Geology of the Twin "J" Mine

By

JOHN S. STEVENSON

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The Author

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INTRODUCTION

THE Twin "J" Mine, operated by Twin "J" Mines, Limited, represents an amalgamation of the old Lenora, Tyee, and Richard III mines (see Figure 1) on mount Sicker, eight miles by road, northwesterly, from the city of Duncan, on Vancouver island.

These mines produced 253,000 tons of copper-gold ore between 1898 and 1909 (see Table I).

TABLE I.—PRODUCTION FROM MOUNT SICKER MINES

MINE	TONS	GOLD, OZ.	SILVER, OZ.	COPPER, lb.
Lenora (1898-1907)	78,983	10,349	279,935	5,951,227
Tyee (1901-1909)	168,290	24,517	441,278	12,876,369
Richard III (1903-1907)	5,405	734	16,806	250,453

During the more recent period of production from these properties, July, 1943, to May, 1944, Twin "J" Mines, Limited, mined and milled ore with values mainly in copper and zinc, and minor values in gold, silver, and lead. Figures are not available for this later production.

Field work at the property was started by the writer in 1941 and continued in 1943 and 1944.

Figure 1.—Dumps from Tyee shaft (centre, at top) **and from No. 1 and No. 2 levels, Lenora** (centre foreground). **Richard III shaft is over crest of hill.**

Early published descriptions of the properties include those in annual reports of the Minister of Mines, British Columbia, and others by Musgrave(1), Weed(2), Clapp and Cooke(3), and Dolmage(4). Gayer and Williams(5) have described milling practice at the property.

GENERAL GEOLOGY

The rocks in the mine and nearby area (see Figure 2) include cherty tuffs, graphitic schists, sodic-andesite porphyry, sodic-rhyolite porphyry, and sodic-diorite.

Sediments

Cherty tuffs and graphitic schist together form a band (see Figure 2) 100 to 150 feet wide that, near the workings, is at least 2,100 feet long, and may be longer, but the scarcity of outcrops prevents tracing it with certainty. The sediments within this band strike N.70°W. and dip 50° southwest.

The cherty tuffs are light grey rocks, usually consisting of 1/8- to 1/2-inch laminae of chert separated by thin layers of sericite schist. Where relatively undeformed, the rocks are slaty, but where they are deformed they possess laminae that are bent into small canoe-shaped folds. Where intensely deformed, either by close folding or shearing, the tuffs are very schistose and it requires careful examination to recognize the former chert layers, which serve to distinguish these rocks from the more schistose phases of the rhyolite porphyry.

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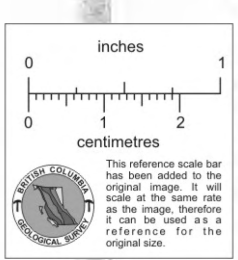
(1) Numbers within brackets refer to Bibliography at end of paper.

Figure 2.—Generalized outcrop map from Key City and XL shafts on the west, easterly past the Lenora and Tyee workings, to the Westholme shaft on the east.



The cherty tuffs are always associated with black graphitic schist. Much of the black schist underground has been folded into a succession of small drag folds (see Figure 3) and, where the drag folding has been so extreme that it passes into shearing, the thin laminae of the schist have been nearly destroyed and are hardly recognizable in the resulting sheared rock.

Figure 3.—Minor drag folds in black schist underground, near North orebody.

Andesite Porphyry

This rock, thought to be extrusive, is found in outcrops south of the ore-zone (see Figure 2). It is a dull grey-green rock with a slightly schistose texture and contains widely spaced, well-shaped crystals of albite ($Ab_{90}An_{10}$) and a few hornblende crystals set in a fine-grained to dense groundmass of alteration products such as chlorite, epidote, and carbonate. Epidote nodules, ⅛ inch to 1 inch in diameter, are characteristic of the rock. They stand out conspicuously on weathered surfaces and are aligned in an east-west direction in conformity with the general trend of the sediments. The nodules consist of a fine-grained intergrowth of epidote and quartz. Some nodules are very smooth and elliptical in outline and seem to fill, or to have worked out from, blow-holes or vesicles in a lava; other nodules are rectangular in outline and include unreplaced areas of plagioclase; these probably represent replacement of the plagioclase phenocrysts of the andesite porphyry. The well-shaped crystals found as phenocrysts, and the vesicles now filled with epidote, suggest that this rock is extrusive rather than intrusive.

