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Geology of the Goldstream Area

By Trygve Höy

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MINISTRY OF ENERGY, MINES AND PETROLEUM RESOURCES
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Geology of the Goldstream Area

SUMMARY

1. The Goldstream area includes about 400 square kilometres of mountainous terrain in the northern Selkirk Mountains of southeastern British Columbia.

2. The geology of the area consists of intensely deformed Late Proterozoic/Early Paleozoic metasedimentary and metavolcanic rocks, which have been intruded by a number of granitic plutons.

3. The metasedimentary and metavolcanic rocks comprise a heterogeneous package of quartzites, schists, phyllites, calc-schists, and carbonates, interlayered with greenstone and chloritic phyllite.

4. The greenstones and chloritic phyllites are metamorphosed equivalents of tholeiitic flows and basic tuffs. Derivatives of more acid volcanic rocks may now be preserved as quartz-sericite phyllite, quartz-augen phyllite, quartz-feldspar-sericite-chlorite phyllite, and perhaps some of the 'grit' unit.

5. The structure of the area is dominated by tight to isoclinal, north-trending Phase 2 folds. These folds are interpreted to have developed in an initially inverted panel of rocks which may be the underlimb of an earlier (Phase 1) nappe.

6. The most important mineral deposits of the area are stratabound copper-zinc deposits. They include Standard, in a basic volcanic pile, and Montgomery and Goldstream, contained in metasedimentary rocks.

7. Goldstream is a sheet of massive sulphides (dominated by pyrrhotite, sphalerite, and chalcopyrite) 3 to 4 metres thick, 500 metres wide, and at least 1 200 metres long. It occurs within a quartz-rich phyllite that is structurally overlain by a spessartine-chlorite phyllite and chert unit which in turn is overlain by 220 metres of dark calcareous phyllite. The massive sulphide layer and quartz-rich phyllite are underlain by a grey limestone.

8. Massive sulphide deposits in the Goldstream area are similar to the 'bedded cupriferous iron sulphide' or 'Besshi' deposits. They are commonly bed-like in form, are composed primarily of iron sulphide/chalcopyrite ore, and occur in geosynclinal crystalline schists associated with basic submarine volcanism.

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INTRODUCTION

The Goldstream map-area is within the northern Selkirk Mountains in southeastern British Columbia (Fig. 1). The area includes approximately 400 square kilometres of mountainous terrain, bounded by the Columbia River on the west and the Goldstream River on the north. Access to the western part of the area is provided by the Big Bend Highway which follows the east bank of the Columbia River north from Revelstoke. Well-maintained gravel roads extend east for limited distances along the south bank of Goldstream River and Downie Creek. The nearest permanent helicopter bases in 1978 were at Mica, 40 kilometres to the north, and Revelstoke, 50 kilometres to the south.

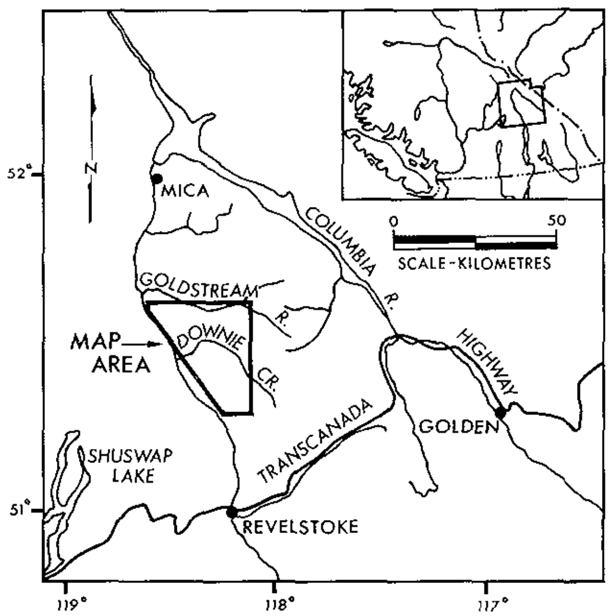

Figure 1. Location map.

The area is generally very rugged and exploration is difficult. Valleys are filled with till, rock exposures are rare, and thick underbrush hampers traversing. Above treeline, at 1 800 to 1 950 metres elevation, exposures are abundant although precipitous cliffs, névé, and glaciers hamper exploration and geological mapping.

The Goldstream area is within the Big Bend map sheet of Wheeler (1965). The geology of the area is described in an M.Sc. thesis (Lane, 1977), and published in a British Columbia Ministry of Energy, Mines and Petroleum Resources preliminary map (Brown, Höy, and Lane, 1977). The areas to the north and east have been mapped recently in more detail by R. L. Brown and his graduate students from Carleton University, Ottawa (*see* Franzen, 1974; Van der Leeden, 1976; and Brown and Tippett, 1978).

HISTORY OF EXPLORATION

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 8 000 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 the Montgomery, Keystone, and Standard deposits. Development of the Standard property in the early 1900's included numerous open cuts and extensive underground workings.

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 per cent copper, 3.123 per cent zinc, and 20 grams per tonne silver. News of this discovery renewed interest and activity in the Goldstream area, and by the end of 1976 more than 120 new claim units had been located in the area.

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2

LITHOLOGIC UNITS

INTRODUCTION

Metasedimentary rocks in the Goldstream area comprise a heterogeneous package of arenaceous to relatively pure quartzites, schists, phyllites and calc-schists, and carbonates. These are interlayered with tholeiitic flows and basic tuffs, now metamorphosed to greenstone and chloritic phyllite. These rocks are subdivided into five major lithologic packages. These include dominantly pelitic and calcareous schists of units A-1 and A-2 exposed along the eastern part of the map-area (Fig. 2), overlain by a succession of rocks that has been subdivided into four main divisions:

(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;

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

The sequence of rock units outlined above is believed to represent an original stratigraphic succession, with units A-1 and A-2 being the oldest, and the dominantly calcareous rocks of the carbonate-phyllite division, the youngest. The succession has been established by matching lithologic packages across second phase fold closures, and the order of superposition determined from a number of stratigraphic tops recognized throughout the area. However, even though the broad outlines of the stratigraphic succession are established, the detailed lithologic succession within divisions is not well known. Hence, units within divisions are described without particular regard to their relative position within the division.

The age of these rocks and their correlation with formations to the east and south is speculative. Units A-1 and A-2, the oldest rocks in the map-area, have tentatively been correlated (Brown, Höy, and Lane, 1977) with the upper part of the Horsethief Creek Group of Hadrynian age. Stratigraphically (?) overlying rocks to the west have been tentatively correlated with the Hamill Group and the Mohican and Badshot Formations of Eocambrian and Early Cambrian age.

UNITS A-1 AND A-2

Units A-1 and A-2 are exposed only in the east, in areas mapped by Lane (1977) and Gibson, *et al.* (1977). They comprise 'pelitic schists which grade laterally into black graphitic schist, white calcite marble, thin bands of brown-weathering quartz feldspar grit, and minor rusty weathering pelitic marble' (Brown, Höy, and Lane, 1977). Dolomite and limestone are designated A-1 on Figure 2.

The upper boundary of these units, tentatively correlated with the Horsethief Creek Group, is placed at the transition from dominantly interlayered schist and marble to schist that contains layers of grit and impure quartzite.

QUARTZITE–SCHIST DIVISION

Several thousand metres of pelitic schist and quartzite of this division are exposed on a southerly trending ridge due south of the Goldstream pluton. Northward, the succession grades stratigraphically upward from a sequence of interlayered pelitic schist and micaceous quartzite (unit Q-3, Fig. 2), to massive thick-bedded pure to micaceous quartzite of unit Q-4. These, in turn, are overlain to the north by interlayered pelite, rusty weathering biotite-hornblende gneiss and some rusty weathering calcareous phyllite.

On the east side of the Downie antiform, the thickness of rocks that can be assigned to this division is restricted on the east by exposures of rocks correlated with the Horsethief Creek Group and on the west by rocks assigned to the overlying metavolcanic-phyllite division. This loss of stratigraphy is due to tectonic thinning, either in the core of a Phase 1 fold, or along a fault that may lie somewhere east of rocks of the metavolcanic-phyllite division. The rocks consist of interlayered psammite, quartz-sericite schist, and rare thin marble layers.

In the western and northern parts of Keystone area, rocks of this division include impure quartzite, pelitic schist, calcareous schist, and minor chlorite schist. The Keystone lead-zinc±copper occurrences (Fig. 2) are hosted by limestone and micaceous quartzite of unit Q-2. Lithologically similar exposures of Q-2 in the eastern part of the Keystone area may be in the core of a tight Phase 2 synform which is flanked by greenstones and calcareous units of the metavolcanic-phyllite and carbonate-phyllite divisions.

In the western part of the Standard area quartz-rich phyllites and pelitic schist (Q-1) are overlain by Q-2, comprising sericite and chlorite-sericite phyllite interlayered with thin feldspathic grit units. East of the Standard Basin, unit Q-2 comprises 'quartzite and psammite' (Brown, Höy, and Lane, 1977).

