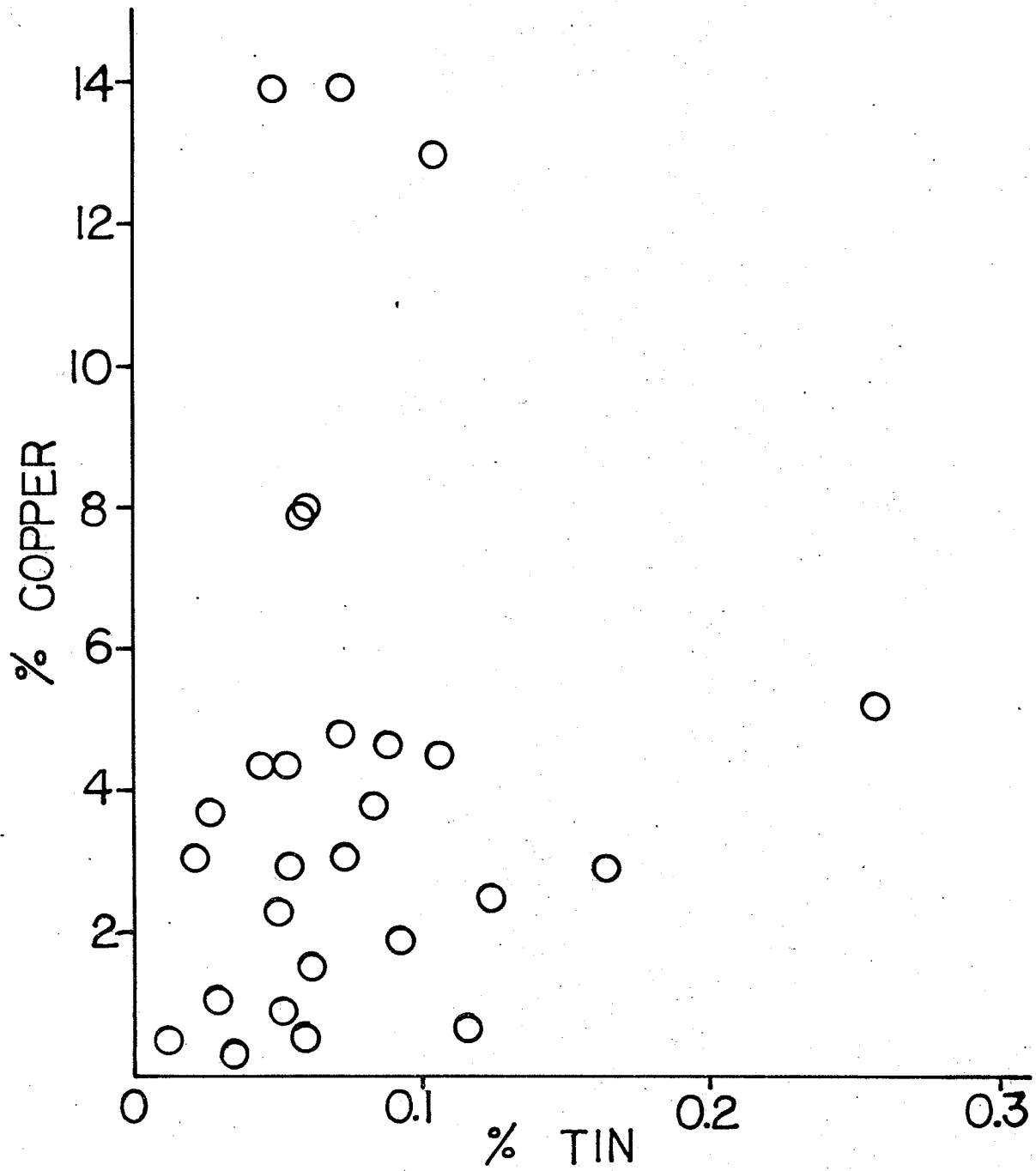


Figure 27: % Copper vs % Tin

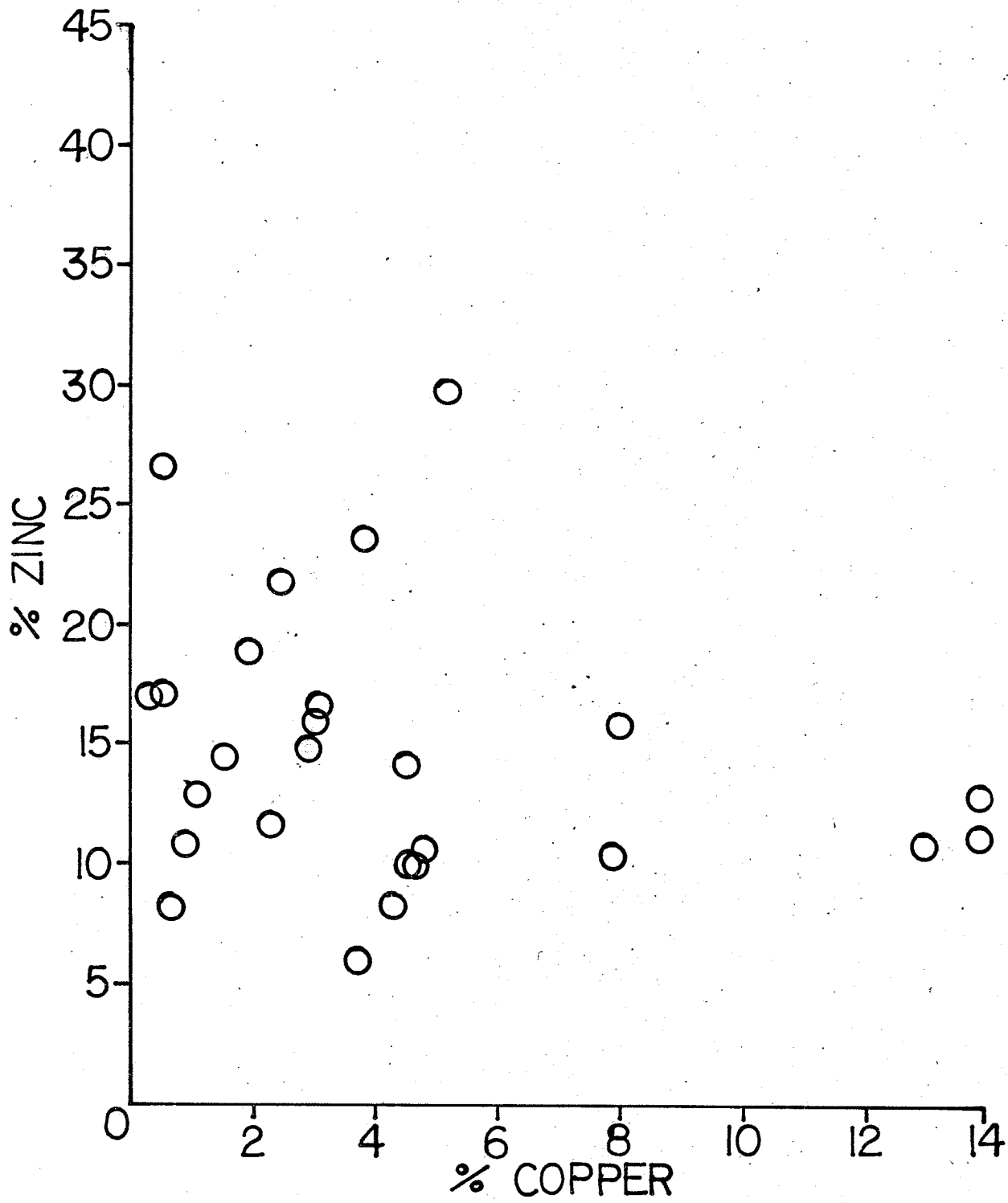


Figure 28: % Zinc vs % Copper

Table 2
ATOMIC ABSORPTION RESULTS

Sample No.	% Tin	% Zinc	% Copper	ppm Lead
22	0.257	29.8	5.20	---
20	0.187	41.8	0.09	---
3c	0.164	14.8	2.90	---
6c	0.124	21.9	2.45	---
4e	0.116	8.1	0.64	20
15c	0.106	14.0	4.50	---
21	0.104	10.6	13.0	---
5c	0.092	18.9	1.90	40
14c	0.088	9.9	4.62	30
10w	0.083	23.7	3.80	---
15e	0.073	16.7	3.05	---
11c	0.072	10.5	4.80	---
17w	0.072	11.0	13.9	---
18c	0.061	14.4	1.54	60
2c	0.060	15.6	8.0	---
6w	0.058	10.1	7.90	---
7c	0.058	17.2	0.53	30
4w	0.054	0.3	2.95	---
12c	0.053	8.1	4.34	40
16e	0.051	10.8	0.90	---
9e	0.050	11.7	2.30	60
19	0.049	12.7	13.9	---
13c	0.044	9.9	4.39	30
1c	0.034	17.0	0.32	---
8c	0.029	12.8	1.05	70
7e	0.026	5.9	3.70	---
13e	0.021	15.9	3.06	50
9w	0.012	26.6	0.53	---

Table 3 TRACE ELEMENT DISTRIBUTION

Sample #	In	Ag	Nd	W	Lu	Ca	I	Ti	Fe	Sb	Zn	Ta	Yb	Ir	Rb	Mn
a. Cassiterite																
1c	X	X	X	X												
2c-1	X	X	X		X		X									
2c-2	X	X	X	X	X	X	X						X	X		
3c-2	X	X	X	X	X	X	X	X	X	X		X	X			
4e-2	X	X	X	X	X			X		X						
4w	X	X	X	X												
6c	X	X	X	X	X	X	X			X	X	X		X		
Frequency of Occurrence (%)	100	100	100	86	71	43	57	29	14	43	14	29	29	29	0	0
b. Sphene																
5c-1	X	X	X	X		X		X	X		X	X			X	X
9w	X			X	X	X		X	X						X	
Frequency of Occurrence (%)	100	50	50	100	50	100	0	100	100	0	50	50	0	0	100	50

scandium and cadmium are notably absent in the Dickstone cassiterites.