Rhyolite Porphyry

This rock is referred to as feldspar porphyry in the legends in Figures 2, 5, and 7. Rhyolite porphyry and the diorites are the two most widespread rocks (see Figure 2). The porphyry is found in irregular areas both north and south of the orebodies. Where it was possible to study the relation of the rhyolite to the sediments underground, the rhyolite was seen to intrude the sediments as sills that follow the folding of the sediments. Dykes of rhyolite porphyry cut early phases of the diorites.

The rhyolite is intrusive and possesses no features to suggest that it is extrusive. It intrudes the sediments, andesite porphyry, and early phases of the diorite, but it is cut by later phases of the diorite.

The rhyolite porphyry is a light grey-green to white schistose rock, characterized by albite ($Ab_{90}An_{10}$) phenocrysts. Some phases of the rock have prominent quartz phenocrysts or 'eyes' in addition to the albite phenocrysts. In the less schistose phases of the rock, the phenocrysts help to

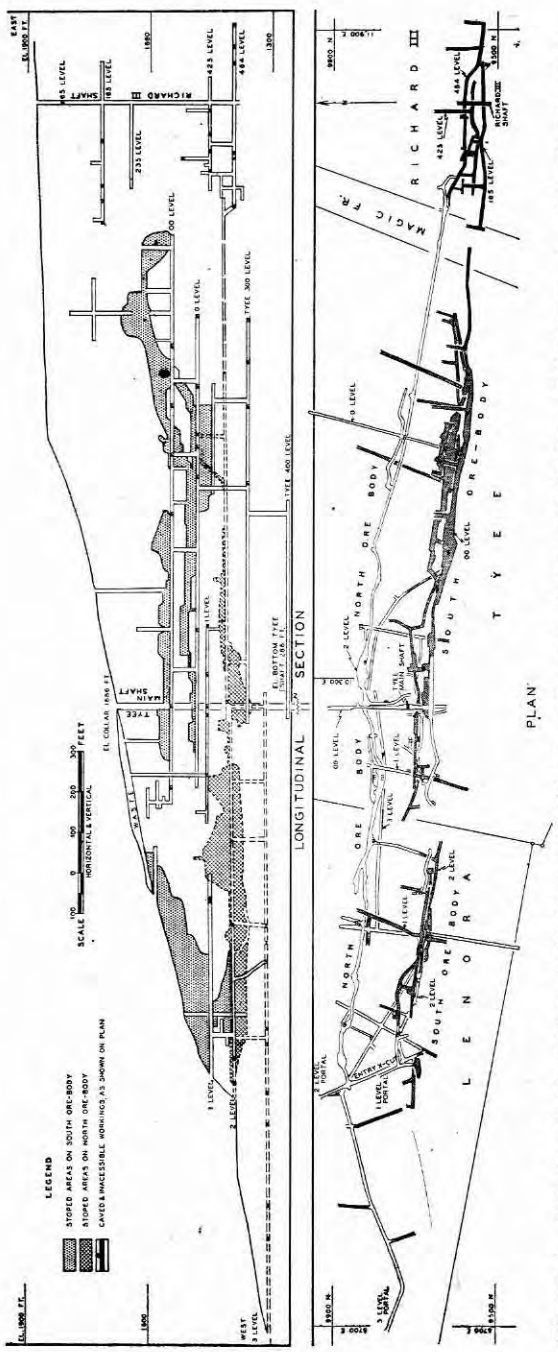


Figure 4.—Longitudinal section and plan of workings on Lenora, Tyee, and Richard III claims. Longitudinal section is in plane of the South orebody, with the North orebody projected 150 feet southward into plane of the South.

distinguish the porphyry from schistose phases of the tuff. However, where the rhyolite is so schistose that the phenocrysts have been partly destroyed and are not readily visible, the rock may be recognized by the warty appearance of the cleavage surfaces, caused by unsheared remnants of the phenocrysts.

Diorites

Numerous outcrops of fine-grained and coarse-grained diorite are found. The fine-grained diorite is sill-like and conforms to the strike and dip of the adjacent sediments, but the coarse-grained phases form irregular intrusive bodies, some of which are well-defined dykes.

Although all the diorites are older than both the sediments and the andesite porphyry, some phases are younger than the rhyolite porphyry and other phases are older than the rhyolite.