As rocks of the quartzite-schist division in the eastern parts of the Downie Peak, Keystone, and Standard areas are lithologically similar to part of the sequence of rocks of the metavolcanic-phyllite division in the Downie Peak area, their assignment to the quartzite-schist division is not definite.

CALC–SILICATE GNEISS DIVISION

Interlayered calc-silicate gneiss, pure to siliceous marble, and biotite gneiss are exposed along the southern contact of the Goldstream pluton. Quartzite, biotite-hornblende gneiss, and thin amphibolite layers are also common within the calc-silicate gneiss unit. In general, exposures consist of a heterogeneous package of thinly layered, rusty weathering calcareous phyllite and quartzite, intruded by numerous foliated granite bodies, pegmatite, and aplite. Skarns are commonly developed in marbles immediately adjacent to the Goldstream pluton.

METAVOLCANIC–PHYLLITE DIVISION

The metavolcanic-phyllite division consists of massive greenstone units, chlorite phyllite, ultramafic pods, and dark calcareous to pelitic schist. The more prominent mineral occurrences, including the Goldstream deposit, occur within metasedimentary and metavolcanic rocks of this division.

The most prominent metavolcanic unit (V-3) is a massive, fine to medium-grained greenstone that is composed primarily of chlorite, actinolite, epidote, plagioclase, and minor carbonate. Only one sample was collected for chemical analysis (H76G19-1, Appendix A). It, and six samples collected and analysed by Lane (1977) from east of Goldstream area and within the Goldstream area, were plotted on Church's (1975) triaxial oxide plot. These samples were all within or along the edge of the 'basalt' field. The greenstone is intercalated with chlorite phyllite, dark calcareous to pelitic schist, and, north of Keystone Peak, with greenstone that has well-developed though deformed pillow structures (Plate I). The massive greenstone is generally not at a discrete stratigraphic horizon; rather it is a series of lenses that thin and thicken appreciably along strike, and commonly grade laterally and vertically to chlorite phyllite that may originally have been pyroclastic or volcaniclastic rocks.

The calcareous phyllite unit (Plate II) is dark grey to black in colour; weathered surfaces are typically very pitted (due to leaching of carbonate) and sometimes rusty due to oxidation of iron in either dolomite or pyrite. Alignment of elongate clear quartz eyes, micaceous minerals, and dark carbonaceous material (graphite ?) produce a well-defined foliation. Grey limestone layers and discontinuous thin chlorite-phyllite layers are common within the unit. In the Keystone area, the phyllite grades laterally into rusty weathering, noncalcareous biotite schist.

Ultramafic pods, brown-weathering, coarse-grained, talc-chlorite-serpentine-dolomite pods, are common with the massive and phyllitic greenstone units. In the Standard area, the ultramafic pods are at a specific stratigraphic level and are repeated on both sides of the Standard antiform. Here the sequence from the core of the fold to the limbs (younger to older ?) is:

carbonate-phyllite division	dark-banded calcareous phyllite (C-1) grey limestone (C-2)
metavolcanic-phyllite division (V-3)	ultramafic layer coarse-grained 'diorite' layer greenstone (massive to phyllitic) quartz-sericite phyllite interlayered with dark-banded calcareous phyllite

The basal part of the metavolcanic-phyllite division comprises more than 500 metres of dark calcareous phyllite, dolomite, and one greenstone layer.

West of the Standard antiform, unit V-3 is underlain by a light green, sericite, quartz feldspar phyllite (unit V-5) that commonly contains minor chlorite. Quartz eyes and augens are common throughout the unit.

The greatest thickness of metavolcanic rocks in the map-area occurs in the Keystone area. Approximately 1 100 metres of massive to phyllitic greenstone is exposed in the lower limb of the Keystone antiform around Keystone Peak. It thins to several tens of metres to the east and north. In the Standard area to the south several hundred metres of greenstone is exposed, and well to the north, in the Downie Peak area, greenstones (and higher grade equivalents, amphibolites) are restricted to a number of discrete and continuous layers up to several hundred metres thick.

CARBONATE–PHYLLITE DIVISION

Rocks of the carbonate-phyllite division include dolomites, limestones, and calcareous phyllites exposed in the core of the Downie, Keystone, and Standard antiforms. The carbonates (C-2) are typically grey to buff-coloured, thin-bedded limestone or dolomite layers intercalated with less pure rusty weathering calcareous schist, biotite schist, and less commonly chlorite schist (or amphibolite) layers (C-1 and C-3). Both Keystone and Downie Peaks are composed of massive limestone, considerably thickened in the fold cores.

Southward, the total thickness of exposed carbonate of the carbonate-phyllite division decreases. At Standard, it is restricted to a single grey limestone layer in the core of the Standard antiform.

SEDIMENTARY FACIES CHANGES

A number of problems in the proposed assignment of units to lithologic divisions are apparent. The four-fold subdivision of the succession above units A-1 and A-2 is fairly straightforward in the western part of the area. However, east of the antiformal structures, the total thickness of metasedimentary rocks is tectonically thinned. It is possible that the quartzite-schist division is missing entirely in the eastern part of the Keystone (and Standard ?) areas and that the rocks assigned to this division belong to the metavolcanic-phyllite and carbonate-phyllite divisions.

Units are considerably thinned in limbs of Phase 2 folds and probably thickened in cores and hence conclusions regarding original absolute or relative thicknesses are rather speculative.

Despite these structural complications, some observations regarding regional sedimentary facies changes within the confines of the map-area are worthy of comment. As noted previously, the greatest thickness of massive greenstone occurs in the Keystone area. The greenstones thin to the north and south, replaced by a larger proportion of clastic sedimentary rocks. As well, the proportion of chlorite phyllite appears to increase to the south, at the expense of the more massive greenstone in the Keystone area. The carbonates of the carbonate-phyllite division are thickest in the north and appear to shale-out in the Standard area to the south. Alternatively, these carbonates may simply not be exposed in the Standard area, due to a structurally higher level of exposure here. In any case, the total thickness of rocks of the metavolcanic-phyllite and carbonate-phyllite divisions and the proportion of coarser clastics is greater in the northern (Downie) than in the southern areas.

DEPOSITIONAL ENVIRONMENT – SPECULATIONS

A change from deposition of clean, massive quartzites interbedded with pelitic shales of the quartzite-schist division to thin-bedded impure carbonates and dark carbonaceous and calcareous shales of the metavolcanic-phyllite division is probably indicative of deepening water conditions at that time; rocks of the quartzite-schist division are more typical of a platform or shelf environment whereas the younger rocks indicate deposition in a more reducing, restricted basin environment. Infilling of the basin by dark calcareous shales was periodically interrupted by eruptive basic volcanism in the form of thick massive flows, pillow basalts, and tuffaceous sedimentary rocks (now preserved as the chlorite phyllites).

In summary, a suggested tectono-stratigraphic model involves development of a restricted basin in the area south of the Goldstream River at the edge of or within a platform that extended well beyond the confines of the map-area. The voluminous extrusion of basaltic magma may indicate that faulting played an important part in the development of the basin, and the thickening and coarsening of sedimentary rocks to the north indicate both a deepening of the basin and a sediment source to the north. These observations suggest that the northern edge of the basin, perhaps in the region of the Goldstream River, may have been fault bounded, and that a local sediment source may have been a topographic high north (or northeast ?) of a fault scarp.

REGIONAL CORRELATIONS

Based on lithologic similarities, rocks in the area south of Goldstream River have been correlated by Wheeler (1965) with the Lower Paleozoic Lardeau Group. Those along the eastern edge of the map-area (including units A-1 and A-2) are tentatively correlated with a more calcareous western facies of the upper part of the Proterozoic Horsethief Creek Group of Hadrynian age (Brown, Höy, and Lane, 1977). Immediately to the west of units A-1 and A-2 is a relatively thin package of psammites, grits, pelites, and metavolcanic rocks (unit Q-2, east of Downie Peak) exposed in the core of a Phase 1 synform. These belong to the 'quartzite-schist division' and based on their similarity to the Eocambrian/ Lower Cambrian Hamill Group and their position overlying the Horsethief Creek Group are tentatively correlated with the Hamill Group. A thick sequence of quartzites and pelitic schists west of the Downie and Keystone antiforms are also lithologically similar to Hamill rocks and are therefore correlated with these rocks.

It is probable that the rocks of the metavolcanic-phyllite division are correlative with the upper part of the Hamill Group or the Mohican Formation, a heterogeneous package of calcareous phyllites, thin carbonates, and quartzites that overlies the Hamill Group in the Kootenay Arc (Fyles, *et al.,* 1962; Fyles, 1964; Read, *et al.,* 1975; and Höy, 1977). Correlation of these rocks to the Lower Paleozoic Lardeau Group would require the presence of the intervening Lower Cambrian Badshot Formation marble between these rocks and those of the quartzite-schist division. Furthermore, metavolcanic rocks of this division are chemically similar to metavolcanic rocks in known Hamill rocks further to the east (Lane, 1977).

