Goldstream massive sulphide deposit

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The Goldstream deposit, located in southeastern B.C., is a stratabound high-grade copper-zinc massive sulphide body. It occurs within an extensive belt of meta-sedimentary and meta-volcanic rocks. This stratigraphy hosts several other similar, previously known occurrences. It is a new discovery made by prospecting despite the fact that the mineralization is not exposed at surface. The deposit is characterized by its simplistic geometry, continuity of mineralization, and consistent grade.

The Goldstream River, located in southeastern B.C., is one of the many large tributaries of the Columbia River system. It flows westward out of the rugged Selkirk Range of the Columbia Mountains. The deposit is located 90 km by road north of Revelstoke. It subcrops on the south side of the Goldstream River, 14 km upstream from its confluence with the Columbia. Access to the property is excellent. The first 80 km north of Revelstoke are on the paved Mica Creek Highway, from where a system of good logging roads leads up the Goldstream Valley.

The Goldstream River valley is typically U-shaped, has floor elevations of 600 m to 650 m (above sea level) and is flanked on both the north and south by mountain peaks of between 2400 m and 2700 m.

Elevations on the claims range from 600 m in the valley bottom to 1500 m. The showings occur at an elevation of 945 m where slopes are in the order of 15° to 22°, becoming more gentle towards the river.

Climate is Interior Rain Belt, with temperatures ranging between −15°C to +30°C. Annual precipitation averages 1.15 m, more than half of which falls as up to 6 m of snow. Below the 1200 m elevation the ground is often not frozen beneath the snow. Snowpack at any one time does not exceed 1.5 m.

This paper was originally presented to the 46th annual convention of the Prospectors and Developers Association.

King and the Brieds dug a series of hand pits during the summer of 1974, which revealed an increasing incidence of sulphide fragments with depth

Vegetation is typical Rain Forest, tree cover being predominantly cedar with lesser hemlock, balsam and spruce. Cottonwood grows as groves in swampy sections along the river. Most trees are mature, varying in size from 0.5 m to 2.0 m in diameter at the base and average over 30 m in height. Tree density is in the order of 75 per hectare. Large windfalls of over mature cedar are common and the underbrush is mainly prolific Devil's Club. These factors along with the slope make ground traverses unpleasant and arduous.

Reinertson

Logging has been carried on in the general area for the past 15 years, with a "clear cut" type operation being the most common method employed. Almost all the logging has been done below the 900 m elevations and approximately 40 per cent of the claim group has been logged.

Regional geology

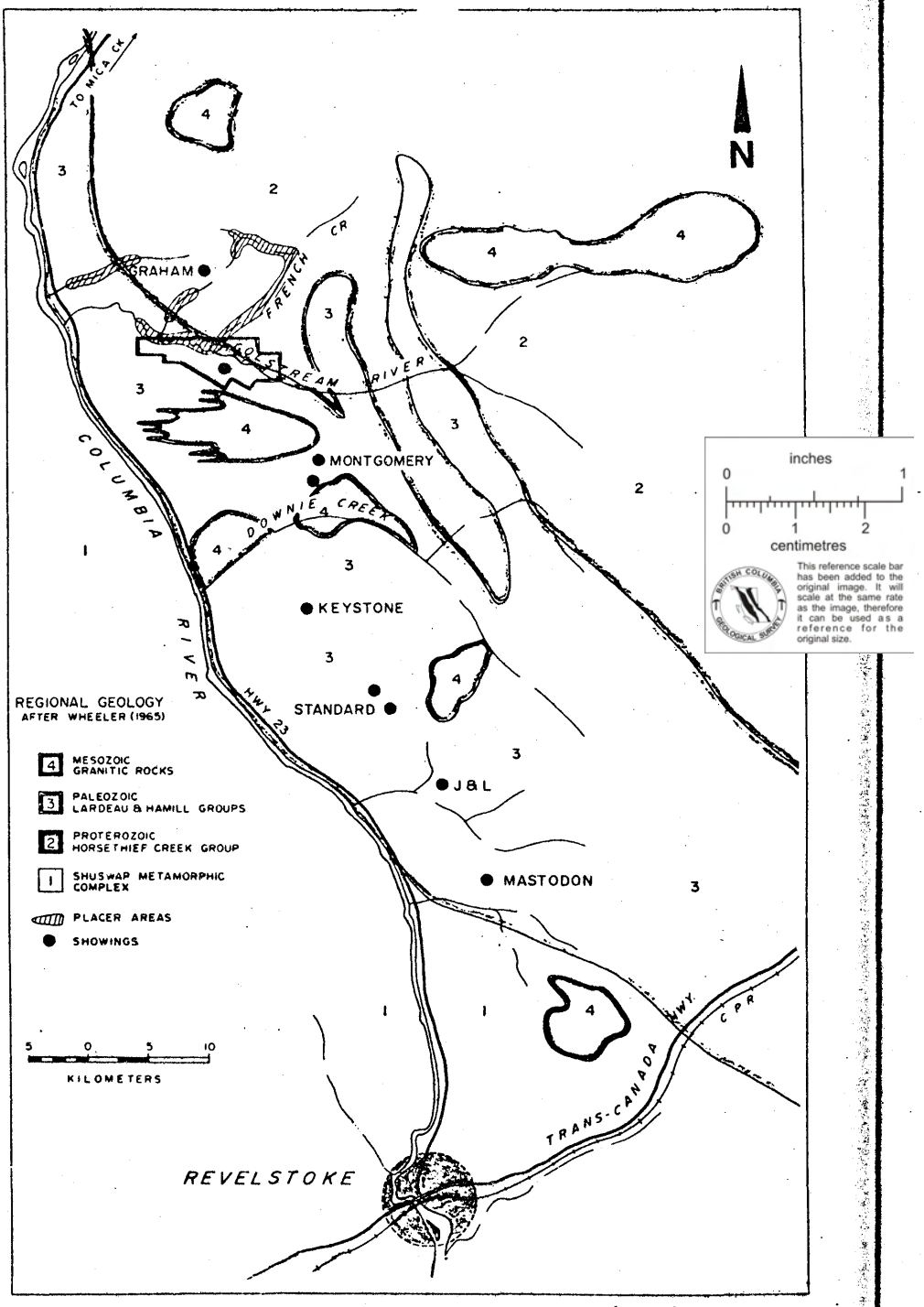
The stratigraphy hosting the Goldstream deposit and other massive sulphide occurrences consists of a package of paleozoic meta-sedimentary and meta-volcanic rocks. It is flanked on the west by the Shuswap Metamorphic Complex of uncertain age, and on the east by Proterozoic rocks. The meta-sediments consist of limestones, micaceous marbles, calcareous phyllites, graphitic phyllites, quartz-sericite phyllites and phyllitic quartzites. The meta-volcanics occur as hornblend-chlorite schist, chlorite schist, talc-

serpentine and chlorite-biotite-qu schist. The meta-volcanic units often take the form of large lenticular bodies, the thinning of which is accompanied by a corresponding thickening of the surrounding sediments. The whole package generally strikes north to northwest with gentle to moderate east to northeast dips. In the area of the Goldstream deposit, average strikes are N 70°W with 35° northeast dips.

Rugged topography, the emplacement of several Mesozoic granitic plutons, and major fold structures combine to give a complicated picture of regional geology.

Mining activity in the Goldstream area started in the 1860s when placer gold was discovered in the lower Goldstream and some of its tributaries, Camp Creek, McCullogh Creek, French Creek and Graham Creek. Several placer leases are still held on McCullogh and French Creeks, with current operations being confined to McCullogh Creek. The source of the gold is considered to be a system of gold-bearing quartz-sulphide veins that outcrop in the uppermost reaches of these creeks.

Considerable "hardrock" exploration took place from 1890 to 1930 with concerted efforts on such properties as; the Mastodon (Zn, Ag, Pb), J & L (Au, Ag, Pb, Zn), Standard (Cu, Zn), Keystone (Pb, Zn, Ag), Montgomery (Cu), and Graham (Au). Sporadic work has been done since then, primarily on or around the old properties. The only producer in the area was the Mastodon, from which 15,000 tons grading 9.5 per cent Zn, 0.2 oz Ag and 0.5 per cent Pb was mined and milled in 1960.



Regional geology of the Goldstream deposit, after Wheeler (1965)

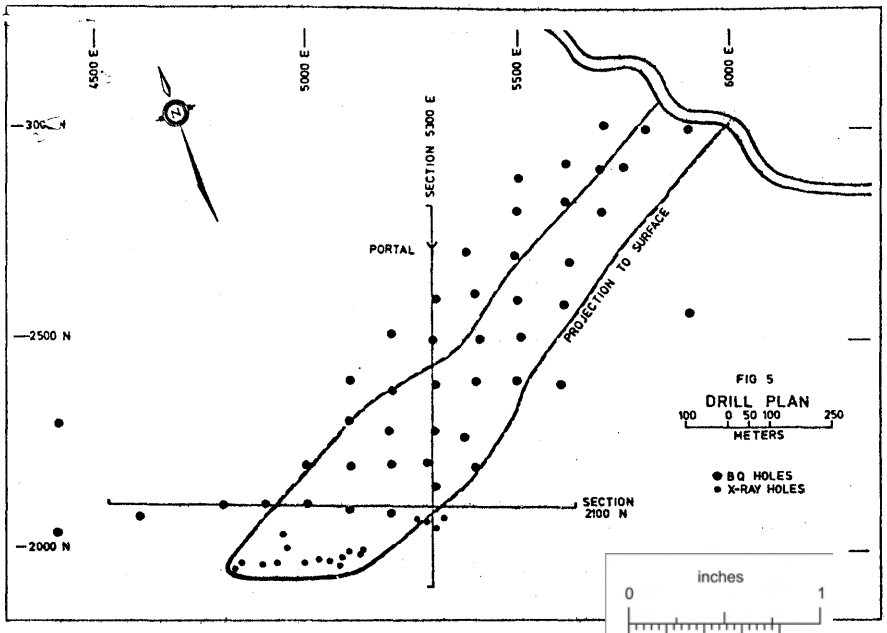
Staking begins

Angular float assaying up to 5 per cent Cu was first discovered in the Goldstream valley in glacial till overburden during logging road construction in 1972. Attempts to locate the source of this material were unsuccessful at that time.

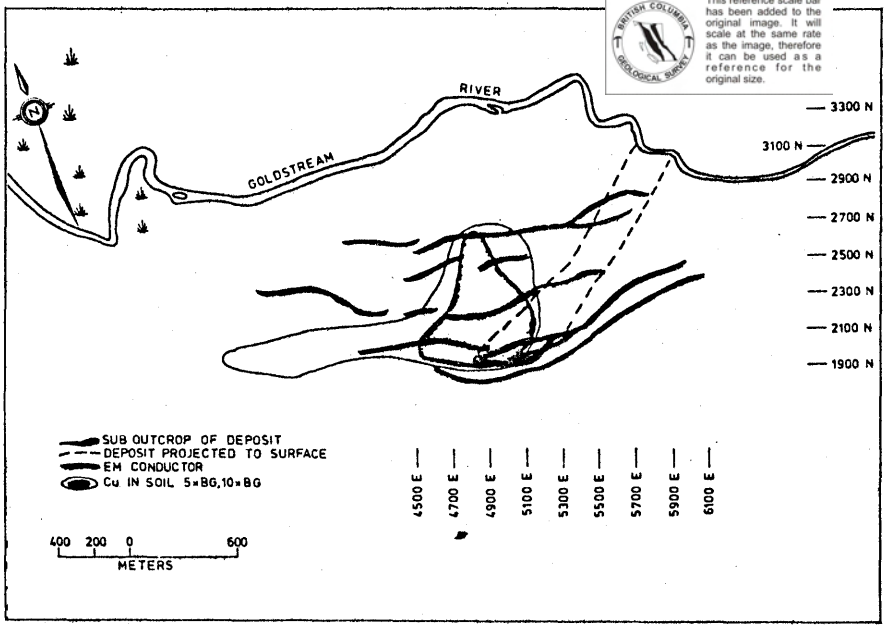
In September of 1973, Frank King of Vernon staked the first claims in the area to cover the mineralized float. At this point he brought in as partners Gordon and Bruce Bried, a father and son prospecting team from Kamloops. Because of the extensive overburden cover, further attempts to find the same material in outcrop met with little success, other than to locate more float in the immediate area. As a result, the owners drilled four x-ray holes in the hillside. These holes intersected a 3 m zone of heavy sulphides, primarily pyrrhotite, that assayed less than 1 per cent Cu. At this stage, a concerted effort was made to farm out the property. However, the owners were unable to convince any majors that additional work was warranted.

Persistent prospecting that fall located more high grade float west of, and uphill from, the original find. The onset of winter prevented any followup of this material that fall. Despite the prevailing snow conditions, the owners were back in March of 1974 to begin digging a series of hand pits in the area of the "new float". The first pit was very successful, after only a few feet it encountered a considerable amount of weathered material consisting mainly of malachite, azurite and limonite. More pitting in the same area gave encouraging results, revealing that the incidence of fresh sulphide fragments in the overburden increased with depth. It is probable that some of these pits actually reached bedrock, but this was difficult to ascertain due to excessive mud and water in the bottoms of the pits.

The next step was to set up the x-ray drill next to the first pit. This hole encountered 3.3 m of overburden, 2 m of weakly mineralized quartz-sericite phyllite, and 4.25 m of massive sulphide that assayed 3.8 per cent Cu. A second hole, 60 m west of No. 1, was better yet, assaying 3.4 per cent Cu over 6.7 m, including 3 m of 7.7 per cent Cu. Step out drilling was done in



Drill plan of the Goldstream deposit



Geophysical and geochemical surveys were carried out in conjunction with the drill plan

both east and west directions until 14 good intersections had been obtained over a length of 300 m. This indicated a zone striking N 70° and dipping approximately 40° NE with an average grade and thickness of 4.4 per cent Cu over 4.1 m. Seven additional holes were unsuccessful, due mainly to overburden problems and the inability of the x-ray to drill deep enough to intersect the zone further down the dip. This pitting and drilling effectively used up the 1974 field season and no further work was done that year.

Noranda takes over

Noranda had been following the 1974 work with considerable interest and although it had expressed a desire to do so, was unable to make an agreement with the owners while the work was in progress. Negotiation of an option was completed that fall and Noranda took over on Dec 31, 1974.

The 1975 program was started in April, as soon as the access roads had been snowplowed and a camp moved in. A transit survey was initiated immediately in order to establish a coordinate and elevation system and to survey the x-ray holes. The latter was necessary to confirm the strike and dip of the mineralized horizon, particularly because no bedrock exposures had been located within at least 1 km.

BQ drilling started in late May and by the time four holes were drilled it had been determined that the deposit had a NE rake. Drilling on a 100 m grid continued non-stop until mid-November, which time 8912 m had been drilled in 50 holes. This outlined a deposit of 3.175 million metric tons grading 4.49 per cent Cu, 3.24 per cent Zn and 20 g/t Ag. The deposit varies in thickness from 3 m to 6 m, in width from 150 m to 250 m, and it has been followed down-dip from 1500 m. At this point it is 300 m below the Goldstream River.

In conjunction with the drilling program, 65 km of grid lines were established. These were used for soil sampling, proton magnetometer and two types of EM survey. A gravity survey was conducted over a portion of the grid at a later date. As can be seen on the compilation map, the presence of the deposit is readily indicated by the copper in the soil geochemistry, while the geophysical data shows a conductor that is somewhat more extensive. The results of the mag survey were inconclusive.

Portal collared

The soil anomaly reveals westerly dispersement following the glacial train of mineralized float, and down-slope dispersement as a result of ground water movement. In both cases anomalous values range from five to 20 times background, with the down-slope anomaly being the more prolific.

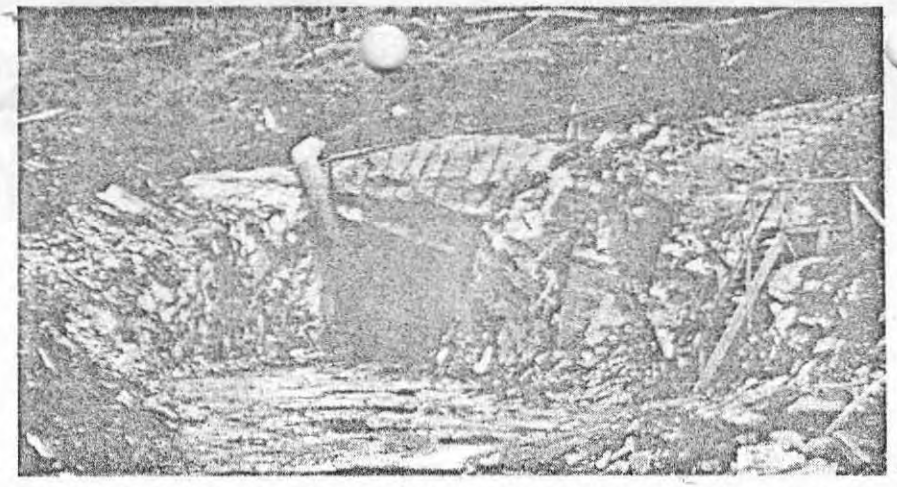
The following year, 1976, a portal was collared at the 700 m elevation on section 5300E. A 3 m by 4.5 m adit was driven grid south for 1300 m at which point it intersected the mineralized zone. The mineralization was drifted on east and west for a total length of 330 m. East and west hangingwall drifts were also driven to facilitate detailed diamond drilling from underground. The purpose of the underground program was to test the continuity of the mineralization between surface drill holes, to obtain bulk samples for metallurgical testing, and to obtain a good indication of ground conditions for use in consideration of possible mining methods.

As well, a legal claim survey which had been started in 1975 was completed in 1976 and application made for a mineral lease.

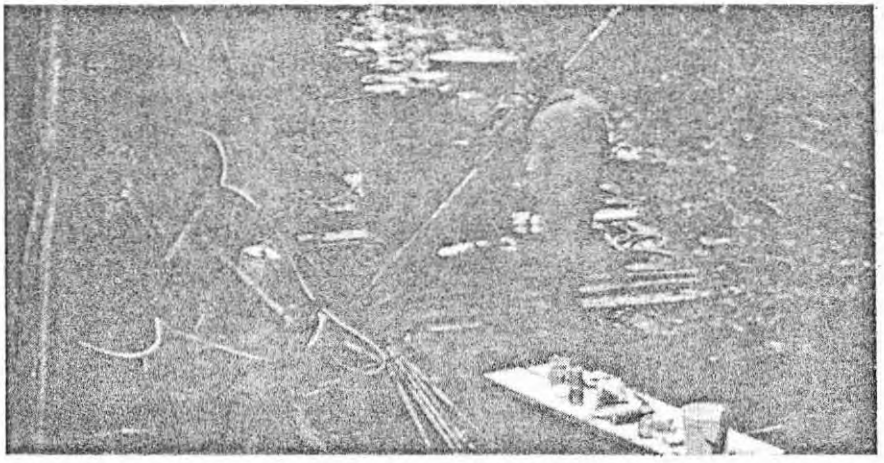
The 1977 program consisted of engineering and design, power studies, and overburden drilling of plant and dam sites.

Property geology

Starting at the collars of the drill holes is Unit 1. This is a 220 m thick calcareous pelitic phyllite referred to as the "Dark Banded Phyllite" (DBP). It is distinctly laminated with individual lamina of grey limestone, white quartz, black hornblende and brown biotite. It



An adit driven during 1976 encountered the mineralized zone 1,300 m into the hillside. Drifts were driven into the mineralized zone, and into the hangingwall, for detailed diamond drilling



The x-ray drill obtained 14 good intersections over a length of 300 m, east and west, indicating a zone grading 4.4 per cent Cu over a thickness of 4.1 m

varies in color from dark grey through dark brown to black, depending on the relative amounts of various lamina constituents. Narrow graphitic zones are common and pyrrhotite is often associated with the amphibole laminations. Quartz often occurs as small boudin structures which appear as layers in the core unless a truncated end is evident.

At the bottom of Unit 1 is what is called the "Garnet Zone". This is a highly contorted, graphitic, foliated, amphibolite containing porphyroblasts of pale orange to buff garnets. This unit varies in thickness from 1 m to 15 m and is occasionally brecciated with white calcite matrix. Sulphide mineralization is common in the garnet zone and may consist of up to 20 per cent pyrrhotite and 2 per cent pyrite. This occurs as irregular bands paralleling the amphibolite laminations.

Unit 3 is considered to be the host rock and is a quartz-sericite-chlorite-biotite phyllite. It varies in color from pale green to brownish green as the quartz content decreases and the biotite content increases. Pyrrhotite, chalcopyrite and sphalerite, where not massive, may comprise up to 25 per cent of the unit and occur as disseminated trains along foliations or thin bands paralleling foliations. Narrow bands of unit 1 are occasionally intercalated with Unit 3 where they may also be mineralized.

Unit 3 is underlain by a light grey crystaline limestone with an average thickness of 15 m. This is followed by a considerable thickness of Unit 6 which is a quartz-chlorite-biotite phyllite containing minor narrow bands of Units 1 and 5.

The massive sulphide zone (Unit 4) occurs within Unit 3 as a continuous layer varying in thickness from 3 m to 6 m. It consists of a medium to coarse grained mixture of pyrrhotite, chalcopyrite, and sphalerite in the relative ratio of 5:3:1. Inclusions of various types may comprise up to 30 per cent of the massive zone. Some of these are eyes of clear glassy quartz, generally less than 2 cm in diameter, eyes of white quartz up to 20 cm in diameter and containing irregular blebs of sulphides, biotite-chlorite-sulphide assemblage, and coarse grained sphalerite-rich sulphides.

Contact well defined

The only definition zoning pattern recognized to date is in the (Zn) to (Zn + Cu) ratio (Hoy and Nelson, 1977). This shows a very well defined lateral zoning with an increase in the relative Zn content to the east as well as in both hangingwall and footwall.

The contacts of the massive sulphide and the mineralized Unit 3 are very sharp and well defined.

In summary, there are a few points that I would like to make along a general exploration theme. The Goldstream deposit is a "new find". Its discovery can be attributed to only one facet of exploration, that being systematic prospecting with extra measures of determination and persistence. Significant contributions were undoubtedly made by the various aspects of incentive and motivation.

The deposit was discovered in an area where several similar occurrences have been known for over 75 years. In at least two of these it was neither the extent nor the continuity of the mineralized horizon that deemed them unattractive. Rather, it was either the grade or thickness that was the negative factor. Because of all the previous work related to these occurrences, the area was generally considered to have been well prospected and, as such, was regarded to be an unfavorable exploration area. **CMJ**

Goldstream (82M/9W) 82M141

(1) GCNL March 20, 1979 - 4,000,000 tons averaging 3.6% copper, and 2.6% zinc.

(2) GCNL June 24, 1976 - 3 million tons averaging 4.4% copper, 3.2% zinc, and 0.6 oz. of silver per ton.

(3) GCNL March 18, 1976 - 3,175,000 metric tons grading 4.49% copper, 3.24% zinc, and 0.68 oz. silver per ton.

(4) Clipping March 2, 1976 - 3,175,000 metric tons of ore assaying 4.49% copper, 3.24% zinc and 0.68 oz of silver a ton.

Valley Copper (92I/6E) 92ISW012

(1) GCNL May 13, 1976 - 800,000,000 tons grading 0.50% copper.

Morrison (93M/01W)

no reserves figures in either file.

Sam Goosly (Placer) (93L/1W) 93L001

(1) W. Miner June, 1979 - 28 million tonnes, averaging 106.3 grams/tonne of silver, 0.96 grams gold, 0.38% copper and 0.08% antimony with a stripping ratio of 2.21.

(2) W. Miner April, 1979 - 30,800,000 tons with an average grade ton of 3.10 oz. silver, 0.384% copper and 0.028% gold.

(3) GCNL March 6, 1979 - 27,970,000 metric tonnes (30,800,000 tons) with average grade per tonne of 106.3 grams (3.10 oz/ton) silver, 0.384% copper, and 0.960 grams (0.028 oz/ton gold.

(4) GCNL December 4, 1978 - 19,000,000 metric tons grading 125 gm of silver per ton (3.64 troy ounces per short ton), 0.44% copper and 1.1 grams of gold per ton (0.032 troy ounce per short ton). Equity has estimated geological reserves of Sam Goosly property at 39,000,000 metric tons grading 97 grams of silver per ton, (2.83 troy ounces per short ton), 0.33% copper and 0.87 grams of gold per ton (0.025 troy ounce per short ton).

(5) N. Miner April 27, 1978 - 43.5 million tons aveaging 1.78 ozs. silver, 0.33% copper and 0.026 oz. gold per ton.

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STRATABOUND BASE METAL DEPOSITS IN SOUTHEASTERN BRITISH COLUMBIA

TRIP 11

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GEOLOGICAL FRAMEWORK
T. Høy

INTRODUCTION

The excursion will visit and examine three major stratabound base metal deposits in southeastern British Columbia. These include Goldstream, a massive copper-zinc sulphide layer in metasedimentary rocks of probable lower Paleozoic age; Reeves MacDonald, a lead-zinc deposit in highly deformed lower Cambrian dolomite in the southern Kootenay Arc; and Sullivan, a lead-zinc deposit in Belt-Purcell rocks in the Purcell Anticlinorium in southeastern British Columbia. The Sullivan (Cominco Ltd.) is presently in production, Goldstream (Noranda Mines Ltd.) was in production in 1983 and 1984, and Reeves-MacDonald ended production in 1977, after having produced 5.8 million tonnes of ore containing 0.98% lead, 3.42% zinc, and 3.4 grams silver per tonne.

This guide draws heavily on previously published material, in particular the GAC/MAC/CGU (1983) field guide "Stratabound base metal deposits in southeastern British Columbia and northwestern Montana" (Høy, et al., 1983).

TECTONIC AND STRUCTURAL SETTING

Southeastern British Columbia comprises a number of distinct physiographic belts, each with a unique structural style and characteristic stratigraphic succession (Wheeler et al., 1972). The most eastern, the Rocky Mountain Belt (Fig. 1). includes dominantly miogeoclinal rocks that were deposited on the western cratonic edge of North America from mid Proterozoic to Mesozoic time, and displaced eastward during the Mesozoic and Tertiary. To the west, the Omineca Crystalline Belt comprises highly deformed and locally highly metamorphosed Proterozoic and Paleozoic miogeoclinal rocks and younger volcanic and pelitic rocks; they are intruded by Mesozoic age granitic rocks.

The Goldstream area, along the western margin of the Rocky Mountain Belt, is underlain by a deformed sequence of Proterozoic and lower Paleozoic metasedimentary and basic metavolcanic rocks. It is on trend with the Kootenay Arc, a north-trending arcuate belt of folded and thrust faulted Hadrynian through early Mesozoic strata. The Badshot Formation (locally called the Reeves member of the Laib Formation) is a shallow water carbonate of Lower Cambrian age; it hosts a number of highly deformed lead-zinc deposits in the Kootenay Arc: the Reeves MacDonald and other deposits in the Salmo area just north of the U.S. border, the Bluebell deposit on the shore of Kootenay Lake, and the Wigwam deposit just south of Revelstoke (Fig. 1). East of Kootenay Arc is the Purcell Anticlinorium, a broad generally north-plunging structure in Proterozoic rocks. The Sullivan deposit occurs along the eastern edge of the Purcell Anticlinorium in Helikian-age turbidites of the Purcell Supergroup. Troy (Spar Lake) is a copper-silver deposit in younger fluvial and lacustrine sedimentary rocks of the Belt Supergroup, the equivalent of the Purcell Supergroup in the United States. West of Kootenay Arc is the Shuswap Metamorphic Complex; it is separated from the Goldstream area and the Kootenay Arc by an east-dipping normal fault zone called the Columbia River fault (Read and Brown, 1981; Lane, 1984). Along the eastern edge of the Shuswap Complex are domal structures with cores (Fig. 1) of highly deformed and metamorphosed ortho and paragneiss; the core rocks are Aphebian (Wanless and Reesor, 1975; Duncan, 1978; R.L. Armstrong, pers. comm., 1981). The core gneisses are overlain unconformably by a shallow water quartzite, marble, and paragneiss; this succession hosts a number of large stratabound lead-zinc deposits, including Ruddock Creek, Cottonbelt, Jordan River, and Big Ledge (Fyles, 1970a; Høy, 1982b).

DAY 1: GOLDSTREAM DEPOSIT
T. Høy, N. Berg (from Høy et al., 1981)

On the morning of Day 1 the excursion follows Highway 23 northward to Goldstream River then east along the south side of Goldstream River to the Goldstream deposit. Just north of Revelstoke we pass the B.C.

Hydro Revelstoke dam. The Columbia River on the west side of Highway 23 follows closely the trace of the Columbia River fault. West of the fault are metamorphic rocks of the Shuswap Complex and on the east side are the deformed lower Paleozoic rocks of the Selkirk terrane.

On the afternoon of Day 1 the excursion returns to Revelstoke, then follows Highways 23 and 91 south to New Denver, generally following the southerly trend of the Kootenay Arc.

INTRODUCTION

The Goldstream deposit is a stratabound massive sulphide layer in metasedimentary rocks of probable early Paleozoic age. It is located at an elevation of 700 m just south of Goldstream River in the Selkirk Mountains in southeastern British Columbia. The deposit is accessible by road from Revelstoke, approximately 100 km to the south.

The Selkirk Mountains in the vicinity of the deposit are rugged and exploration and geological mapping are difficult. Valleys are filled with till and covered with thick underbrush and rock exposures are rare. Above treeline, at 1800 to 1950 m elevation, exposures are abundant although precipitous cliffs, neve, and glaciers hamper exploration and geological mapping.

Mineral exploration in the Goldstream area dates back to 1865 with the discovery of placer gold on Carnes and French Creeks. In 1866 the town of Kirbyville was founded near the mouth of the Goldstream River and by the end of that season it is estimated that there were between 8000 and 10,000 people in the region (Gunning, 1928). Interest in lode mining increased in the late 1800's resulting in renewed exploration in the Goldstream area and discovery in 1895 of Montgomery, Standard, and Keystone, copper-zinc deposits in metasedimentary and basic volcanic rocks south of Goldstream.

The Goldstream deposit was located in 1973 by Gordon and Bruce Bried and Frank E. King. Noranda Exploration Company, Limited optioned the property in December, 1974 and in 1975 drilled 50 holes outlining a deposit with reserves of 3.175 million tonnes grading 4.49% copper, 3.12% zinc, and 20 grams silver per tonne. In 1976 an adit was driven south to the mineralized zone, and an east-west drift developed along the zone. Continued feasibility studies resulted in a decision by Noranda to bring the property into production in 1983. Due to depressed metal prices, the mine was closed in April, 1984, after mining 447,280 tonnes of ore that contained 3.41% Cu and 2.2% Zn.

REGIONAL GEOLOGY

The Goldstream area is within the Big Bend map sheet of Wheeler (1965). The geology of the area has been described by Lane (1977); Gibson, Hughes, and Bradish (1977); and Høy (1979a). The information in this paper is largely summarized from Høy (1979a) and Høy et al. (1974).

The Goldstream area is underlain by dominantly miogeoclinal rocks that were deposited along the western margin of cratonic North America in late Proterozoic to early Paleozoic time (Wheeler et al., 1972). These rocks were deformed in Jurassic time, and intruded by granitic rocks of probable Cretaceous age.

The regional structure of the Selkirk Mountains is dominated by a northwest-trending anticlinal fan structure called the Selkirk fan structure (Wheeler, 1963, 1965). Northeast of the fan axis, regional foliation and axial surfaces of overturned folds dip southwest, whereas southwest of the axis, structures dip to the northeast (Wheeler, 1963, 1965). For a discussion on the nature and evolution of the Selkirk fan structure, refer to Brown and Tippett (1978a, 1978b) and Price (1978).

The Goldstream area, southwest of the Selkirk fan axis, is dominated by tight to isoclinal north-trending folds with nearly horizontal to steeply east-dipping axial surfaces (Lane, 1977; Høy, 1979a). The grade of regional metamorphism ranges from greenschist facies in the south to lower amphibolite facies in the region of the Goldstream pluton in the north.

STRATIGRAPHY

Metasedimentary and metavolcanic rocks comprise five major lithologic packages (Høy, 1979a). The stratigraphically lowest consists of dominantly pelitic and calcareous schists and marble exposed east of the Goldstream deposit (Fig. 2) that are correlated tentatively with the late Proterozoic Horsethief Creek Group (Brown et al., 1977). They are overlain by a succession of rocks that consists of four main divisions (Fig. 3):

(1) dominantly pelitic phyllite and quartzite of the lower 'quartzite-schist' division;

(2) dominantly calcareous rocks of the 'calc-silicate gneiss' division;

(3) greenstone, amphibolite, dark calcareous phyllite, and carbonate of the 'metavolcanic-phyllite' division (host to deposits);

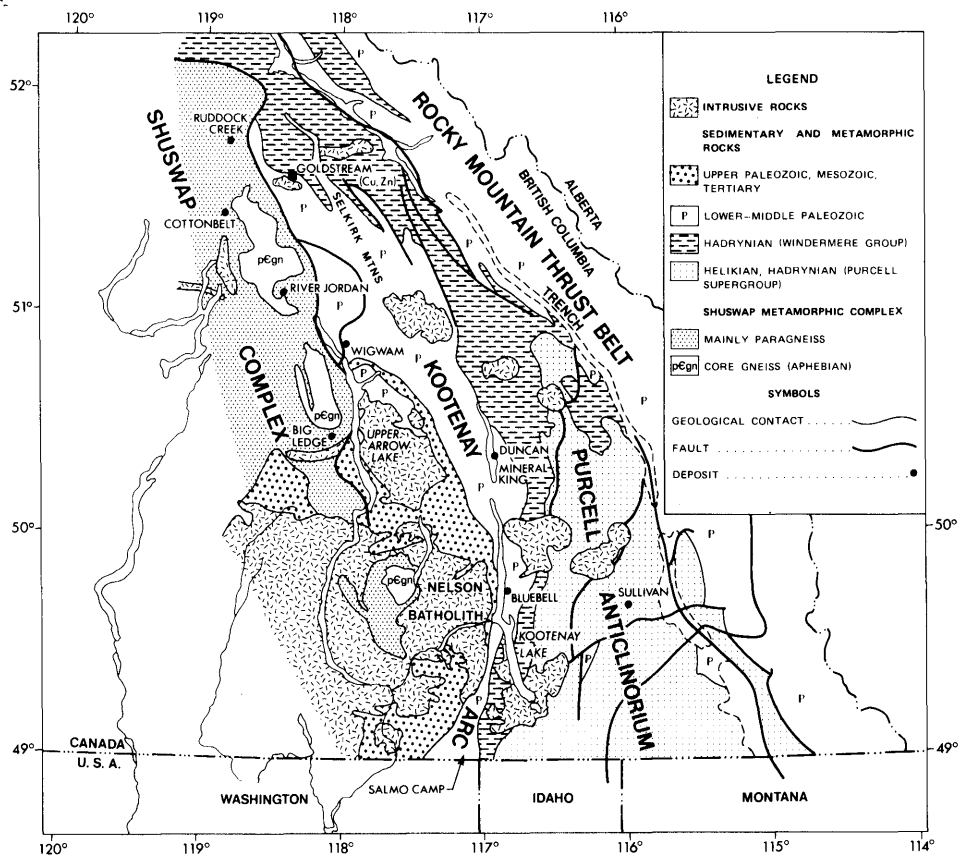
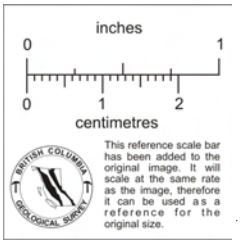


Figure 1. Regional map of southeastern British Columbia showing main tectonic belts and stratabound lead-zinc deposits and the Goldstream deposit.