The diorites are dark-green rocks that are of general dioritic appearance but vary considerably in texture, from fine-grained to coarse-grained and from porphyritic to even-grained rocks. In hand-specimen, all the diorites are characterized by readily visible ilmenite and, under the microscope, by a micrographic intergrowth of quartz and albite ($Ab_{90}An_{10}$). In some thin sections, this intergrowth was seen to comprise as much as 30 per cent of the rock. The intergrowth might belong to the magmatic stage in the history of the diorites, but the fact that it definitely replaces such secondary products as shreddy amphibole and actinolite suggests that it formed much later in the history of these rocks, probably during an early phase of hydrothermal activity.

Laboratory work included the study of 116 thin sections, but, for the present paper, the petrography will not be described in detail.

THE ORE BODIES

The ore, found as a replacement of folded, cherty tuffs and related graphitic schist, is of two closely allied types. One type, called *barite ore*, consists mainly of barite and sulphides, with small amounts of quartz; and the other type, called *quartz ore*, consists mainly of quartz and chalcopyrite.

The ore occurs as two separate, easterly trending bodies about 150 feet apart (see Figure 4) that were formerly known as the North vein and the South vein. Because of the present doubt about these orebodies being veins in the sense of fissure-fillings or shear-replacements, the writer prefers to drop the term vein and refer to them as the North orebody and the South orebody. Most of the ore mined in the early days came from the South orebody, but most of that mined by Twin "J" came from the North orebody. Nearly all of the workings on the South orebody are caved and inaccessible, and only the workings on the North orebody are accessible for study at the present time (1944).

The two orebodies are parallel and lie along two main drag folds in the band of sediments (see Figure 5).

North Orebody

The North orebody measures about 1,700 feet along the strike, 120 feet down the dip, and from one to ten feet in thickness. The ore occurs along a drag fold in southward-dipping sediments.

This drag fold consists of two closely related folds, one above the other, but close enough to be considered almost as one. Many minor wrinkles or

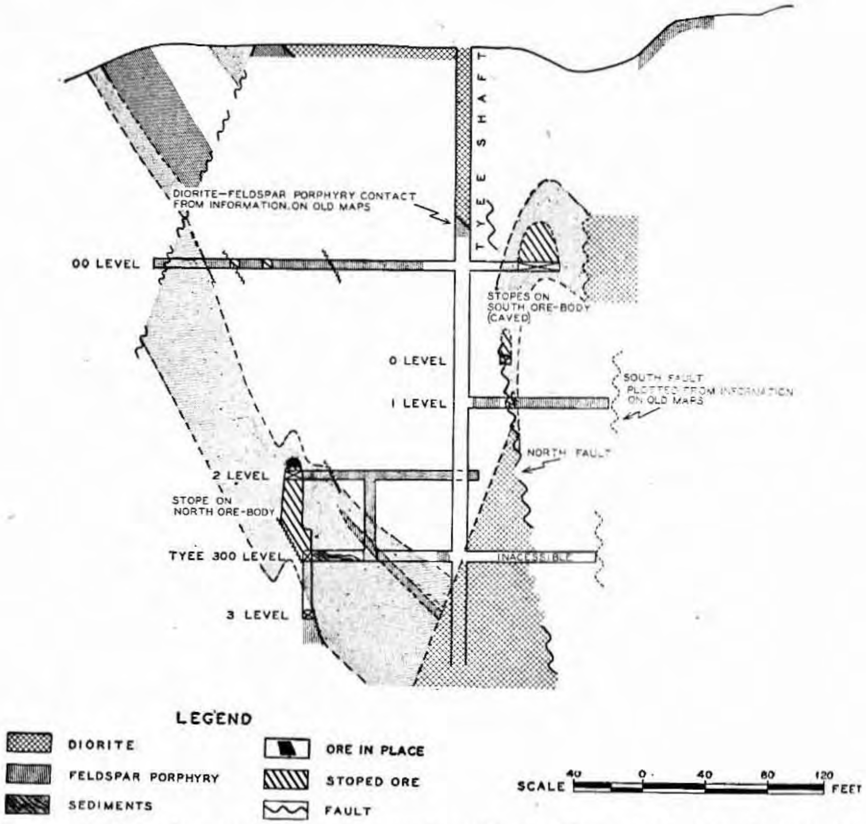


Figure 5.—North-south cross-section through the Tyee shaft, showing stopes on the North and South orebodies. Information not found in those workings in the plane of sections has been compiled from diamond-drill hole data and from nearby cross-sections.

folds are found within the larger folds. The distance measured across the width of each fold ranges from ten to twenty feet, and the distance measured from top to bottom of the double fold is about fifty feet. The crest lines of the double fold strike N.70°E., with the strike of the sediments, and are horizontal.