Carbonates of the carbonate-phyllite division may also be a more calcareous western facies of the upper part of the Hamill Group or may be the Mohican Formation. The thick carbonate that is exposed in the core of the Downie and Keystone antiforms may be the Badshot Formation which it resembles. A similar limestone is not exposed in the Standard area but it may be at a deeper structural level here.

METAMORPHISM AND PLUTONIC ACTIVITY

The regional metamorphic grade ranges from greenschist facies in the south to lower amphibolite facies in the north. Chlorite phyllites and greenstones in the Keystone and Standard areas are metamorphosed to amphibolites in the Downie area. Pelitic schists in the Downie area contain biotite and garnet, as well as large elongate porphyroblasts, now altered to white mica. These altered porphyroblasts are probably kyanite pseudomorphs; kyanite is common in pelitic schists regionally metamorphosed to amphibolite grade. Sillimanite and andalusite are common in pelitic schists along the south margin of the Goldstream pluton. Andalusite porphyroblasts, partially altered to white mica, contain both straight and sinuous inclusion trails indicative of growth prior to or during deformation. Sillimanite needles are aligned in the plane of the Phase 2 foliation.

A number of large plutonic bodies occur throughout the map-area. The Goldstream pluton varies in composition from the granite field to the quartz monzodiorite field (Table 1). The southern contact of the Goldstream pluton consists of a wide zone of skarns, contact metamorphosed limestone, and calcareous schists, intruded by large, concordant east/west-trending masses of fine to medium-grained quartz monzonite and granite. Remnant aligned masses of metasedimentary rocks are common near the edges of the pluton.

TABLE 1. MODAL ANALYSES OF GOLDSTREAM PLUTON*

SAMPLE	DESCRIPTION	qz (%)	Ks (%)	pl (%)	bi + hb (%)	TOTAL COUNTS	ROCK NAME
D76G15–3	foliated, equidimensional	28	18	41	13	658	granodiorite
H77G28–1	foliated, layered	8	21	56	15	600	quartz monzonite
H76G8–1	fine grained, equigranular	28	30	37	5	554	granite
H76G8–2a	foliated, contact phase of pluton	9	10	63	18	624	quartz monzodiorite
H76G8–2b	foliated, contact phase of pluton	9	17	61	13	557	quartz monzodiorite

*All specimens are from near the contact of the pluton and are generally well foliated and compositionally layered (with the exception of H76G8–1), hence modal analyses may not be particularly representative of the pluton as a whole. Locations are plotted on Figure 2; D76G15–3 is from the western edge of the pluton, west of the map-area.

A foliation in the quartz monzonite is deformed by Phase 2 folding (Plate VI). If this foliation is of primary igneous origin, the intrusion predates the Phase 2 deformation. If, however, the foliation is of structural origin, it must be related to Phase 1 deformation, and the intrusion is older than the earliest deformation recognized in the Goldstream area. Brown and Tippett (1978) propose that nappe development in the northern Selkirk Mountains (the Phase 1 deformation) is related to the Devono/Mississippian (?) Caribooan orogeny, and so it is possible that the Goldstream pluton is of Devonian age, as has been determined for some plutonism in the Shuswap Complex (Okulitch, *et al.*, 1975).

Other plutons within the map-area cut the country rock and Phase 2 structures. They are commonly porphyritic, with large crystals of microcline in a finer grained matrix of orthoclase, plagioclase, and varying amounts of quartz, biotite, and hornblende (Wheeler, 1965), and range in composition from granitic to quartz monzonitic. They are clearly post-tectonic, discordant intrusions, of probable Cretaceous age.

3
STRUCTURE

INTRODUCTION

The structure of the Goldstream area is dominated by tight to isoclinal north-trending Phase 2 folds. The folds are overturned with axial surfaces varying from nearly horizontal in the Keystone area to steeply east dipping in the Downie and Standard areas (Fig. 2).

Phase 2 folds are interpreted to have developed in an inverted panel of rocks. It is suggested that this panel may be the underlimb of an earlier (Phase 1) nappe.

Phase 3 structures consist only of small-scale chevron folds and conjugate kink folds.

PHASE 1 FOLDS

The existence in the Goldstream area of a structure that is earlier than the obvious folds assigned to Phase 2 is based on a number of top determinations in grits (Lane, 1977). These indicate that the Phase 2 folds developed in a previously inverted stratigraphic panel. Furthermore, a number of features within the Goldstream deposit on the north limb of the Phase 2 Downie antiform suggest that the deposit is inverted, supporting the development of Phase 2 folds in an inverted panel. The inverted panel may be the underlimb of an early (Phase 1) nappe.

Minor structures that can be related to Phase 1 deformation are not obvious; it is not possible to assign rootless, isoclinal fold hinges, common throughout the area, to Phase 1 or Phase 2.

East of the map-area, Phase 2 structures developed in a right-way-up stratigraphic panel (Brown, Höy, and Lane, 1977). Hence a Phase 1 synclinal core possibly located 'within or along the western boundary of Hamill rocks (unit Q-2, Fig. 3) at the eastern edge of the map-area' (Brown, *op. cit.*) is interpreted to separate the inverted panel on the west from the eastern panel.

The existence of early nappes elsewhere in southeastern British Columbia is better documented. In the McCulloch Creek area immediately north of the Goldstream area, Phase 2 folds are also developed in an inverted stratigraphic panel, implying the existence of an early recumbent nappe (Van der Leeden, 1976). Further north, in the Canoe River area, Ghent, *et al.* (1977) suggest the presence of a large westward-closing recumbent fold that has tight to isoclinal Phase 2 folds superimposed on it.

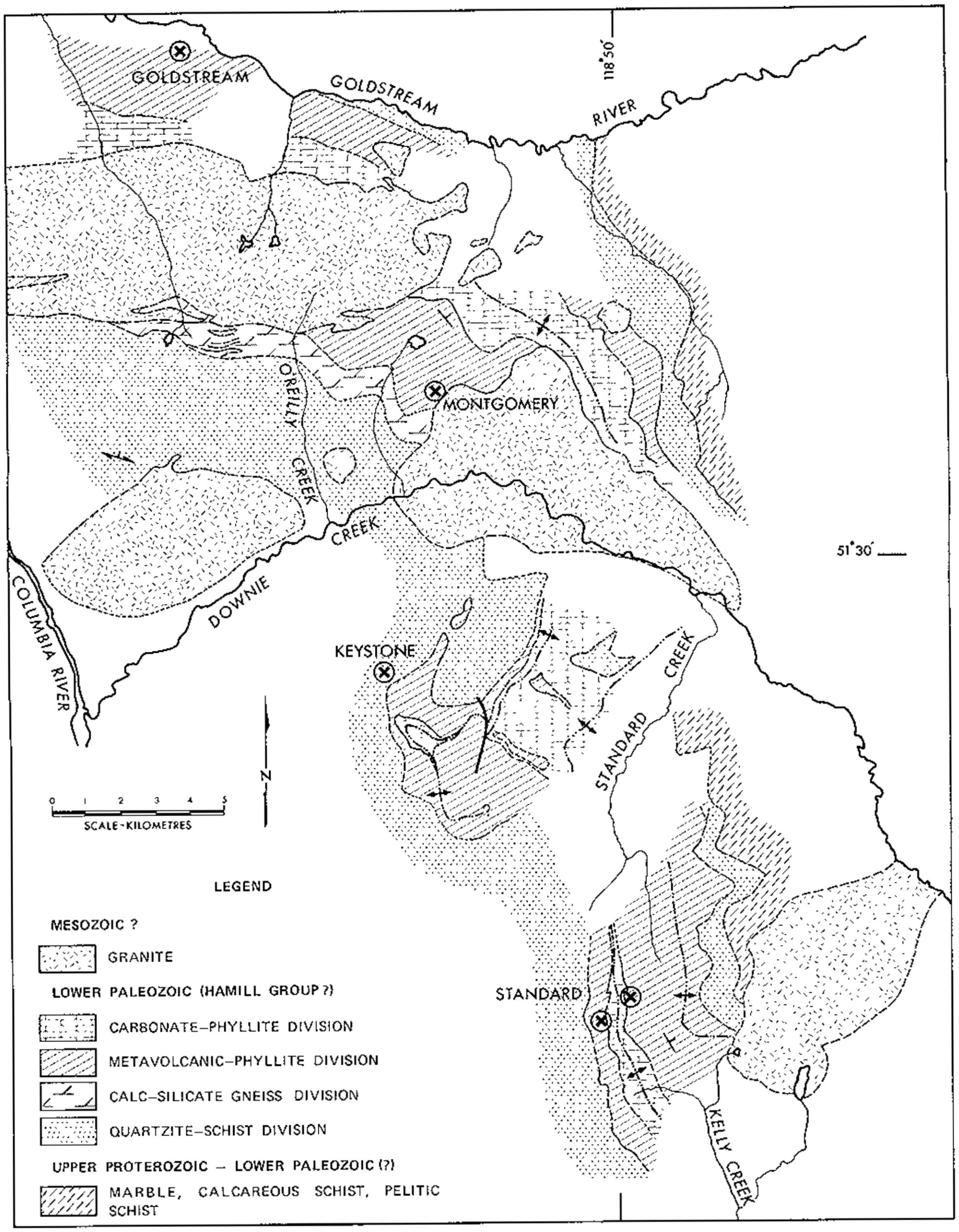


Figure 3. Regional geology, Goldstream area.