(4) limestone, dolomite, marble, calcareous phyllite, and micaceous phyllite of the upper 'carbonate-phyllite' division.

A number of stratigraphic tops recognized in the Goldstream area (Lane, 1977; Høy, 1979a) suggest that the sequence of rock units outlined above is an original stratigraphic succession. Rocks correlated with the Horsethief Creek Group are apparently the oldest, and the dominantly calcareous rocks of the carbonate-phyllite division, the youngest.

Metasedimentary rocks of the quartzite-schist division comprise at least several thousand metres of interlayered pelitic schist and micaceous quartzite, massive thick-bedded pure to micaceous quartzite, and subordinate rusty-weathering hornblende gneiss and calcareous phyllite.

Thin-bedded, rusty-weathering calcareous phyllite and quartzite, pure to siliceous marble, and biotite gneiss that comprise the calc-silicate gneiss division overlie rocks of the quartzite-schist division. These gneisses are exposed along the southern margin of the Goldstream pluton and are probably contact metamorphic equivalents of calcareous rocks in the lower part of the metavolcanic-phyllite division.

The metavolcanic-phyllite division consists of massive greenstone units, chlorite phyllite, ultramafic pods, and dark calcareous to pelitic schist. Copper-zinc occurrences and deposits, including Goldstream, are within these metasedimentary and metavolcanic rocks. The most prominent metavolcanic unit is a massive, fine- to medium-grained greenstone that is composed of chlorite, actinolite, epidote, plagioclase, and minor amounts of carbonate. These metavolcanics are predominantly calc-alkaline basalts (Høy et al., 1984). The greenstone is intercalated with chlorite phyllite, dark calcareous to pelitic schist and, east of Keystone, with greenstone that has deformed but well-developed pillow structures. The massive greenstone is generally not at a discrete stratigraphic horizon; rather it is a series of lenses that thin and thicken along strike and commonly grade laterally and vertically to chloritic phyllite that may originally have been basic pyroclastic or volcaniclastic rocks. In the Standard area coarse-grained ultramafic pods (now altered to a chlorite-serpentine-dolomite assemblage) underlie massive greenstone and associated coarse grained intrusive diorite and are overlain by grey limestone and calcareous and carbonaceous phyllite. The phyllite is medium to dark grey and commonly is interlayered with thin grey limestone lenses or chloritic phyllite layers. It is a common unit in the metavolcanic-phyllite

division and is the dominant unit in the structural hanging wall of the Goldstream deposit.

Dolomite, limestone, and calcareous phyllite of the carbonate-phyllite division overlie rocks of the metavolcanic-phyllite division. The carbonates are typically thin-bedded limestone or dolomite interlayered with rusty-weathering calcareous schist, biotite schist, and less commonly, chlorite schist.

DEPOSITIONAL ENVIRONMENT

The Goldstream area (Fig. 2) is near the western limit of exposed miogeosynclinal rocks in the northern Selkirk Mountains. The change from deposition of clean, massive terrigenous quartzites with interbeds of pelitic shales to thin-bedded, impure carbonates and dark carbonaceous and calcareous shales probably indicates deepening water conditions; rocks of the quartzite-schist division are more typical of a platform or shelf environment whereas the younger rocks indicate deposition in a restricted basinal environment. Infilling of the basin by dark calcareous shales and coarser clastics was interrupted periodically by basic volcanism in the form of thick massive flows, pillow basalts, and tuffaceous rocks (now preserved as the chloritic phyllites).

An estimated 300 m of massive and pillowed greenstones occur in the Keystone area (Fig. 2). They appear to thin to the north, towards the Goldstream deposit area where they comprise a series of thin (100 m) flows separated by several hundred metres of clastic and carbonate rocks. In the Standard area to the south (Fig. 2) a larger proportion of metasedimentary rocks are also present, and, as well, the proportion of chloritic phyllite appears to increase southward at the expense of the more massive greenstone in the Keystone area.

Our depositional model suggests development of a restricted basin near the western edge of the Cordilleran miogeocline. The voluminous extrusion of basaltic magma may indicate that faulting played an important part in the development of the basin. These features are compatible with the general sedimentological and tectonic environment of 'Kieslager' or 'Besshi deposits' (Hutchinson, 1980) which are associated with thick accumulations of greywacke and basalt and formed in unstable subsiding sedimentary basins near the continental margin.

REGIONAL CORRELATIONS AND AGE

Correlation of rocks in the Goldstream area is based on gross lithologic similarities with established stratigraphic successions in the Kootenay Arc to the south and

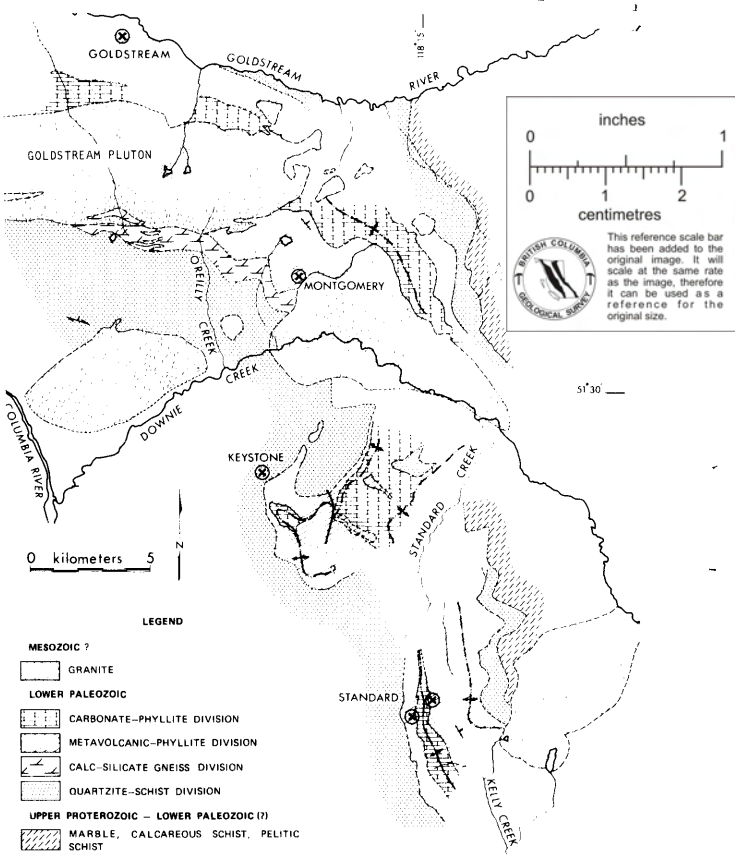


Figure 2. Geological map of the Goldstream area. Goldstream, Montgomery and Standard are copper-zinc deposits; Keystone is a lead-zinc-copper vein deposit. (from Høy et al., 1984).

the Selkirk terrane to the east, and with lead isotope data on Goldstream deposit. The succession along the eastern edge of the map area is right-way-up and has been correlated with a more calcareous western facies of the upper part of the Proterozoic Horsethief Creek Group (Brown et al., 1977 and 1978). Rocks south of the Goldstream River (Fig. 2), host rocks for the Goldstream, Standard, and Montgomery deposits, comprise a highly deformed inverted miogeoclinal stratigraphic panel that may correlate with the Eocambrian Hamill Group and overlying Mohican Formation, but more likely correlates with the lower to middle Paleozoic Lardeau Group as suggested by Wheeler (1965) and Brown et al. (1983). Galena-lead isotope data from Duncan (1982) and R.I. Thorpe (pers. comm., 1983) have been interpreted by C.I. Godwin (pers. comm., 1983), using the 'shale' growth of Godwin and Sinclair (1982) to indicate a probable Devonian age for the Goldstream deposit (see Høy et al., 1984).

Based on these isotopic data, and the recent correlation of the Standard succession with the lower Paleozoic Index Formation (Brown et al., op. cit.), we concur with a lower to middle Paleozoic age

for Goldstream, Standard, and Montgomery, and for the host succession.

STRUCTURE

Large tight to isoclinal east-dipping to recumbent Phase 2 folds dominate the structure of the Goldstream area. They have well-developed axial plane schistosities and variable, but generally northwest-trending fold axes. A number of graded grit beds throughout the Goldstream area indicate that these Phase 2 folds developed in a large inverted stratigraphic panel (Lane, 1977; Brown et al., 1977; Høy, 1979a; Read and Brown, 1979), perhaps the underlimb of an earlier (Phase 1) recumbent nappe. Minor structures that can be related to Phase 1 deformation are not obvious; it is difficult to assess whether many rootless, isoclinal fold hinges formed during Phase 1 or Phase 2.

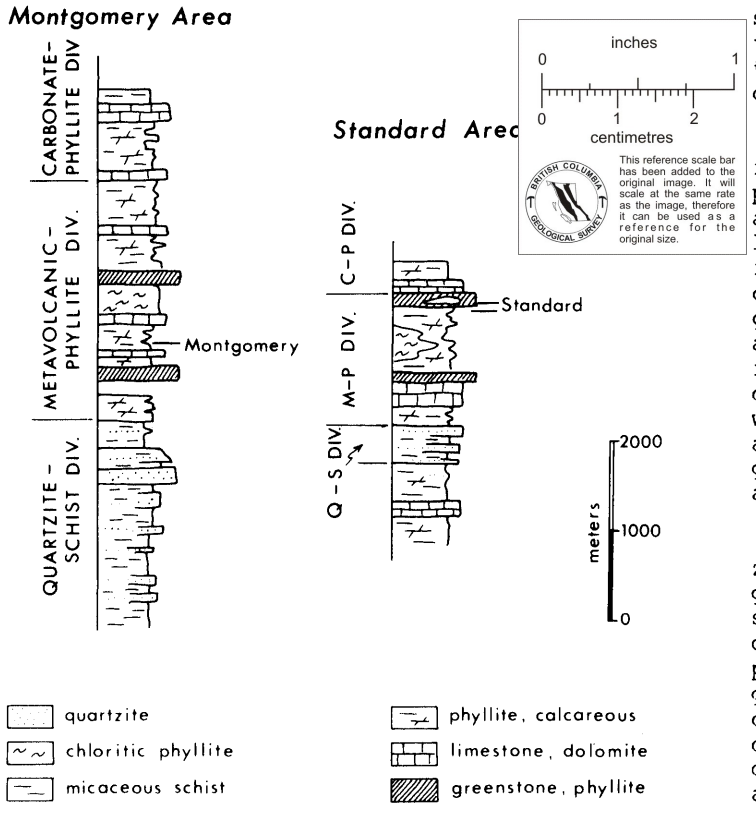


Figure 3. Composite stratigraphic successions in the vicinity of the Montgomery and Standard deposits.

Late small-scale chevron and kink folds, crenulation cleavage, and small open folds in more competent units are superimposed on earlier structures. They are common in the adit of the Goldstream deposit.

GOLDSTREAM DEPOSIT

INTRODUCTION

The Goldstream deposit is a thin conformable sheet of massive sulphides in sericitic quartzite and calcareous and chloritic phyllite. It outcrops on the steep, heavily wooded southern slopes of Goldstream Valley and plunges to the northeast beneath Goldstream River. Structures observed underground include a pronounced mineral foliation, crenulation cleavage, small-scale late folds and brecciation, quartz-carbonate veining, and fault gouge in the hanging wall phyllite.

ROCK UNITS

The Goldstream deposit is within the metavolcanic-phyllite division. Regional structures suggest the succession, illustrated on Figures 4 and 5, is inverted, with the oldest rocks in the hanging wall of the deposit.

Unit 1 (above rocks shown on Fig. 4) includes siliceous chlorite-biotite phyllite, phyllitic quartzite, calcareous and graphitic phyllite,and a few impure limestone layers. Unit 2 includes approximately 220 m of dark carbonaceous and calcareous phyllite interlayered with thin grey limestone layers. Calcite and biotite are common within the unit, and pyrrhotite is ubiquitous. The alignment of sericite, chlorite, and graphite (?) grains produces a well-defined foliation and augen of quartz and carbonate and abundant limy partings give this rock a distinctive layered appearance.

Unit 3, informally called the 'garnet zone', is generally medium to dark green or grey in colour and locally contains abundant spessartine garnets. It includes thin dark chert layers, medium green chloritic phyllite layers, and dark grey to black, greasy-lustered chlorite-rich graphitic and calcareous quartzite layers. Pyrrhotite, concentrated in thin irregular laminations or in discontinuous streaks, is very abundant locally, and grunerite occurs in some dark siliceous layers. Chemical analyses of unit 3 indicate high manganese and iron content but only traces of copper and zinc (Høy et al., 1984). A pronounced fault zone coincides, in part, with unit 3, and rocks in many places are sheared and broken and cut by numerous quartz-carbonate veins. The garnets predate this deformation and predate or are synkinematic with the early stages of Phase 2 deformation that produced the prominent mineral foliation in the metasedimentary rocks. This early foliation is bent and warped around the garnet porphyroblasts.

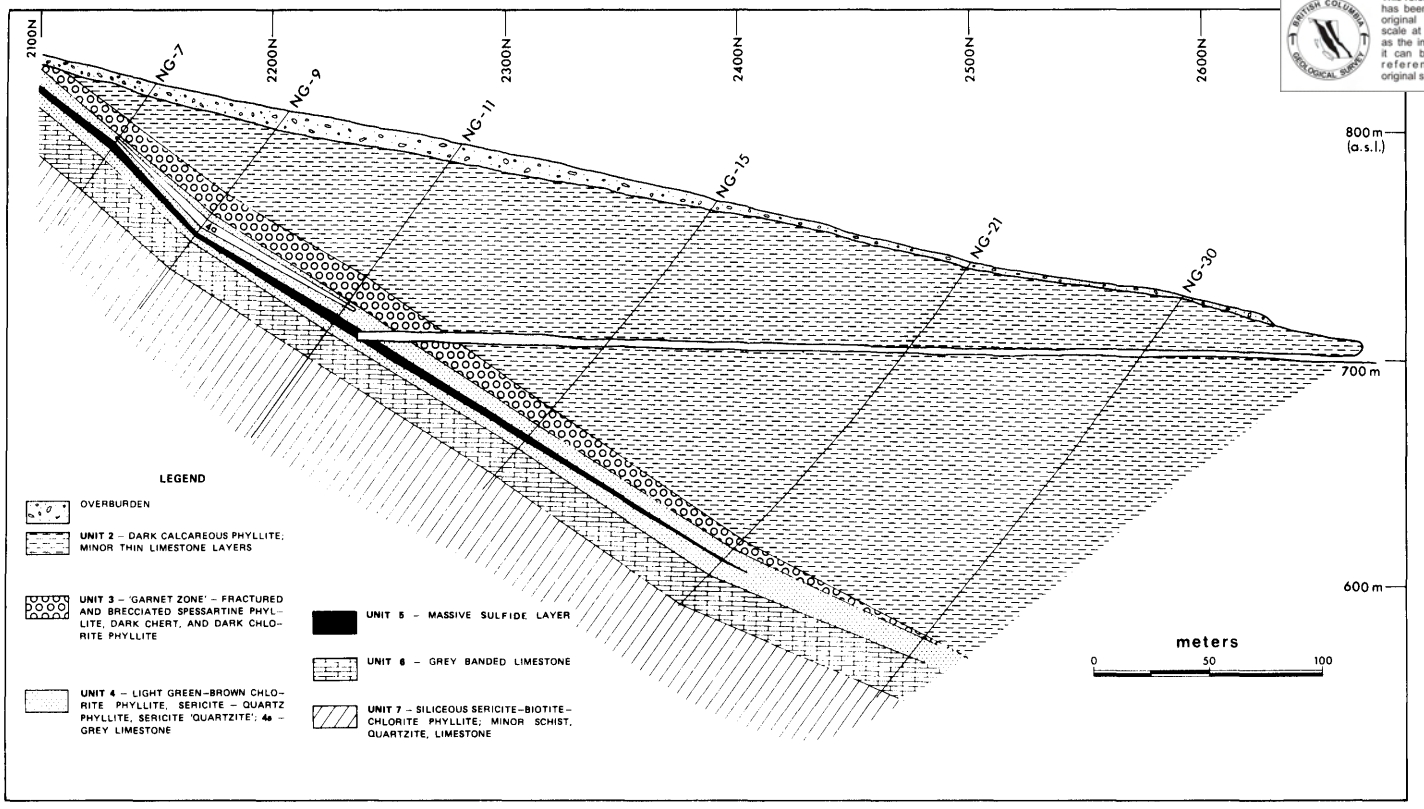


Figure 4. A north-south vertical section (5300E) through the Goldstream deposit, viewed from the east.

The garnet-rich layer is interpreted to be a metamorphosed manganiferous, iron-rich chert. It is areally restricted and terminates to the west away from the massive sulphide layer (Fig. 5). It is probably an exhalite unit.

The massive sulphide layer is enclosed in an envelope of light green to brown, very siliceous chlorite and sericite phyllite (unit 4) that grades to fine grained sericite-chlorite quartzite. Although unit 4 may, in part, represent epiclastic accumulations, it may also include a siliceous exhalative component. A grey limestone layer, 1 to 2 m thick, occurs above the sulphide layer within unit 4. Within the unit pyrrhotite, chalcopyrite, and minor sphalerite increase substantially just above the sulphide layer.

A light grey limestone (unit 6), averaging 10 to 20 m in thickness, occurs structurally below unit 4. The limestone is underlain by interlayered siliceous sericite -biotite-chlorite phyllite, schist, minor quartzite, and limestone of unit 7.

Greenstone was encountered in three drill holes west of the deposit (Fig. 5). A thin grey limestone lying above the greenstone is tentatively correlated with the footwall limestone (unit 6) suggesting that the greenstone lies structurally below the ore horizon. However, it is possible that the grey limestone correlates with the limestone in unit 4 and therefore, the greenstone would be at approximately the same stratigraphic level as the massive sulphide layer. The greenstone varies from fine grained, massive varieties to chloritic phyllite. It is very altered and composed dominantly of actinolite, chlorite, epidote and albite. Although the greenstone has not been analysed, it is correlated with the predominantly subalkaline basalts of the metavolcanic division in the Keystone and Standard areas to the south (Fig. 2).

STRUCTURE

The most conspicuous structures in the deposit are late folds and faults. These are related to Phase 3 deformation as they deform both layering and the most obvious Phase 2 structures, a penetrative mineral foliation. Phase 1 structures were not recognized underground but an earlier deformation is inferred from regional considerations as Phase 2 structures throughout the Goldstream area are developed in an inverted stratigraphic panel. Phase 3 folds are generally fairly open with rounded hinge zones. Their trends vary from east-west to northeast and their fold axes,

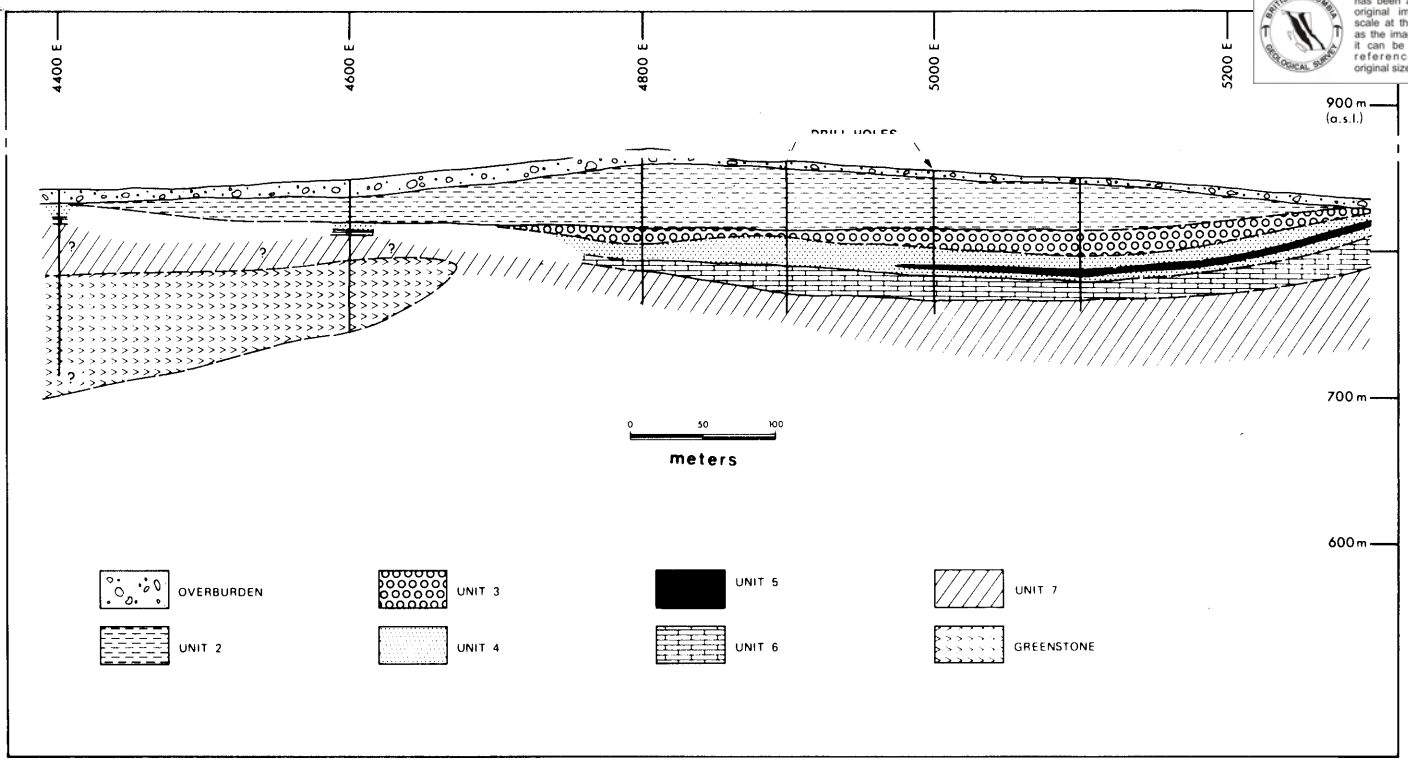


Figure 5. An east-west vertical section (2100N) through the Goldstream deposit, looking north (see Fig. 4 for lithologies).

although variable, generally plunge to the east-northeast. Phase 3 structures verge toward the south; that is, they indicate reverse strain in north-dipping surfaces with structurally higher rocks overriding footwall rocks.

Numerous zones of fault gouge and pronounced shearing in the dark phyllites overlying the deposit appear to be related to the Phase 3 deformation. Abundant breccias, quartz-carbonate veins, numerous Phase 3 minor folds, and a substantial increase in the intensity of crenulation cleavage are associated with these faults. A wide zone of shearing and brecciation is concentrated in the garnet zone above the sulphide layer. The vergence of associated minor folds and numerous slickensides indicate a reverse movement on this fault.

The deposit is on the inverted northern limb of a large Phase 2 isoclinal fold. Within the deposit a pronounced Phase 2 mineral foliation trends east-west and dips 30 to 40° north, essentially parallel with layering indicating isoclinal to subisoclinal Phase 2 folding. A mineral lineation within this foliation plane, presumably related to Phase 2 fold axes, plunges 30 to 40° to the northeast. The present sheet-like form of the deposit, its elongation parallel to Phase 2 stretching lineations, and its gneissic textures are due largely to the intense Phase 2 deformation. Its position within an inverted stratigraphic panel is due to the earlier Phase 1 deformation.

SULPHIDE LAYER

The massive sulphide layer averages from 1 to 3 m in thickness, has a strike length of at least 400 m, and continues down plunge for at least 1200 m (Fig. 6). Near its western and eastern limits it splits into two layers separated by a narrow zone of quartzitic phyllite that has abundant disseminated sulphide. Only the western and truncated southern boundaries of the deposit have been well defined. It continues down plunge to the northeast at least as far as the Goldstream River where it is 350 m below surface. The massive sulphide layer thins gradually to the east and is restricted in extent by a barren hole (at 2562N, 5900E) approximately 300 m east of the last known sulphide intersection (Fig. 6).

The contacts of the sulphide zone with hanging wall and footwall rocks vary from sharp to gradational and from smooth to highly contorted and brecciated. In general, the structural footwall contact is more sharply defined than the structural hanging wall contact. Irregular blocks of country rock, ranging up to 1 m in size, are engulfed locally by sulphides to produce megabreccias. Folding and shearing, with irregular sulphide injections into the wallrocks, are also common along the upper and lower margins of the deposit.

The sulphide layer consists mainly of intimately intermixed pyrrhotite, chalcopyrite, and sphalerite with numerous subrounded inclusions of quartz, phyllite, and carbonate. A fine grained recrystallized matrix of gneissic sulphides, mainly pyrrhotite, is swirled around the gangue inclusions to produce 'Durchbewegung' fabric as described by Vokes (1969, 1971). Gneissic textures in compact sulphide ore are more characteristic of the margins of the massive sulphide layer; coarse grained equigranular textures are more typical of the center.

Some massive sulphide samples show a crude compositional layering into chalcopyrite-rich and chalcopyrite-poor units, the latter accompanied by a relative increase in pyrrhotite and decrease in large gangue fragments. Mylonitic textures with crushed and comminuted gangue dispersed in a fine granular sulphide matrix have also been noted.

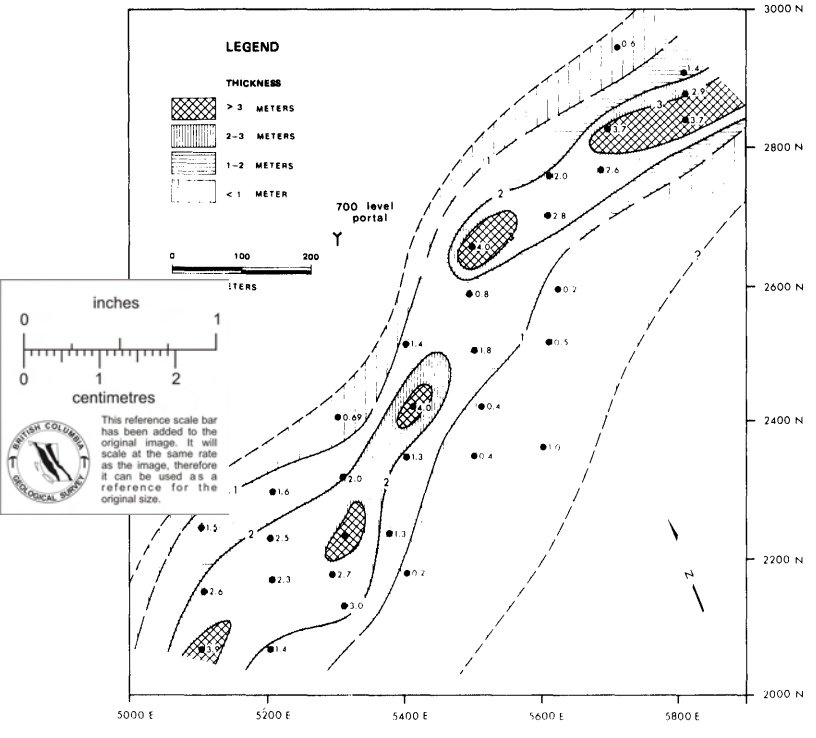


Figure 6. Isopach map of the massive sulphide layer, Goldstream deposit. Surface projections of sulphide intersections and calculated true thicknesses are shown on the plan (from Høy, 1979).

METAL DISTRIBUTION

Massive Sulphide Layer

The distribution of copper, zinc, and silver in the massive sulphide layer, based on weighted averages of 31 drill intersections, closely parallels the massive sulphide isopachs (compare Figs. 6 and 7). These metal grades have a simple and regular plan distribution, with increasing values toward the central, thicker parts of the layer. Furthermore, a decrease in grades at approximately 2600N is coincident with a thinning of the sulphide layer. The plan distribution of lead is not as well known because it was not assayed for routinely during exploration and pre-production drilling. However, underground sampling indicates a tendency toward higher lead grades near the center of the deposit (Høy et al, 1984). Furthermore, this sampling shows a strong positive correlation between lead and copper, zinc, and silver, which suggests that the distribution of these elements is similar in the massive sulphide layer.

The sulphide layer has a pronounced lateral zonation, with Zn/(Zn + Cu) increasing to the east (Fig. 8). This zonation is independent of the thickness of the sulphide layer or copper or zinc grades. Results of the limited underground sampling show that Cu/Ni ratios increase from between 0.5 to 1.0 in the west to between 2.0 to 3.0 in the east; Pb/(Pb + Cu + Zn) ratios also tend to increase to the east.

A consistent vertical zonation within the massive sulphide layer is not apparent. Eight drill intersections have slightly enriched Zn/(Zn + Cu) values near the footwall, but nine intersections, as well as a series of chip samples, showed no enrichment patterns (Høy et all, 1984).

Hanging wall and Footwall

Metal contents of hanging wall rocks within a few metres of the sulphide layer are variable. Copper and zinc values range from less than 0.1 to 2.5%, with averages of 0.6 to 0.7%. Silver averages from 2 to 7 grams per tonne. Grades are lower in footwall rocks, and the average thickness of mineralized footwall is less (Høy et al., 1984). The pronounced lateral zoning in the massive sulphide layer is not apparent in footwall or hanging wall rocks. Rather, an irregular distribution of higher Zn/(Zn + Cu) ratios (0.5 to 0.7) appears to be concentrated in the footwall approximately beneath the thicker central part of the sulphide layer, with lower values (0.3) toward the margins of the deposit. Ratios in the hanging wall are very irregular, with no consistent zonation pattern. The weighted average Zn/(Zn + Cu) ratio in the hanging wall is somewhat more than that in the massive sulphide layer and in the footwall.

Discussion

The two most noticeable features of metal distribution in the Goldstream deposit, a pronounced lateral zonation of zinc versus copper and high metal values in

the central, thicker portion of the sulphide lens, are probably due to an original depositional configuration. They may simply reflect an original high-grade core in the deposit with a superposed lateral zonation with higher Zn/(Zn + Cu) values along the eastern margin (Fig. 9A). Alternatively, they may be due to intense shearing of a massive sulphide lens also with a high-grade core but with an original vertical zonation, an extreme example of shear deformation of a massive sulphide deposit as described by Sangster (1972). The deposit is on the northern inverted limb of a major isoclinal fold and, therefore, was undoubtedly subjected to intense sinistral (viewed down-plunge to north) shear. Such shear strain, concentrated in the incompetent massive sulphide lens, could shift the upper part of the lens to the west and eventually result in a very attenuated sulphide layer with pronounced lateral zonation (Fig. 9B). In this model, the higher grade core zone would also retain its position in the central, thicker part of the lens during the deformation. However, it does not explain metal ratios in the hanging wall or footwall of the deposit. It is possible that less intense shearing of more competent footwall rocks allowed approximate retention of relatively high zinc in these rocks.

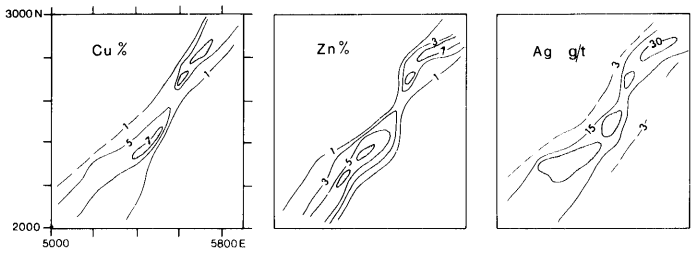


Figure 7. Distribution of copper, zinc, and silver in the Goldstream deposit; Cu - %, Zn - %, Ag - g/tonne.

SUMMARY AND DISCUSSION

A number of small massive copper-zinc sulphide deposits and the major Goldstream deposit occur in geosynclinal rocks in the northern Selkirk Mountains of southeastern British Columbia. Host rocks include either basic metavolcanics or dark carbonaceous and calcareous phyllites, associated with thick accumulations of impure quartzite, greywacke, and calcareous rocks. Locally they are associated with ultrabasic rock.

The deposits resemble Besshi-type bedded cupriferous iron sulphide deposits. They are bed-like or lenticular in form, are composed primarily of pyrrhotite (or pyrite), chalcopyrite, and sphalerite, and are within or associated with basic volcanic rocks. Their regional tectono-stratigraphic setting, in metamorphosed and highly deformed geosynclinal rocks, is also similar to Besshi deposits. In contrast, some of the typical features of polymetallic or Kuroko-type volcanogenic deposits are absent, only poorly developed, or perhaps difficult to recognize due to metamorphism; this includes the association with acid volcanic rocks, a clearly defined cross-cutting alteration pipe, association with sulfates, or obvious vertical metal and ore-type zoning (Sangster, 1972; Hutchinson, 1973).