The isometric projection, Figure 6, and the detailed cross-sections, Figure 7, show the drag fold on the North orebody. Figure 6 is an isometric projection of several adjacent stopes that, taken together, make up the largest single block of ore mined on the North orebody. The boundaries of these stopes were chosen arbitrarily by the Twin "J" management for purposes of mining only. The tops and ends of the stope as shown on the diagram represent the limits of mineable ore, and not the limits of mineralization. The outlines of the various stope floors are considered as contours on the orebody. The mineable ore extended from the 9th floor down the upper limb of the fold to the 4th floor, then took a roll and widened between the 4th and 2nd floors, then steepened to the sill floor on No. 2 level; below this it took

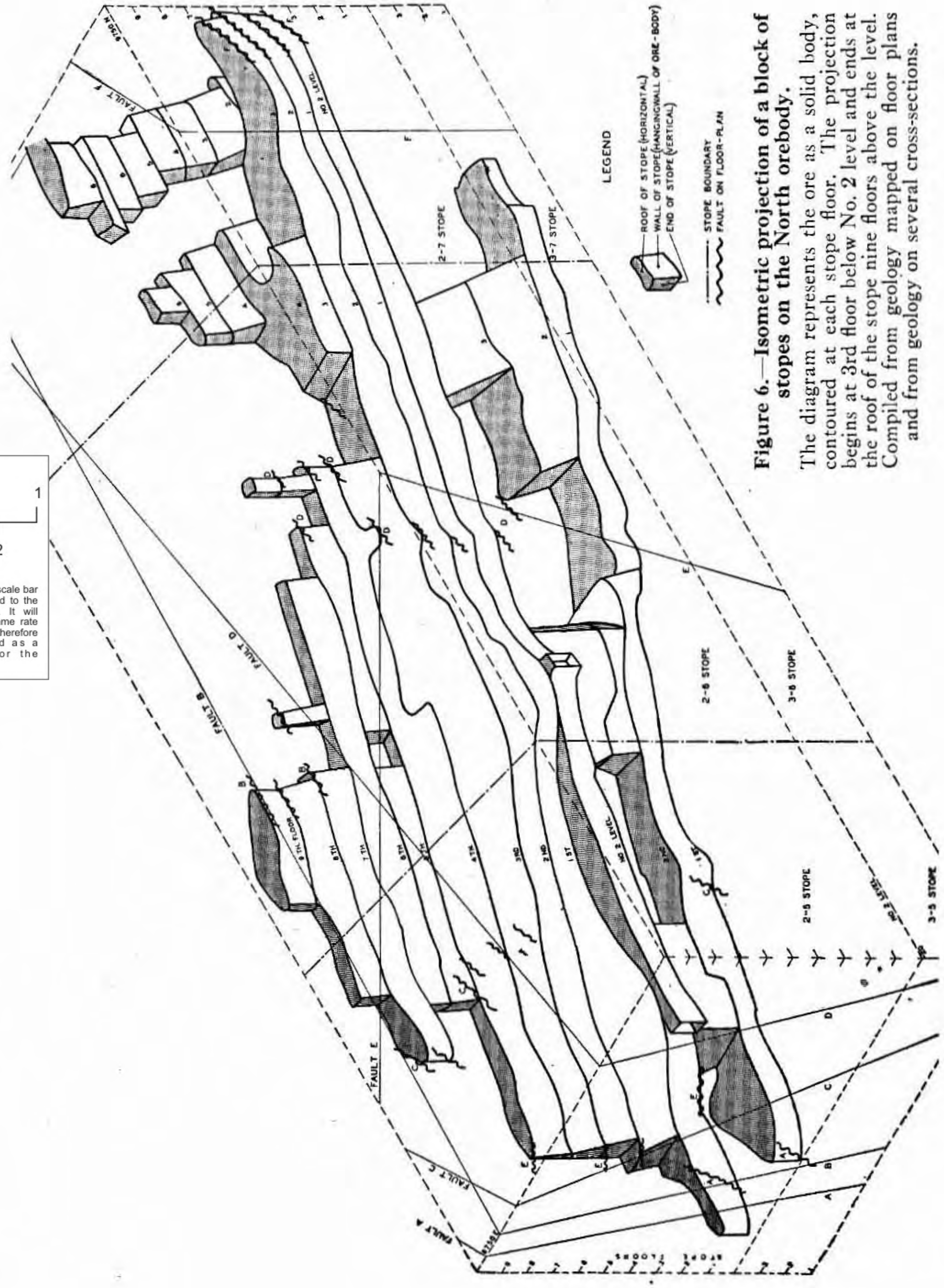


Figure 6.—Isometric projection of a block of stopes on the North orebody.