Similar nappes are described in the Kootenay Arc to the south. In the Akolkolex River area near Revelstoke, a large recumbent fold, the Akolkolex anticline, is a nappe that closes to the northeast (Thompson, 1979). Coaxial warps and upright open folds are superimposed on the nappe. In the Duncan Lake area, recumbent isoclinal folds root in a westerly direction and are sharply overturned to the west by large, upright to west-dipping Phase 2 folds (Fyles, 1964). In the Riondel area further to the south, a nappe is also overturned to the west by later tight to isoclinal Phase 2 folds (Höy, 1977).

PHASE 2 FOLDS

Phase 2 folds are the most conspicuous structures in the map-area. They are tight to isoclinal folds with a well-developed axial plane schistosity.

In the Downie Peak area (Fig. 2), carbonates of the carbonate-schist division are exposed in the core of an antiformal structure on the steep southeast-facing slope of Downie Peak (Plate III). The fold, named the Downie antiform, is a tight Phase 2 structure with an east-dipping axial surface and north-plunging fold axis (Fig. 4a). Poorly graded grits within unit V-4a just west of Downie Peak indicate that the metasedimentary rocks here are younger toward the core of the antiform, hence the Downie antiform appears to be an antiformal syncline that may have developed in an initially inverted structural panel. However, a graded grit observed in unit Q-4 west of O'Reilly Creek faces in the opposite direction casting some doubt on the validity of this structural interpretation. It is necessary to determine the structural position of a stratigraphic top determination on any minor folds on the limbs of the major structure before conclusions can be reached regarding inverted or right-way-up stratigraphy; a top determined on the short limb of a minor fold faces in the opposite direction to a top determined on the long limb. No major Phase 2 folds are recognized southwest of the Downie antiform and the sequence of rocks from Downie Peak to west of O'Reilly Creek (Fig. 2) represents the most complete stratigraphic section within the map-area.

The structural panel on the northeast side of the Downie antiform trends approximately east/west on the north side of the Goldstream intrusive. The axial plane of the antiform is located south of the Goldstream deposit, and therefore younger rocks, assumed to be in the core of the antiform, occur south of and at deeper structural levels within the deposit.

A recumbent antiformal structure, the Keystone antiform, dominates the structure of the Keystone area (Fig. 3). The closure of this fold is well displayed on cliff faces northeast of Keystone Peak (Plate IV) and on the southwest slope of Keystone Peak (Plate V). It opens toward the east and closes to the west. The orientation of Phase 2 minor folds and mineral lineations related to Phase 2 folding indicate that the antiform plunges at a low angle to the southeast (Fig. 4b). Rock units are considerably thickened in the core of the fold and thinned in its limbs.

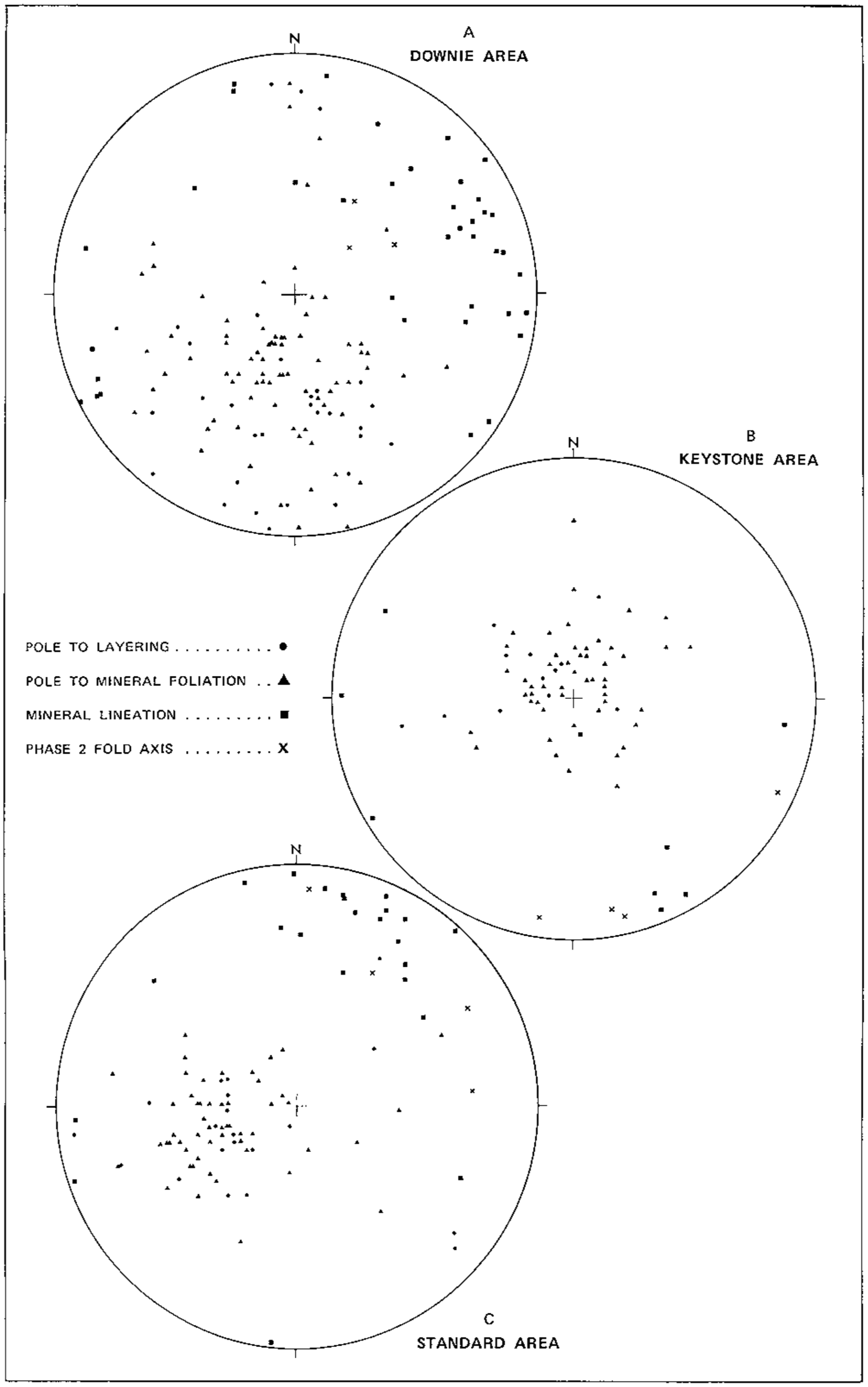


Figure 4. Equal-area projection of Phase 2 structural elements; (a) Downie area, (b) Keystone area, (c) Standard area.

A series of antiform/synform structures with east-dipping axial surfaces and north-plunging fold axes (Fig. 4c) repeat rocks of the metavolcanic-phyllite and carbonate-phyllite division in the Standard area (Fig. 3). The folds are overturned, with an S-shape when viewed down-plunge. A top determined in a graded grit in unit V-3 suggests that younger rocks occupy the cores of antiforms and older rocks the cores of synforms, suggesting that these Phase 2 folds also developed in an initially overturned stratigraphic panel.

PHASE 3 FOLDS

The effects of a late, Phase 3 deformation are minimal. In general, the map pattern of units is not altered appreciably by Phase 3 folds. They consist of small-scale chevron folds and kink folds in units displaying a well-developed Phase 2 schistosity, and small open folds in more competent units (Plate II).

The orientation of linear and planar structures parallel with Phase 3 fold axes and axial planes respectively are plotted on Figure 5. In general, Phase 3 folds have shallow-dipping axial surfaces and plunge at variable angles to the east.