The Goldstream deposit is on the inverted northern limb of a major isoclinal fold. Features within the deposit that tend to support structural inversion include a more gradational massive sulphide/hanging-wall contact than footwall contact, a thicker mineralized hanging wall section, extensive disseminated pyrrhotite in hanging-wall rocks, and pronounced dark chlorite alteration in the immediate hanging wall rocks that might be the remnants of a sheared sulphide-rich footwall stringer zone. The massive sulphide layer has a well-defined lateral zonation. It is suggested that this zonation is due either to an original lateral zonation or to extreme shearing of a vertically zoned deposit (Høy et al., 1984). The iron-rich, manganiferous chert horizon in the hanging wall of the deposit records a period of silica exhalation that preceded sulphide deposition.

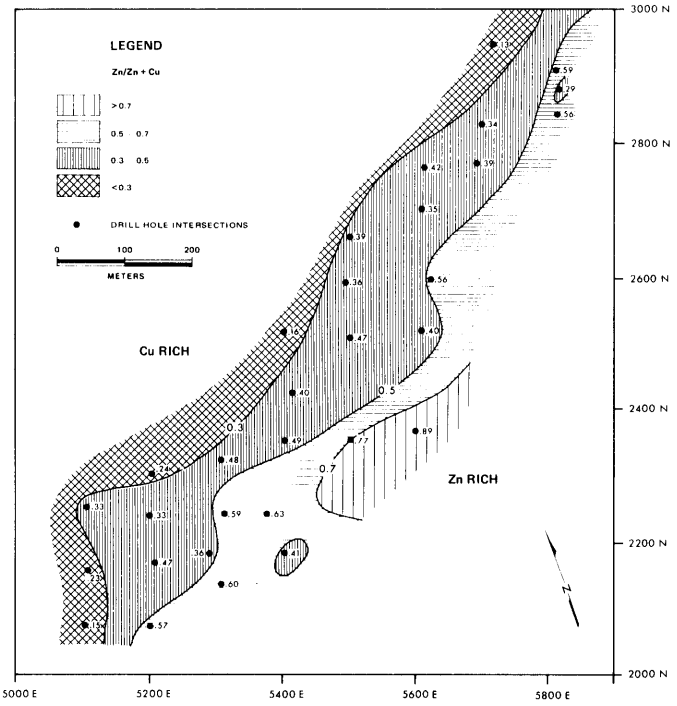


Figure 8. Weighted Zn/Zn+Cu ratios in the massive sulphide layer, Goldstream deposit.

DAY 2: KOOTENAY ARC - REEVES MACDONALD MINE

T. Høy, J.T. Fyles

INTRODUCTION

On the morning of Day 2 the excursion crosses the famous Slocan silver camp in the Selkirk Mountains between New Denver and Kaslo, and then continues south along Kootenay Lake to Nelson, passing through the Ainsworth silver camp. The Reeves MacDonald mine, one of a number of carbonate-hosted Pb-Zn deposits in the Salmo camp at the southern end of the Kootenay Arc, will be visited on Day 2. The excursion then proceeds east through Creston to Kimberley, crossing the Purcell Anticlinorium.

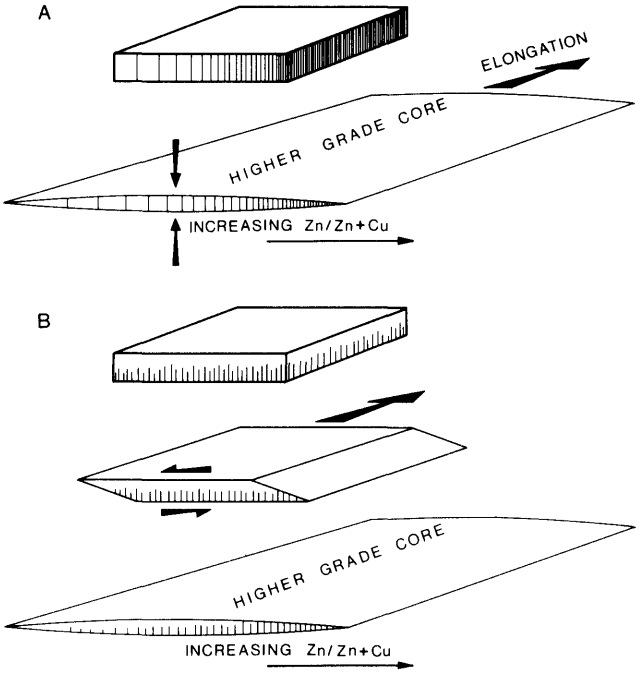


Figure 9. Two models that illustrate flattening and elongation of a massive sulphide lense during extreme deformation (note that the vertical hatching indicates higher Zn/Zn+Cu ratio).

AINSWORTH AND SLOCAN CAMPS

The geology of the Ainsworth-Kaslo area and the Ainsworth silver-lead-zinc camp is described by Fyles (1967) and lead isotope data on the Ainsworth and Slocan camps by Reynolds and Sinclair (1971), Le Couteur (1973), and Andrew et al. (1984). The Ainsworth area is underlain by intensely deformed Lower Cambrian to upper Triassic rocks of the Lardeau, Milford, Kaslo and Slocan Groups. More than 50 properties have produced in excess of 700,000 tonnes of ore since production began in 1889. The deposits are small; the largest stoped areas are about 200 m along strike, 250 m parallel to the dip, and 1-2 m thick. They are mainly simple quartz-carbonate veins containing shoots and lenses of galena, sphalerite, pyrite, and locally pyrrhotite. In the Ainsworth camp there are three dominant vein attitudes striking generally north, northwest, and west/northwest and dipping variably toward the west or southwest. The vein fractures have been the locus of small and repeated movements and the fracture system and mineralization postdate the regional deformation, metamorphism, and granitic intrusion.

The geology of the Slocan camp is described by Hedley (1952). Deposits in the camp are in veins associated with faults that crosscut deformed argillites, quartzites, and limestones of the Triassic Slocan Group.

The only present producers are the Silmonac mine (Dickenson Mines Ltd.) which handles 100 to 125 tonnes of ore/day, and the Little Tim silver-lead mine (Skagit Mining Ltd.), both in the Sandon area.

STRUCTURAL AND STRATIGRAPHIC SETTING OF KOOTENAY ARC DEPOSITS

Introduction

Stratabound lead-zinc deposits in the Kootenay Arc are essentially restricted to a "platformal" carbonate unit of Lower Cambrian age. The deposits consist generally of lenticular masses of pyrite, sphalerite and galena in dolomite or chert zones within highly deformed limestones (Fyles, 1970a). The larger deposits generally range in size from 6 to 10 million tonnes and contain 1-2% Pb, 3-4% Zn and trace silver (Høy, 1982b). None are presently in production.

Tectonic and Structural Setting

The Kootenay Arc is a north-trending arcuate structural zone that developed in a succession of rocks ranging in age from Hadrynian to early Mesozoic. In general, the earliest recognized structures in the Arc are tight to isoclinal, north-trending recumbent folds. In the Lardeau area in the northern Kootenay Arc there is some evidence that indicates that these structures may have developed during the Devono-Mississippian Caribooan orogeny. Here, a Phase 1 syncline in lower Paleozoic rocks is truncated by an uncomformity at the base of the lower Mississippian Milford Group (Read, 1976). As well, a conglomerate at the base of the Milford Group contains clasts of the underlying Broadview Formation in which the earliest foliation varies from clast to clast (Read, 1975, p. 29). More open but locally isoclinal, north-trending Phase 2 folds with upright to steeply west dipping axial surfaces are superposed on the Phase 1 folds (Fyles, 1964; Høy, 1977, 1980). These

folds dominate the structure of the Kootenay Arc and account for the pronounced north-south structural grain. Intrusion of synkinematic and post-kinematic plutons indicates a mid Jurassic age for this deformation (Read and Wheeler, 1975; Archibald et al., 1983). The latest discernible deformation in the Arc caused faulting and gentle folding of the earlier structures.

Stratigraphy

Stratigraphic successions and their regional correlation in the southern and northern parts of the Kootenay Arc are shown in Figure 10. They include dominantly coarse clastics and carbonates of the Hadrynian Windermere Supergroup, overlain by quartzite and pelite of the Hamill Group, interlayered clastics and carbonates of the Mohican Formation or Truman member and a regionally extensive Lower Cambrian marble called Reeves Limestone in the Salmo area and the Badshot Formation to the north. Argillite, shale, calcareous shale, quartzite and basic volcanic rocks of the Laib or Lardeau Groups overlie the Reeves-Badshot marble. This succession is described below in more detail.

The Toby Formation at the base of the Windermere Supergroup is a conglomeratic mudstone (diamictite) unit generally consisting of boulder to pebble-sized clasts of dolomite, quartzite, and argillite that are derived primarily from the underlying Dutch Creek and Mt. Nelson Formations (Rice, 1941; Lis and Price, 1976). The clasts are supported by a fine argillaceous, dolomitic or rarely, silty matrix. Aalto (1971) has suggested that the formation is a tillite. Elsewhere, the Toby Formation consists of well-sorted and closely packed clasts within a sandy mudstone matrix, suggestive of fluvial deposition (Lis and Price, 1976).

The overlying Horsethief Creek Group consists of up to 8500 m of pelite, slate and grit, with several quartzite and polymict units (Rice, 1941; Lis and Price, 1976). Lis and Price (1976) suggested that the polymict conglomerate units were deposited as mud flows and gravels, derived from the upper part of the Purcell Supergroup. They suggest that these units are fanglomerates which accumulated adjacent to a fault scarp that separated the uplifted source area south of the scarp from a developing structural basin on the north. Southeast of the fault scarp (now marked by the St. Mary Fault, a northwest dipping reverse fault), lower Cambrian quartzites of the Cranbrook Formation lie unconformably on Upper Purcell rocks. The Upper Proterozoic Windermere Supergroup is missing completely and 4 km of Middle Proterozoic strata, exposed further to the northeast, has been eroded away.

The Lower Cambrian Hamill Group (called the Quartzite Range and Reno Formations in the Salmo area) unconformably overlies the Horsethief Creek Group (Rice, 1941). It comprises micaceous quartzite, quartz-rich schist, micaceous schist and a 60 to 200 m thick, white orthoquartzite marker unit (the upper Nevada, Fig. 11). In the Riondel area massive amphibolite units in the central part of the Hamill are probably metamorphosed basic volcanic layers (Høy, 1980). The Truman member of the Laib Formation is a gradational unit between the Reno formation and the Reeves Limestone. It consists of a thin-bedded succession of calcareous schist and quartzite, rusty-weathering micaceous schist, and limestone (Fig. 11). The Badshot-Reeves Formation is an extensive, relatively pure limestone several tens to greater than 100 m thick. Irregular zones of dolomite and chert within the limestone host the lead-zinc deposits. In the northern part of the Kootenay Arc, the Badshot is overlain by up to several hundred metres of dark argillite or micaceous schist at the base of the Index Formation, calcareous schist of the Upper Index, a succession of dark argillite and argillaceous quartzite of the Triune Formation, the Ajax Formation quartzite, and argillite of the Sharon Creek Formation (Fyles and Eastwood, 1962). Metamorphosed andesitic volcanic rocks of the Jowett Formation overlie the Sharon Creek Formation and are overlain by dominantly coarse clastic rocks of the Broadview Formation (Fig. 10). In the Salmo area at the southern end of the Kootenay Arc, argillite, calcareous phyllite and minor micaceous quartzite of the Laib Formation is overlain by a thick limestone-dolomite unit of Middle Cambrian age called the Nelway Formation (Fig. 11). The Nelway Formation dies out to the north, supplanted by more argillaceous rocks of the Lardeau Group.

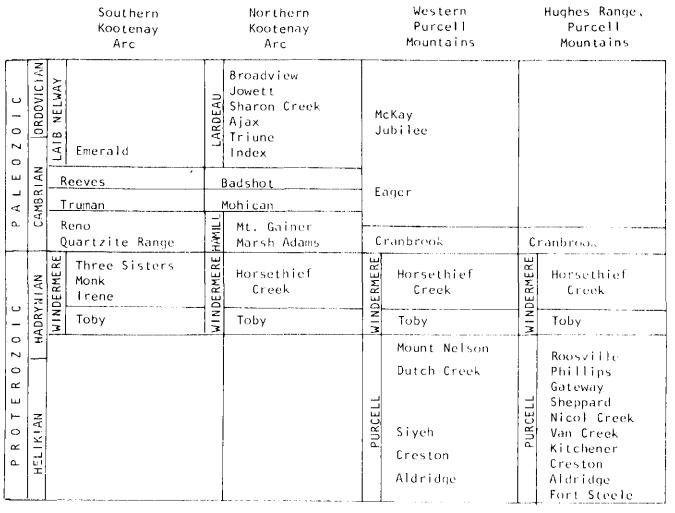


Figure 10. Correlation chart southeastern British Columbia.

Lead-Zinc Deposits

Lead-zinc deposits in the Kootenay Arc are concentrated in two areas, the Salmo camp at the southern end of the Arc (Fyles and Hewlett, 1959; Fyles, 1970a) and the Duncan camp north of Kootenay Lake (Muraro, 1962; Fyles, 1964). The Bluebell deposit, described as a vein replacement deposit (Ransom, 1977a; Høy, 1980) is situated on the east shore of Kootenay Lake between the Duncan and Salmo camps (see Fig. 1).

Kootenay Arc deposits are hosted by intensely deformed Lower Cambrian marble or limestone. Dolomitization and associated brecciation of the limestone is common. The deposits consist of lenses, irregular bands, disseminated grains, or massive bodies in dolomite. They are irregular in outline and commonly elongated parallel to the regional structural grain. Contacts with country rock may be sharp or gradational.

The origin of Kootenay Arc deposits is enigmatic. Fyles and Hewlett (1959) describe the deposits as replacement deposits controlled by Phase 2 folds and locally, faults. They describe the close spatial association of mineralization to structures and the brecciated nature of some of the ore. Sangster (1970) and Addie (1970) describe the deposits as syngenetic, with sulphides accumulating in small basins in a deep-water carbonate platform. Muraro (1962), based on detailed studies of the Duncan deposit, suggests that Kootenay Arc deposits are hydrothermal replacement deposits, controlled by stratigraphy and formed before deformation and metamorphism, whereas Høy (1982b) suggests the deposits span the syngenetic-diagenetic interval, in part accumulated along with shallow water carbonates, but also locally accumulated in cavities or collapsed breccia zones in lithified Reeves/Badshot marble.

REEVES MACDONALD

The Reeves MacDonald mine is one of a number of lead-zinc deposits that were mined in the Salmo camp in the southern part of the Kootenay Arc (Fyles and Hewlett, 1959; Addie, 1970). These also include the Jersey and H.B. deposits. The Reeves MacDonald mine produced, until its closure in 1977, 5.8 million tonnes of ore containing .98% Pb, 3.42% Zn and 3.4 g/tonne Ag.

Formation	Member	Sheep Creek Anticline, South Side of South Salmo River: Approximate Thickness (Feet)	Sheep Creek Anticline, South Side of South Salmo River: Lithology	Truman Hill-Emerald Mine Area, Composite Section: Approximate Thickness (Feet)	Truman Hill-Emerald Mine Area, Composite Section: Lithology	Reeves MacDonald Mine Area, Composite Section: Approximate Thickness (Feet)	Reeves MacDonald Mine Area, Composite Section: Lithology
Nelway.		Top not exposed.	Grey dolomite containing distinctive black masses with small white spots.				
		500 (?)	Dark blue-grey fine-grained limestone with thin argillaceous beds.				
Gradational contact.							
Laib.	Upper Laib.	3,000	Grey calcareous phyllite, grey brown and green phyllite; thin calcareous lenses.	Top not exposed.	Grey and brown micaceous quartzite; minor green phyllite, black argillite, and limestone.	Top not exposed.	Green and grey phyllite, grey and brown micaceous quartzite, minor limestone lenses.
	Emerald.		Brown-weathering grey siliceous argillite.	200–300	Black calcareous argillite.	500	Black, crenulated calcareous phyllite.
	Reeves.	450	Grey, poorly banded limestone.	350	Interbanded white grey and black crystalline limestone.	130	Banded grey and white limestone.
	Truman.	350	Green phyllite.	100	Brown skarny calcareous argillite.	60	Green and brown phyllite, white limestone.
			Grey-green and brown phyllite, with calcareous lenses most common near the base.		Brown micaceous argillite.		
					Brown argillite with thin calcareous beds.		
					10–20 feet of white crystalline argillaceous limestone.		
Conformable contact.							
Reno.	Upper Reno.	60	Blocky grey quartzite, of which the upper 30 feet contains coarse calcareous quartzite; cross-bedded.	40–50	Blocky grey quartzite with lenses of calcareous quartzite, micaceous quartzite, and minor limestone.	5–10	Blocky grey quartzite.
	Lower Reno.	560	Grey micaceous quartzite and dark-grey to black phyllite.	500	Grey-brown to grey micaceous quartzite with grey blocky beds near the base.	230	Dark-grey micaceous quartzite interbedded with dark-grey to black phyllite.
Conformable contact.							
Quartzite Range.	Upper Navada.	250	White quartzite beds as much as 2 feet thick.	135	White quartzite, beds less than 1 foot thick.	35	Thin-bedded white quartzite.
	Lower Navada.	400	Thin-bedded greyish-white quartzite and dark grey-brown micaceous quartzite, some greenish-grey phyllite.	100	Brown micaceous quartzite with greyish-white beds.	100	White grey and brown quartzite interbedded with grey and green phyllite.
						65	Greenish phyllite and grey-brown quartzite.
						20	Interbedded grey and white limestone and greyish-brown phyllite.
						100	Greyish-brown phyllite and quartzite.
	Nugget.	Base not exposed.	Massive white quartzite.	Base not exposed.	Nugget (?) massive white quartzite.	Base not exposed.	Massive white quartzite.

Figure 11. Columnar sections of Cambrian rocks, Salmo area (from Fyles and Hewlett, 1959).

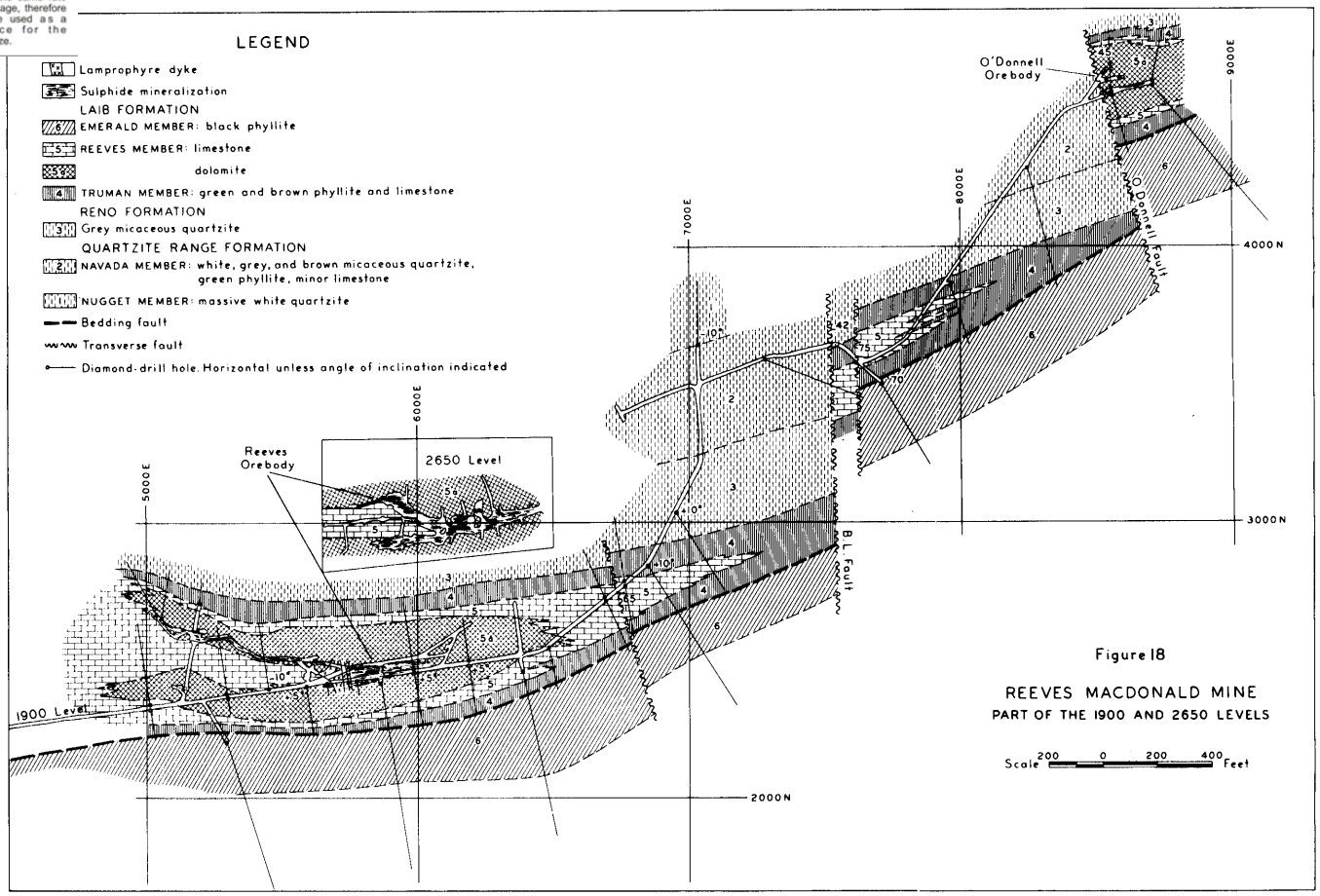


Figure 12. Plan views of the Reeves MacDonald Mine (from Fyles and Hewlett, 1959).

Deposits in the Salmo camp are within fine grained dolomite in the Reeves limestone. The dolomite is texturally different from the barren, generally well-banded limestone. It is poorly banded, flecked with black, irregularly streaked or crackled. Breccia zones with dolomite fragments surrounded by sulphides are present in many of the deposits. Massive dolomite which is not uncommon contains only sparse mineralization.

Ore deposits at the Reeves MacDonald mine are on the south limb of a major fold called the Salmo River Anticline. They consist of bands, lenses and disseminated grains of pyrite, honey-coloured sphalerite and galena, in dolomite. The Reeves orebody is in the limbs and hinge zone of an attenuated syncline. It is shown in plan on the 1900 and 2650 levels in Figure 12 and is described by Fyles and Hewlett 1959, pp. 144, 145) between these levels as follows.

> "The orebody has the form of an attenuated syncline with limbs striking eastward and dipping 50 to 60° to the south and axis plunging south 35° west at about 55°. In detail, outlines of the orebody are irregular, but the general synclinal shape persists from the 1900 level to the surface 900 feet above. The main trough section of the Reeves orebody is about 350 feet long, and has been stoped at the widest part to widths of about 80 feet. The footwall or north limb of the orebody thins westward from the thick trough section, and on the 1970 level where mining has been most extensive it is 10 to 20 feet thick and about 500 feet long. The hanging wall limb of the Reeves orebody has been stoped for a few tens of feet west of the thick trough section. Sparse mineralization continues along the hanging wall limb for a few hundred feet west of the stoped area, but has not been continuous enough or high enough in grade to be mined.
>
> "Much of the ore in the Reeves orebody has a more or less well-pronounced banding. Bands of sulphides, which range from a fraction of an inch to a few inches wide, are

generally discontinuous and locally highly contorted. Seen together they show the orebody to have a uniform dip and plunge and a folded lenticular form in a plane perpendicular to the plunge. Folds within the orebody are irregular, but some of them can be recognized from one level to the next and appear to be persistent along the plunge. Some ore is a breccia composed of rounded and angular rotated fragments of dolomite, and locally of limestone, in massive sulphides. Breccias are commonly rich in pyrite and are more abundant on the limbs than in the trough section of the orebody. Banded ore is cut by veinlets of coarsely crystalline white calcite, dolomite, and quartz a fraction of an inch wide and a few inches long. They either crosscut the banding or are parallel to it. Minor amounts of sphalerite and galena are found in the veinlets. Details of the relationships between ore, dolomite, and limestone on the 2650 level are shown by Green (1954, Fig. 2).

The dolomite zone with which the Reeves orebody is associated has the same synclinal form as the orebody. The limbs dip 50 to 60° to the south, and the axis plunges about 55° to the southwest. Dolomite on the limbs lenses out into limestone to the west. On the south limb another lens of dolomite is found a few tens of feet along strike from the end of the dolomite containing the Reeves orebody. This western lens is known only on surface and in part on the 1900 level. The outline on surface suggests that it has the form of a syncline. No ore is known in this western lens of dolomite.

The Reeves orebody and associated dolomite zone are in the Reeves syncline. The orebody, the dolomite, and the syncline have similar form and attitude. The dolomite is more or less centrally located within the limestone. The orebody is well up in the dolomite syncline, close to the limestone wedge between the two dolomite limbs. It is apparent that dolomitization has been controlled by the Reeves syncline and that sulphide mineralization has followed essentially the same structure in the dolomite."

The orebody maintains these characteristics below the 1900 level to the limits of mining which was close to sea level (55 level). Faulted extensions of the Reeves orebody occur on surface to the east (B.L. and O'Donnel orebodies) and underground to the west. Reconstruction of the faulted segments gives a plunge length of at least 1.5 km.

DAY 2 (P.M.)
THE PROTEROZOIC PURCELL SUPERGROUP
T. Høy

INTRODUCTION

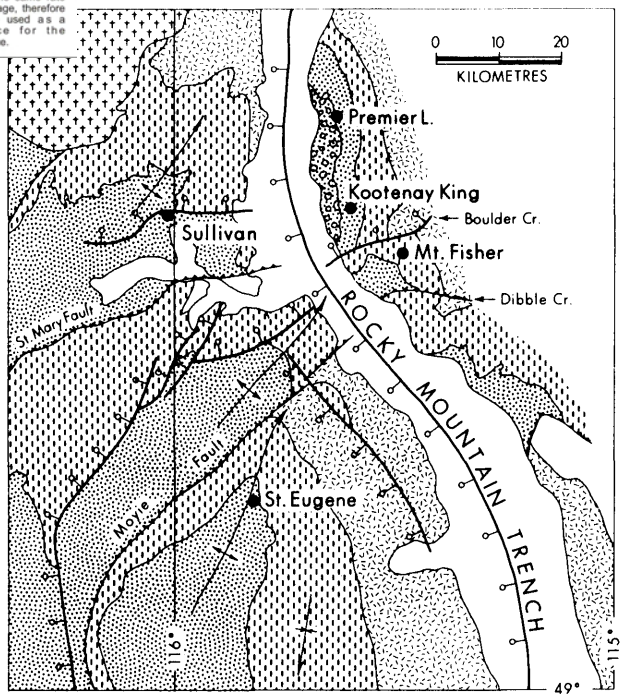
A number of lead-zinc deposits occur in the Proterozoic Purcell Supergroup. These include the stratabound Sullivan mine, Kootenay King, and North Star deposits, and the Vulcan occurrence, in clastic rocks of the Aldridge Formation. Transgressive deposits include the Stemwinder and the St. Eugene. Replacement deposits in younger Purcell platformal carbonates include the Mineral King and Paradise deposits 80 km north of the Sullivan. The Sullivan mine will be visited on Day 3 of the excursion, and, if time permits, the Purcell succession in the vicinity of Moyie Lake, 30 km south of the Sullivan, will be examined in the afternoon of Day 2.

STRATIGRAPHIC AND TECTONIC SETTING

Purcell rocks are exposed in the Clark Range within the Lewis Thrust sheet in the southeast corner of British Columbia and southwest corner of Alberta, the Hughes, Lizard, and Galton Ranges on the east side of the Rocky Mountain Trench, and the Purcell Mountains within the Purcell Anticlinorium. In the Clark Range, arenaceous and carbonate facies are relatively more important and formations are thinner and more diverse (Price, 1964; Fermor and Price, 1983). Coarse grained fluvial and shallow water sediments host a number of widespread, low-grade stratabound copper occurrences in the Clark Range (Morton et al., 1973; Collins and Smith, 1977).

In the Kootenay King-Premier Lake area due east of the Trench (Fig. 13), coarse fluvial quartzite and tidal flat deposits of the Fort Steele Formation are at the base of the exposed Purcell succession (Fig. 14; Høy, 1979b, 1982a). They are overlain by deeper water siltstone and quartzite of the Aldridge Formation, and dominantly shallow water tidal flat, flood plain, and deltaic deposits of the Creston Formation, and platformal carbonates of the Kitchener Formation. The Kootenay King is a laminated, stratiform lead-zinc deposit in Middle Aldridge siltstone.

The Boulder Creek fault (Fig. 13) coincides approximately with a marked transition in the character of lower Purcell rocks, from the dominantly fluvial and shallow marine with only minor turbidites to the north to a thick succession of basinal turbidites to the south that are similar to turbidites in the Purcell Mountains west of the trench (McMechan, 1981; Høy and Diakow, 1982).



PHANEROZOIC
- Undifferentiated
- White Creek batholith

HELIKIAN-PURCELL SUPERGROUP
- Van Creek, Nicol Creek and younger
- Creston and Kitchener
- Aldridge / Fort Steele

Thrust fault
Normal fault
Anticlinal fold

Figure 13. Geological map of the Purcell Supergroup in Fernie west half map sheet and part of Nelson east half.

The oldest rocks exposed in the Purcell Anticlinorium to the west, including the area crossed on the afternoon of Day 2 of the excursion, are quartzites, siltstones, and argillites of the Aldridge Formation (Fig. 15). The Lower Aldridge comprises at least 1500 m (base not exposed) of rusty-weathering argillite, siltstone, and quartzite. The contact between the Lower and Middle Aldridge is gradational over a few tens to several hundred metres. Locally an intraformational conglomerate occurs at or near the top of the Lower Aldridge.

The Middle Aldridge comprises thick, grey quartz wacke beds and interlayered laminated siltstone layers, intruded by a number of regionally extensive metagabbro sills (Fig. 15). In general quartz wacke beds become thinner, less pure, and volumetrically less important higher in the Middle Aldridge section (Høy and Diakow, 1981, 1982). The quartz wacke beds "possess sole markings, including grooves, poor flutes, and longitudinal ridges, and internal sedimentary structures of cross and convolute bedding, that suggest their similarity to units ascribed elsewhere to turbidity currents (Bishop, Morris and Edmonds, 1970).

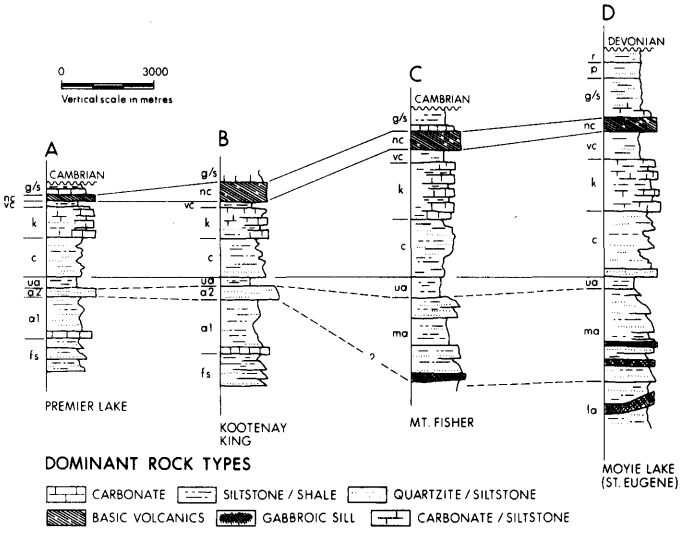


Figure 14. Composite stratigraphic sections; data from Høy, 1979 (Sections A and B); McMechan, 1981 (Section C); Høy and Diakow, 1982 (Section D).

Internal stratification of these units permits recognition of the standard Bouma (Bouma, 1962) intervals, although Bouma's B, C, and D Layers do not appear to fit a regular pattern of superposition in the Aldridge Formation" (Edmunds, 1977, p. 22). Paleocurrent data in the Moyie Lake and Kimberley areas (Fig. 16) indicate a northerly current transport direction (Edmunds, 1977; Høy and Diakow, 1981).

Interturbidite argillaceous siltstone in the central part of the Middle Aldridge commonly consists of a sequence several metres thick of alternating dark and light laminations less than a millimetre to a few millimetres thick. Laminations in about a dozen of these laminated siltstone sequences can be matched across distances of up to 300 km (Edmunds, 1973, 1977; Huebschmann, 1973). They are reliable stratigraphic markers that allow correlation within the 3-km-thick Middle Aldridge succession.

The Upper Aldridge includes 300 to 400 m of generally rusty-weathering laminated dark grey argillite and lighter grey siltstone. The overlying Creston Formation consists of light green, brown, and pale purple argillaceous quartzite, siltstone, and argillite that contain numerous shallow-water sedimentary structures. The Creston is overlain by shallow-water carbonates and clastics of the Kitchener Formation,

subtidal to supratidal clastic rocks of the Van Creek Formation, and andesite volcanic rocks of the Nicol Creek Formation (Fig. 15). These volcanics only occur east of the Trench and along the eastern flank of the Purcell Anticlinorium. Elsewhere grey and green argillite, dolomite, and quartzite of the Dutch Creek Formation (Fig. 10) overlies the "Siyeh" Formation (Reesor, 1973) and is overlain by oolitic and stromatolitic dolomite and dolomitic limestone, argillaceous limestone, and argillite of the Mount Nelson Formation (Rice, 1941; Reesor, 1973).

Laterally extensive sills, which are predominantly gabbroic in composition (Høy, 1984a), intrude the Lower and the lower part of the Middle Aldridge Formation. They are generally a few tens to several hundred metres thick, with medium to coarse grained equigranular central parts and finer grained margins. A thin hornfelsic zone occurs adjacent to some sill contacts. Locally, Moyie intrusions also form dykes. Although Moyie intrusions have isotopic ages indistinguishable from the host Aldridge rocks (approximately 1433 Ma, Zartman et al., 1982), it has generally been accepted that they are coeval with deposition of the Upper Aldridge Formation or Creston rocks (Zartman et al., 1982; Hamilton et al., 1983), or perhaps with Nicol Creek lavas (McMechan, 1981). However, Høy (1984a, 1984b) presents evidence that suggests that they are early and were emplaced into water-saturated Aldridge sediments a few tens to a few hundreds of metres below the sediment surface. If this is correct, the Moyie sills may be evidence of a regional igneous/thermal event during deposition of Lower to Middle Aldridge rocks, hence during formation of contained stratiform sulphide deposits. A modern example of intrusion of basaltic sills into highly porous unconsolidated turbidite sediments was described by Einsele et al. (1980) from drill sites in the Guaymas Basin, Gulf of California.