The diagram represents the ore as a solid body, contoured at each stope floor. The projection begins at 3rd floor below No. 2 level and ends at the roof of the stope nine floors above the level. Compiled from geology mapped on floor plans and from geology on several cross-sections.

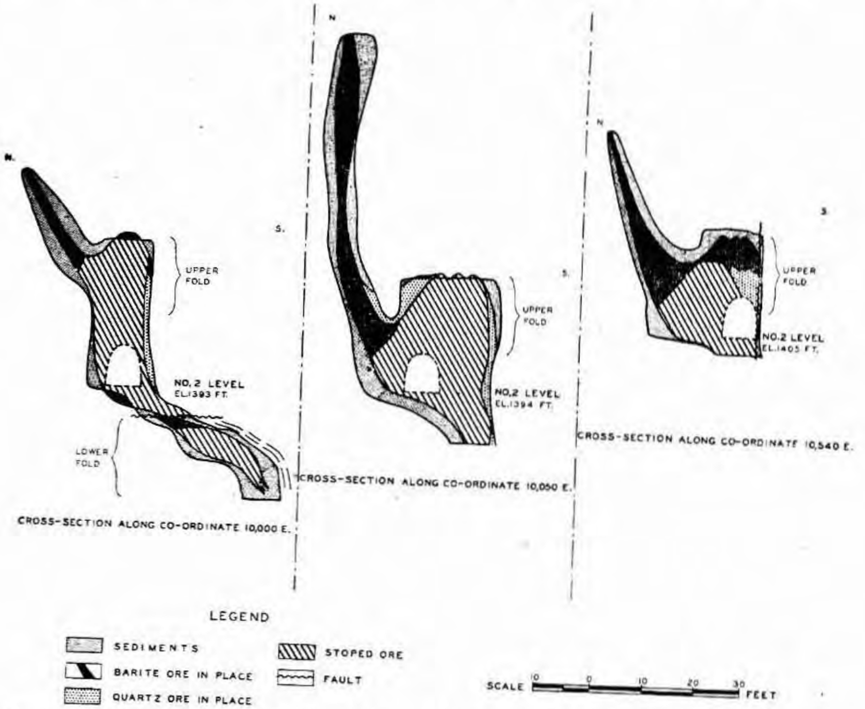


Figure 7.—North-south cross-sections through stopes on North orebody, showing details of drag fold in this orebody.

another roll between this level and the 2nd floor below, after which it steepened again and petered out on the second and third floors below the level. The cross-sectional details of the orebody are shown in Figure 7; the sections along co-ordinates 10,000 East and 10,050 East are through the middle and east ends of the diagram in Figure 6 and the section along co-ordinate 10,540 East is at the easterly limit of stoping on the North orebody.

South Orebody.

Most of the workings on the South orebody are caved (see plan in Figure 4) and information about the orebody has had to be obtained from old plans and sections of the workings.

This orebody is 150 feet south of the North orebody, and its upper limit is 150 feet higher than that of the North. The plan relations may be seen in Figure 4 and the cross-sectional relations in Figure 5. The orebody has a length of 2,100 feet, a vertical extent of about 150 feet, and a thickness of about 20 feet. The few parts of the orebody that were accessible belong to parts of folds, probably similar to, but larger than, those of the North orebody.

Faults

Two main faults, striking east and west and nearly vertical, displace the orebodies. These faults and their relation to the orebodies are shown in Figure 5.

The north fault is between the two orebodies. This fault, in going westward, strikes into the South orebody at a small angle. Near the Richard shaft, it is 26 feet north of the ore, but farther west, near the Tyee shaft, it is much closer; and toward the portal of No. 1 adit, it is along the north wall of the ore.

This fault displaces the South orebody about 200 feet upward (see Figure 5) and an unknown distance eastward with respect to the North orebody. Long sections of barite drag-ore may be seen in the north fault below the South orebody.

The south fault has been seen by the writer only in the lower workings, toward the west end of the mine. For the construction of the section through the Tyee shaft, as shown in Figure 5, the position of the south fault has been taken as that shown on a cross-section made through the Tyee shaft during the early period of operations. On this old section, the fault is shown as 80 to 100 feet south of the shaft and definitely south of the South orebody.