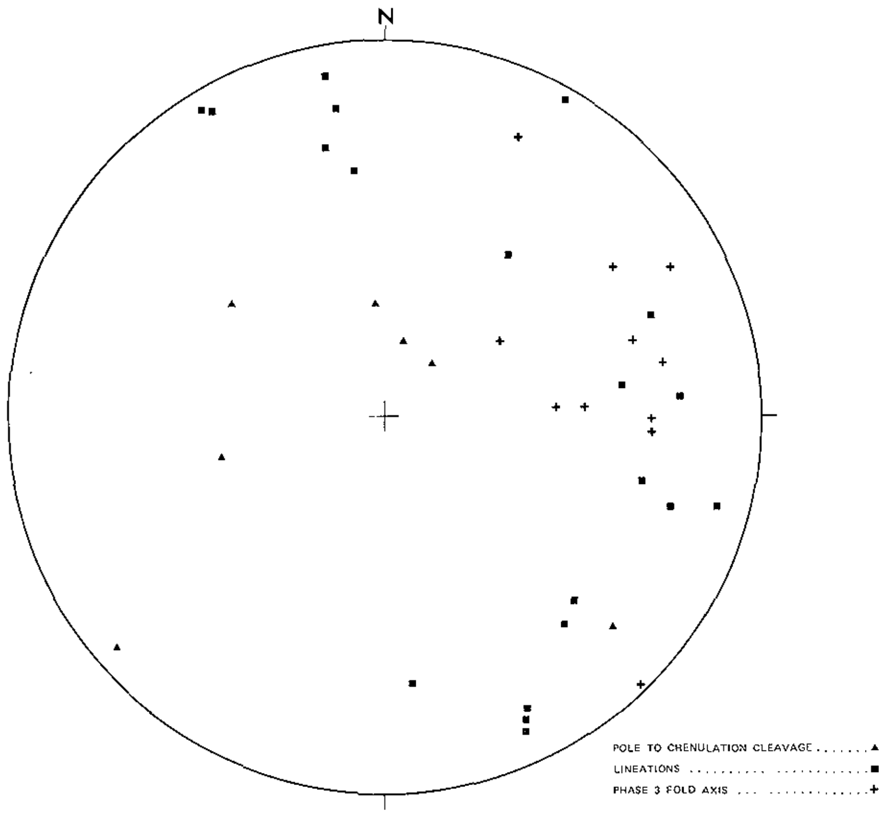


Figure 5. Equal-area projection of Phase 3 structural elements.

FAULTS

Only one well-defined crosscutting fault is apparent in the map-area. In the Keystone area, a steeply dipping northerly trending fault cuts across the nose of the Keystone fold.

Layer parallel faults are not apparent, probably due to the difficulty of identifying them in an area where stratigraphy is not well known. The displacement on a major layer-parallel shear zone in the hangingwall of the Goldstream deposit is not known, although slickensides and the rotation of minor folds associated with this fault indicate a reverse movement.

4

MINERAL DEPOSITS

The most important deposits in the Goldstream area are stratabound copper-zinc deposits in metasedimentary and metavolcanic rocks of the metavolcanic-phyllite division (Table 2). The Goldstream deposit, discovered in 1975, is the largest of these; the Montgomery and Standard deposits were both discovered in 1896 and have been extensively explored since. One important lead-zinc deposit, Keystone, and a vein gold deposit are within rocks of the quartzite-schist division. A number of placer and vein gold deposits immediately north of the map-area in the McCullough and French Creek drainage basins have been intermittently worked since the turn of the century.

STANDARD (82M/8E)

The Standard property, located around Standard Peak and the headwaters of Standard Creek, was originally staked in 1896 and developed by the Boston and B.C. Copper Mining and Smelting Company in 1898 and 1899, and the Prince Mining and Development Company from 1900 to 1906. This development work consisted of 700 metres of tunnels and raises on five levels, and numerous open cuts. Noranda Exploration Company, Limited optioned Crown-granted claims, owned by G. Rayner (Vancouver), in October 1975, and, in August and September 1976, conducted an electromagnetic and a geochemical soil survey and drilled nine holes totalling 888.9 metres (Plates VII and VIII). Three of the holes, centred at approximately 95 E – 95 + 00 N (Fig. 6), each intersected a massive sulphide section approximately 0.2 to 1 metre thick, and a fourth hole intersected four 1 to 2-metre-thick sections grading 2 to 3 per cent copper and 0.3 to 1.15 per cent zinc (Assessment Report 5070). The remaining five holes intersected only thin (< 0.5-metre) massive sulphide sections.

The structure of the Standard area is dominated by a north/south-trending tight antiform that plunges at a low angle to the north (Fig. 6). Limestone and dark graphitic and calcareous phyllite of the carbonate-phyllite division are exposed in the core of the antiform, and greenstone, limestone, and phyllite of the metavolcanic-phyllite division, in its limbs. A detailed stratigraphic section from the limbs of the fold to the core is described in Table 3.

TABLE 2. MINERAL OCCURRENCES, GOLDSTREAM AREA

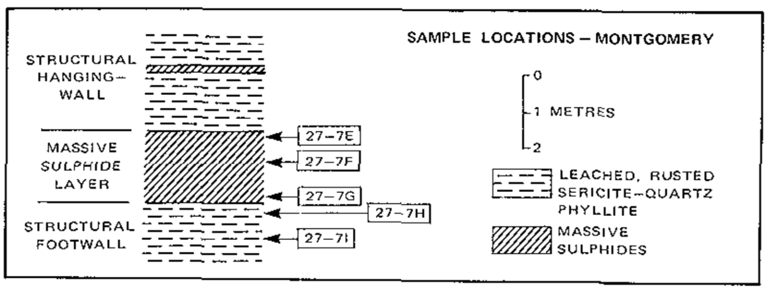
NO. (FIG. 2)	NAME (OWNER OR OPERATOR, 1976)	COMMODITY	MODE OF OCCURRENCE	HOST	WORK DONE (1975–1977)	REFERENCE
1.	Standard (Noranda Expl.)	Cu, Ag, Zn, Au	layers and lenses of massive and disseminated sulphide	greenstone, calcareous phyllite	extensive – 888.9 metres of drilling	this report
2.	Keystone (Noranda Expl.)	Pb, Zn, Cu	vein, replacement	quartz - rich phyllite, limestone	geochemical (soil); EM	Assess. Rept. 6104; this report
3.	KS (Kerr Addison)	Cu, Pb, Zn	vein, replacement	quartz - sericite schist, limestone	geochemical (soil)	Min. Inv. 82M-140
4.	Montgomery (Seaforth Mines)	Cu, Zn, Ag	layer of massive sulphide, associated disseminated sulphides	quartz - chorite schist	geochemical (rock)	this report
5.	KJ (Cent Pac Dev.)	Pb, Zn, Au, Ag	disseminated vein	limestone	geochemical (soil); magnetometer	this report
6.	O'Reilly (Noranda Expl.)	Cu	lenses, disseminated	quartz - sericite schist, quartzite	geochemical (soil); EM	Assess. Rept. 6103
7.	Bend (Seaforth Mines)	Cu	disseminated	quartz - talc - chlorite - tremolite - garnet schists	geochemical (soil); magnetometer	Assess. Rept. 6176
8.	Tri (B. Bried, G. Bried, F. King)	Cu	in float	greenstone schist, limy and siliceous bands	geochemical (soil); VLF–EM	Assess. Rept. 5884, 6185
9.	Goldstream–Pat (Noranda Expl.)	Cu, Zn, Ag	layer of massive sulphide	siliceous zone in phyllite	extensive – underground development; drilling	this report

TABLE 3. SEQUENCE OF ROCK UNITS FROM THE CORE OF THE STANDARD ANTIFORM TO ITS LIMBS
(thickness of units approximate)

DIVISION	MAP UNIT (FIG. 2)	THICKNESS (METRES)	DESCRIPTION
CARBONATE–PHYLLITE	C–1	>150	dark-banded calcareous phyllite; carbonaceous phyllite; minor limestone and chlorite phyllite
	C–2	30	dominantly grey limestone, minor quartz-rich phyllite, grit, and chlorite phyllite
METAVOLCANIC–PHYLLITE		0–15	'ultramafic layer' – coarse-grained talc-chlorite - serpentine - carbonate unit; rusty weathering
		~10–100	diorite layer' — coarse-grained chlorite-hornblende-plagioclase unit
	V–3	150–200	'greenstone' — massive to phyllitic; minor dark calcareous phyllite and grey limestone (copper mineralization in 'greenstone' close to upper contact with 'diorite layer')
	V–1		dominantly dark calcareous phyllite; also chlorite phyllite, limestone; minor micaceous quartz-rich phyllite

TABLE 4. ASSAYS FROM STANDARD, KEYSTONE, AND MONTGOMERY SHOWINGS (GRAB SAMPLES)