Moyie intrusions are restricted to early Aldridge and early Middle Aldridge time, dying out in late Middle Aldridge time at the same time as the volume of coarse turbidites decreased. Their abundance, volume, spatial, and suggested temporal restriction to a stratigraphic interval dominated by turbidite deposition suggests that Lower Aldridge and early Middle Aldridge sedimentation took place during a period of continental rifting.

In summary, the lower exposures of Purcell rocks in the Kootenay King area are dominantly fluvial and shallow marine deposits, in contract with considerably thicker, basinal turbidite facies to the south and west. This indicates that in lower Purcell time, the Kootenay King area was near the platformal edge of a deep, structural basin that lay to the south and west. Rapid thinning and fining of King area, northward-directed paleocurrents, dramatic thickening of turbidites just to the south, and coarse pebble conglomerates located near the basin/platformal transition (Høy, 1979b, 1982a) suggest that the basin edge developed by growth faulting.

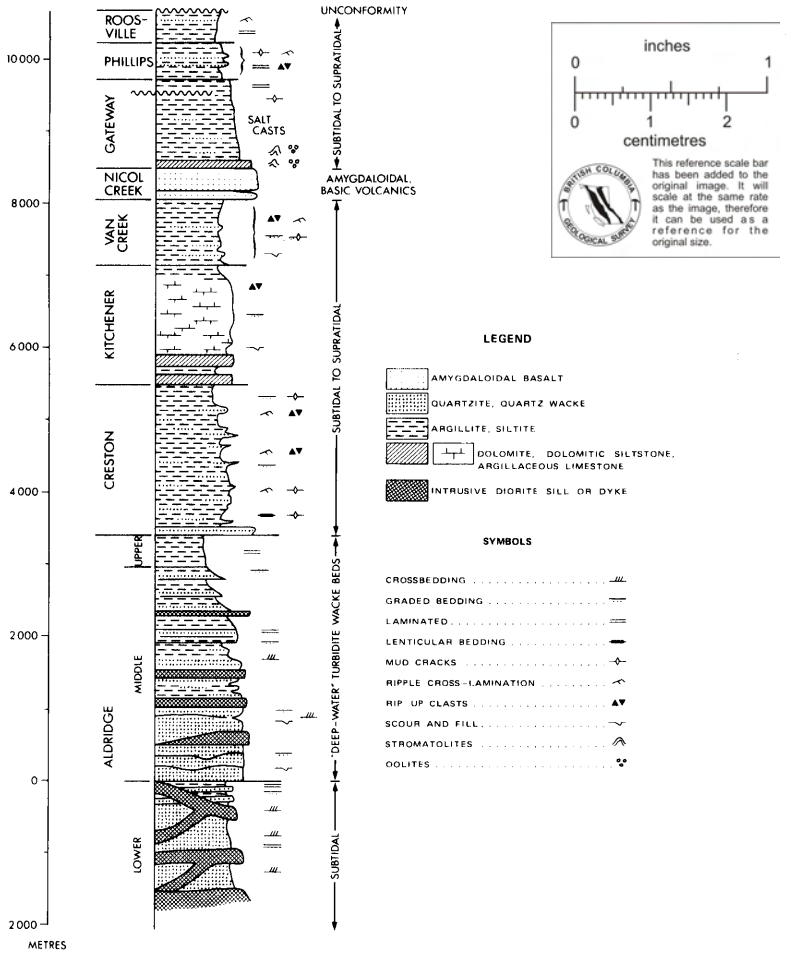


Figure 15. Composite stratigraphic column of the Purcell Supergroup in the Moyie Lake area.

Facies trends and palinspastically restored isopach maps (Høy, 1984b) indicate a marked westward deflection in the basin margin near the present position of the St. Mary and Boulder Creek faults (Fig. 16). The deflection coincides approximately with the northern edge of a postulated older, southwest-trending, Precambrian rift structure, recognized from geophysical data and postulated to extend in Hudsonian basement rocks beneath the cover rocks into southeastern British Columbia (Kanasewich et al., 1979). It is suggested that bowing up of the crust near the northern margin of the older, southwest-trending, tectonic zone, recorded in northward shedding of fluvial Fort Steele sediments (Høy, 1979b), preceded continental rifting (Price, 1981). Early stages in the development of the basin are

marked by thick accumulations of Aldridge turbidites and voluminous intrusions of basic sills. North to northwest and locally westerly directed paleocurrents generally paralleled the margin of the basin (Fig. 16A). Upper Purcell platformal rocks prograded westward over the basin margin and turbidite flysch package, but differential downwarping continued within the basin (for example, see Creston isopachs, Fig. 16B). In later Purcell time, faults along the basin margin were reactivated, probably to deep crustal levels, and resulted in local surface relief that produced erosional contacts with locally coarse, fluvial conglomerates, and in the extrusion of late Purcell basalts centered near the early Purcell platform-basin hinge line (Fig. 16C).

In summary, it is evident that deep crustal structures in underlying crystalline basement affected the eastern margin of the Purcell basin. Furthermore, the distribution of base metal concentrations, such as Sullivan, North Star, Stemwinder, and Kootenay King, appears to be tectonically controlled (Kanasewich, 1968). Such concentrations occur near the intersection of the north-trending, rifted, continental margin and a pronounced southwest-trending, tectonic zone (Høy, 1982b). The tectonic control may be direct, with zones of crustal weakness localizing deep-rooted basement faults that controlled the outflow of metal-charged fluids, or indirect, with these zones localizing geothermal convective cells that controlled sulphide deposition.

ROAD LOG: YAHK TO KIMBERLEY

Highway 3/95 - Yahk to Cranbrook
Highway 95a - Cranbrook to Kimberley

INTRODUCTION

On the afternoon of Day 2 the excursion crosses the Purcell Anticlinorium, from Yahk to the Sullivan deposit at Kimberley just west of the Rocky Mountain Trench. After a brief visit to the St. Eugene mine, a mined-out silver vein deposit, successive stops show the main lithologies of the Purcell Supergroup, beginning with a Kitchener exposure at Moyie Lake and moving generally down section to a Lower Aldridge exposure a few kilometres south of Kimberley. Most stops are in the Moyie Lake area (Høy and Diakow, 1982), in the southern Purcell Mountains near the central part of the Purcell Anticlinorium. The area (Fig. 17) is cut by the northeast trending Moyie fault, that continues northeast across the Rocky Mountain Trench and southwest into Montana. The fault appears to follow the locus of an older fault along which the north side was relatively down-dropped (Leech, 1958) in pre-late Devonian time. North of the Moyie fault a thick sequence of Cambrian rocks lies unconformably on Upper Purcell rocks. Late right-lateral and reverse movement on the Moyie fault has resulted in a net vertical displacement of several kilometres, and at the north end of Moyie Lake, Lower Aldridge rocks on the north hanging wall of the fault are juxtaposed against Kitchener Formation footwall rocks (Fig. 17). As suggested by Leech (1962), a "basal Devonian" unit, comprising a fluvial conglomerate and gypsum horizon,

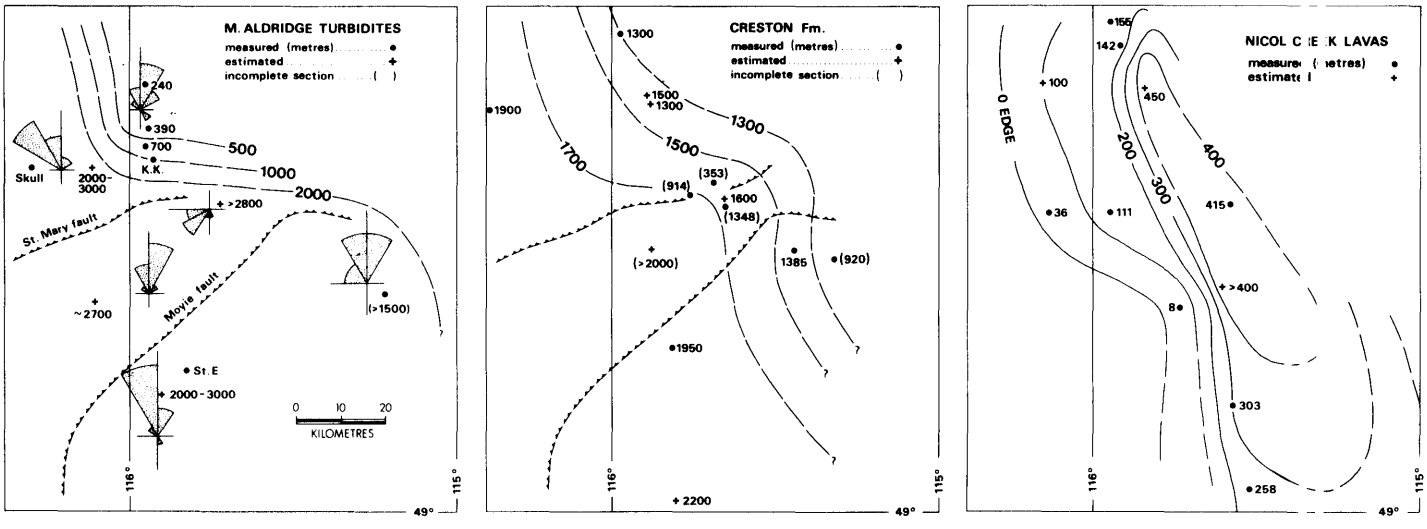


Figure 16. Isopach maps of middle Aldridge turbidites and Creston Formation, and isolith map of Nicol Creek lavas, southeastern B.C., restored for movements on Moyie, St. Mary, Dibble Creek and Boulder Creek faults; data source: Benvenuto and Price (1979), Høy (1979, 1983), Høy and Diakow (1982), McMechan (1981) and unpublished data.

has acted as a glide zone for the Moyie fault. The conglomerate has been recognized in a number of places in the footwall of the fault (Høy and Diakow, 1982).

The structure of the area south of the fault, the "Moyie block" of Benvenuto and Price (1979), is dominated by the Moyie anticline, a northeast plunging upright anticlinal fold. The western limb of the Moyie anticline is cut by the Moyie fault. Lower and Middle Aldridge rocks are folded into moderately tight to open north to northeast trending folds that are outlined by metagabbro sills. In the hanging wall immediately adjacent to the Moyie fault, folds are tight and locally overturned. The Lower Aldridge is exposed in two overturned anticlinal folds just west of the north end of Moyie Lake and west of Cranbrook Mountain (Fig. 17).

ROAD LOG

0 km Town of Yahk. The lowest stratigraphic exposures of Middle Aldridge rocks in the block south of the Moyie fault occur in the vicinity of Yahk. For the first 40 km the route along Highways 3/95 generally ascends through Middle Aldridge stratigraphy as it passes obliquely through the western limb of the north plunging Moyie Anticline.

24.0 km Midway Mine lies on the north side of the road. This is a small but high-grade gold-quartz vein deposit. Associated metallic minerals are arsenopyrite, pyrite, galena, sphalerite, and chalcopyrite. The earliest records are from 1933 when the property was acquired by the B.C. Cariboo Goldfields Limited. Only a few ore shipments have been made.

STOP 1, 30.8 km St. Eugene Mine. The entrance to the St. Eugene Mine is on the east side of the highway. Adits and associated dumps can be seen up the hillside to the east. On the far shore of Moyie Lake the Aurora Mine dump is visible.

The St. Eugene Mine lies about 2000 m above the base of the Middle Aldridge Formation. It was discovered in the late 1890's by a Kootenay Indian and acquired by the owners of the Trail smelter in 1905 to supplement diminishing supplies of concentrates. The mine is ladder-vein, striking WNW and dipping steeply south. The ore is essentially galena and silver. By 1916, when reserves were exhausted at 620 m below the headframe, production had amounted to 931,430 tonnes grading 12% Pb, 1% Zn and 200 g/tonne Ag.

The following description of mineralization is taken from a Cominco Report:

"Lead, silver and zinc are the most important metals of the St. Eugene vein system and are mainly derived from argentiferous galena and sphalerite. Tetrahedrite is present in some areas, and small amounts of chalcopyrite are generally common in occurrence. Gangue minerals of the productive veins include quartz, biotite, chlorite, garnet, amphibole, pyrrhotite, pyrite and magnetite. Some epidote, grunerite and fluorite is found locally.

Commercial concentrations of these minerals occur in tabular ore shoots within steep-dipping veins and in multiple orebodies within extensive cymoid structures. The average width of mineable material, in both vein-type and cymoid-type deposits is in the order of 2 to 3.5 m.

The main break in which the vein-type shoots form is generally uniform in trend but irregularly refracted in detail. The break is sometimes wide and other times narrow, and may be either filled with gangue minerals or barren.

The cymoid structure is bounded by two main breaks with parallel veins ('parallels') and cross veins ('avenues') transecting the inter-area. The structure is generally well mineralized throughout and larger deposits sometimes reach 10 m in width with one or more bands of near-massive galena up to 1.3 m thick.

All the shoots tend to be longer down their dip than along their strike. The Lake Shore and St. Eugene shoots of the St. Eugene Mine are apparently of the cymoid type and appear to pitch moderately to the east, whereas the Moyie shoot, which occurs in a warped area of the North Vein, is of the vein-type with a near-vertical pitch. The Aurora shoots, across the lake at the Aurora mine are in the same vein system and are also related to a warped break, but apparently pitch moderately west.

The overall vein system, including ore shoots and barren sections, can be traced for some 3500 m along its strike and some 1400 m down its dip."

31.4 km Town of Moyie.

31.7 km Highest exposures of Middle Aldridge turbidite units. For the next 2.4 km the highways runs over recessive weathering Upper Aldridge Formation carbonaceous argillite and siltite.

35.4 km Transition between the Upper Aldridge Formation and the Creston Formation. The Upper Aldridge is a dark, carbonaceous, thin-bedded argillite succession. The Creston in the transition zone is a green coloured alternation of thin argillites and wackes, weathering rusty (Aldridge character -istic) but slightly green on relatively fresh surfaces. Some sand lenses can be found as well as silt "intrusions" and penecontemporaneous pull-apart structures.

STOP 2, 36.8 km Creston Formation outcrops on the cliffs on the east side of the highway, east side of Moyie Lake. In general, the outcrops are subtidal to supratidal argillite, quartzite and wacke beds in different shades of green, dull grey-green, and maroon from near the top part of the Creston Formation. Sedimentary structures are numerous and include desiccation and synereses cracks, mud-chip breccias, scour-and-fill structures, ripple marks, cross-bedding, and graded bedding. The characteristic bed-form is thin bedded, commonly laminated argillite-siltite couplets.

STOP 3, 38.6 km Highway outcrops east of Moyie Lake. Lower units of the Kitchener Formation occur on both sides of the road. They are interbedded argillaceous dolomites and dolomitic argillites. Of particular interest here is a structure referred to as "molar tooth". Small crenulated veinlets of calcite, approximately perpendicular to the bedding, weather in negative relief. Their form is quite varied, in some places being almost tubular. In addition, ripple-marked surfaces and scour-and-fill structures can be found in the more argillaceous units. Elsewhere in the Kitchener (and Kitchener-equivalent) stromatolites have been identified. The transitional contact with the underlying Creston Formation occurs about 100 m south of the de-bussing point.

39.9 km Cross Peavine Creek and enter the steep north-plunging nose of the Moyie anticline. Moyie Lake lies on the west and the top of the Kitchener Formation lies on the east.

42.5 km Trace of Moyie fault. Lower Aldridge exposed in an anticlinal fold on the northwest hanging wall side of the fault is juxtaposed against Upper Purcell Kitchener Formation on its southeast side (Fig. 17). The Moyie fault is one of a number of northeast trending faults that transect the Purcell Anticlinorium. Repeated movements in the vicinity of these faults since Proterozoic time have had a fundamental control on stratigraphy and tectonics in southeastern British Columbia. The most recent displacement on the Moyie fault is right-lateral and reverse.

STOP 4, 43.8 km Outcrop on north side of highway just east of Moyie River bridge. Exposures of Middle Aldridge Formation includes a "Marker Argillite" in the cliffs east of the road and south of the river. The Marker Argillite occurs at the base of the cliff towards the north end. It is about 3.5 m thick, but includes up to a metre of non-laminated sedimentary rock. The corroded condition of the unit is due to the weathering of a relatively high proportion ($\pm$4%) of iron sulphides.

STOP 5, 44.5 km Outcrops of a metagabbro sill on both sides of the highway and in a railway cut 50 m to the north. Metagabbro sills comprise a considerable portion of the Lower and Middle Aldridge succession in the Purcell Mountains. They are regionally extensive and in the Moyie Lake area have been used as stratigraphic markers (Høy and Diakow, 1981). The sills are correlated with the Crossport "C" sill in Idaho which yielded a concordant U-Pb zircon age of 1433$\pm$10 m.y. (Zartman *et al.*, 1982).

STOP 6, 49.5 km Outcrop on Highway 3/95 just opposite Lumberton turn-off. A sequence of turbidite units and interbedded argillites is exposed on the east side of the highway. It lies in the Middle Aldridge Formation, about 1000 m above the base. The presence of AE turbidites up to 1 m thick may be contrasted with the Lower Aldridge lithology of Stop 7 and rocks encountered in the Sullivan Mine.

The turbidite units are generally graded only at the top, but occasionally graded in a reverse manner in their basal part; the central part of coarser grained turbidite beds is commonly massive. Within the finer grained silt and fine sand-sized turbidites, parallel laminations, convolute laminations, ripple bedding, and flame structures occur. Sole markings, including grooves, flute marks, furrows and ridges, tool marks, and load casts, are common. Current indicators in Middle Aldridge turbidite deposits in the Moyie Lake area show a northerly transport direction. Concretionary bodies and rip-up clasts occur in some beds, and large crystal casts with the swallow tail form of selenite are in some of the more argillaceous beds.

The route continues through essentially flat-lying poorly exposed lower Middle Aldridge Formation. Cliffs visible occasionally on the north side of the highway are metagabbro sills.

62.1 to 68.5 km City of Cranbrook.

68.9 km Junction with Highway 3/95 from Radium and Fernie.

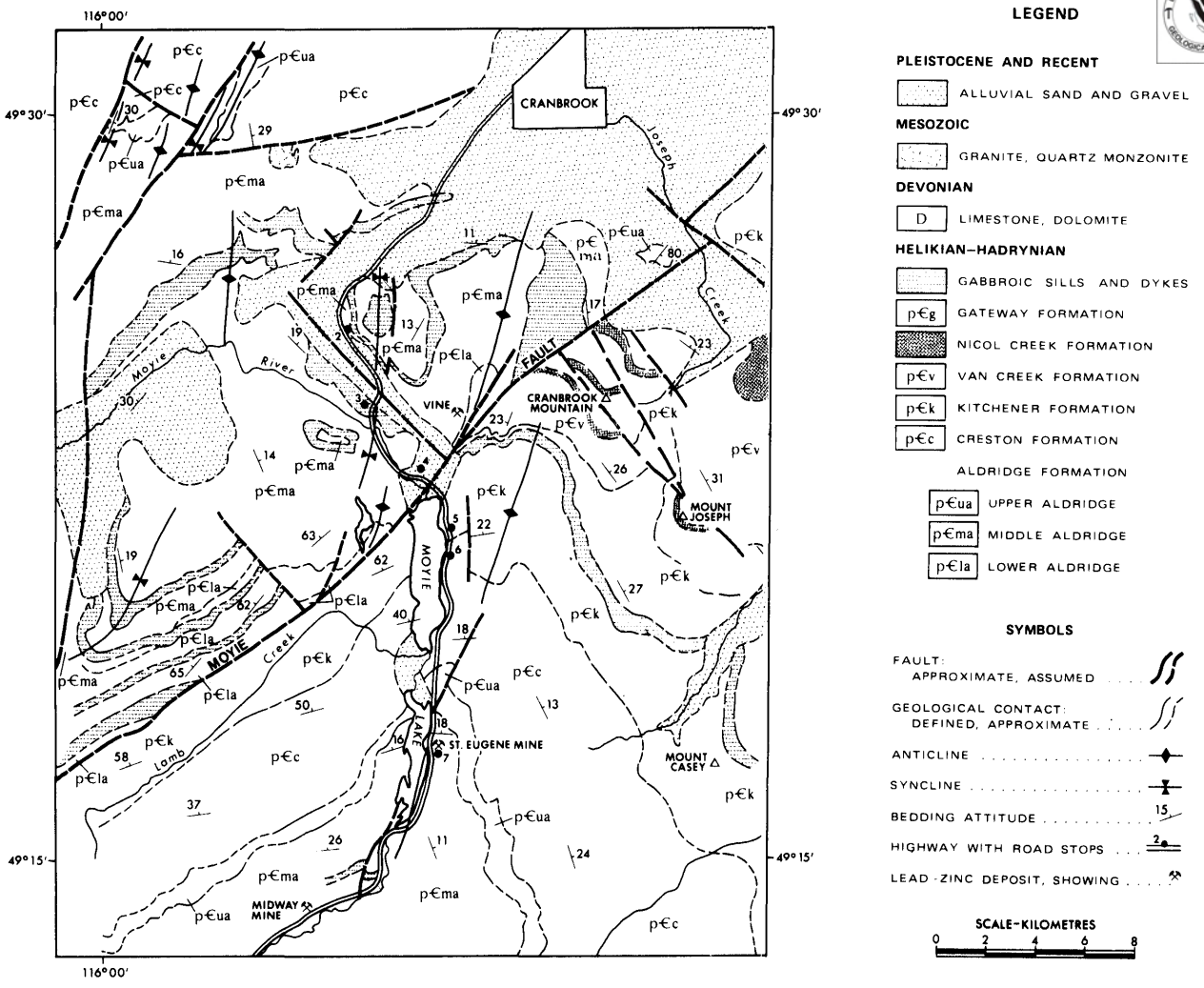


Figure 17. Geological map of the Moyie Lake area, showing excursion route.

69.3 to 77 km The route runs on glacial gravels that overlie Creston and Kitchener Formation rocks (Fig. 18).

77 km St. Mary River. Outcrops of Kitchener Formation occur along the river bank.

88.5 km The trace of the St. Mary fault, a right-lateral reverse fault with 12 km of apparent strike separation (Fig. 18). South of the fault, Cambrian rocks lying unconformably on Nicol Creek and Gateway Formations are exposed whereas north of the fault, Lower and Middle Aldridge rocks are exposed (Høy, 1984c).

STOP 7, 91.3 km Mark Creek and Marysville. Lower Aldridge sedimentary rocks within a few metres of the Sullivan Mine horizon are exposed in the gorge below the bridge. In general, these are thin-bedded sub-wackes and argillites although meta-sandstone units occur. The Stop permits a comparison with the turbidite-bearing Middle Aldridge Formation at Stop 6. Particularly note the bedding thickness, which is thinner and less well-defined than in the Middle Aldridge.

DAY 3: THE SULLIVAN OREBODY

P.W. Ransom, G.D. Delaney and D. McMurdo

INTRODUCTION

The Sullivan sulphide orebody, hosted by the Middle Proterozoic Aldridge Formation, is estimated to have originally contained 160,000,000 tonnes of 6% lead, 6% zinc, 28% iron and 67 gm per tonne silver. The orebody overlies a feeder system, represented by a zone of fragmental rocks, boron alteration and sulphide-rich veins. The feeder system formed as result of penecontemporaneous tectonic disturbance and submarine hydrothermal activity within an otherwise stable sedimentary environment. Pyrite-chlorite alteration of ore and albite-chlorite-pyrite alteration of hanging wall rocks indicate hydrothermal activity

continued subsequent to deposition of sulphides.

GEOLOGICAL SETTING

The Aldridge Formation in the Purcell Mountains is divided into Lower, Middle and Upper (Fig. 15). The Lower Aldridge comprises at least 1500 m of rhythmically graded thin- to medium-bedded very fine grained wacke. The Middle Aldridge contains 2000 m of medium- to thick-bedded wacke and quartzitic wacke. Most of these rocks were deposited as turbidites. The Upper Aldridge consists of 300 m of thin-bedded to laminated argillite. The Aldridge Formation has been metamorphosed to lower and middle greenschist facies. It has been folded into generally broad, open north-plunging folds of the Purcell Anticlinorium (Fig. 1). The Sullivan orebody lies conformably at the top of the Lower Aldridge on the east side of the Purcell Anticlinorium (Figs. 1 and 18).

The Moyie gabbroic intrusions total up to 700 m of thickness in the Lower Aldridge and up to 400 m in the Middle Aldridge (Fig. 15). Some gabbro bodies are coarse-grained and thick, indicating intrusion at substantial depths; others are chilled and erratic in a manner that suggests intrusion into wet sediment (Høy, 1984a).

Zircons from differentiates of a sill near the top of the Lower Aldridge have uranium-lead ages of 1433±10 Ma (Zartman et al., 1982). LeCouteur (1973) determined lead isotope ages of 1200 to 1400 Ma on galena from the Sullivan orebody; Godwin (1982) subsequently reinterpreted this data and obtained an age of 1490 Ma. Biotite in

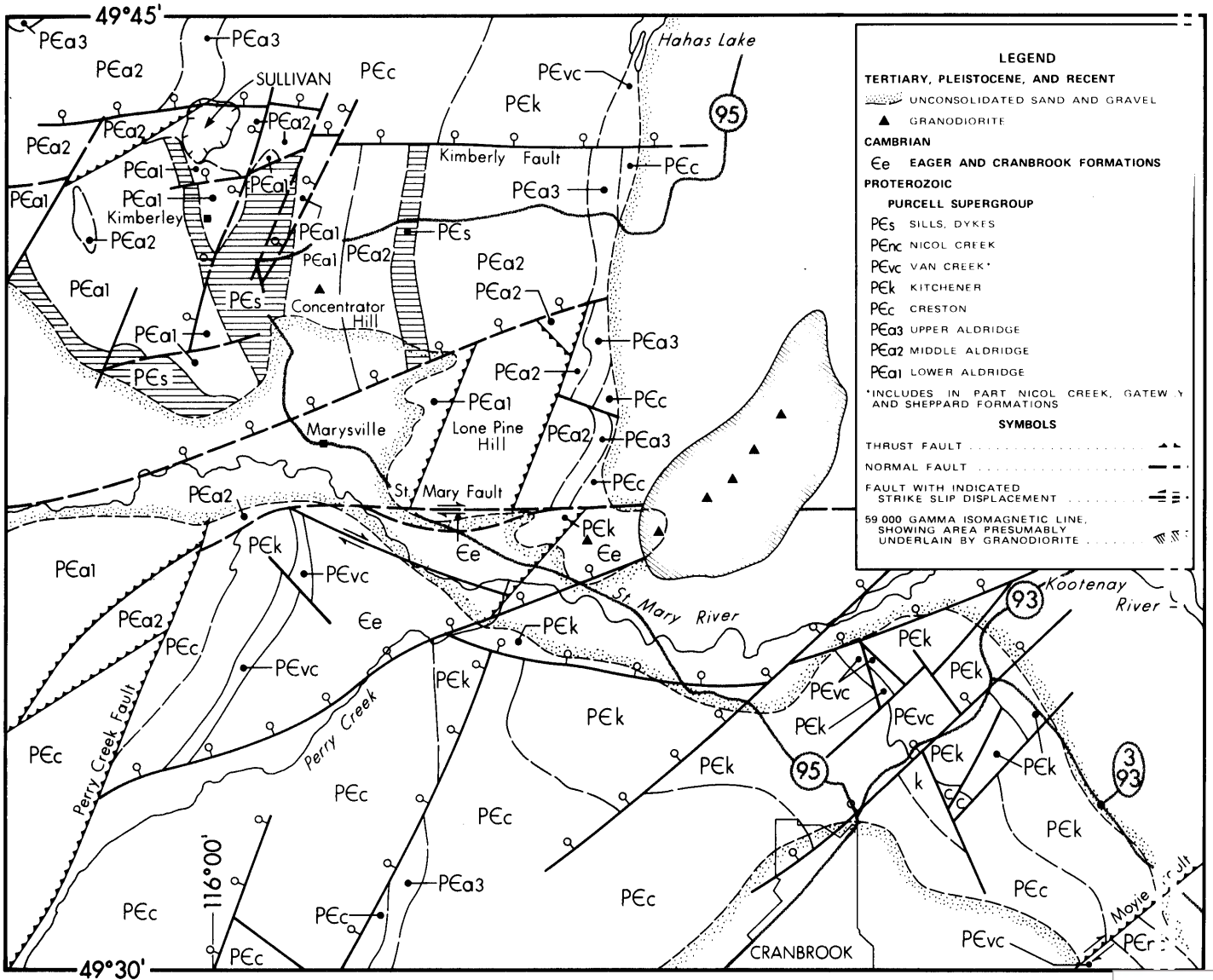


Figure 18. Geological map of the Kimberley area, showing excursion route.

the zone of associated hanging wall alteration has a K/Ar age of 1436 Ma (LeCouteur, 1979).

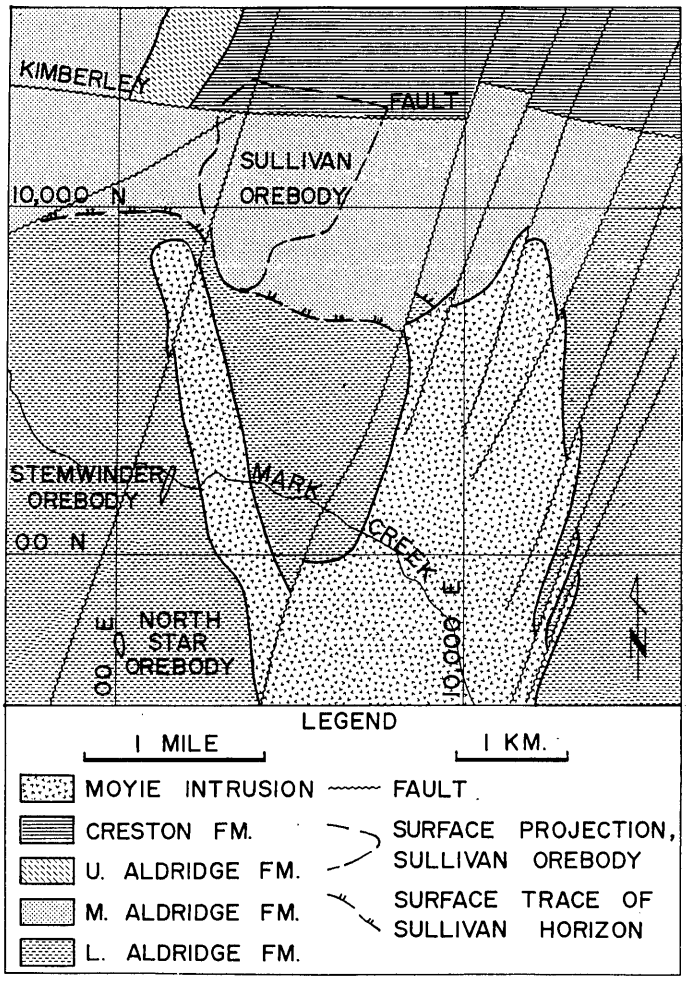


Figure 19. General geology in the vicinity of the Sullivan orebody.

PRE-ORE FEATURES

Bedded Sediments

The interval of Lower Aldridge sediments immediately underlying the orebody consists of 150 m of thin- and medium-bedded, very fine grained wacke. The main mineral constituents are quartz, sericite, biotite, pyrrhotite and minor carbonate. Near the top these rocks are interbedded with pyrrhotite laminated wacke.

Fragmentals

Bodies of discordant and conformable fragmental sedimentary rocks underlie much of the orebody and extend several kilometres south. Where unaltered, composition of matrix and clasts of the fragmentals is indistinguishable from enclosing Lower Aldridge strata.

Isolated near-vertical discordant fragmental bodies up to several metres wide and transecting several tens of metres of strata have been mapped adjacent to a major and central fragmental complex that is almost 1 km wide and cuts in excess of 100 m of strata under the central part of the orebody (Figs. 20 and 21; Delaney and Hauser, 1983). Clasts in these fragmentals are sand- to cobble-size and are angular to rounded. Where discordant fragmental bodies have coalesced, blocks of bedded sediment up to 10 m across have been incorporated. Bodies of these large blocks have been named chaotic breccia (Jardine, 1966). Most chaotic breccia is found in north trending zones up to 150 m wide and 1000 m long (Fig. 21).

The central discordant fragmental merges into a conformable body (conglomerate) that underlies most of the eastern part of the orebody. From a maximum thickness of about 50 m the conformable fragmental tapers to the east where it averages 15 m (Fig. 21). In the central area it is separated from ore by up to 12 m of laminated wacke; to the east the overlying wacke thins out and ore rests on the fragmental. clasts in this fragmental are sand- to cobble-size and are typically pebble-size; most are rounded to subrounded.

The discordant fragmentals are interpreted to have resulted from localized release of pore overpressure within the sedimentary pile. Once initiated, the release of hydraulic pressure was probably rapid and violent. As ascending turbulent fluids stoped through the sedimentary pile fragments of sediment were incorporated and abraded. The resulting slurry was expelled through discharge centres onto the sea floor and accumulated as a mound that ultimately slumped toward the east. The conspicuous, generally north-south alignment of chaotic breccias, which flank the dislocation zones, reflect prevailing tectonic forces acting within the basin of deposition. As material was withdrawn from depth a depression developed, possibly in conjunction with a larger downwarp of this part of the basin to form a sub-basin. The lower parts of the irregular topography were filled by bedded sediment prior to the onset of ore deposition. The discharge pipes became the conduits for upwelling hydrothermal solutions. Fragmentals are evidence that substantial cross-strata permeability developed prior to deposition of sulphides.