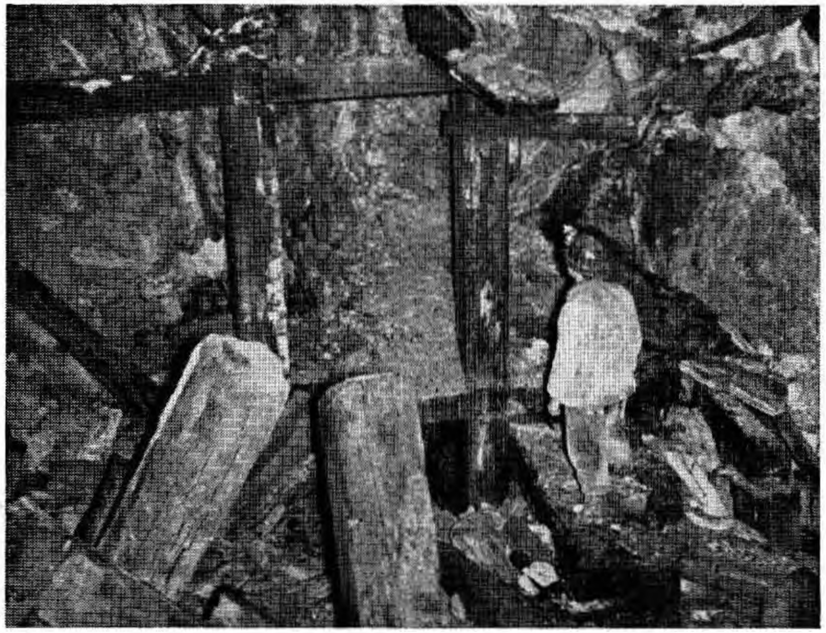


Figure 8.—Stope on North orebody, showing wall of diagonal fault in upper right cutting ore in middle background. Picture taken in 1941.

Several diagonal faults cut the North orebody (see Figure 8) and probably also cut the South orebody, but these could not be observed. Some of the diagonal faults may be seen in the isometric projection (Figure 6). In this projection, the faults are shown by their traces on the top and front sides of the enclosing block and by their intersections (short sine-curve lines) on some of the stope-floors. They have been arbitrarily lettered from *A* to *E*, inclusive, for purposes of correlation on the projection only. As may be seen in the projection, the diagonal faults displace the orebody only a few feet horizontally and vertically. Most of these faults displace westerly segments of the ore southward and downward for distances ranging from 3 to 15 feet; in some faults, however, although the direction of the horizontal displacement is the same as in others, the direction of the vertical displacement is reversed. The displacement along the diagonal faults gives a resultant plunge to the ore that is steeper by 15 degrees than the horizontal crest-lines of the dragfold. However, because of a reversal of the vertical displacement in some of the diagonal faults, the orebody as a whole does not have any appreciable plunge.

A few flat, or very gently dipping, faults also cut the North orebody, but these displace the ore even less than most of the diagonal faults.

In addition to movement along the well-defined faults described above, considerable slippage has occurred between sharply folded beds in the graphitic schists.

ORES AND MINERALOGY

Analyses of the Ores

Ore analyses, with a description of the material analysed, are given in Table II. Analyses in columns 3 to 7 are of samples collected by the writer and do not indicate the average grade of ore mined. The average grade of ore is naturally lower than the analyses given, because it was necessary to mine large amounts of barren chert along with the mineralized material.

The ore is very massive and breaks with a blocky fracture like that of an igneous rock. This blocky, or almost conchoidal, fracturing of the ore makes it readily distinguishable underground from its schistose wall-rocks.

TABLE II.—ANALYSES OF MOUNT SICKER ORES
Analyst, G. C. B. Cave

	1	2	3	4	5	6	7	8
Gold, oz./ton...............	0.14	0.075	0.20	0.01	0.01	0.03	0.026	0.04
Silver, oz./ton...............	2.87	2.05	4.0	4.8	0.3	1.5	3.6	0.9
Copper, per cent............	4.56	1.32	1.05	2.06	0.84	2.10	0.86	7.06
Lead*, per cent............	....	0.6	0.4	2.3	1.0	0.9	1.1	trace
Zinc, per cent..............	....	6.12	7.6	19.7	8.8	12.3	17.8	0.21
Iron, per cent..............	....	....	21.9	5.23	8.59	4.77	3.42	8.43
Lime, per cent..............	6.60	....	....	....	....	....	....	....
SiO_2, per cent..............	13.50	....	6.10	13.20	2.88	9.62	4.40	68.14
$BaSO_4$, per cent............	37.30	....	26.3	32.5	59.3	51.9	47.7	1.12