SAMPLE NO.	Au *ppm*	Ag *ppm*	Pb *per cent*	Zn *per cent*	Cu *per cent*	SAMPLE DESCRIPTION
STANDARD						
H76G17–7a	1	29	0.00	0.84	9.98	massive, fine-grained py-cp
H76G17–7b	<1	10	0.018	0.21	1.65	finely disseminated po-py
KEYSTONE						
H76KS–1A	<1	43	6.70	5.45	0.16	sulphides in siliceous limestone
H76KS–1B	<1	71	3.95	31.00	0.72	massive sulphide
H76KS–1C	<1	24	1.75	3.75	0.17	sulphide streaks in siliceous limestone
H76KS–2	<1	62	2.83	0.29	0.04	crosscutting py-rich vein
MONTGOMERY						
H77G27–7	<1	10	0.028	0.10	0.40	massive, fine-grained pyrrhotite
H77G27–7E	<1	43	0.041	0.18	2.97	po-cp stringers in finely layered siliceous rocks
H77G27–7F	<1	10	0.027	0.26	0.50	massive, fine-grained pyrrhotite
H77G27–7G	<1	10	0.073	0.44	0.033	massive, fine-grained pyrrhotite
H77G27–7H	<1	11	0.008	0.015	0.48	py-po blebs and stringers in dark chlorite-quartz-sericite phyllite
H77G27–7I	<1	49	0.006	0.013	0.30	py-po blebs and stringers in dark chlorite-quartz-sericite phyllite



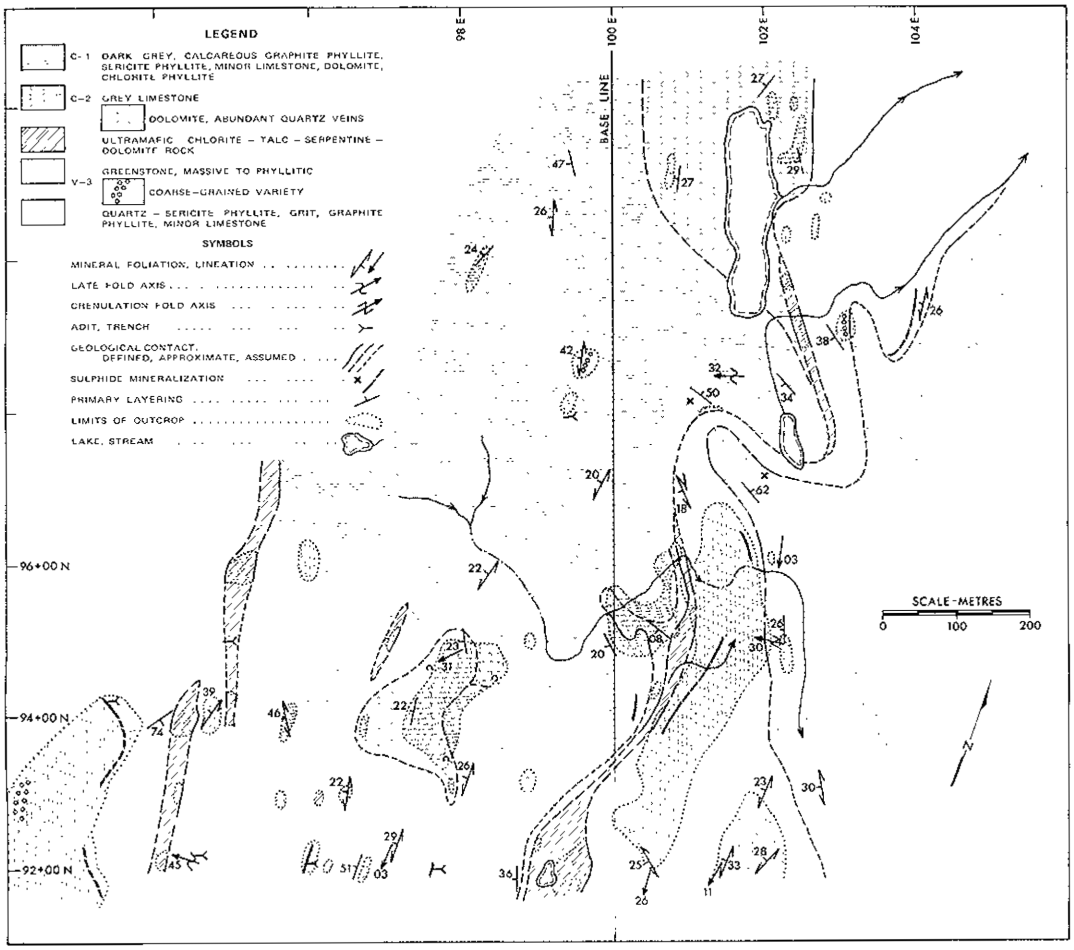


Figure 6. Detailed geology of the Standard Basin.

Massive sulphide mineralization on the Standard property is most dominant within a distinct stratigraphic interval in the greenstones (V-3) but some also occurs within calcareous phyllite of unit C-1. It consists of a series of layers and lenses of massive pyrrhotite and pyrite containing minor chalcopyrite and sphalerite. The sulphide minerals are repeated on both sides of the Standard antiform and on the east limb can be traced intermittently through a strike length of 1 500 metres. Copper concentrations in the massive sulphides generally range from 1 to 3 per cent (*see also* Table 4) and zinc, from 0.3 to 1 per cent.

In detail, the massive sulphides consist of fine to medium-grained pyrite interlayered with much finer grained pyrrhotite. Chalcopyrite occurs as massive, fine-grained concentrations intimately mixed with pyrrhotite, as irregular blebs commonly associated with dark phyllite or quartz fragments, and as thin discontinuous layers with diffuse boundaries in the pyrrhotite and pyrite. Mylonitization of the massive sulphides produces dull, fine-grained, layered pyrrhotite and gneissic textures (Plate IX). Porphyroblasts of euhedral pyrite in the pyrrhotite and complete recrystallization of pyrrhotite layers to coarse-grained pyrite are common. Many small late minor folds and augens of clear to micaceous quartz and angular fragments of dark phyllite are common within the massive sulphides (Plate X).

Sulphides also occur as disseminations of wispy, intergranular pyrrhotite and chalcopyrite and as concentrations along shears in greenstones and dark chlorite phyllite.

KEYSTONE (82M/8W)

Numerous claims were staked in the area surrounding the headwaters of Keystone Creek in 1895, and two short adits were driven to test observed lead-zinc-copper mineralization (Plate XI). The property was restaked by Noranda Exploration Company, Limited in 1976, and work during 1976 included grid preparation, an electromagnetic survey, and soil geochemistry.

The original showing is described by Gunning (1928) and Wheeler (1965) as occurring at an elevation of 2 100 metres at the headwaters of Keystone Creek, just west of Keystone Peak. Mineralization is described as replacement of limestone for about 15 metres by quartz, pyrite, pyrrhotite, sphalerite, and minor chalcopyrite, and as fissures and veins in the surrounding rock.

Two small trenches north-northwest of Keystone Peak (plotted on Fig. 2) expose lead-zinc-copper mineralization in limestone, micaceous quartzite, and pelitic schist of the quartzite-schist division. Mineralization in the more southerly of the two trenches, at an elevation of 2 100 metres, is within or underlying a thin grey limestone layer. The maximum width of the exposed mineralization is approximately 1 metre, and its length is unknown but is believed to be only a few tens of metres. Mineralization (Plate XII) appears to pre-date Phase 2 deformation and consists dominantly of augens of massive pyrrhotite 2 to 3 centimetres long and 1 to 2 centimetres thick. Sphalerite and galena occur as thin rims around and in the pressure shadows of the pyrrhotite and of some dark siliceous augens, as well as being concentrated in angular, but elongate blebs in the pyrrhotite. Pyrite commonly occurs as euhedral to subhedral grains entirely enclosed by pyrrhotite. Chalcopyrite, present in only trace amounts, occurs most commonly as tiny disseminated grains or in hairline fractures in the siliceous augens. The second trench, several hundred metres north, exposes a crosscutting quartz vein several metres wide that contains coarse-grained pyrite and minor sphalerite and galena.

MONTGOMERY (82M/9E)

The Montgomery property was discovered in 1896. In 1917, The Granby Consolidated Mining, Smelting and Power Company Limited took an option on the property, and made several large open cuts. Seaforth Mines Limited acquired the property (the MONT claims) and did some prospecting and rock sampling in 1976.

The claims are located on the steep southern slope of Downie Peak between Boulder and Long Creeks. The showings are at an elevation of approximately 1 400 metres and can only be reached by climbing down slope from the closest helicopter landing spot several hundred metres above the showing.

The Mont claims are underlain by a:

> 'series of pure white to grey crystalline limestone interbedded with quartzites, argillaceous quartzites, black and grey slates, mica schists, chlorite schists, and impure calcareous members (that) strike north 25 degrees to 40 degrees west and dip 25 degrees to 40 degrees northeast. Limestones occur principally near and above (northeast of) the mineralized zone. Below the latter the rocks are mica schists, light green chlorite schists, andalusite schists, and impure argillaceous and quartzitic sediments'

(Gunning, 1928, p. 160A). The metasedimentary rocks belong to the metavolcanic-phyllite division (V-1) near its lower boundary with the calc-silicate gneiss division. The southeastern part of the claim group is underlain by a granite stock, and many fine-grained dykes cut the metasedimentary rocks near the showings.