Pre-ore Alteration

The western half of the orebody is underlain by a funnel-shaped zone of tourmalinite that extends at least 450 m below the sulphide footwall (Figs. 20 and 21); within this zone, matrix and clasts of discordant fragmentals are intensely tourmalinized.

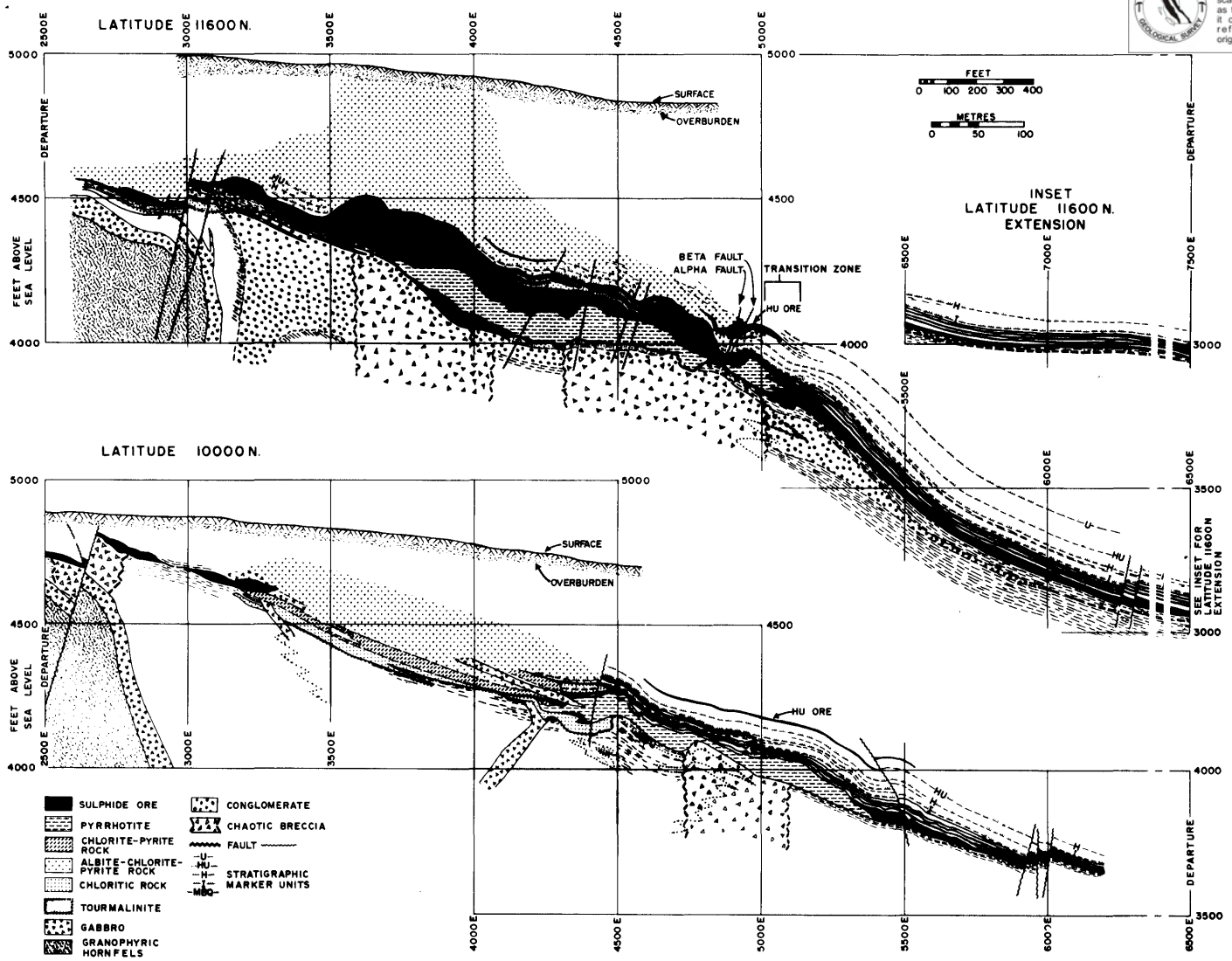


Figure 20. East-west vertical sections through the Sullivan orebody.

Although rare, tourmalinite clasts are present within the concordant fragmental at sites remote from the discharge centre. Boron-rich lenses have been recognized in sediments adjacent to the tourmalinite 'funnel' as much as 50 m below the sulphide footwall (Shaw and Hodgson, 1980). In hand specimen tourmalinite resembles black or dark brown chert. Most tourmalinite appears to have resulted from the addition of boron to unlithified sediments, however Shaw and Hodgson have cited synsedimentary deposition of boron-rich muds (op. cit.). Recent oxygen isotope data (Nesbitt et al., 1984) is interpreted to indicate that tourmalinite was formed by low temperature (<100^{0}C) solutions.

Extensive tourmalinization of the discordant fragmentals and proximal footwall strata shows large volumes of hydrothermal fluids rich in boron passed through the discharge pipes prior to sulphide deposition. The presence of tourmalinite in clasts in the concordant fragmental is convincing evidence that the tourmalinization process was active before completion of fragmental formation. Synsedimentary tourmalinite lenses in footwall strata suggest the combined tourmalinization - fragmental development process was prolonged.

SULPHIDE DEPOSITS

The principal sulphide deposit is a stratiform upwardly convex lens and subordinate bands covering an area 1.6 x 2.0 km composed almost entirely of pyrrhotite, sphalerite, galena and lesser pyrite. Associated silver is economically important. Trace metals include Mn, As,Cu, Sn, W, Sb, Cd, Bi, In, Tl, and Hg, some of which are

recovered commercially. The orebody overlies a system of sulphide veins and is in sharp conformable contact with adjacent clastic sediments. It is truncated on the north by the Kimberley Fault.

The sulphide deposits are conveniently described in three parts; footwall sulphide veins, a thicker western zone of continuous sulphides that are either massive or internally banded, and an eastern zone of bedded sulphides and intercalated clastic sediments.

Veins

A system of north-trending sulphide veins is associated with the discordant fragmentals and tourmalinite beneath the orebody. Massive veins are less than 1 m wide but sulphide stringer zones occur which are several tens of metres wide. Both inter- and intra-clast sulphide impregnations occur within the fragmentals. The veins typically contain pyrrhotite, galena and sphalerite. Some veins contain quartz, arsenopyrite, chalcopyrite, cassiterite, tourmaline or scheelite. The network of veins is persuasive evidence of an underlying feeder system to the Sullivan orebody.

Western Part of the orebody

The thicker western part of the Sullivan orebody overlies the discordant fragmentals, tourmalinite and sulphide veins. Its average thickness is 50 m; the range in thickness is 10 to 100 m (Fig. 21). In general it is about twice as thick as the eastern ore zone. In the northern part the lower two-thirds of the sulphide mass is a subeconomic pyrrhotite lens up to 35 m thick and 350 m long that contains sphalerite and galena disseminations, fracture fillings and veins. The pyrrhotite grades upward and laterally into ore of massive pyrrhotite containing laterally discontinuous layers of galena and sphalerite. This is overlain by higher grade ore of well banded galena, sphalerite and pyrrhotite with clastic interbeds. In some locations massive galena is up to 10 m thick. Much of the uppermost western ore is extremely deformed.

Sulphide veins within the pyrrhotite lens indicate an extension of the discordant footwall feeder structures through initial stages of mineralization. The thick section of internally homogeneous sulphides containing only a minor clastic component is indicative of rapid accumulation which may have been sufficient to create a sulphide mound over the vent. Some pyrrhotite has transgressed well-laminated galena and sphalerite; Shaw and Hodgson (1980) proposed that formation of the pyrrhotite lens was by replacement of lead-zinc sulphides by pyrrhotite. Layering of sulphides and the presence of intercalated clastic beds near the top of the western part of the ore zone indicate a relatively reduced rate of sulphide deposition.

A transition zone between the western and eastern ores overlies the eastern margin of the footwall tourmalinite (Fig. 20). This zone is up to 75 m wide and is characterized by a thinning of the ore and by complex folding of bedded sulphides.

Eastern Part of the orebody

The eastern ore sequence averages about 30 m in thickness (Fig. 21) and consists of five laterally persistent bedded sulphide units ("Bands") in sharp contact with interbedded wacke (Fig. 20). From base to top the sulphide bands are named "Main Band", "A", "B", "C", and "D Bands". A stratigraphic section through this sequence is shown on Figure 22. The basal one-half to two-thirds of the "Main Band" is a succession of fine grained pyrrhotite, sphalerite and galena in beds in which one of the minerals is predominant. The beds are generally less than 3 cm thick but may be as thick as 30 cm.

The upper portion of the "Main Band" and the overlying bands have up to 15% interbedded wacke. Individual sulphide layers are thin beds or laminae and almost monomineralic. Laterally persistent intervals up to 20 cm thick of nearly monomineralic lamellae .3 to 10 mm thick are common in the eastern ore zone. One or two thick graded, turbiditic wacke beds separate each of the five ore "Bands" and make up to 25 to 40% of the eastern ore section or about 60% of that part of the interval above the "Main Band".

Eastern ore is believed to represent distal accumulations of metallic sulphides derived from a brine cell which spread from the central feeder. Delicate and laterally extensive monomineralic bands of galena, sphalerite and pyrrhotite are indicative of rhythmic precipitation caused by minor changes in physical-chemical conditions within the inferred brine cell. Composition of the brine fluctuated both as individual sulphides were precipitated and as metals continued to be replenished through the feeder system. The basal part of the "Main Band" most likely postdates the early rapid accumulation of sulphides over the vent area.

Metal Distribution

The planar distributions of Pb, Zn, Ag, and Sn are shown in Figure 23. The distributions show concentration of these metals and the highest ratios of silver to lead and lead to zinc are central to the western part of the orebody. Vertical metal distribution in the western part of the orebody trends

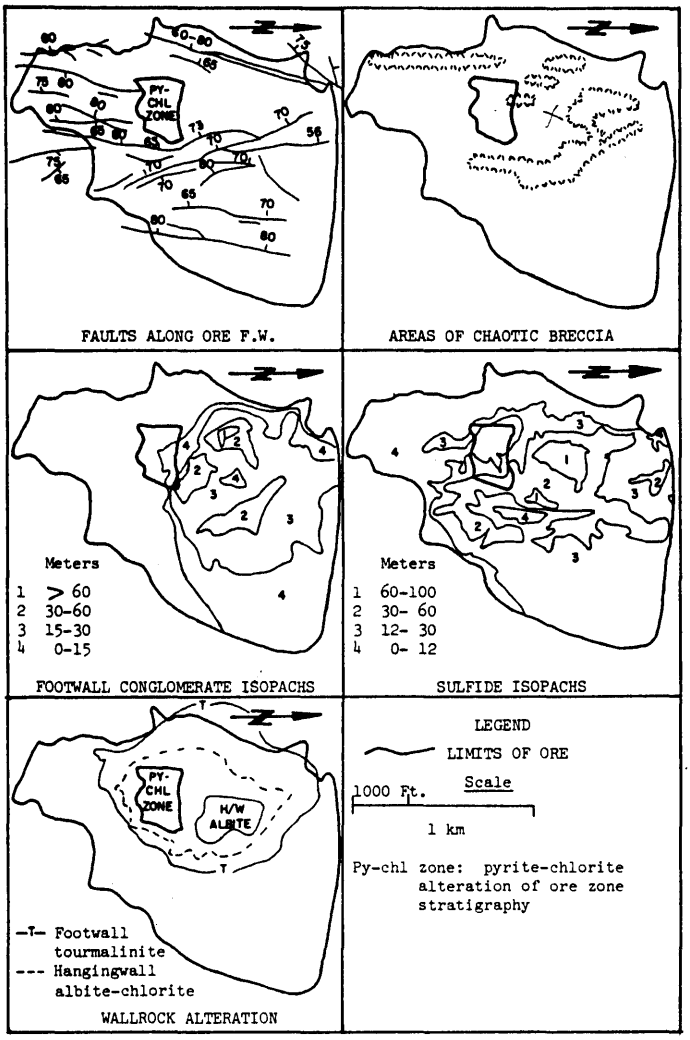


Figure 21. Faults, breccia distribution, conglomerate and sulphide isopachs, and wallrock alteration, Sullivan orebody.

toward increasing Pb and Zn and decreasing Fe up-section. In contrast, vertical metal variations through portions of the Eastern ore sequence show a general decrease in lead, zinc and silver and relative enrichment in iron up-section (Fig. 24; Hamilton et al., 1983).

The concentricity of metal distributions and coincidence of metal concentration over footwall features described in this paper support the hypothesis of a central feeder system. Theories of evolution of the metalliferous brine and of physical-chemical conditions in the inferred brine cell are complicated by contrasting vertical trends of mineralization. These phenomena themselves may be indicative of distinct physical-chemical conditions in the brine cell or the mode of origin of the basal pyrrhotite.

POST-ORE FEATURES

Stratigraphy

Three distinct stratigraphic intervals, I, H, and Hu conformably overlie the eastern ore and parts of the western ore. The base of each interval is a very thick (1 to 5 m) bed that grades from quartzitic wacke to argillite. The top of each interval is 2 to 6 m of argillite characterized by disseminations and thin laminae of pyrrhotite. Distinctive pyrrhotite laminations have been matched (Freeze, 1966) over distances of 1000 m. Up dip and to the south the pyrrhotite laminations pass into ore grade material.

Beneath the H sulphide laminations is the Hanging Wall Conglomerate which has an average thickness of 4 m and has been traced about 1000 m along the southern margin of the orebody. In contrast to fragmental rocks in the footwall, it contains some ore grade clasts.

The Hanging Wall Conglomerate overlies a north trending discordant fragmental that crosscuts the southwest part of the orebody to this stratum. Where the Hanging Wall

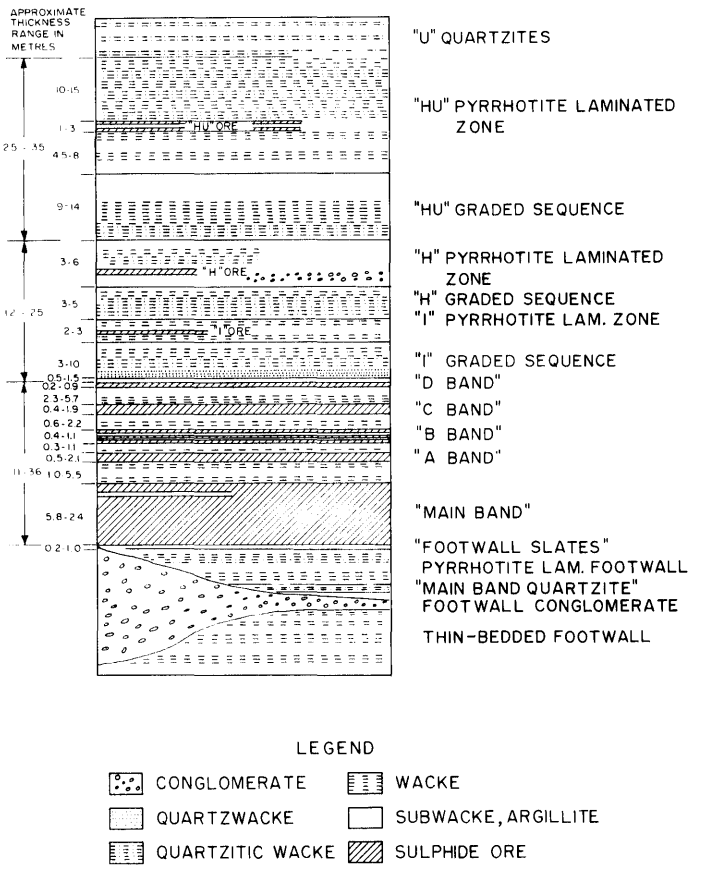
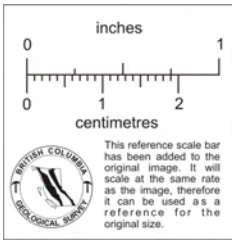


Figure 22. Ideal geological column, eastern part of the orebody.



Conglomerate is absent, up to 2 m of strata at this horizon appear to have been subjected to soft sediment deformation.

The Hu stratigraphic interval is overlain by the U Quartzites which are regarded as the base of the Middle Aldridge (Fig. 22).

Post-ore Alteration

Chlorite alteration is found along the eastern margin of the footwall tourmalinite zone. Below the centre of the orebody chlorite also occurs both in crosscutting zones of large vertical extent and in a conformable layer up to 10 m thick which is in contact with sulphides. Albite veins are present in the vertical zones of chlorite alteration.

The western ore sequence is cut by a cylindrical zone of pyrite-chlorite-calcite alteration approximately 350 by 250 m across that overlies albite-chlorite alteration in the footwall. In the core of this zone pyrrhotite is almost completely replaced by pyrite; galena and sphalerite are essentially absent. Enveloping the core is an outer shell in which replacement of pyrrhotite by pyrite is incomplete and some sphalerite and galena remain. Chlorite and calcite are present throughout the entire zone (Shaw and Hodgson, 1980).

Hanging wall rocks above the western portion of the orebody are altered to an albite-chlorite-pyrite assemblage as much as 125 m thick (Fig. 21). Massive albitite grades outward into albitic and chloritic rock in which original sedimentary layering is preserved. The albitite core is 225 m northeast of the pyrite-chlorite-calcite alteration assemblage of the ore zone. That this relationship represents a decollement is supported by displacements on gabbro dikes.

The coincidence of all footwall alteration features, both pre- and post-ore together with sulphide veins, indicate continued use of a footwall hydrothermal feeder system. The hanging wall alteration represents the extended development of this system and the final phase of hydrothermal activity which continued beyond deposition of sulphides.

Moyie Intrusions

Beneath eastern ore and also to the immediate west of the orebody broadly conformable Moyie gabbro intrusions are present 450 m below the ore horizon. These intrusions comprise a 60 m thick basal gabbro and a 15 m thick upper gabbro, separated by 90 m of recrystallized sediment. Below the western side of the orebody the gabbro units abruptly transgress the footwall sequence and form a 1 km wide north plunging arch, the crest of which is in direct contact with western ore. Apophyses of gabbro transect the orebody as small dikes. Regional field observations and age dating show some of the Moyie intrusions were being emplaced in the Aldridge basin at or about Sullivan time.

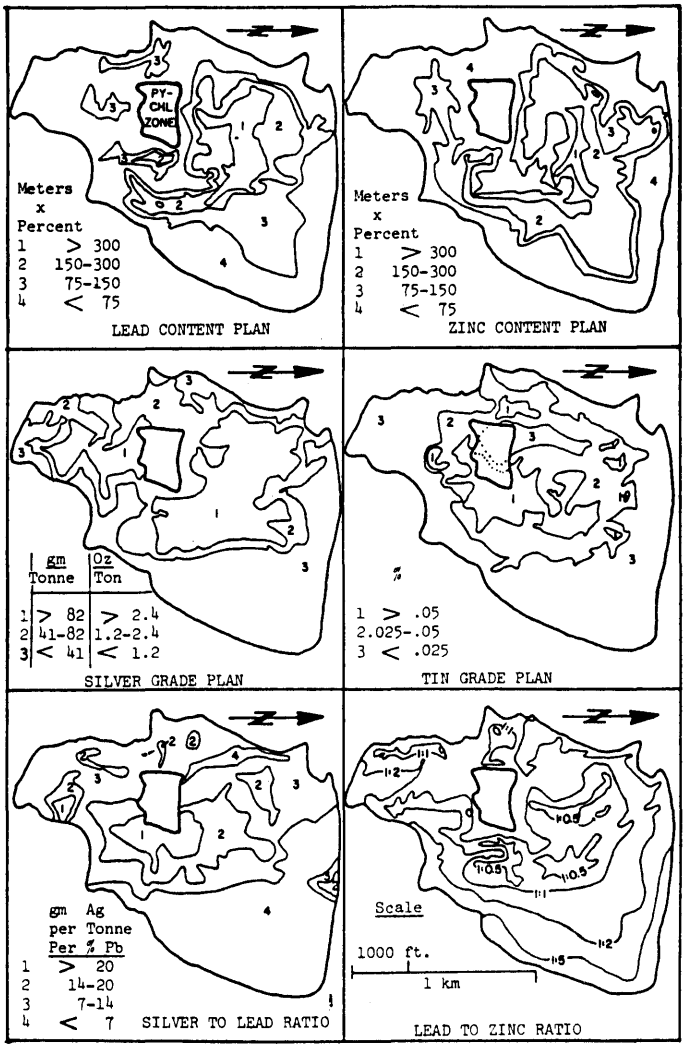


Figure 23. Metal distribution maps, Sullivan orebody.

Structural History

Complex structures within the Sullivan orebody amplify regional tectonic events due to ductility contrast between sulphides and clastic rocks (McClay, 1982a,b). Initial overriding of the hanging wall to the east, displayed by offset of the hanging wall alteration zone and segmentation of gabbro dikes in the orebody, caused recumbent isoclinal folds in the sulphides. Continued deformation caused asymmetric folds, commonly overprinting isoclinal folds, and thrust faults at the orebody, as similar

structures developed regionally. This phase of deformation probably included displacement on the Kimberley Fault. Subsequently lamprophyre dikes were intruded. Later structures include relatively minor west verging thrusts and folds. All these deformational events are ascribed to the Laramide orogeny. Crustal extension during the Eocene (Price et al., 1981) resulted in west-dipping normal faults. Where they offset the orebody (Figs. 20 and 21) these faults have displacements of up to 30 m.

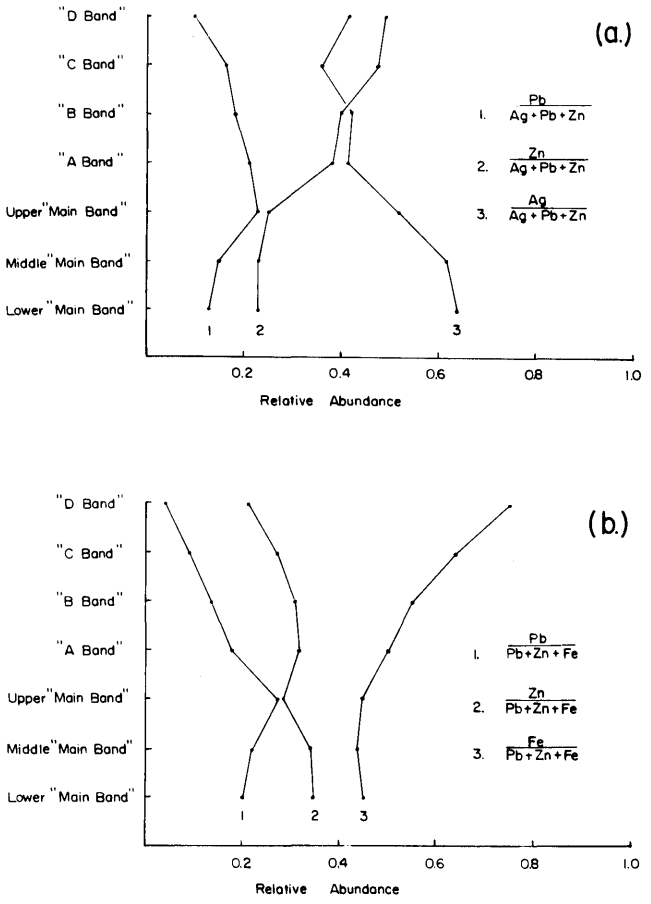


Figure 24. Vertical metal variations, eastern part of the orebody.

ORE GENESIS

The ore-Moyie gabbro age and spatial relationships have led several authors (Hamilton et al., 1982 and 983; Hamilton, 1984) to speculate that the heat dissipated from a parent magma body could be sufficient to cause widespread convective leaching and transportation of metals from Lower Aldridge sediments. Additional or alternate sources of heat have been cited as radioactive decay and exothermic reactions in Lower Aldridge sediments, and high heat flow through an area of thin crust (op. cit.).

Essential to the formation of a mineral deposit by any heat related process of intra-formational elemental scavenging and transportation is a feature to focus solution flow and provide an outlet to an environment where prevailing conditions will cause precipitation of transported elements. Such a feature is seen below the Sullivan ore body in the form of north-trending near-vertical fragmental bodies. These and the localized discordant gabbro arch in proximity are evidence of lines of crustal weakness.

SUMMARY

The Sullivan orebody is interpreted as a hydrothermal synsedimentary sulphide deposit which formed in a sub-basin on the Aldridge marine floor. It is located directly over cross-cutting bodies of fragmental rocks, products of pore overpressure release along lines of crustal weakness. Dislocation zones so formed became conduits for boron-rich fluids which permeated sediments in and adjacent to them and discharged onto the sea floor. Composition of the fluids changed and sulphides were deposited.

The initial sulphide assemblage comprised pyrrhotite and unknown amounts of galena and sphalerite. Sulphide deposition near the vent area was rapid. Galena and sphalerite were remobilized from parts of the basal sulphide accumulation and were redeposited with pyrrhotite in layers throughout the western part of the orebody.

The distal eastern ore is considered to be slightly later than the basal sulphide accumulation and to be derived from a brine cell eminating from the vent. Continued deposition resulted in well layered sulphides interbedded with wacke to form the upper parts of the entire orebody.

Infilling of the sub-basin was completed with deposition of the I, H and Hu stratigraphic intervals. Although clastic sedimentation was predominant there was further deposition of some sulphides.

Some chlorite alteration in the footwall and above the feeder took place during the early stages of sulphide mineralization. A post sulphide phase of hydrothermal activity produced albite-chlorite-pyrite alteration in the footwall, pyrite-chlorite-calcite alteration in the ore zone and albite-chlorite-pyrite alteration of the hanging wall. Hydrothermal solutions are believed to have resulted from widespread convective leaching of Lower Aldridge sediments. Possible sources of thermal energy include high heat flow from magmatic intrusion or region of thin crust and radioactive decay and exothermic reactions in the sedimentary pile. Focused discharge of hydrothermal solutions was along lines of crustal weakness.

ACKNOWLEDGMENTS

Observations and conclusions on genesis of the Sullivan orebody and associated unique rocks have been made by several generations of geologists and the authors wish to acknowledge that it is mostly on the work of others that this field guide is based. Many of the concepts presented in this paper are embodied in Geology of the Sullivan Deposit, Kimberley, B.C., Canada (Hamilton et al., 1983). Some of the new thoughts on origin of fragmental rocks and the relationship of these to genesis of the Sullivan orebody are from G.D. Delaney and R.L. Hauser (1983). Most figures that accompany this article have appeared in previous publications by Sullivan geological staff. We wish to thank E.D. MacDonald and M.E. Knapp for reviewing the manuscript and Cominco Ltd. for permission to publish this field guide.

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CMJ Capital Spending Report

Company	Purpose of expenditure	$000s to be spent 1981	1982	1983	Beyond 1983
Equity Silver (continued)	Regional exploration		100		111
	Replace mill equipment	155	6		6
	Buy on-stream analyzer	200			
	Additions to flotation	200			
	Mill expansion				2,500
	Replace plant equipment	121	300	70	280
	Move carpenter shop	55			
	Replace misc. equipment	41	177	39	363
	New warehouse storage	50			
	Buy computer facilities		75	75	
	Replace telephone system	20			
	Total: $11.64 million				
Esso Minerals Canada	Having just bought the Byron Creek colliery in southeastern BC, Esso plans to expand it.	35,000	35,000		
	Total: $70 million				
Fording Coal Ltd	The $115 million coal mine expansion at Elkford is well under way.	38,000	26,000	20,000	
	Total: $84 million				
Lornex Mining Corp Ltd	The $160 million expansion of the copper mine at Logan Lake, BC, is complete. Project included upping the milling rate to 80,000 tpd and purchasing additional pit equipment.	78,300			
	Total: $78.3 million				
Noranda Mines Ltd	The Goldstream copper-zinc mine near Revelstoke is scheduled to be in production late in 1982 at a rate of 1350 tpd. Total cost of the project is estimated at $62 million.	27,600	16,300		
	Studies have started on modifications to the ore handling and processing systems at the Granisle mine.	300	300		
	Total: $44.5 million				
Norco Resources	A hydraulic and longwall coal mine is planned at Bowron River, near Prince George, BC. Output will be sold to Taiwan Power Co.	40,000	41,000		
	Total: $81 million				
Placer Development Limited	The bulk of spending at the Endako moly mine will be for upgrading the mill.				
	Replace mobile equipment	50	1,291	1,511	
	Upgrade and replace process equipment	536	1,815	1,040	
	Complete flotation expansion	185			
	Complete roaster expansion	1,697			
	Total: $8.125 million				
Ruth Vermont Mine Limited	This silver-lead-zinc producer was reopened this summer in southeastern BC.	4,000			
	Total: $4 million				

(GIBSON)

Goldstream massive sulphide deposit

By L.C. REINERTSON
District geologist
Noranda Exploration Co Ltd

The Goldstream deposit, located in southeastern B.C., is a stratabound high-grade copper-zinc massive sulphide body. It occurs within an extensive belt of meta-sedimentary and meta-volcanic rocks. This stratigraphy hosts several other similar, previously known occurrences. It is a new discovery made by prospecting despite the fact that the mineralization is not exposed at surface. The deposit is characterized by its simplistic geometry, continuity of mineralization, and consistent grade.

The Goldstream River, located in southeastern B.C., is one of the many large tributaries of the Columbia River system. It flows westward out of the rugged Selkirk Range of the Columbia Mountains. The deposit is located 90 km by road north of Revelstoke. It subcrops on the south side of the Goldstream River, 14 km upstream from its confluence with the Columbia. Access to the property is excellent. The first 80 km north of Revelstoke are on the paved Mica Creek Highway, from where a system of good logging roads leads up the Goldstream Valley.

The Goldstream River valley is typically U-shaped, has floor elevations of 600 m to 650 m (above sea level) and is flanked on both the north and south by mountain peaks of between 2400 m and 2700 m.

Elevations on the claims range from 600 m in the valley bottom to 1500 m. The showings occur at an elevation of 945 m where slopes are in the order of 15° to 22°, becoming more gentle towards the river.

Climate is Interior Rain Belt, with temperatures ranging between −15°C to +30°C. Annual precipitation averages 1.15 m, more than half of which falls as up to 6 m of snow. Below the 1200 m elevation the ground is often not frozen beneath the snow. Snowpack at any one time does not exceed 1.5 m.

This paper was originally presented to the 46th annual convention of the Prospectors and Developers Association.

King and the Brieds dug a series of hand pits during the summer of 1974, which revealed an increasing incidence of sulphide fragments with depth

Vegetation is typical Rain Forest, tree cover being predominantly cedar with lesser hemlock, balsam and spruce. Cottonwood grows as groves in swampy sections along the river. Most trees are mature, varying in size from 0.5 m to 2.0 m in diameter at the base and average over 30 m in height. Tree density is in the order of 75 per hectare. Large windfalls of over mature cedar are common and the underbrush is mainly prolific Devil's Club. These factors along with the slope make ground traverses unpleasant and arduous.

Reinertson

Logging has been carried on in the general area for the past 15 years, with a "clear cut" type operation being the most common method employed. Almost all the logging has been done below the 900 m elevations and approximately 40 per cent of the claim group has been logged.

Regional geology

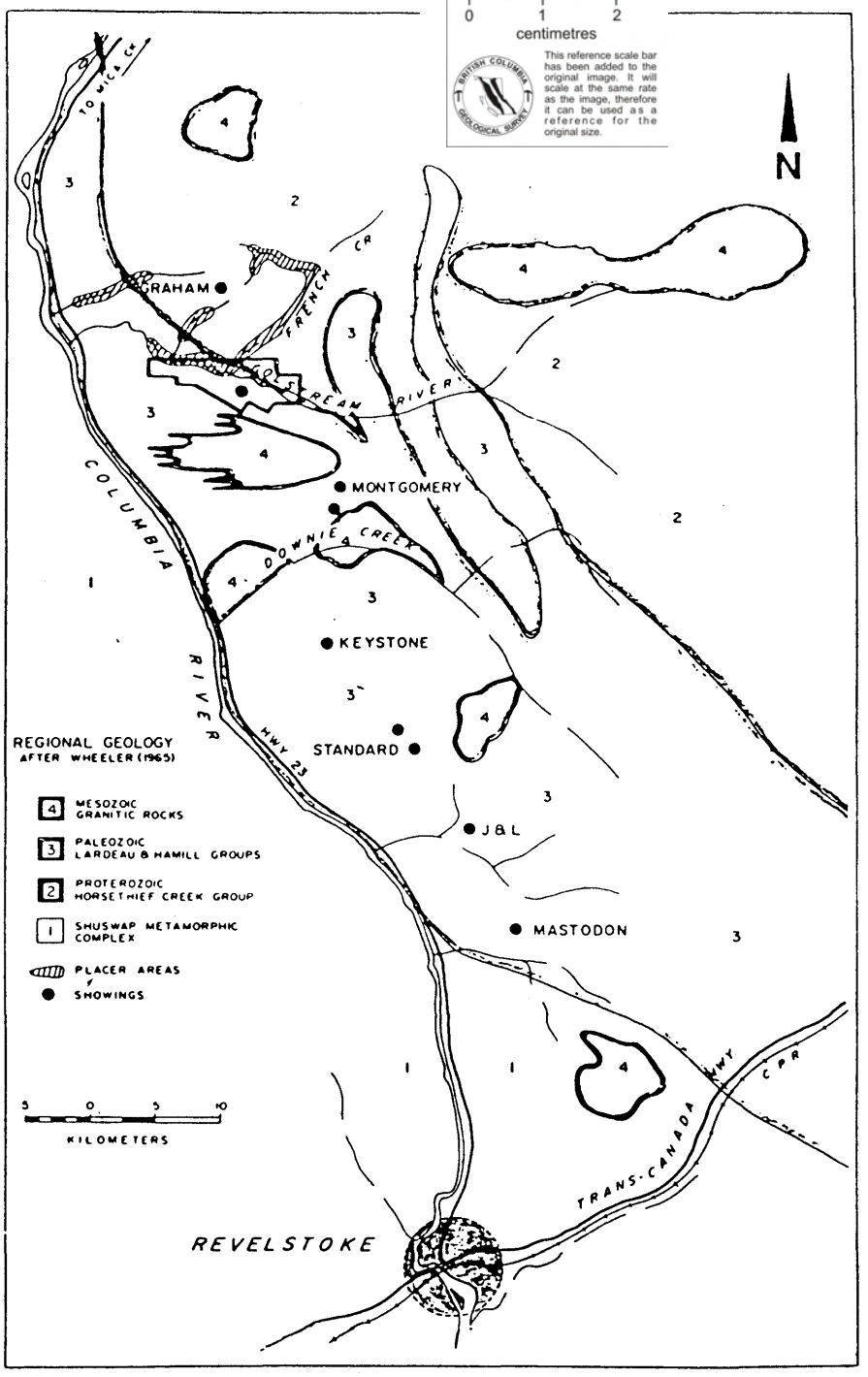
The stratigraphy hosting the Goldstream deposit and other massive sulphide occurrences consists of a package of paleozoic meta-sedimentary and meta-volcanic rocks. It is flanked on the west by the Shuswap Metamorphic Complex of uncertain age, and on the east by Proterozoic rocks. The metasediments consist of limestones, micaceous marbles, calcareous phyllites, graphitic phyllites, quartz-sericite phyllites and phyllitic quartzites. The meta-volcanics occur as hornblend-chlorite schist, chlorite schist, talc-

serpentine and chlorite-biotite-quartz schist. The meta-volcanic units often take the form of large lenticular bodies, the thinning of which is accompanied by a corresponding thickening of the surrounding sediments. The whole package generally strikes north to northwest with gentle to moderate east to northeast dips. In the area of the Goldstream deposit, average strikes are N 70°W with 35° northeast dips.