1.—Average assay of ore from Tyee mine during 1904, quoted by Musgrave (*op. cit.*) and probably mostly from South orebody.
2.—Average assay of ore mined by Twin "J", 1943-44, mainly from North orebody. (C. Rutherford, personal communication).
3.—'Barite ore', North orebody, No. 2 Level
4.—'Barite ore', North orebody, No. 2 Level
5.—'Barite ore', North orebody, No. 2 Level
6.—'Barite ore', South orebody, 0 Level (Tyee 200)
7.—'Barite ore', South orebody, 0 Level (Tyee 200)
8.—'Quartz ore', North orebody, No. 2 Level
} Specimens taken by writer

*In separating lead from barium-bearing ores, care is needed in selecting a reliable procedure. The usual procedure for the lead assay of barium-free ores is inadequate, and requires modification. The above reported lead assays were secured using an original method, found to give most consistent checks with quantitative spectrographic analyses.

A finely laminated or banded appearance produced by layers of chalcopyrite and pyrite alternating with layers of sphalerite is characteristic of much of the ore. The banding has been largely destroyed in places where the grain of the sulphides is coarser than average, or where the barite ore has been replaced by quartz ore. This banding has been caused by preferential replacement of different bands in the laminated chert or cherty-tuff by the sulphides; small unreplaced remnants of schistose tuff and chert may still be seen in some of the ore.

The barite ore is a fine-grained mixture of pyrite, chalcopyrite, sphalerite, and a little galena in a gangue of barite, quartz, and calcite. The order of mineralization, from oldest to youngest, is as follows: barite, calcite, pyrite, sphalerite, chalcopyrite, and galena, quartz, and late calcite.

Table III gives the mineralogical composition of representative specimens of barite ore, re-cast from chemical analyses given in Table II.

TABLE III.—MINERALOGICAL COMPOSITION OF 'BARITE ORE'
(per cent)

COLUMN IN TABLE II	PYRITE	CHALCO-PYRITE	SPHAL-ERITE	GALENA	BARITE	QUARTZ	CALCITE (calculated)
3..........	45.0	3.4	11.3	0.5	26.3	6.1	7.4
4..........	7.4	6.0	29.4	2.7	32.5	13.20	8.8
5..........	17.0	2.4	13.2	1.2	59.3	2.88	4.0
6..........	6.3	6.1	18.3	1.0	51.9	9.62	6.7
7..........	5.5	2.5	26.6	1.3	47.7	4.40	12.0

Quartz Ore

The quartz ore is found in long, lenticular masses replacing both barite ore and the enclosing schists along the double drag fold. It ranges from one to five feet in thickness and varies considerably in depth. The distribution of the quartz ore in some cross-sections may be seen in Figure 7.

Where the quartz replaces barite ore, any one cross-section consists wholly of massive quartz, but where it replaces schist, a cross-section of the ore consists of many smaller lenses of quartz separated by layers of schist. In some faces of quartz ore, the rock amounts to 50 per cent of the area, in others it amounts to a very small percentage and consists of a few thin partings of schist between the thicker quartz lenses. The individual quartz lenses follow the folding in the enclosing sediments and may be flat or may dip steeply southward. Quartz extends upward from the main fold only as a few scattered areas of quartz in the barite, and extends downward as a few narrow lenses of quartz in the schist.

The quartz ore is fairly uniformly mineralized with chalcopyrite and for that reason it is the type of ore that was mainly sought by the early operators. The mineralogical composition of a typical example of quartz ore is as follows: pyrite, 4.1 per cent; chalcopyrite, 20.5 per cent; sphalerite, 0.3 per cent; galena, trace; barite, 1.1 per cent; quartz, 68.1 per cent; calcite, 5.6 per cent. Much of the chalcopyrite is evenly distributed through the quartz but some of it occurs as layers or streaks that follow unreplaced layers of schist in the quartz. Quartz containing evenly distributed chalcopyrite replaces fairly massive barite ore, but the quartz containing layers or streaks of chalcopyrite replaces schist. Both types of quartz occur together.