Nd, Lu, and Yb all belong to the lanthanide or rare earth elements with Nd being, by far, the most abundant of the three. Nd and Lu show a high frequency of occurrence at Dickstone while Yb occurs moderately (Table 3). The author does not know of any other occurrence of these rare earth elements in cassiterite. The rare earth elements show a wide distribution in nature with higher concentrations occurring in some acid igneous rocks. Yb is present in fluorite and hydromicas at Mount Pleasant, in amounts ranging from 0.001% to 0.01% (Petruk, 1964), suggesting an affinity for some Ca minerals (Goldschmidt, 1954).

Tungsten, which shows a high frequency of occurrence at Dickstone, occurs elsewhere in cassiterite in amounts ranging from 0.1% to 1.0% (Petruk, 1964; Novák et al., 1962). Tungsten is a well documented trace element constituent of cassiterite where it may substitute for tin (Greaves et al., 1971; Hosking, 1963; Petruk, 1964; Sainsbury, 1969).

Indium has a high frequency of occurrence in the cassiterite at Dickstone. Ivanov and Lizunov (1960) found that indium concentrates in minor amounts (0.001% - 0.01%) in cassiterite-sulphide deposits, especially those with extensive development of sulphide stages of mineralization, high temperature paragenesis of early mineral associations, and complex composition of the ore. They also found that indium is widely distributed in various types of Pb - Zn deposits enriched in tin, as at Sullivan, and that the concentration of indium is directly proportional to the tin concentration. They concluded that the chemistry of the ore solutions is important in controlling the concentration of indium. Deposits with a low concentration of indium have a low sulphide con-

centration or an absence of, or a low concentration of, tin.

Titanium has a very similar geochemistry to tin. With similar ionic radii these elements are interchangeable and, in fact, rutile (TiO_2) is isomorphous with cassiterite (SnO_2). Novák et al., (1962), in their study of the Kutná Hora ore deposit found that the cassiterite contains Ti in amounts ranging from 1% to 10%; Ca, Fe, Pb and W, 0.1% to 1.0%; Ag and Cu, 0.01% to 0.1%; and Ga, Sb, V, and Zn in amounts less than 0.01%. Similar results were obtained by Petruk (1964) for the Mount Pleasant deposit although titanium was present in lesser amounts (0.1% - 1.0%) in the cassiterite.

Chapter 6

SUMMARY AND CONCLUSIONS

With the exception of trace amounts of Sn in sphene, cassiterite is the only tin mineral found in the Dickstone No. 2 orebody.

Cassiterite occurs as discrete grains, ranging in size from less than 0.001 mm. to approximately 0.6 mm. in diameter. Subhedral crystals greater than 0.1 mm. in diameter account for approximately 99% of the cassiterite. The trace element content of the cassiterite is similar to that which has been documented in the literature. Indium, silver, neodymium, tungsten, lutetium and iodine occur most frequently in the cassiterite at Dickstone. Calcium, antimony and ytterbium occur less frequently, while titanium, iron, zinc, tantalum and iridium occur infrequently.

One other tin-bearing mineral was encountered, although only in minor amounts. This mineral was not positively identified, although qualitative microprobe data has shown it to be a calcium-titanium silicate, possibly sphene.

A direct relationship between concentrations of tin and either copper or zinc could not be ascertained for the Dickstone No. 2 orebody.

The ores at Dickstone contain tin in amounts which average 0.08% to 1.6 pounds per ton. 99.8% of the principle tin mineral, cassiterite, ranges in size from 0.1 mm. to 0.6 mm. A comparison with the Sullivan Mine, where cassiterite is profitably extracted as a by-product from the Pb-Zn-Ag ores, shows that this mine contains 0.06% tin, 90% of

which occurs as cassiterite grains ranging in size from 0.085 - 0.5 mm. Assuming that >90% of the tin at Dickstone occurs as cassiterite, the author believes that all other things being equal the cassiterite could be profitably extracted from the Dickstone ores.

The employment of a Denver Buckman Tilting Concentrator, as at Sullivan, should ensure effective recovery (>70%) of the extremely fine cassiterite (Denver Equipment Co., 1962). The recovered cassiterite would be sold, as Cominco does with the Sullivan cassiterite, as tin concentrate to a United States smelter.

The Dickstone ores contain 1.6 pounds of Sn per ton or 2.04 pounds of SnO₂ per ton. Allowing 10% dilution and 70% recovery by tabling, and assuming 95% of the tin occurs as cassiterite, it would be possible to recover 1.22 pounds SnO₂ per ton.

An approximate price of \$0.78 per pound of tin ore concentrate was obtained from the Canadian Mines Handbook (1970-71) by dividing the value of tin ore exports by the quantity of tin ores exported and averaging over the two year period 1969-70. Applying this price to the Dickstone concentrate, it is found that the Dickstone ore is worth \$0.95 per ton in tin concentrate.

The small size of the Dickstone No. 2 orebody coupled with the fact that the Dickstone ore is mixed with ore from other mines before it is milled at Flin Flon, however, would discourage any attempts at the extraction of the cassiterite from the ore.

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