The following description of the mineralization on the Montgomery property is summarized from published reports by Gunning (1928, pp. 160A-163A) and Wheeler (1965, p. 32). The mineralization consists of pyrrhotite, some pyrite, chalcopyrite, minor sphalerite, and trace galena.

> 'The gangue is quartz and silicified wall-rock, with occasional garnet, epidote, and actinolite and, in some places, considerable dark green chlorite. The sulphides occur in grey to greenish, siliceous, vitreous rocks which probably varied originally from quartzitic to calcareous sediments.'

(Gunning, 1928, p. 161A). The main mineralized zone:

> 'has been followed by open-cuts along strike for several thousand feet and over a vertical range of over 1000 feet'

(Wheeler, 1965, p. 32). Massive sulphide lenses up to 3 metres thick within this zone consist mainly of pyrrhotite and pyrite, with only minor chalcopyrite. Commonly, higher concentrations of copper occur in grey, silicified hangingwall rocks immediately above the massive sulphide layers.

Assays of rock samples collected from a cut across the hangingwall, massive sulphide layer, and footwall are tabulated in Table 4.

A second zone of mineralization occurs 200 to 300 metres vertically above the main mineralized zone. It consists of a 12-metre thickness of disseminated pyrrhotite and trace chalcopyrite in siliceous and calcareous metasedimentary rocks.

KJ (82M/9E)

The KJ claims, centred on Downie Peak, are located over an old lead-zinc prospect. The property does not include the original Montgomery showings which are located due south of the claim group. Work on this property includes trenching and diamond drilling in 1957, and a magnetometer survey and soil sampling for Cent Pac Development Inc. in July 1976 (Assessment Report 5810).

Mineralization consists of narrow stringers or blebs of galena, sphalerite, pyrrhotite, or pyrite in calcite marble, calc-silicate gneiss, or quartz veins that cut the marble and gneiss. The mineralization appears to be stratabound, distributed very sparsely and erratically through a pure to very siliceous marble/calc-silicate gneiss layer several tens of metres thick. Drilling results summarized in Assessment Report 5810 indicate that the true width of the mineralized zone is approximately 35 metres and its continuity downdip, greater than 200 metres.

The mineralized marble layer is within a heterogeneous sequence of rusty weathering biotite gneiss, psammite, grit, amphibolite, calc-silicate gneiss, and marble that has been included within the metavolcanic-phyllite division.

GOLDSTREAM (82M/9W)

INTRODUCTION

The Goldstream deposit is a stratabound massive sulphide layer in metasedimentary rocks of probable Early Cambrian age. It is located at an elevation of approximately 700 metres just south of Goldstream River and is accessible from the Big Bend Highway by a dirt road that follows the southern tributary of Goldstream River. The deposit is in an area of relatively deep glacial till overburden. The only exposures are restricted to a number of weathered pits where the south end of the deposit subcrops.

The property was first staked in 1973 by Gordon and Bruce Bried and Frank E. King following the discovery of oxidized copper-bearing float along a logging road. Development work by these prospectors included trenching and drilling of 22 X-ray holes. Noranda Exploration Company, Limited optioned the property in December 1974 and in 1975 drilled 50 holes outlining a deposit with announced reserves of approximately 3.175 million tonnes grading 4.49 per cent copper, 3.124 per cent zinc, and 19 grams silver (0.68 ounce) per tonne. Work during 1976 included approximately 1 200 metres of underground development (Plate XIII) and 3 500 metres of underground drilling.

STRUCTURE

The most conspicuous structures in the deposit and host rocks are late folds and faults. These are related to Phase 3 deformation as they deform both layering and the most obvious Phase 2 structure, a penetrative mineral foliation. This foliation is essentially parallel to layering, indicating isoclinal Phase 2 folding. Two mineral lineation measurements, taken underground and probably related to Phase 2 fold axes, plunge 34 degrees and 39 degrees to the northeast (Fig. 7).

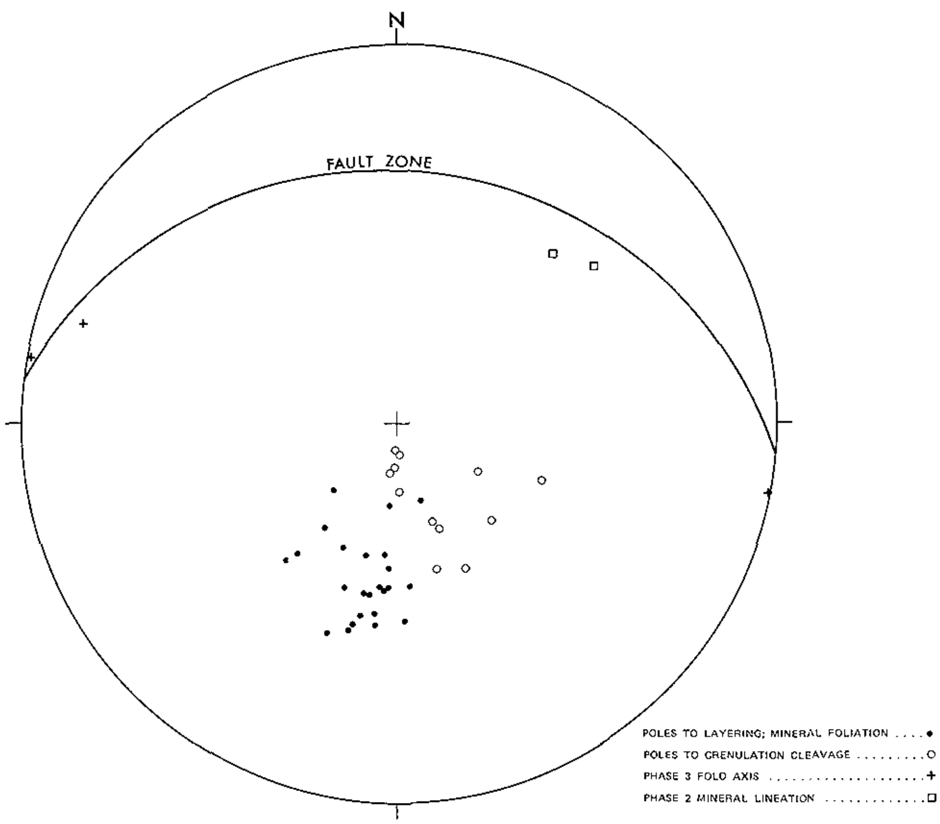


Figure 7. Equal-area projection of structural elements, Goldstream deposit.