Age of the Ore

In age, the ore is later than both the folding and metamorphism of the sediments. Narrow veins of barite ore that cut folded sediments indicate a post-folding age, and unreplaced fragments of schistose sediments within the ore indicate a post-metamorphism age. This is in accord with the findings of Newhouse and Flaherty(6) who, after microscope study of polished sections of deformed ores from several mines, said, of ores from the Tyee mine: "It appears that there has been some deformation of this ore, but that it has been small" (4, p. 603).

This minor deformation could have been caused by strains set up in the ore when the post-ore faults, such as diagonal faults and the north and south faults, formed.

RELATION OF THE ORE TO SODIC ROCKS

The ore is closely related to sodic rhyolite porphyry and sodic diorite. Both rocks are found underground, but whereas the diorite is found only at a few places, the rhyolite porphyry lies immediately above and below the narrow band of folded tuffs in which the ore is found. Both rock types are older than the ore.

A further relation of the ore to sodic material may be seen in the narrow albite-barite-quartz veinlets that have been found in the ore. Although the total amount of albite in the ore is small, its presence indicates that the vein-solutions themselves were in part sodic.

It is interesting to note that sodic porphyries have been found associated with important pyritic deposits in the Rio Tinto district, Spain, most recently described by Williams(7); in Shasta county, California(8); at the Eustis mine, Quebec(8); and at Buchans, Newfoundland(9&10). Of these pyritic deposits, the copper-lead-zinc deposit at Buchans is the only one which contains barite comparable in amount to that found in the Sicker deposits.

In recent years, the close association of albite and gold has received much attention and has been discussed particularly by Gallagher(11), Reid(12), Bruce(13), and Wisser(14). Gallagher notes that "where gold is the only valuable metal, and other metallic minerals are not abundant, the genetically related rocks are commonly high in albite" (11, p. 699); but "where gold is subordinate to other metals, or where other metallic minerals are very abundant, soda feldspars are generally lacking, and not uncommonly the genetically related rocks are notably potassic" (11, p. 700).

The Sicker deposits are an exception to the second generalization for, although they contain gold in amount subordinate to other metals, and other metallic minerals in greater abundance, they are associated with rocks high in albite, and also contain some albite themselves. Gallagher does, however, list as exceptions to his generalization several "pyrite-chalcopyrite deposits, without gold, but associated genetically with magmas that give rise also to highly albitic rocks" (11, p. 728).

Although the Sicker deposits contain as much gold per ton as do some larger low-grade gold deposits, they are structurally and mineralogically comparable to those listed by Gallagher (11, p. 727-728) and may therefore be added to his list of exceptions to the generalization (11. p. 700) noted above.

ORIGIN OF THE OREBODIES

Origin of Ore Solutions

The ore is later than the intrusion of both the rhyolite porphyry and the diorites. It is improbable that the ore solutions came directly from either of these rocks, but it is probable that they originated in the same magma from which these rocks differentiated. A small area of granodiorite, one mile square, is found three miles to the northwest on mount Brenton, but larger areas lie six miles northwest of and 14 miles southeast of mount Sicker. The granodiorite is too far away to be directly related to the Mount Sicker orebodies, but probably it underlies them at no great depth and is the crystallized part of the magma responsible for both the sodic rocks and the ore solutions, themselves sodic in part.

Structural Control of the Orebodies

The localization of the orebodies has been controlled structurally by a regional fracture zone and by drag folds in the narrow band of tuffs and graphitic schists. It has not been controlled genetically by the nearby rhyolite or diorite. The fracture zone, now silicified and pyritized, is a regional feature which, though poorly defined, can be traced by isolated mineralized outcrops from mount Richards on the east past mount Sicker to mount Brenton on the west, a total distance of eight miles. The displacement along this break is unknown. The mineralization along this zone consists mainly of replacement lenses of quartz containing pyrite and small amounts of chalcopyrite and, although several mineralized outcrops along this zone were seen by the writer, barite was seen only on mount Sicker.

The mineralizing solutions responsible for the Mount Sicker orebodies probably found access from the magma chamber along this fracture zone and deposited much of their load of minerals in the drag-folded sediments. Although the fracturing probably extended upward through the overlying fine diorite, neither the physical nature of the fracturing in the diorite nor the chemical conditions in that rock were favourable to the deposition of ore. When the solutions entered the sediments, they rose up the dip and deposited their main load of minerals in the drag folds, where relatively open conditions or zones of tension prevailed. Thus were formed, first, the South orebody, and, farther upward, the North orebody, but subsequent faulting displaced the South orebody upward with respect to the North orebody, so that its upper limit is now above that of the North orebody.

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