Rugged topography, the emplacement of several Mesozoic granitic plutons, and major fold structures combine to give a complicated picture of regional geology.

Mining activity in the Goldstream area started in the 1860s when placer gold was discovered in the lower Goldstream and some of its tributaries, Camp Creek, McCullogh Creek, French Creek and Graham Creek. Several placer leases are still held on McCullogh and French Creeks, with current operations being confined to McCullogh Creek. The source of the gold is considered to be a system of gold-bearing quartz-sulphide veins that outcrop in the uppermost reaches of these creeks.

Considerable "hardrock" exploration took place from 1890 to 1930 with concerted efforts on such properties as; the Mastodon (Zn, Ag, Pb), J & L (Au, Ag, Pb, Zn), Standard (Cu, Zn), Keystone (Pb, Zn, Ag), Montgomery (Cu), and Graham (Au). Sporadic work has been done since then, primarily on or around the old properties. The only producer in the area was the Mastodon, from which 15,000 tons grading 9.5 per cent Zn, 0.2 oz Ag and 0.5 per cent Pb was mined and milled in 1960.



Regional geology of the Goldstream deposit, after Wheeler (1965)

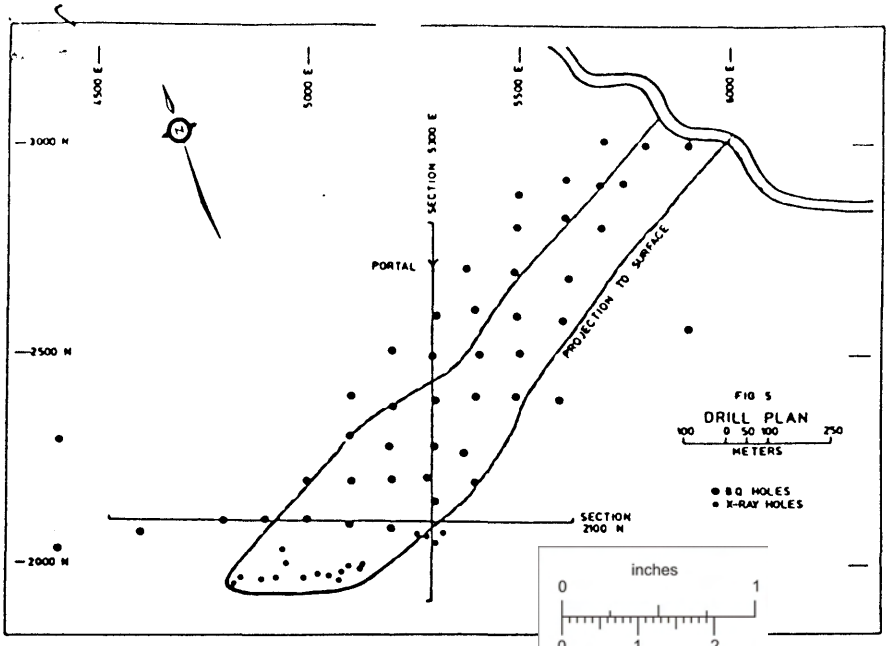
Staking begins

Angular float assaying up to 5 per cent Cu was first discovered in the Goldstream valley in glacial till overburden during logging road construction in 1972. Attempts to locate the source of this material were unsuccessful at that time.

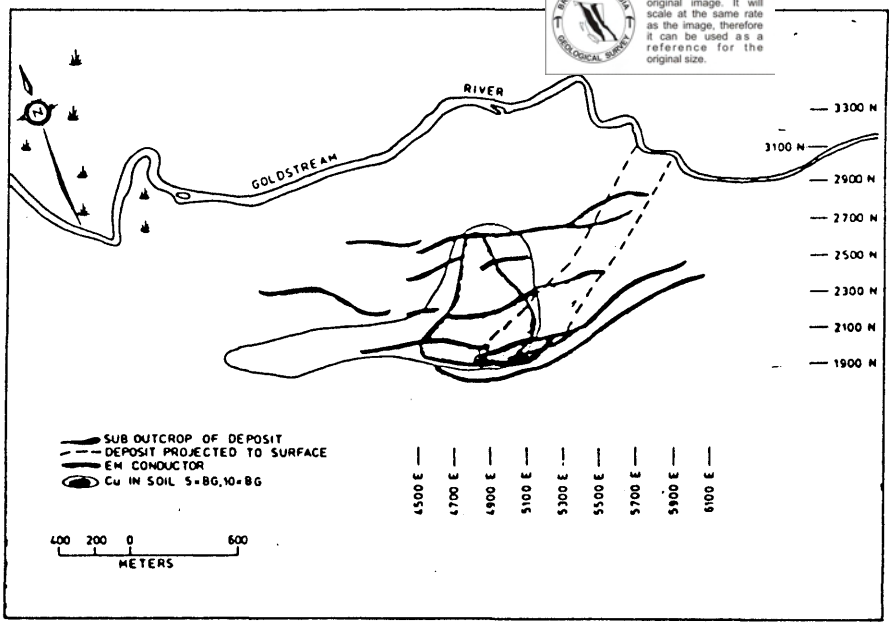
In September of 1973, Frank King of Vernon staked the first claims in the area to cover the mineralized float. At this point he brought in as partners Gordon and Bruce Bried, a father and son prospecting team from Kamloops. Because of the extensive overburden cover, further attempts to find the same material in outcrop met with little success, other than to locate more float in the immediate area. As a result, the owners drilled four x-ray holes in the hillside. These holes intersected a 3 m zone of heavy sulphides, primarily pyrrhotite, that assayed less than 1 per cent Cu. At this stage, a concerted effort was made to farm out the property. However, the owners were unable to convince any majors that additional work was warranted.

Persistent prospecting that fall located more high grade float west of, and uphill from, the original find. The onset of winter prevented any followup of this material that fall. Despite the prevailing snow conditions, the owners were back in March of 1974 to begin digging a series of hand pits in the area of the "new float". The first pit was very successful, after only a few feet it encountered a considerable amount of weathered material consisting mainly of malachite, azurite and limonite. More pitting in the same area gave encouraging results, revealing that the incidence of fresh sulphide fragments in the overburden increased with depth. It is probable that some of these pits actually reached bedrock, but this was difficult to ascertain due to excessive mud and water in the bottoms of the pits.

The next step was to set up the x-ray drill next to the first pit. This hole encountered 3.3 m of overburden, 2 m of weakly mineralized quartz-sericite phyllite, and 4.25 m of massive sulphide that assayed 3.8 per cent Cu. A second hole, 60 m west of No. 1, was better yet, assaying 3.4 per cent Cu over 6.7 m, including 3 m of 7.7 per cent Cu. Step out drilling was done in



Drill plan of the Goldstream deposit



Geophysical and geochemical surveys were carried out in conjunction with the drill plan

both east and west directions until 14 good intersections had been obtained over a length of 300 m. This indicated a zone striking N 70° and dipping approximately 40° NE with an average grade and thickness of 4.4 per cent Cu over 4.1 m. Seven additional holes were unsuccessful, due mainly to overburden problems and the inability of the x-ray to drill deep enough to intersect the zone further down the dip. This pitting and drilling effectively used up the 1974 field season and no further work was done that year.

Noranda takes over

Noranda had been following the 1974 work with considerable interest and although it had expressed a desire to do so, was unable to make an agreement with the owners while the work was in progress. Negotiation of an option was completed that fall and Noranda took over on Dec 31, 1974.

The 1975 program was started in April, as soon as the access roads had been snowplowed and a camp moved in. A transit survey was initiated immediately in order to establish a coordinate and elevation system and to survey the x-ray holes. The latter was necessary to confirm the strike and dip of the mineralized horizon, particularly because no bedrock exposures had been located within at least 1 km.

BQ drilling started in late May and by the time four holes were drilled it had been determined that the deposit had a NE rake. Drilling on a 100 m grid continued non-stop until mid-November, at which time 8912 m had been drilled in 50 holes. This outlined a deposit of 3.175 million metric tons grading 4.49 per cent Cu, 3.24 per cent Zn and 20 g/t Ag. The deposit varies in thickness from 3 m to 6 m, in width from 150 m to 250 m, and it has been followed down-dip from 1500 m. At this point it is 300 m below the Goldstream River.

In conjunction with the drilling program, 65 km of grid lines were established. These were used for soil sampling, proton magnetometer and two types of EM survey. A gravity survey was conducted over a portion of the grid at a later date. As can be seen on the compilation map, the presence of the deposit is readily indicated by the copper in the soil geochemistry, while the geophysical data shows a conductor that is somewhat more extensive. The results of the mag survey were inconclusive.

Portal collared

The soil anomaly reveals westerly dispersement following the glacial train of mineralized float, and down-slope dispersement as a result of ground water movement. In both cases anomalous values range from five to 20 times background, with the down-slope anomaly being the more prolific.

The following year, 1976, a portal was collared at the 700 m elevation on section 5300E. A 3 m by 4.5 m adit was driven grid south for 1300 m at which point it intersected the mineralized zone. The mineralization was drifted on east and west for a total length of 330 m. East and west hangingwall drifts were also driven to facilitate detailed diamond drilling from underground. The purpose of the underground program was to test the continuity of the mineralization between surface drill holes, to obtain bulk samples for metallurgical testing, and to obtain a good indication of ground conditions for use in consideration of possible mining methods.

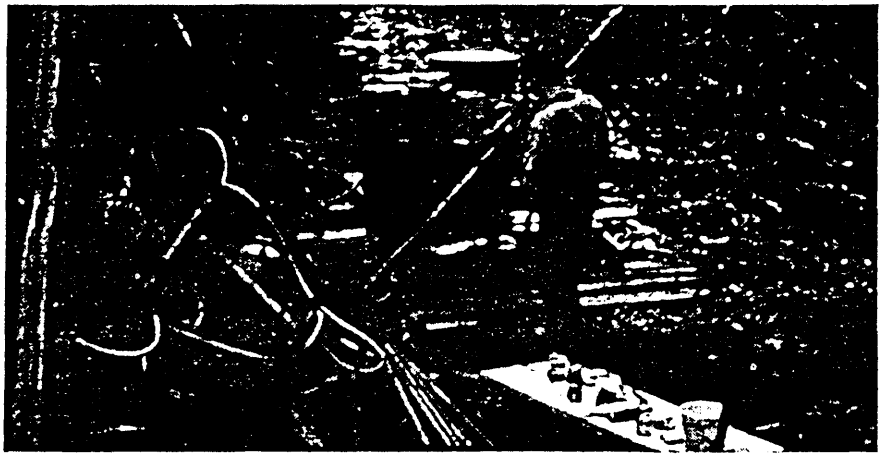
As well, a legal claim survey which had been started in 1975 was completed in 1976 and application made for a mineral lease.

The 1977 program consisted of engineering and design, power studies, and overburden drilling of plant and dam sites.

Property geology

Starting at the collars of the drill holes is Unit 1. This is a 220 m thick calcareous pelitic phyllite referred to as the "Dark Banded Phyllite" (DBP). It is distinctly laminated with individual lamina of grey limestone, white quartz, black hornblende and brown biotite. It

An adit driven during 1976 encountered the mineralized zone 1,300 m into the hillside. Drifts were driven into the mineralized zone, and into the hangingwall, for detailed diamond drilling



The x-ray drill obtained 14 good intersections over a length of 300 m, east and west, indicating a zone grading 4.4 per cent Cu over a thickness of 4.1 m

varies in color from dark grey through dark brown to black, depending on the relative amounts of various lamina constituents. Narrow graphitic zones are common and pyrrhotite is often associated with the amphibole laminations. Quartz often occurs as small boudin structures which appear as layers in the core unless a truncated end is evident.

At the bottom of Unit 1 is what is called the "Garnet Zone". This is a highly contorted, graphitic, foliated, amphibolite containing porphyroblasts of pale orange to buff garnets. This unit varies in thickness from 1 m to 15 m and is occasionally brecciated with white calcite matrix. Sulphide mineralization is common in the garnet zone and may consist of up to 20 per cent pyrrhotite and 2 per cent pyrite. This occurs as irregular bands paralleling the amphibolite laminations.

Unit 3 is considered to be the host rock and is a quartz-sericite-chlorite-biotite phyllite. It varies in color from .le green to brownish green as the quartz content decreases and the biotite content increases. Pyrrhotite, chalcopyrite and sphalerite, where not massive, may comprise up to 25 per cent of the unit and occur as disseminated trains along foliations or thin bands paralleling foliations. Narrow bands of unit 1 are occasionally intercalated with Unit 3 where they may also be mineralized.

Unit 3 is underlain by a light grey crystaline limestone with an average thickness of 15 m. This is followed by a considerable thickness of Unit 6 which is a quartz-chlorite-biotite phyllite containing minor narrow bands of Units 1 and 5.

The massive sulphide zone (Unit 4) occurs within Unit 3 as a continuous layer varying in thickness from 3 m to 6 m. It consists of a medium to coarse grained mixture of pyrrhotite, chalcopyrite, and sphalerite in the relative ratio of 5:3:1. Inclusions of various types may comprise up to 30 per cent of the massive zone. Some of these are eyes of clear glassy quartz, generally less than 2 cm in diameter, eyes of white quartz up to 20 cm in diameter and containing irregular blebs of sulphides, biotite-chlorite-sulphide assemblage, and coarse grained sphalerite-rich sulphides.

Contact well defined

The only definition zoning pattern recognized to date is in the (Zn) to (Zn + Cu) ratio (Hoy and Nelson, 1977). This shows a very well defined lateral zoning with an increase in the relative Zn content to the east as well as in both hangingwall and footwall.

The contacts of the massive sulphide and the mineralized Unit 3 are very sharp and well defined.

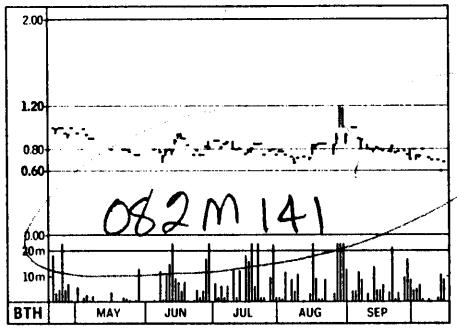
In summary, there are a few points that I would like to make along a general exploration theme. The Goldstream deposit is a "new find". Its discovery can be attributed to only one facet of exploration, that being systematic prospecting with extra measures of determination and persistence. Significant contributions were undoubtedly made by the various aspects of incentive and motivation.

The deposit was discovered in an area where several similar occurrences have been known for over 75 years. In at least two of these it was neither the extent nor the continuity of the mineralized horizon that deemed them unattractive. Rather, it was either the grade or thickness that was the negative factor. Because of all the previous work related to these occurrences, the area was generally considered to have been well prospected and, as such, was regarded to be an unfavorable exploration area. **CMJ**

Bellwether Resources Ltd **BLW**
Shares issued: 2,372,701 Oct 16 close: $0.65
Cease Trade Company

A section 146 cease trading order has been issued against the company effective October 17 1989. Members are prohibited from trading in the shares of the company during the period of the cease or until further notice.

Bethlehem Resources Corp **BTH**
Shares issued: 14,415,071 Oct 17 close: $0.68



News Release . . . *Bethlehem and Goldnev acquire more claims near Goldstream deposit*

Goldnev Resources Inc (GNZ)

Mr Henry Ewanchuk reports

Three mineral projects have been newly added by the Bethlehem (50%)/Goldnev (50%) joint venture on the Goldstream copper/zinc mine. Each of the claim groups is close to the mine and the 1100 tonne per day concentrator located 80km north of Revelstoke, BC.

Approximately 280 new claims have been staked to the southeast of the mine to acquire continuation of the favourable geology that hosts the Goldstream deposit. Preliminary exploration has discovered three new massive sulphide showings and a skarn showing containing molybdenum. Initial grab samples of one of the showings returned an assay of 0.138 oz/ton gold and 0.20 oz/ton silver. Check samples from the same area assayed 0.102 and 0.106 oz gold per ton. Detailed sampling and geological mapping will continue as long as weather conditions permit, and will resume as early as possible in the 1990 field season.

Bethlehem recently completed an agreement to acquire a 20-unit claim approximately 12km southeast of Goldstream that includes the Montgomery showings, a series of massive and disseminated sulphide lenses up to 3m thick. Bethlehem is required to make $75,000 in payments and do $150,000 in work within three years to earn a 100% interest in the property, subject to a 10% net profit royalty interest. A follow-up program of geological mapping and sampling is planned.

Bethlehem has also reached an agreement in principle with a prospector on a property approximately 20km south of Goldstream that covers Goldstream-type geology and a copper showing. Under the proposed option terms, Bethlehem can earn a 2/3 interest. Trenching and diamond drilling are scheduled to start in late October.

Black Thunder Petroleum Corporation **BTP**
Shares issued: 5,116,909 Jun 30/88 close: $0.20
Reactivation Plan

The company has been suspended for an extended period of time. The company has submitted a reactivation plan to the VSE and must complete this plan by January 5 1990 in order to avoid being delisted shortly thereafter.

Bondell Industries Inc **BLI**
Shares issued: 5,777,000 Feb 3 close: $0.10
Reactivation Plan

The company has been suspended for an extended period of time. The company has submitted a reactivation plan to the VSE and must complete this plan by January 5 1990 in order to avoid being delisted shortly thereafter.

Bradsue Resources Ltd **BDU**
Shares issued: 3,041,293 Dec 8/88 close: $0.10
Reactivation Plan

The company has been suspended for an extended period of time. The company has submitted a reactivation plan to the VSE and must complete this plan by January 5 1990 in order to avoid being delisted shortly thereafter.

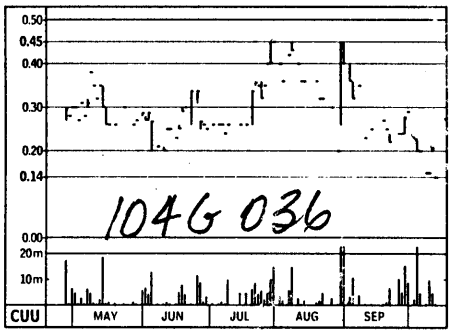
Butler Mountain Minerals Corp **BMM**
Shares issued: 5,131,260 Jan 25 close: $0.04
Reactivation Plan

The company has been suspended for an extended period of time. The company has submitted a reactivation plan to the VSE and must complete this plan by January 5 1990 in order to avoid being delisted shortly thereafter.

Caliente Resources Ltd **CIT**
Shares issued: 2,589,226 May 27/88 close: $0.10
Reactivation Plan

The company has been suspended for an extended period of time. The company has submitted a reactivation plan to the VSE and must complete this plan by January 5 1990 in order to avoid being delisted shortly thereafter.

Calnor Resources Ltd **CUU**
Shares issued: 5,198,880 Oct 13 close: $0.14



News Release . . . *Drilling results from Spectrum property, BC*

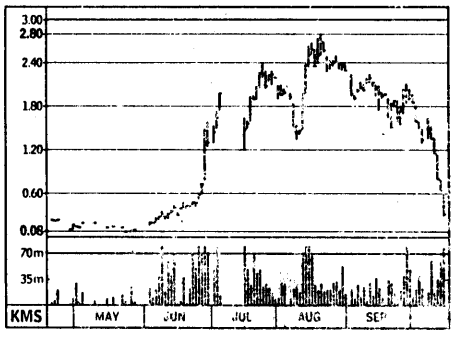
Mr Donald McLeod reports

Cominco has reported to Calnor on the results of the 1989 surface drilling program on the Spectrum property in northwest BC. A 4000 ft, 10 hole surface diamond drilling program was completed. The program was conducted to test the possible projected surface trends of quartz-carbonate veins/gouges containing high grade gold encountered in previous surface drilling.

Entire holes were analyzed for gold by geochemical method and all samples of greater than 1000 ppb were reassayed by standard fire assay methods. Average copper values were reported where significant grades occurred over longer intervals. Holes S89-37 and 42 contained no significant values.

INTERVAL(FT)	LENGTH(FT)	OZ/T AU	CU%
S89-33			
2.0- 30.9	28.9	0.295	
S89-34			
201.4-207.0	5.6	0.520	
497.7-503.9	6.2	0.161	
S89-35			
5.0-301.8	296.8		0.15
Including			
45.6- 71.8	26.2	0.036	
88.9-113.2	24.3	0.039	
225.4-238.9	13.9	0.066	
S89-36			
22.0- 27.6	5.6	0.178	
40.3- 43.2	2.9	0.128	
65.9- 74.8	8.9	0.266	
114.8-121.4	6.6	0.144	
158.8-161.4	2.6	0.104	
S89-38			
278.5-646.9	368.4		0.26
Including			
316.9-329.7	12.8	0.059	
355.9-368.4	12.5	0.167	
S89-40			
170.9-221.5	50.6		0.16
Including			
187.6-208.6	21.0	0.038	
S89-41			
205.4-302.2	96.8		0.18
Including			
211.9-225.0	13.1	0.040	

Camas Resources Ltd **KMS**
Shares issued: 2,383,000 Oct 17 close: $0.33



News Release . . . *No material changes*

Mr Ludvik Skalicky reports

The company is unaware of any reason, other than general market conditions, for the recent trading activity in its shares on the VSE. A statement of material facts was filed with the VSE and comments have been received, which comments are presently being addressed. To the knowledge of the directors of the company, no material changes in the affairs of the company have taken place.

82M14 PROPERTY FILE

MINING Week

PROJECT FILE

Noranda's New B.C. Venture

THE GOLDSTREAM massive copper-zinc sulphide deposit (*MJ*, March 14, p.210) is located in the valley of the same name, some 60 miles north of the town of Revelstoke in south east British Columbia. The deposit itself is strata-bound, lying within an extensive zone of meta-sedimentary and meta-volcanic rocks which forms the host to several previously discovered similar deposits. Goldstream was described in the April 1978 issue of *Canadian Mining Journal*.

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MEMBER OF THE AUDIT BUREAU OF CIRCULATIONS

Mining began in this area of B.C. as long ago as 1860 when prospectors discovered placer gold deposits in the lower reaches of the Goldstream river and its tributaries. Old base metal deposits in the area include Mastodon (Zn, Ag, Pb), Standard (Cu, Zn), Keystone (Pb, Zn, Ag) and Montgomery (Cu). However, in more recent years, only the Mastodon property has worked — 15,000 tonnes of ore was mined and milled in 1960, at an average grade of 9.5% Zn, 0.5% Pb and 0.2 oz/tonne silver.

Private concerns showed renewed interest in the general area in the 1970s when mineralised float was discovered in glacial till during road construction. Subsequently, a programme of pitting and drilling outlined a mineralised zone extending some 300m on strike, dipping to the north east, with an average copper content in excess of 4% and a thickness of 4.1m.

Noranda had followed the efforts and the findings of these exploration activities at Goldstream for some time, and finally negotiated an option on the property late in 1974, taking over control at the end of the year. By late 1975, the company had outlined 3.17 million tonnes of ore at an average grade of 4.49% Cu, 3.24% Zn and 20 g/tonne silver. The thickness of the mineralised horizon varied from 3-6m over a strike length of 150-250m. The mineralisation had been proved down to a depth of 300m below the Goldstream river.

A portal was collared in 1976 from which an adit was developed into the valley side for a length of 1,300m where it intersected the mineralised zone. Drifting east and west in the orebody from this adit confirmed a total strike length of 330m of mineralisation. This development also permitted the extraction of a large sample of ore for bulk sampling tests, and enabled engineers to assess ground conditions in the immediate vicinity of the deposit. It also confirmed the presence of both massive and disseminated mineralisation in the form of pyrrhotite, pyrite, chalcopyrite and sphalerite.

More recent work at Goldstream has consisted mainly of further drilling and feasibility, design and engineering studies. At the end of 1978 the published ore reserves at the property stood at 4 million s tons at an average grade of 3.6% Cu, 2.6% Zn and minor silver.

Noranda has been considering exploiting Goldstream for some time but has been delayed in making a decision because of a major dam construction in the region, and also by adverse copper prices. It will now develop the property at a cost of $C62 million as an underground operation having an extraction rate of 1,300-1,400 s ton/day of ore (40,000 s ton/month). Operating on a double shift basis, five days a week, the concentrator will have an annual output of 75,000 s ton/year copper concentrates and 11,800 s ton/year zinc concentrates, together with some silver. The zinc concentrates will probably be shipped to Cominco's Trail smelter whilst the copper concentrate will probably be sold to Japan.

Preliminary work at the Goldstream property is expected to start later this year, but the major construction programme is not scheduled until 1981. The mine is expected to start production in the third quarter of 1982, with a full time operating staff of 185.

Although the Goldstream property is a small project when compared with some of Noranda's other mining operations, it is located in an area where similar deposits have been worked in the past. In several cases it was not the extent or the continuity of the mineralisation which made these prospects unattractive. Either the grade or the thickness was the limiting factor. Once a new mining-milling facility is established at Goldstream, with its related infrastructure, the prospects for the exploitation of other deposits at a later date will be considerably enhanced.

U.K.

Wheal Jane on Schedule

THE PROGRAMME of refurbishing and development at the Wheal Jane-Mt. Wellington tin mine near Truro in Cornwall, is being carried out on behalf of RTZ's 95% owned Carnon Consolidated Tin Mines at a total estimated cost of £8.5 million. Apart from a few senior personnel, Carnon has no employees on site as yet. The underground work has been carried out by Thyssen (G.B.) whilst the surface plant modifications have been contracted to William Press and Sons. The mine, which closed in April/May 1978 — after a period of working under Wheal Jane Ltd, a former Consolidated Gold Fields subsidiary — is scheduled to resume full production in January 1981, as a single combined operation based on the Wheal Jane surface facilities.

The programme includes the refurbishing of all the underground levels which give access to potential ore reserves, together with major development work to open up additional reserve tonnage. The three main surface shafts, the Clemow and No.2 at Wheal Jane, and the Mt. Wellington shaft at the adjoining property, have been made safe and are prepared for hoisting and/or ventilation. Another task is to overcome the effects of percolating acid waters which have left a deposit of iron oxide in the underground workings and have seriously corroded tracks and pipe ranges.

Development is underway on 7, 8, 9, and 11 levels at Wheal Jane in order to provide sufficient reserve tonnage for the start up of operations. An underground crusher is

Depreciation	10,953	6,243
Income Taxes	54,854*	28,457
Tax Loss Carry-Forward	--	3,400
NET INCOME	$180,402	$ 75,993
Per Share	19¢	8¢
Common Shares Issued	937,950	937,950

* Includes $15,057 deferred tax

improvement in net profit is primarily attributable to the Meadowbrook development in Chilliwack, B.C., which he describes as an aggressive project now reaching maturity.

In addition to being a joint venturer, the company also acted as manager of Westlang Industrial Estates, a 100-acre industrial development in Langley. This project was successfully brought to the development stage and sold during the past year.

Currently, the company is in the final construction stages of a shopping mall in Mission, B.C., and of a 9,000-square foot commercial building, a Big 'T' Restraurant, a Brownies Fried Chicken outlet, and a Pizza Hut Restaurant , all in Chilliwack. Approval has also been obtained for a fully designed subdivision of 144 small lots. Management believe that a freehold residential lot, even though small in size, is still more desirable than a strata-title townhouse. Construction of roads in this development should commence this fall.

82M 149 Bend. 82 M/9 & Goldstream R.

SEAFORTH MINES LTD.

THREE PROJECTS UNDERWAY OTHERS ARE BEING SOUGHT - Gordon A.Keevil, president of Seaforth Mines Ltd., has reported that Canex Placer has completed one 154-meter long diamond drill hole on the Goldstream River property, 50 miles north of Revelstoke,B.C. The hole was intended to test a geophysical anomaly developed last season. The hole failed to intersect any significant sulphide mineralization and did not supply any explanation for the geophysical anomalies. It is felt that additional drilling will be required to explain the anomalies, he states. It is expected that a decision on further drilling will be taken soon.

82M/14

On the Fission uranium property in the Kelowna area,B.C., which was optioned to Mattagami Lake Mines in January 1977, the first phase of exploration has been completed. The work has included detailed geological mapping, ground geophysics and radiometric surveys. Mr.Keevil states that Mattagami has received encouraging results from the work to date and approximately 50 kilometers of grid lines have been cut in preparation for an IP survey. The IP method has been successful in the area to detect the presence of pyrite which is closely associated with the uranium mineralization.

Exploration is continuing for the second year on the company's Key Lake, Saskatchewan, property. Union Carbide Exploration has renewed its option for 1977 and intends to carry out further surface work in an attempt to identify drill targets. An air photo study has indicated definite structural features underlying Seaforth's claims, which may represent faults similar in nature to those that host the existing uranium deposits in this area. The Uranerz group has recently discovered a third uranium deposit in the Key Lake area and is currently testing the size and the grade of the new discovery called the Black Forest deposit.

Company geologists are studying several new uranium prospects and have conducted field examinations in Saskatchewan, N.W.T. and B.C. Exploration emphasis will continue in southern B.C.

Mr.Keevil concludes by stating,"The company is presently participating in a Joint Venture in an area of southern B.C. that has a high potential for the discovery of massive sulphide deposits. This project, started as a regional program, has defined three targets that are now being more accurately identified and studied. It is felt that this project will ultimately lead to the discovery and development of several massive sulphide prospects."

FOR THE RECORD

La Ronge Mining Ltd. has been renamed La Teko Resources Ltd. following a three old for one new share consolidation. La Teko has amalgamated with Agean Explorations Inc. under the continuing name of La Teko Resources Ltd. and on the basis of one issued share of Agean for on share of the new company, and one issued share of Ta Leko for one share of the new company.

On Aug.11,1977, LaRonge shares were replaced by La Teko shares on the Resources and Development board of Vancouver Stock Exchange, symbol LAO. Of 10,000,000 shares of no par value authorized, 1,759,624 shares are issued including 41,667 shares in escrow. Transfer agent is Guaranty Trust Co.

Continental Minerals Corporation's underwriter ,Fisher Securities Corp., did not exercise its option to buy 200,000 shares at 35¢ each that expired Aug.9,1977. Continental Minerals shares are out of primary distribution effective Aug.10,1977.

There is also a potential for expanding the reserves of the more recently discovered Lake Zone which is completely open to the northwest. This northwest extension is indicated by surface mineralization and a recent IP survey. This area has never been drilled.

The Carmi property was optioned to Craigmont in 1976. The option was terminated in April 1977. Mr.Greig says most of the Craigmont activity consisted of further percussion drilling with some diamond drilling and focussed on the southern sector of the property away from the known zones.

In August this year, the price of molybdenum increased by 60¢ per pound to US $4.01 (Can $4.29) per pound. Mr.Greig states that many experts anticipate further increases over the coming year.

Considering the Carmi molybdenum deposit to be perhaps the best undeveloped molybdenum reserve in Canada today, Mr.Greig notes that the large capital requirements, however, require that the property be developed in conjunction with a major mining group. (For another Vestor interest, see story below).

Goldstream 82M/9

SEAFORTH MINES LTD. VESTOR EXPLORATIONS LTD. PACIFIC CASSIAR MINES LTD.

MASSIVE SULPHIDES ARE BEING SOUGHT - Copper-zinc massive sulphide deposits in south-central B.C. are the object of exploration currently being conducted by Seaforth Mines Ltd., Vestor Explorations Ltd. and Pacific Cassiar Mines Ltd. under a joint venture agreement.

82M/11W

Seaforth's president, Gordon A.Keevil, reports that field exploration has concentrated on a geologically favorable belt where numerous sulphide showings have previously been discovered. As well as this joint venture's activities, this area has recently drawn the attention of major companies who are also conducting field programs.

Field crews have carried out geochemical surveys over an area of at least 600 square miles. Five exceptionally promising targets have now been delineated and an aggressive land acquisition program is now in progress. In some areas, base metal sulphides have been discovered in place and economic grades of sulphides have been discovered in boulders.

Mr.Keevil comments that the discovery of Noranda's Goldstream deposit near Revelstoke stimulated exploration for massive sulphides throughout B.C. by both junior and major companies. This industry-wide interest stems from the fact that under the present economic conditions, this type of mineralization provides the best potential for developing a viable ore deposit.

(A separate story on Vestor Explorations is printed above on this page).

SUSIE GOLD MINES LTD.

FIRST DRILLING OF LEAD-ZINC PROPERTY IS NOW UNDERWAY - On 19Sep77, J.Paul Stevenson, director, reported that drilling started last weekend on the lead-zinc property of Susie Gold Mines Ltd. in the Wasi Lake-Osilinka River area, some 30 miles NW of Germansen's Landing, B.C. Geophysical surveying is now completed on the property for this season. Work thus far has shown the lead-zinc belt in which the property lies has development potential. The unsurveyed portion of the property will be surveyed next year. Sufficient work has been completed and the reduced field data has outlined enough drilling targets to drill throughout the winter if it is physically possible. The anomaly which was outlined in 1976 on the Carie claims was confirmed by further gravity surveying and additional I.P. surveying. The property has large tonnage potential.

Susie share trading has been active and higher on Vancouver Curb Exchange in recent sessions. Trading was halted pending release of the following information.

Mr.Stevenson left Vancouver for the property on 21Sep77 in order to supervise completion of the first hole and to bring the core to Vancouver for assay. A company spokesman says the assay results will be reported as soon as possible.

Share trading resumed on 22Sep77.

FOR THE RECORD

Trinity Resources Ltd. received $2,362,124 from sale of that number of shares at $1 each pursuant to the recent rights offering.

NewCoast Silver Mines Ltd.'s underwriter Canarim Investment Corp., has not exercised its option to buy 200,000 shares at 26¢ each that expired 11July77. NewCoast shares are out

Noranda Mines will close down its Goldstream operation near Revelstoke in mid-April for about a year, making it the fifth mine in the company's B.C. group to shut down in the past two years. Only the Bell division near Granisle has reopened but even that is not producing any metal. About 100 people are employed removing overburden in preparation for mining at a later date.

Goldstream has been on line for less than a year and ironically its first month of operation was the most profitable. At the time, the company was receiving about 97.5¢ for its copper about 21¢ more than January's price.

It's a nice little mining operation which at startup had a mine life of eight years based on a reserve in inventory of four million tonnes grading 3.67% copper and 2.67% zinc.

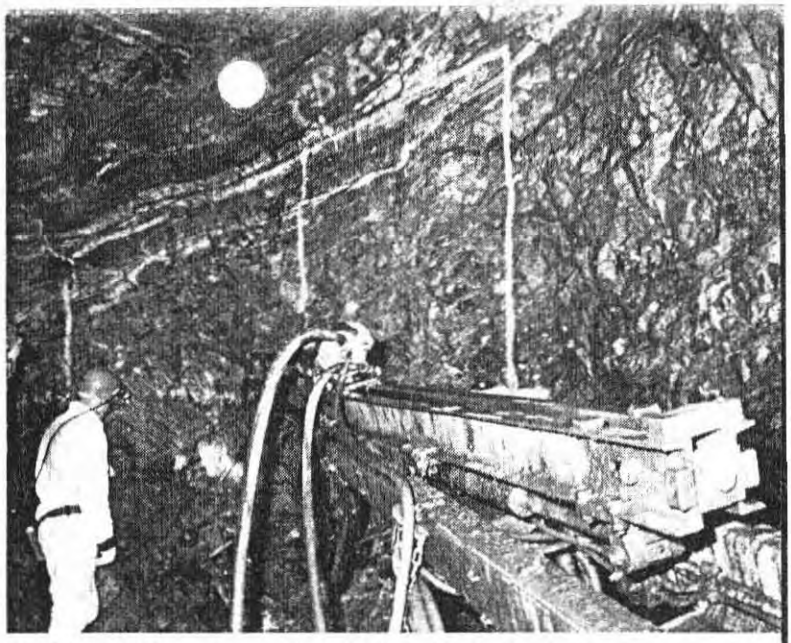
Originally intended for development from 1977-80, poor metal prices delayed the project until 1983 when it came on stream after $70 million in capital expenditures.

The mill is capable of handling approximately 1,360 tonnes per day but the mine was primarily a copper producer. Recent price increases for zinc did little to offset losses from copper, says Mine Manager James Smith, who also notes zinc recoveries never reached the projected rate of 40%. He also points out it would take 2-3 years to prepare deeper regions of the operation for mining and part of that program would have included testing the known orebody at depth and along strike where there is still good potential for expanding reserves.

The mine workings will be kept pumped out during the shutdown and Mr. Smith says they will be able to use the time "for engineering and lab work." About 150 people will be laid off but some will be employed on fire watch and to keep mine equipment in good running order.

The company utilized a step-room-and-pillar mining method which was quite productive but he claims there is "just nothing else we can squeeze out of here." There is some custom milling potential in the region, he admits, adding the material would have to be compatible with Goldstream ore.

Goldstream. Open pit blast



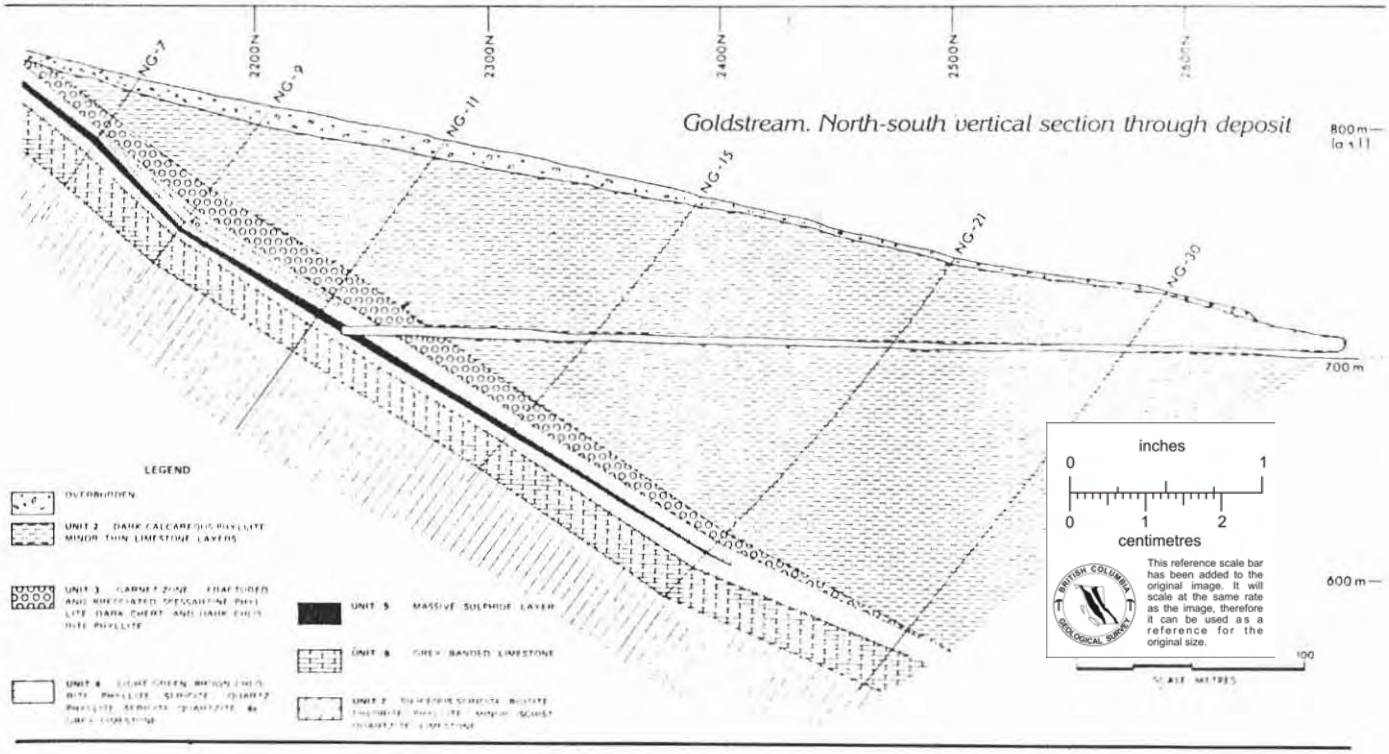
Goldstream. Stope preparation drilling; photo shows slope of back which follows top of ore zone

Noranda's Goldstream mine a welcome newcomer

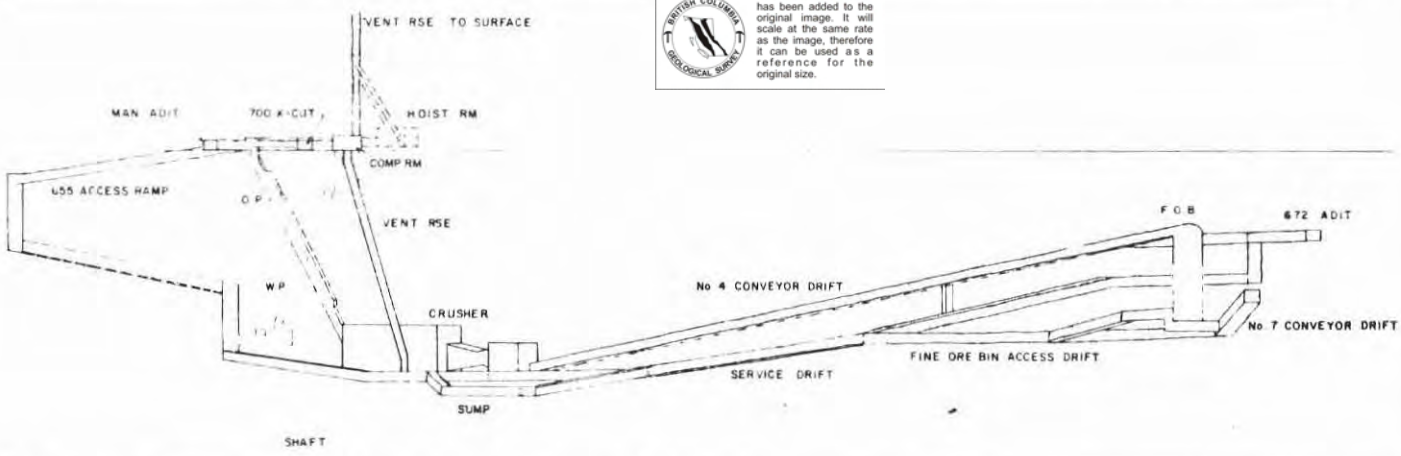
The opening of the new Goldstream mine of Noranda Mines Limited, north of Revelstoke, British Columbia, is a very welcome sign in 1983, after a period in which mine closures were almost weekly news. That Goldstream is an underground operation (principally) and that the orebody is mainly copper and zinc may seem even more unusual in these times of low metal prices and poor markets, not to mention rising operating costs.

The dimensions and attitude of the orebody also require some ingenuity and flexibility in planning the mining method, but work has proceeded gradually since 1976 (with several postponements of production dates) until it appears that the mine can produce with better economics than the large open pit mines of the Babine Division (Bell and Granisle), in BC, which have been closed for some time.

Goldstream is a relatively small operation, aiming at 75,000 tonnes/year of 25% copper concentrate and 12,000t/y of 50% zinc concentrate. The ore grades are fairly high at 3.7% copper and 2.7% zinc in a sulphide deposit which averages 200 metres wide and



Goldstream. North-south vertical section through deposit



Goldstream. Elevation, looking south, shows location of main 700m adit and crusher station

Goldstream. (From left) Jim Smith, mine manager; Betty O'Keefe, Noranda Mines Limited; Frank King (who staked the first claims); Mrs King

2-8m thick. Proven reserves (at May 83, when the mine opened) indicated a mine life of more than eight years (with hopes for additional reserves).

DISCOVERY

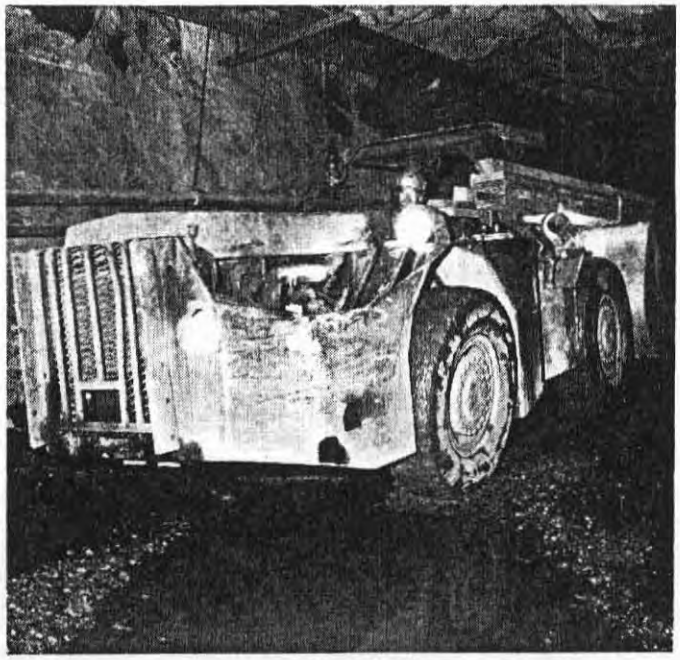
The Goldstream deposit is a stratabound high-grade copper-zinc massive sulphide orebody which occurs within an extensive belt of metasedimentary and metavolcanic rocks. It was a new discovery, made by prospecting, and the mineralization was not exposed at surface. The regional geology is complicated.

The Goldstream River is a tributary of the Columbia River system, and flows westward out of the Selkirk Mountains. The river valley lies 600-650m above sea level, is typically U-shaped, and is flanked north and south by 2400-2700m mountain peaks.

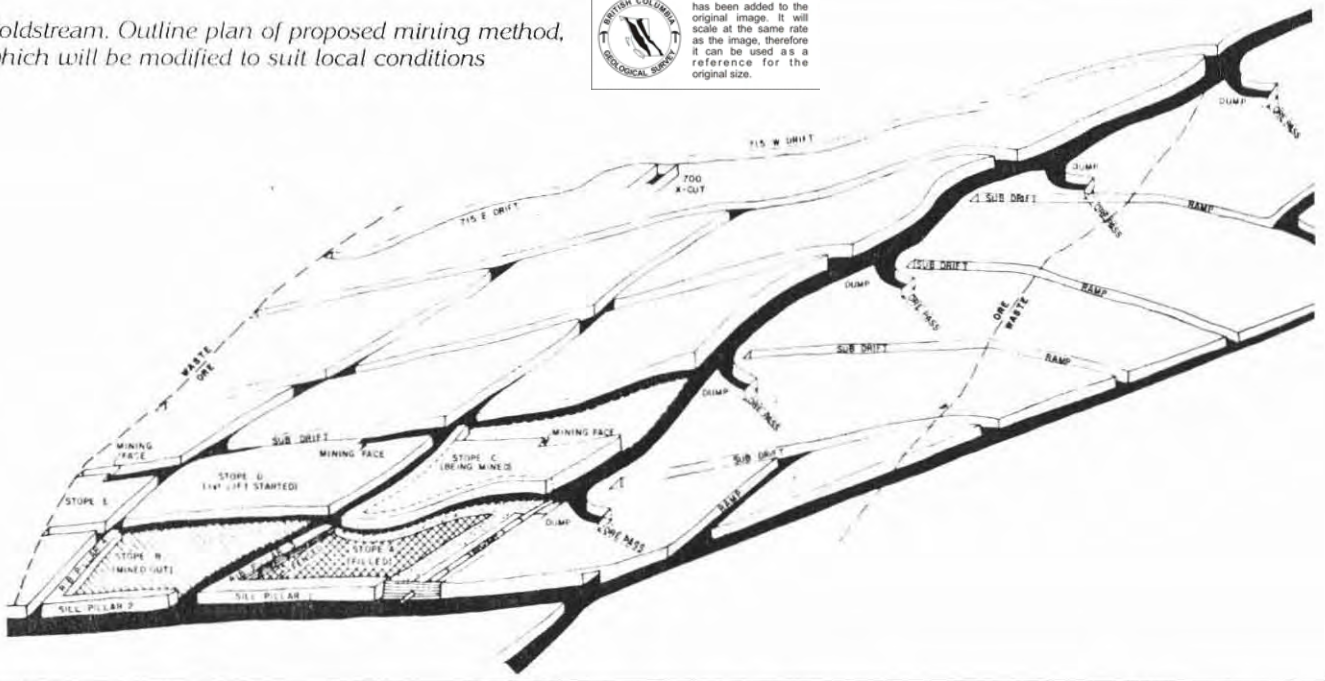
In the 1860s placer gold was

Goldstream. Tamrock Fixtrack DHA Turbo drill used for blasthole drilling in the open pit

Goldstream. One of several Jarvis Clark Scooptrams used underground



Goldstream. Outline plan of proposed mining method, which will be modified to suit local conditions



discovered in the Goldstream and several of its tributary creeks, and at one time there was a community of several thousand people within sight of the present Goldstream office and concentrator site.

Hardrock exploration in the area (1890-1930) disclosed some interesting properties, on which some work has since been done from time to time. The only producer was the Mastodon, which mined and milled 15,000 tons grading 9.5% Zn, 0.5% Pb, and 0.2oz Ag in 1960.

During construction of a logging road in 1972 some angular float assaying up to 5% Cu was found, but the source was not located. In September 1973, Frank King, of Vernon, staked claims to cover the mineralized float. With his new partners, Gordon and Bruce Bried, of Kamloops, more work was done, leading to extensive trenching and the drilling of 22 X-ray holes.

Noranda had followed the progress this (1974) work, and optioned the property at the end of December 1974. Noranda Exploration carried out extensive drilling, sampling, and other survey work, leading to an underground program which started in April 1976.

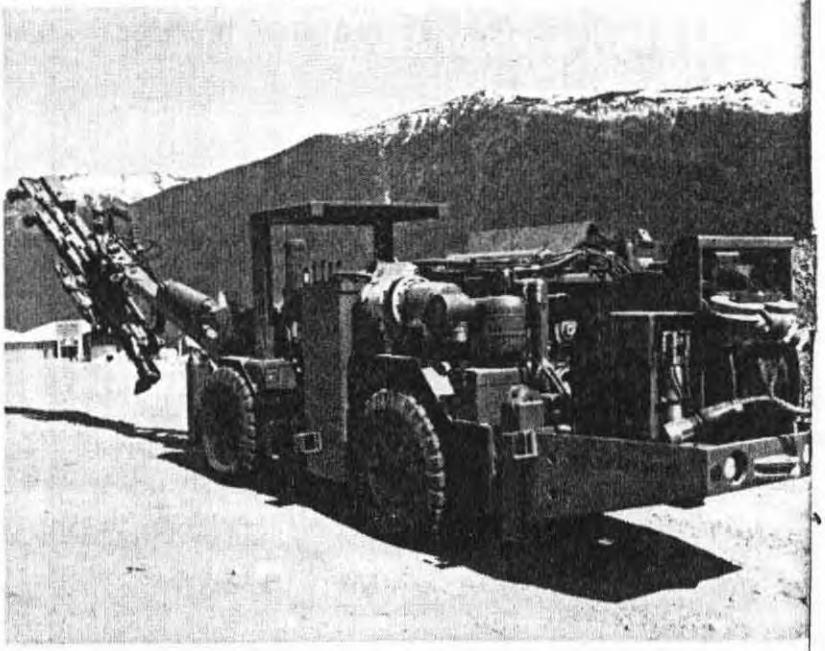
The program of tunnelling and drifting included a 400m adit at the 700m elevation, drilling drifts, and ore drifts. Samples and data from the program were used in further engineering and metallurgical studies.

DEVELOPMENT

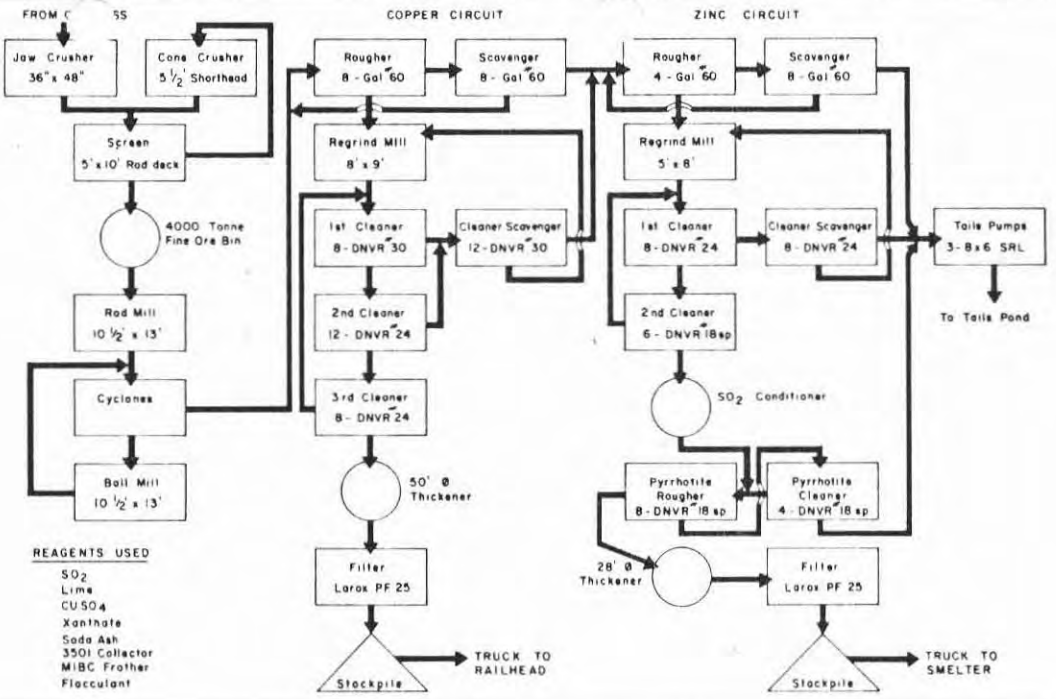
In January 1980, the BC government approved development of the Goldstream orebody, and Noranda later announced plans to proceed towards production of copper-zinc concentrates, with major construction to start in the spring of 1981. It was estimated that the property would be producing by the third

Goldstream. Tamrock Minimatic DH107L drilled the first round

Goldstream. Two Tamrock Minimatic H107L electro-hydraulic drill jumbos will be used for underground mining development



Goldstream
Concentrator flowsheet



quarter of 1982 at a cost of some $62-million.

The original plans for the mine included a proposed dam and hydro-electric plant to be built and operated by Noranda to supply power to the mine. Detailed engineering modified the design and raised the cost of power above that which could be supplied by BC Hydro. Power is supplied by a 69kV line from Mica Dam.

During 1981, construction of the concentrator and service buildings, and a permanent camp, were essentially completed. Work was planned to develop a small open pit and an underground mine to start up in November 1982 at 1500 tons/day.

By the end of 1982, the construction and equipment installation phase was nearly complete, but mine development was extended to a start-up date of 1 May 1983, partly in the hope that metal prices might improve.

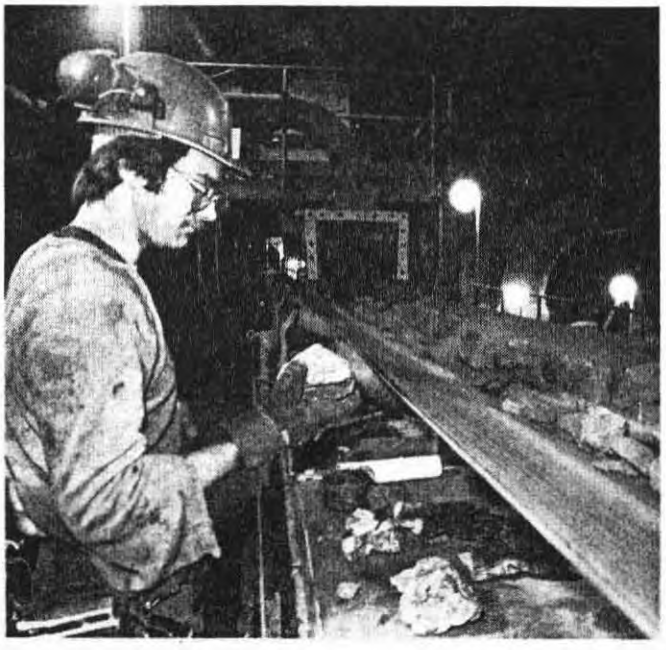
Development of the property was originally postponed from 1977 (when the feasibility work was completed) to 1980, because of poor metal prices. The development cost was about $70-million.

CURRENT OPERATIONS

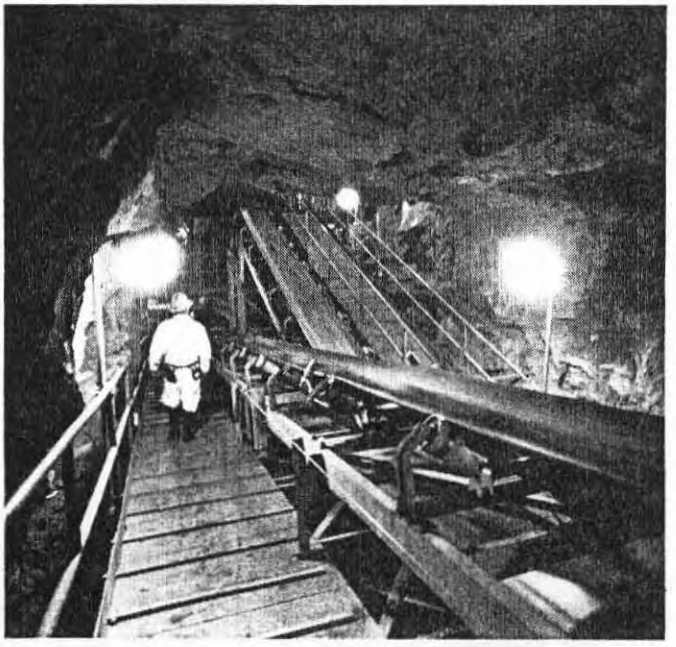
An accompanying diagram shows a section through the Goldstream deposit and the 700m access adit. The top of the orebody is very close to surface (about 830m elevation), and is being mined as an open-pit operation. Some 400,000 tonnes (or about half the mill feed through 1984) may be mined from the pit, before production comes entirely from underground operations.

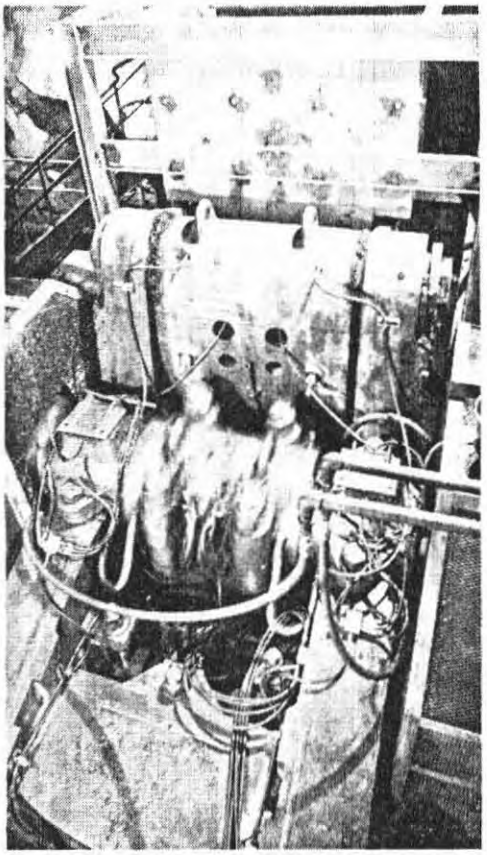
The underground mining method, as mentioned above, has to be flexible in concept, but is based on a stepped room excavation to follow the run of the ore zone. The rooms are backfilled, and pillars are recovered, as mining progresses.

Goldstream. Conveyor from screens returns oversize to crusher

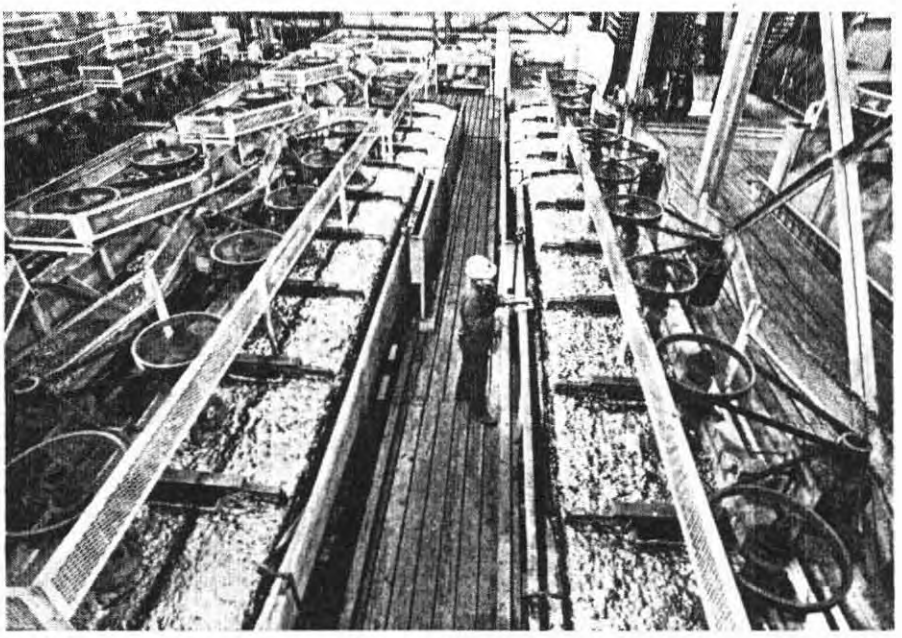


Goldstream. Conveyors are part of underground crushing and screening system





Goldstream. Nordberg primary crusher in the underground station



Goldstream. Flotation cells in concentrator

The ventilation compressor room is on the 700m level, from which the 655 access ramp leads to the underground crushing and screening complex. From the higher levels, now being developed, ore passes are provided.

When mining moves below the crusher level, it is possible that a hoist (at 700m level) and vertical shaft will be used for raising ore from the deeper levels.

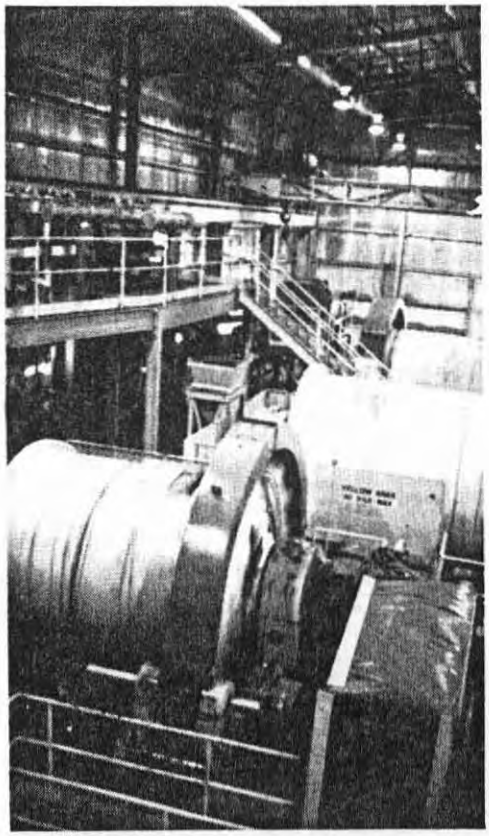
The ore is crushed underground to −⅜in and taken by a 150m conveyor to a fine ore bin and the concentrator on surface. After grinding in rod and ball mills, copper and zinc are separated by flotation. The process includes a reverse flotation in which copper is depressed and the waste floated.

Current operations (May/June 83) produce some 200 tonnes/day of copper concentrate (shipped to the smelter at Noranda, Québec) and 30t/d of zinc concentrate, which is trucked to Trail, BC, for treatment in the Cominco smelter.

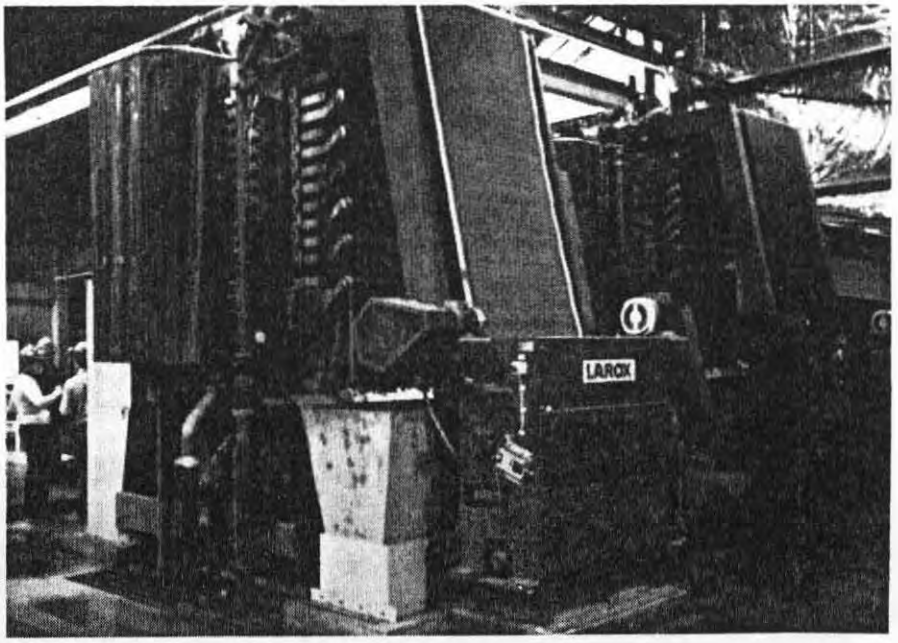
Workforce at the mine (May-June 83) was about 150 people, and not more than 210 are expected during the life of the mine.

Staff. J B (Jim) Smith is mine manager, Goldstream Mining Division; he has been responsible for work on the property since 1976, and was project

Goldstream. Rod and ball mills



Goldstream. Larox pressure filters are used in the concentrator to provide concentrate cake with about 8% moisture, eliminating the need for a kiln dryer



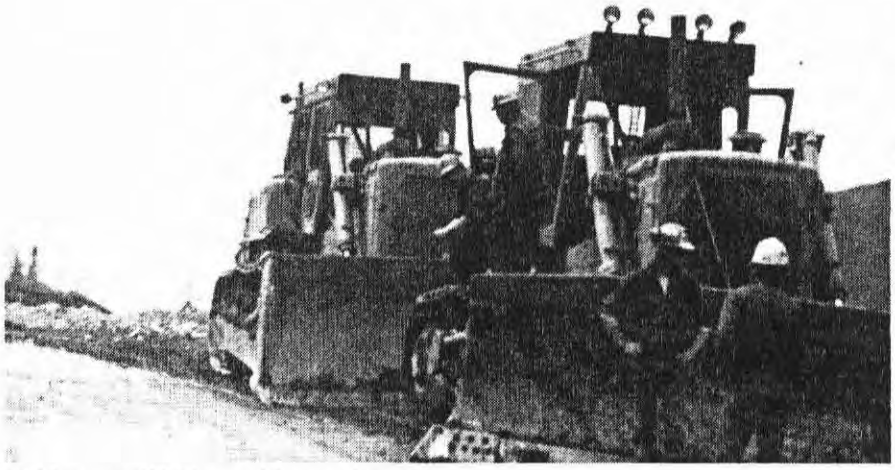
manager for the development phase. Other staff: chief geologist, Norm Berg; mine superintendent, Bob Hinkkuri; chief engineer, Bruce Humphrey; mill superintendent, Stu McTavish; office manager, Paul Smith; plant superintendent, Bob Sweet.

Union. The International Union of Operating Engineers, Local 115, represents about 100 unionized employees.

Ownership. Goldstream Mining Division, Maclaren Forest Products Inc, is a subsidiary of James Maclaren Industries Inc, which is a wholly-owned subsidiary of Noranda Mines Limited. The original owners, Frank King and Gordon and Bruce Bried, retain an interest in the property.

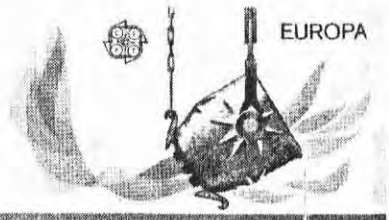
Access. The mine is located off a new highway that links the Mica and Revelstoke Dams (parts of the old road will be submerged when the present water level rises behind the Revelstoke Dam). Many of the mine employees commute from Revelstoke, and no serious problems occurred in the 1982-3 winter, though slides are not unexpected in bad weather.

There is also a good modern camp on site.



Goldstream. Waiting to blast at the pit

Photo credits. Deborah MacNeill; Martti Huttenen (Tamrock); *Western Miner*



SUOMI FINLAND 1,30

The European Conference of Postal and Telecommunications Administrations, CEPT, has arranged for the issue of a series of stamps depicting notable human achievements. This Finnish stamp depicts Outokumpu Oy's flash smelting method.

The method was developed in 1949 for the smelting of sulphidic concentrates and is used today in 31 copper and nickel smelters all over the world. The method is known for its ecological advantages and low energy consumption. It has been continuously developed by Outokumpu Oy and can now also be used for smelting sulphidic lead concentrates.

Western Miner April 1980

Canada-wide

Noranda gives go-ahead to new Goldstream mine

Noranda Mines Limited has given the green light to development of a new copper-zinc underground mine in the Goldstream Valley, some 80km north of Revelstoke, BC.

The 1500 tons/day operation, estimated to cost $62-million, will produce 75,000 short dry tons of copper concentrate and 11,600 short dry tons of zinc a year.

To be known as the Goldstream Division, the property is scheduled to come on-stream in the third quarter of 1982 and will be Noranda's fifth producing mine in BC. Noranda's other mines in the province produce copper and molybdenum primarily by open pit, although the Boss Mountain Division, near 100 Mile House, mines molybdenum by both open pit and underground methods.

Little on-site activity has been undertaken since 1976 when a major underground exploration program was completed on the property. The following years have been spent working mainly on environmental requirements and metallurgical test work necessary for licencing and government approvals.

Detailed engineering work will be carried out and orders for some of the equipment will be placed in 1980, with major construction and development work slated to begin in spring of 1981.

The operation will be primarily underground, using mechanized methods, including some hydraulic drilling. There will also be a small open pit on the surface.

Undiluted reserves are estimated at 3,177,000 tonnes grading 4.49% copper, 3.24% zinc and 0.68 oz/ton silver. The diluted reserves are 3,940,000 tonnes grading 3.7% copper, 2.7% zinc and 0.56 oz/ton silver, sufficient for a mine life of eight years.

Once in production, the mine will employ 185 full-time people, although some 250 people will be required during the peak construction period. Project Manager is Jim Smith who has been responsible for work done on the property since 1976.

The Northern Miner

JUNE 9, 1983 VOL. 69 NO. 14

FOUNDED 1915 CANADA'S MINERAL RESOURCES NEWSPAPER — MINES, OILS, GAS — $1.00

Eight-year mine life predicted

Noranda's Goldstream now producing

By David Duval

VANCOUVER — Without much fanfare Noranda Mines has launched its Goldstream operation near Revelstoke, B.C., into production at a cost of $70 million. Although the name doesn't imply it, the mine is actually a base metal producer — and quite a high-grade situation at that.

Its 8-year mine life is based on a reserve estimate of four million tonnes grading 3.67% copper and 2.67% zinc, according to Mine Manager James Smith.

The mill tune-up, although not yet completed, is proceeding satisfactorily and a "saleable concentrate" is being produced, he tells The Northern Miner. Throughput now averages 1,200 tonnes per day compared to a design capacity of 1,360 tonnes and ultimately copper recoveries are expected to reach 93% with zinc considerably lower at 40%. The zinc requires a much finer grind and its flotation characteristics are similar to that of pyrrhotite, preventing higher recoveries for the metal.

The mining development was postponed from 1977 to 1980 because of poor metal prices and then delayed again from 1982 to this year for the same reasons, says Noranda. Prices for both these metals are still depressed by historical standards but the mine opening seems timely, given the economic recovery under way today, The Northern Miner gathers.

Mr. Smith explains that Goldstream's orebody is relatively flat dipping (inclined at 35°) and there is only one known deposit at the moment which runs about 1,000 ft. along strike (on surface) and averages 10 ft. thick. The orebody has been traced down dip for 4,500 ft. Minor amounts of gold and silver occur in the ore and go out in concentrate and are a credit from the smelter.

The copper concentrate is shipped to the Noranda smelter while zinc concentrate is processed by Cominco at Trail. Mr. Smith says consideration was given to shipping copper concentrates to Japan but negotiations with Noranda, the CNR and CPR railways proved fruitful and it was more economical to process the concentrate here.

Each Noranda operation is basically an autonomous unit and it has the right to process concentrate wherever it's most economical, he points out.

Some of the Goldstream ore will be mined by open pit because the orebody reaches surface. About 40,000 tonnes is believed minable by open pit and it will supply about 50% of mill feed for the next 18 months.

Underground mining involves a step-room and fill method, which was developed in the Elliot Lake mining camp. Pillars are recovered as mining progresses (hydraulic back jumbo drills, fitting in with management's philosophy of maintaining the best underground environment possible. Original development work underground was done with a diesel jumbo, although two electric jumbos (Tamrock) are now on site for stoping purposes. The drills are cleaner (there is no mist associated with drilling) and much quieter than percussion machines. Mr. Smith admits there is no real cost advantage to using hydraulic jumbos (they are single boom and "equivalent to two percussion drill jumbos") and he claims it's strictly an environmental issue.

fill is used in old stopes) and the choice of this method was largely related to the flat dipping nature of the orebody. The only alternative would have been a scraper stoping method, also used in Elliot Lake. But this is very labor-intensive and physically hard on workers because it isn't highly mechanized.

Goldstream has three hydraulic

See Page 2

Present production from the underground totals 6-8,000 tonnes per month and 15,000 tonnes is mined from the pit. In about four months, the underground and open pit will totally supply the mill, he predicts. The difference is being made up from stockpiled ore (there were 100,000 tonnes when production commenced). Estimating that approximately 30,000 tonnes was milled during May, he points out that 18,000 tonnes came from the underground.

The ore is crushed underground to -⅝ in., then relayed to a rod mill on surface by a 500-ft.-long conveyor. The mine has a jaw crusher and a cone crusher underground and four portals allow access to the workings.

The mine employs about 150 people and will not exceed 210 during the life of the operation. Most employees live in Revelstoke, about 55 miles away, but during the winter when heavy snowfall occurs, many are forced to stay at the minesite.

GCNL #56 20-03-79

NORANDA MINES LIMITED

SOME B.C. OPERATIONS AS REVIEWED IN ANNUAL REPORT - The recently issued report of Noranda Mines Limited, covering the year ended Dec.31,1978, shows revenues of $1,691,000,000, earnings of $135,200,000 or $5.72 per share.

About the Boss Mountain Division in central B.C., the report states that from processing 597,000 tons grading 0.152% Mo there were 1,660,600 pounds of Mo recovered in concentrate produced. The re reserves are reported as a mineral inventory of 2,700,000 tons grading 0.18% Mo.

The report states that extraction of the original proven ore reserves was completed. However, improved prices for molybdenum concentrate encouraged the development of additional drill indicated sources of ore. A small open pit was in production by mid-year and will provide most of the mill feed until 1980, supplemented with current development material from new underground sources. Grade of the pit material is lower than anticipated, but with continuing strong markets, production should be extended for another four years.

About the Bell Copper Division, north of Smithers,B.C. the annual report states from 4,927,000 tons grading 0.43% copper and 0.01 oz. gold per ton there were 68,000 tons of concentrate produced containing 18,000 tons of copper and 23,000 oz. of gold. The mineral inventory was 21,193,000 tons grading 0.49% copper and 0.01 oz. gold per ton.

Modifications were completed to the grinding and tailings curcuits to increase the milling rate, but the extra capacity was not utilized as mine production was below plan due to mainterance difficulty with haulage trucks. Operating costs were 16% higher and capital expenditures were limited to essential production items. Labour turnover remained high and safety performance, though good, was at a higher compensable frequency rate than in 1977. A two-year labour agreement was ratified in March.

Assets of this division and the Morrison Lake copper property were sold to Granby Mining Corporation on Oct.4,1978, subject to approval by the Foreign Investment Review Agency. Approval had not been received at year end. The base sale price is $22,000,000, plus the value of stores inventory, assumption of housing mortgages and working capital freed. The concentrate will be treated at the Horne smelter under a ten year agreement and Noranda will act as contractor to expand the concentrator to 17,000 tons per day. An expanded Bell pit is estimated to have a mineral inventory of 50,000,000 tons, grading 0.52% copper and 0.011 ounces of gold per ton at a 0.35% cutoff grade for copper and the Morrison property at a 0.30% copper cutoff is 61,000,000 tons averaging 0.41% copper.

Brenda Mines Ltd., 50.9% owned by Noranda, treated 11,018,000 tons grading 0.165% copper, and 0.040% Mo. to produce 58,000 tons of concentrate containing 15,550 tons of copper and 3,650 tons of Mo. The mineral inventory is reported as 97,659,000 tons grading 0.165% copper and 0.040% Mo. An all time high of 19,268,000 tons of waste rock and ore were removed from the open pit. The ore grade was lower than expected due to a temporary pit slope stability problem which is now corrected. The tonnage of ore milled, at an average rate of 30,187 tons per day, was on target.

About the Goldstream division, 50 miles north of Revelstoke,B.C. the report states, environmental studies to obtain water use permits to develop a power supply for this copper-zinc property some 58 miles north of Revelstoke are continuing. Indicated mineral inventory is 4,000,000 tons averaging 3.6% copper and 2.6% zinc.

[redacted]

GCNL #51 12-03-80

NORANDA MINES LIMITED

NEW COPPER-ZINC MINE DECISION IS ANNOUNCED - Noranda Mines Limited announced their intent to develop a copper-zinc mine in the Goldstream Valley some 80 kilometers north of Revelstoke, B.C., at an estimated cost of some $62,000,000. The property is scheduled to be in operation by the third quarter of 1982 and will be Noranda's fifth producing mine in B.C.

Noranda's other B.C. mines produce copper and molybdenum primarily by open pit although the Boss Mountain division, near 100 Mile House, mines molybdenum both by open pit and from underground.

To be known as the Goldstream division, the new operation will produce 75,000 short dry tons a year of copper concentrate and 11,600 short dry tons per year of zinc concentrate. The mine has an indicated life of over 8 years.

There will be limited activity on the site this year while detailed engineering is completed. Major construction will start in the spring of 1981 when peak employment will be about 250 people. In operation, the mine will employ 185 people. Project manager will be Jim Smith who has been responsible for work done on the property since 1976.

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JUNE 24, 1976 GCNL 121

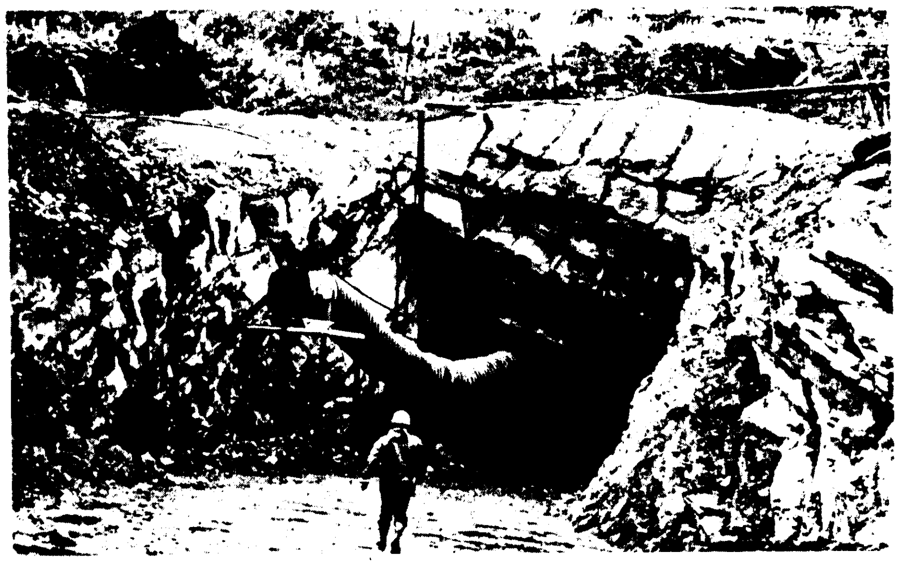
NORANDA MINES LIMITED

GOLDSTREAM VALLEY PROGRAM - Noranda Mines Limited is proceeding with a $1,500,000 engineering and underground examination of its high grade copper/zinc property in the Goldstream Valley, 57 miles north of Revelstoke, B.C.

A temporary camp, capable of supporting 20 men, has been established in the Goldstream Valley to support this year's activities. The primary objective is to drive a 400-metre tunnel to determine the mining method and obtain metallurgical samples. Concurrently with the work being carried on underground, engineering and environmental studies will also be conducted. A firm of consultants has been retained to carry out baseline studies.

The mineralization zone is estimated to contain more than 3 million tons averaging 4.4% copper, 3.2% zinc and 0.6 ounces of silver per ton. The deposit is a massive sulphide occurrence averaging 200 metres in width and dipping 40° to the N.E. The thickness varies from two to eight metres. Despite the high grades the deposit is only marginally economic due to its narrow width and thickness and the lack of cheap power available in the area.

New tax legislation introduced recently, which will supercede the B.C. Mineral Royalties Act, will have a beneficial impact on the economics of the project, a company spokesman said.



At the Goldstream project of Noranda Exploration Co, development work in 1976 included driving a 1200-ft adit to the copper-zinc deposit; development was by Mining Corporation of Canada (1964), South Porcupine, Ontario

Noranda Exploration's Goldstream project

Development work at Noranda Exploration Company's Goldstream Project in the Selkirk Mountains, 60 miles northeast of Revelstoke, BC, was completed in late September, one month ahead of schedule. The work began in April 1976.

The contract called for 3600 feet of development work, including the 1200-foot adit (10'x15') to the ore body, two 600-foot drifts (10'x15') for diamond drilling, and two 600 foot ore drifts (9'x12'). Average advance was 11feet a shift, with each crew completing a full cycle — scaling, mucking, drilling, loading and blasting.

The explosive used was 'Tovex' SD-20 (1.5x18in), a Du Pont of Canada product. Initiation was by long-delay electric blasting caps. Holes at the face were 1¾-inch diameter, drilled to a depth of 12 feet on 24-inch centres. The cut consisted of nine holes, including four holes that were loaded with explosives. It was one of the first times 'Tovex' small-diameter water gel explosives have been used in this application in Western Canada.

Du Pont of Canada's technical sales representative on the project was Don Schultz of Kamloops. Completing his first assignment as project superintendent, Bob Hinkkuri said the big factor in the early completion was the efficient and experienced staff of 20 miners, mechanics, and cooks who made up the development team. Crews adapted quickly to the water-gel cartridges, and efficient loading and blasting schedules were maintained throughout the summer.

Equipment used included two Scoop-Trams of 5yd³ capacity (ST5A); a Jarco truck of 9yd³ capacity (JDT413); a two-boom jumbo Paramatic drill (MJM20), and two Joy 850 compressors.

Noranda is expected to have spent $1.5-million on development and examination of the property before the year end. A feasibility study will be completed in the near future and a production decision on the underground copper-zinc deposit is expected early in 1977.

Feverish activity in B.C. N. Miner March 18th, 1976

Massive sulphide finds spur copper search

VANCOUVER – The era of low-rade porphyry copper deposits as n integral part of the B.C. mining :ene is beginning, it seems, to come) an end.

A decade began in the mid-sixties iat saw many large-tonnage, low-rade porphyry discoveries come nto production by open pit ıethods, aided by giant machinery nd new techniques. Now, however, uch developments are becoming on-economic, due to several fac-ors. These have included fluc-uating copper prices, rapidly in-reasing operating and labor costs nd taxation.

In the face of these negative in-luences, the search for potentially rofitable copper deposits is neces-arily turning more to higher grade nassive sulphides.

Early results of this search are ow coming to light: three copper-inc massive sulphide occurrences are now known to be under investigation by major mining firms. This type of deposit is considered by many to represent a significant new target for exploration in British Columbia.

Noranda's recent find

The most recently announced find of this sort, and the most impressive thus far, is Noranda's Goldstream River discovery, 52 miles north of Revelstoke (N.M., March 4, 1976).

Approximately 30,000 ft. of drilling has provided a preliminary estimate of 3,175,000 metric tons grading 4.49% copper, 3.24% zinc, and 0.68 oz. silver per ton.

Grades at most B.C. copper producing mines, operating from porphyry deposits, are generally less than 1% copper.

The geology of the area has not been clearly determined. Noranda geologists are currently drawing up reports. Government geologists will be looking closely at the entire region this year.

According to one geologist with the provincial mines department, Noranda's massive sulphide find "looks like something right out of the Canadian Shield." He called the discovery "pretty darn significant", and felt that it would touch off a considerable amount of exploration in the area.

Noranda will begin an underground program on its discovery property in early summer.

B.C. copper search

Continued from Page 1

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GEORGE CROSS NEWS LETTER LTD. NO.113(1976) (Page Two) JUNE 14,1976

ABACA RESOURCE INDUSTRIES LTD.

INDUSTRIAL PROJECT AND TWO MINERAL PROPERTIES REVIEWED – Abaca Resource Industries Ltd. has reached agreement, subject to the Vancouver Stock Exchange approval, to acquire an additional 50% interest in approximately 450 units or 27,000 acres of mineral land in the North Revelstoke area adjoining, or in close proximity to, the important copper-zinc Goldstream discovery by Noranda. Abaca also holds an 11.1% interest in DMS Explorations Ltd., the vendors. Abaca has a crew of 6 men on the ground carrying out a program of geological mapping, magnetometer surveying and soil sampling. Other companies with crews in the area besides Noranda are Conwest, Seaforth Mines, McIntyre-Porcupine and others.

Abaca also owns 36 claims adjoining Northair to the North-west, where further work is planned this year. Last year a vein was exposed by bulldozer over one foot to six feet width and fifty feet long. A general sample assayed 2.12% copper, 0.92 oz. silver and 0.06 oz. gold. The geology is comparable to Northair. Near the town of Superior, Montana, the company owns a former gold-silver producing mine where a diamond drill program has been recommended.

The industrial division of Abaca includes a 51% interest in Selectrotel Mfg. Co. Ltd. which is completing design and production of a fully solid state telephone answering machine, including remote control and dictation functions. In addition, the company is developing a multi-function, high speed cassette tape transport to be incorporated in the new telephone answering machine, and to be marketed as a separate package for the communication and home entertainment industry.

Since the beginning of 1976, the company has sold in excess of 100 "Waiter Mk. I" version of the telephone answering machine on a test market basis. The groundwork has been laid for wider distribution. An effective marketing program is planned for this summer when the Waiter Mk. II version, with remote control, is in production.

Abaca intends to continue its major emphasis in the design and engineering phase of its operations for the next 12 months. With a gradual increase in production as the market demand for the product increases, acquisitions of other industries in related and complimentary fields are being considered by Abaca.

SEAFORTH MINES LTD.

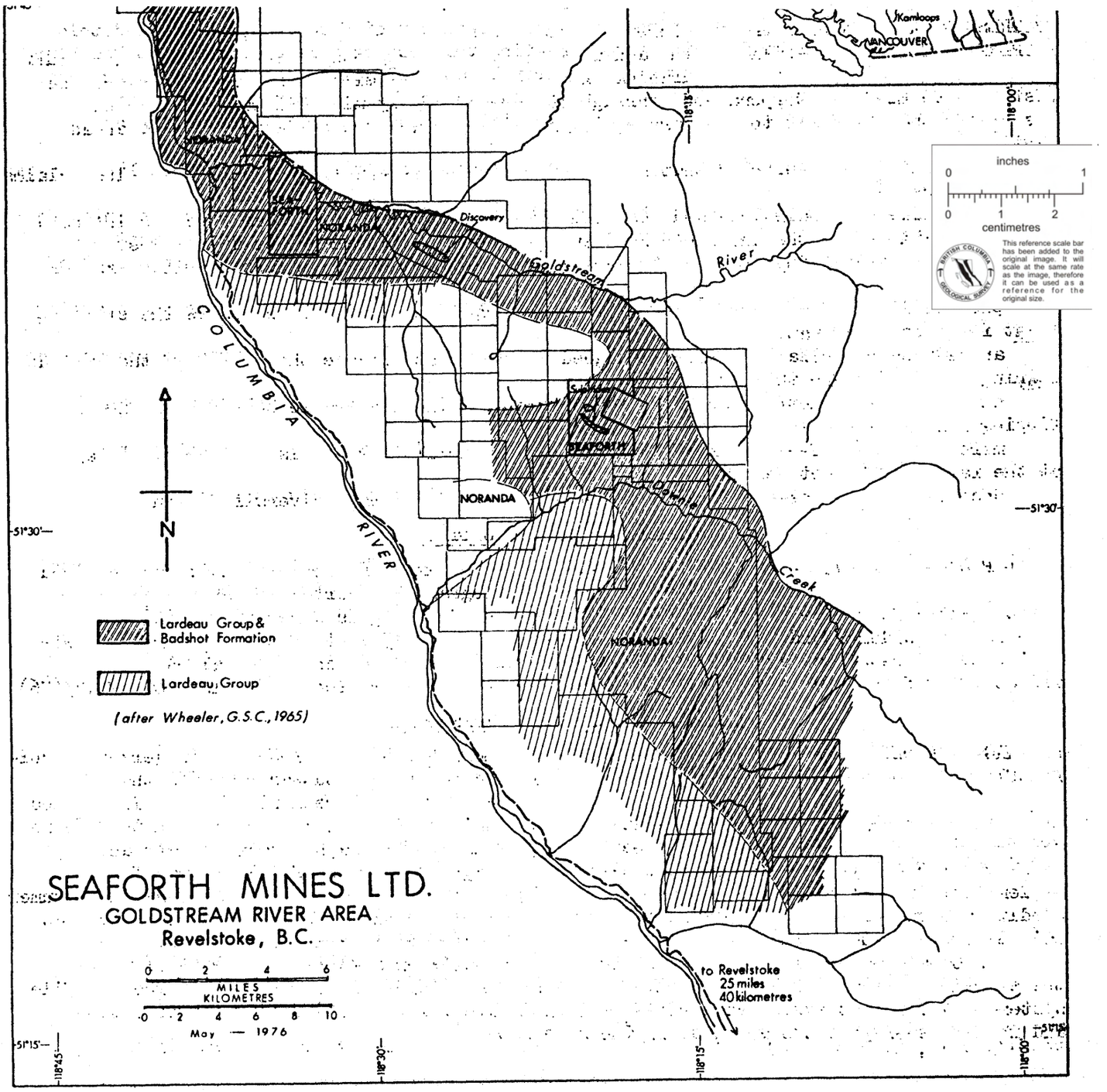
INFORMATION ON PROPERTIES IN NORANDA'S GOLDSTREAM AREA B.C. - G.A.Keevil, president of Seaforth Mines Ltd., has announced some of the details concerning the acquisition of two large blocks of claims in the Goldstream River area, 50 miles north of Revelstoke, B.C. where a massive sulfide deposit has been discovered by Noranda. On March 1,1976, Noranda announced 3,175,000 metric tons of 4.49% copper, 3.24% zinc and 0.68 oz. silver per ton. The possibility of locating further deposits of this type in the area is considered excellent, the president says.

The Seaforth claims were staked in January 1976 after the company received early information on the Noranda discovery. At the time of the Seaforth staking, only Noranda's original discovery claims existed in the area. Seaforth was able to quietly evaluate the entire area and acquire what was considered the best available ground. The Seaforth properties are located on the same geological formation that contains the Noranda deposit. Immediately following Seaforth's staking, Noranda staked additional large claim blocks to the northwest and southeast, covering most of the remainder of the key geological formation.

Seaforth's northern claim block, called the Bend group, adjoins Noranda's discovery claims to the northwest and is on strike with the ore bearing formation. The Noranda ore body is known to have a distinct northwest strike and northern dip.

The southern claim block, called the Mont group, was staked to cover a pyrrhotite-chalcopyrite sulfide horizon with a strike length of at least several thousand feet. This prospect, called the Montgomery showing, was up to the time of Noranda's discovery, considered the best mineralization in the area according to earlier geological reports. The fact that Noranda's discovery is also a pyrrhotite-chalcopyrite deposit within the same formation, lends particular importance to the Montgomery prospect.

A full exploration program on these two properties is planned to start this spring.



B.C. mining news

March 2nd '76

New copper find reported

Noranda Exploration Co. Ltd. announced Monday that it has found a "potentially economic" deposit of copper, zinc and silver in the Goldstream River area, 52 miles north of Revelstoke.

Preliminary estimates by Noranda put the deposit at 3,175,000 metic tons of ore assaying 4.49 per cent copper, 3.24 per cent zinc and 0.68 ounces of silver a ton.

A Noranda statement on the find said it was discovered by prospectors Gordon and Bruce Bried and Frank King who originally staked 52 mining claims. The property was optioned to Noranda under an agreement dated Dec. 31, 1974.

News of the discovery prompted a rash of claim staking last month. The claims recording officer at Revelstoke said Monday that 59 claims were staked in the Goldstream area in February.

Noranda described the deposit as outcropping on the south slope of the river about 1,000 feet above it. The deposit varies from between 8 to 25 feet in thickness and from 500 to 800 feet in width. The deposit dips at an angle of 30 degrees and passes beneath the river at a depth of 1,000 feet.

Noranda said initial work by the prospectors on the claims had included extensive trenching and 22 X-ray holes (relatively shallow drilling with diameter less than one inch.)

During 1975 Noranda completed 50 diamond drills, and these allowed the preliminary estimates of the deposit.

At 4.49 per cent avarage grade, the deposit is one of the richest sizeable orebodies to have been found in British Columbia. The richest currently being mined is the Granduc copper deposit which averages about 1.7 per cent copper.

Brameda Resources

Coal deposits in the Peace River area of British Columbia could make the area the most important in the province's resource development over the next decade, R. E. Hallbauer, is the Sukunka property, 30 sources Ltd., said in the company's annual report.

Brameda holds 122 coal licences in the area and the most important of these, said Hallbauer, is the Sunkunka property, 30 miles south of Chetwynd.

Brascan Resources Ltd. holds an option over 47.5 per cent of the Sukunka properties and this option expires on June 30. Reserves have been calculated at 120 million long tons.

South of Sukunka, Brameda holds 19 licences in the Bullmoose group. Hallbauer said that drill reserves for the Chamberlain seam are currently estimated at 60 million tons. "At least an equal tonnage potential has been indicated in the Bird seam which has good coking characteristics but contains 2 per cent sulphur," Hallbauer said.

R. E. HALLBAUER

"Recent studies of the Gates seams, above the Chamberlain and Bird seams, have indicated the possibility of significant amounts of near-surface coking coal which may be mineable by open-pit methods. Work next field season will be concentrated in this area," he said.

Afton Mines

The feasbibility study of the Afton copper project cost Afton Mines Ltd. $800,000, according to the company's annual report which was released Monday.

The cost of the study was financed by the issue of 1,133,151 shares to Teck Corporation Ltd. and Iso Mines Ltd., the major shareholders of Afton.

In the report the president of Afton, Dr. Norman Keevil Jr., said the smelter and mine project will have an important effect on the economy of Kamloops which is eight miles east of the project.

Estimated permanent employment at the mine and smelter is 350 people, and he expects Afton to spend $15 million a year on its payroll and supplies. During construction, slated to begin this month, the employment peak will be 450.

The company's balance sheet reflects little of the estimated $80 million project cost. In the year to Sept. 30, expenditures totalled $1,778,051, taking deferred costs on the project to $3,336,821. The cost of the feasibility study was by far the biggest item.

Noranda drills outline copper deposit in B.C.

March 4 1976

N Andes

Noranda Exploration Co. has outlined a potentially economic mineral deposit in the Goldstream River area, 52 miles north of Revelstoke B.C.

A preliminary estimate from drilling 50 holes indicates approximately 3,175,000 metric tons with a grade, before dilution, of 4.49% copper, 3.24% zinc, and 0.68 oz. silver per ton.

The deposit outcrops on the south slope of the Goldstream River valley about 1,000 ft. above the river. It varies from 8 ft. to 25 ft. in thickness and from 500 ft. to 800 ft. in width. Dipping at an average of 30°, it passes under the river at a depth of approximately 1,000 ft.

The minability of the deposit and its possible extension north of the river will have to be investigated from underground workings. A program of underground development is to be undertaken this year together with metallurgical testing of the ore.

The discovery was made by prospectors Gordon and Bruce Bried and Frank E. King who were attracted by copper-bearing float. The originally staked 52 claims, completed extensive trenching and drilled 22 X-ray holes. The property was optioned to Noranda on Dec. 31, 1974.

A staking rush could well develop in the area of Noranda copper discovery, although claims recorded so far this year are not overly impressive. However, there is considerable activity in this generally quiet area where four to five ft. of snow presently covering the ground make staking operations difficult. Most of the staking has been along the Columbia River north from the Goldstream River, which is a tributary of the Columbia.

According to rumors about 1,000 claims have been staked. The Revelstoke mining recorder's office reports for the first two months of this year only 59 claims recorded, all of them in February. Under B.C.'s new modified grid system a claim now covers much larger territory than under the previous system when a claim covered 51.65 acres. A claim now consists of from one to 20 units each unit having area of 61.7 acres.

A Noranda spokesman told The Northern Miner that the company holds 198 claims and/or units in the area. Others rumored to be in the area include Cominco, Rio Tinto Canadian Exploration and Vestor Explorations. Cominco would not comment on the rumor, and a Rio Tinto spokesman said the company holds no ground there.

Kerr Dawson, a prospecting group operating out of Kamloops, is said to have claims in the area: Bethlehem Copper is "doing something" in the region, and Brascan Resources has been reviewing the situation in the district but holds no ground in the copper discovery area.

Pumice imported to Canada from Greece and the northwestern part of the United States, is mainly used in the manufacture of concrete blocks.

82M

SEAFORTH MINES LTD.

GOLDSTREAM RIVER PROPERTY PROGRAM FOR 1976 UNDERWAY - G.A.Keevil, president of Seaforth Mines Ltd., has reported that crews have moved onto the claim blocks held by the company in the Goldstream River area, 50 miles north of Revelstoke, B.C. Geological mapping, prospecting and geochemical surveying are being carried out on the Bend claims which adjoin to the northwest of the Noranda discovery containing 3,175,000 tons grading 4.49% copper, 3.24% zinc and 0.68 oz. silver per ton. 82M149

Mr.Keevil has reported that Noranda has recently started a large program on its property with approximately 40 men in camp.

Surface mineralization has been reported on the Seaforth Bend group. 1976 GCNL

New Chief Mines Ltd. says it is currently organizing a public financing so it can carry out the $15,000 work program on the BRI mineral group in the Noranda - Goldstream River area in Revelstoke mining division as recommended by J.W.McLeod, B.Sc., in his geological report dated 26May76. New Chief's option to acquire 100% interest in the BRI property is detailed in GCNL 137(76). New Chief received 291,250 shares of August Petroleums Ltd. in 1974 for oil/gas leases in Monkman Pass area of B.C. and has since sold 138,250 leaving a balance of 153,000 still held on 1Jun76. The August shares were valued at 20.36¢ per share on acquisition and were trading at 21¢ per share as of 1Jun76. The remaining holding of August shares is hypothecated against an outstanding bank loan of $13,325.

Directors are John L.Wilson, Geo.A.Richardson and Stanley J.O.McClay. 1976 GCNL

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WESTERN CANADIAN INVESTMENTS

NORANDA MINES LIMITED

COPPER-ZINC-SILVER OREBODY DRILLED IN REVELSTOKE AREA - Discovery of a potentially economic mineral deposit in the Goldstream River area, 52 miles north of Revelstoke, B.C. is announced by Noranda Exploration Co.Ltd., a wholly owned subsidiary of Noranda Mines Limited.

Fifty diamond drill holes were completed in 1975. These allow a preliminary estimate of the deposit of some 3,175,000 metric tons, before dilution, grading 4.49% copper, 3.24% zinc, 0.16 oz. silver per ton.

The deposit outcrops on the south slope of the Goldstream River valley about 1,000 feet above the river. The deposit varies from 8 to 25 feet thick and from 500 to 800 feet wide. It dips at an average of 30°, passing under the river at a depth of about 1,000 feet. The mineability of the deposit and its possible extension north of the river will have to be investigated from underground workings.

Copper-bearing float led to the deposit's discovery by prospectors Gordon and Bruce Bried and Frank E.King. They staked 52 claims, completed extensive trenching and drilled 22 x-ray holes. The property was optioned to Noranda by a Dec.31,1974 agreement.

Noranda plans underground examination of the orebody and completion of metallurgical testing during 1976.