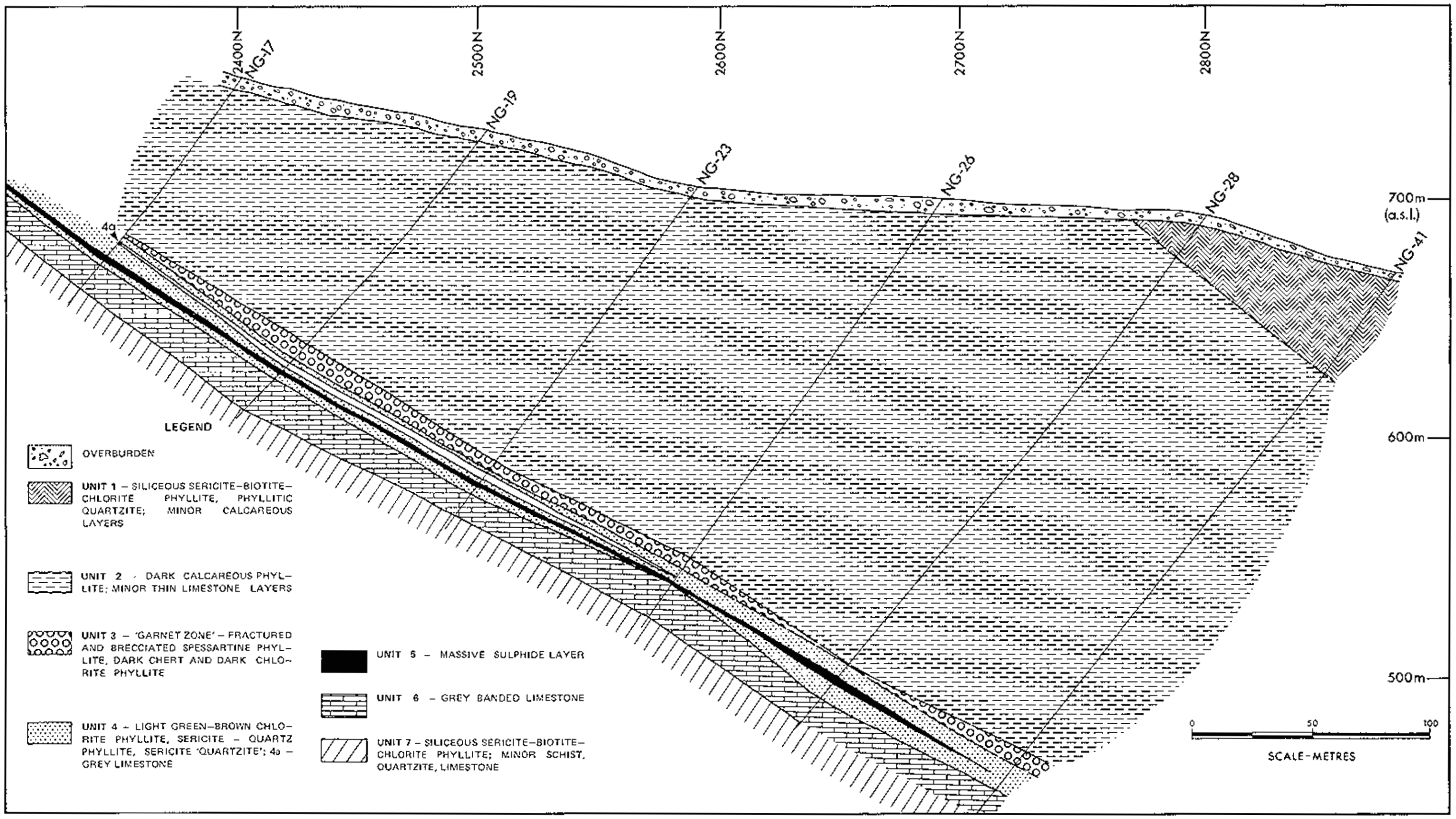


Figure 8. North/south vertical section (5500 E) through Goldstream deposit.

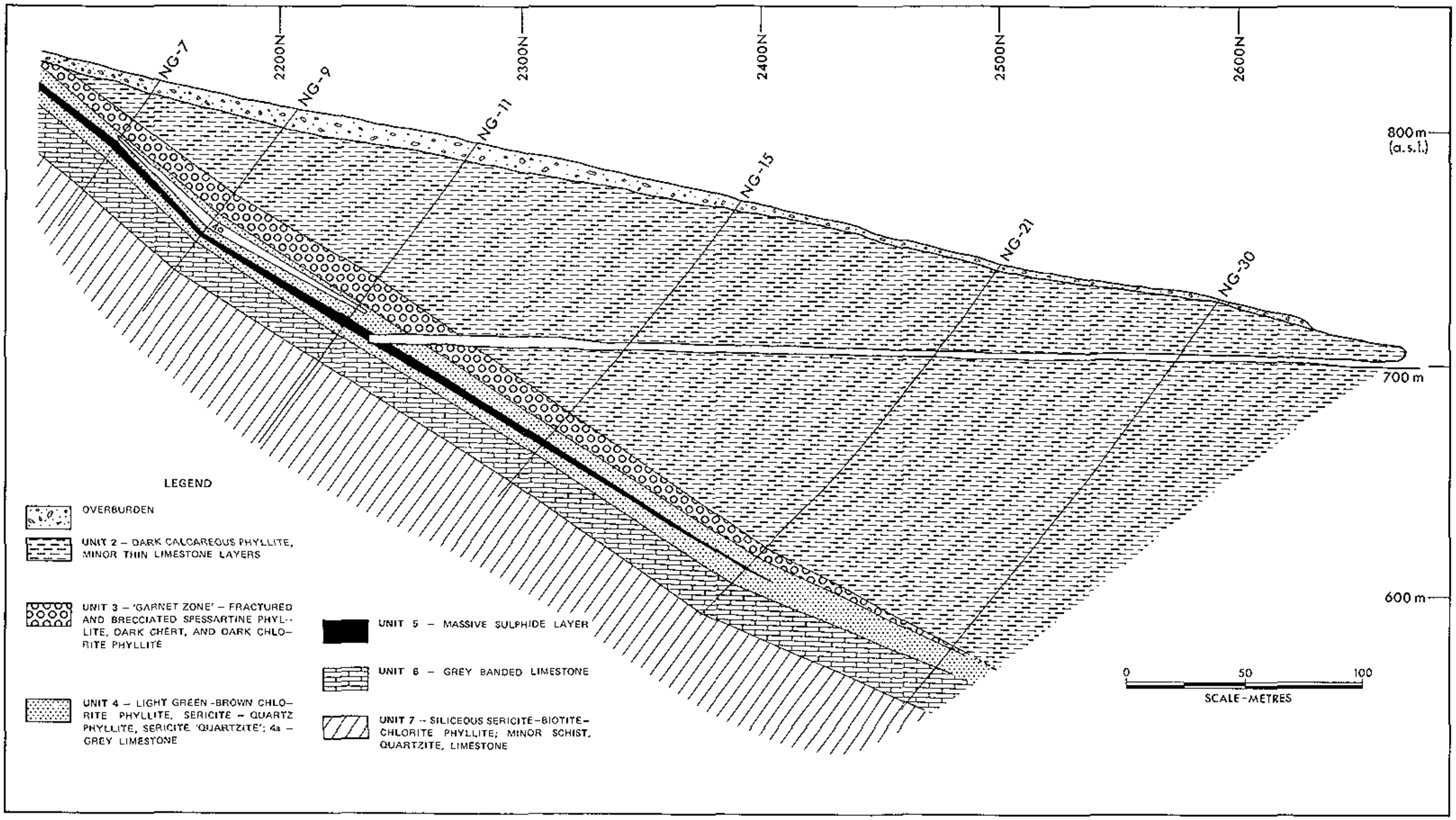


Figure 9. North/south vertical section (5300 E) through Goldstream deposit.

Phase 3 folds are generally fairly open, with rounded hinge zones. Their trend varies from east/west to northeast and their plunge, from horizontal to moderately steep to the northeast. A crenulation cleavage, dipping from approximately 10 degrees north at the adit portal to 30 degrees to 35 degrees north just north of the sulphide layer, is parallel to the axial planes of these folds. Viewed down-plunge, Phase 3 folds are Z-shaped, indicating an antiformal culmination to the south.

Numerous zones of fault gouge and pronounced shearing are obvious in the dark phyllites overlying the deposit. Abundant brecciation, quartz-carbonate veining, numerous Phase 3 minor folds, and a substantial increase in the intensity of crenulation cleavage are associated with this faulting. A wide zone of shearing and brecciation above the sulphide layer coincides with the 'garnet zone.' The vergence of associated minor folds and numerous slickensides indicate a reverse movement on this fault.

ROCK UNITS

The north/south sections (Figs. 8 and 9) illustrate the sequence of metasedimentary rocks above and below the sulphide layer. These appear to belong to unit V-1 of the volcanic-phyllite division, and show the considerable variation in that unit. The rocks structurally highest are described first. It is not known for certain whether or not these are the oldest or youngest rocks in the succession but, as described later, they are probably stratigraphic footwall rocks; that is, the succession may be inverted in the immediate vicinity of the deposit. The structurally highest rocks, unit 1 (Fig. 8), are only intersected in the top part of the drill holes north of 28 + 00 N (Fig. 10). They include approximately 30 metres of siliceous sericite-chlorite-biotite phyllite and phyllitic quartzite, underlain by 15 metres of dark grey calcareous graphitic phyllite, a 3-metre layer of grey-green siliceous chlorite phyllite, and 10 metres of biotite and chlorite phyllite that contains thin calcareous and limy layers (Plate XIV).

Unit 2 includes approximately 220 metres of dark carbonaceous phyllite interlayered with thin grey limestone layers (Plate XV). Calcite and biotite are common within this unit, and pyrrhotite is ubiquitous. The alignment of sericite, chlorite, and graphite (?) grains produce a well-defined foliation, and augens of quartz and carbonate and the abundant limy partings give this rock a distinctive layered appearance. Chemical analyses of a number of samples of unit 2 are listed in Appendix A.

The 'garnet zone,' unit 3, coincides with a pronounced fault zone. The rock is generally medium to dark green or grey in colour and contains abundant spessartine garnets (Plates XVI, XVII, and XVIII). In part, it consists of dark, banded 'chert' layers, medium green chlorite-phyllite layers, and dark grey to black greasy lustered chlorite-graphite-calcite-quartz layers. Pyrrhotite may be very abundant, concentrated in layers or in discontinuous streaks. Grunerite (an Fe-Mg amphibole typically occurring in metamorphosed iron-rich siliceous sediments) was identified by X-ray in some dark siliceous layers. Chemical analyses of unit 3 (Appendix A) show an abnormally high manganese content and only trace copper and zinc.

The garnet zone is sheared and broken, and cut by numerous quartz-carbonate layers. The garnets pre-date this deformation and probably an earlier deformation which produced the prominent mineral foliation in the metasedimentary rocks. This early foliation is bent and warped around the garnet porphyroblasts.

The garnet-rich layer is interpreted to be a metamorphosed manganiferous iron-rich chert horizon. It is areally restricted and terminates to the west away from the massive sulphide layer (Fig. 11).

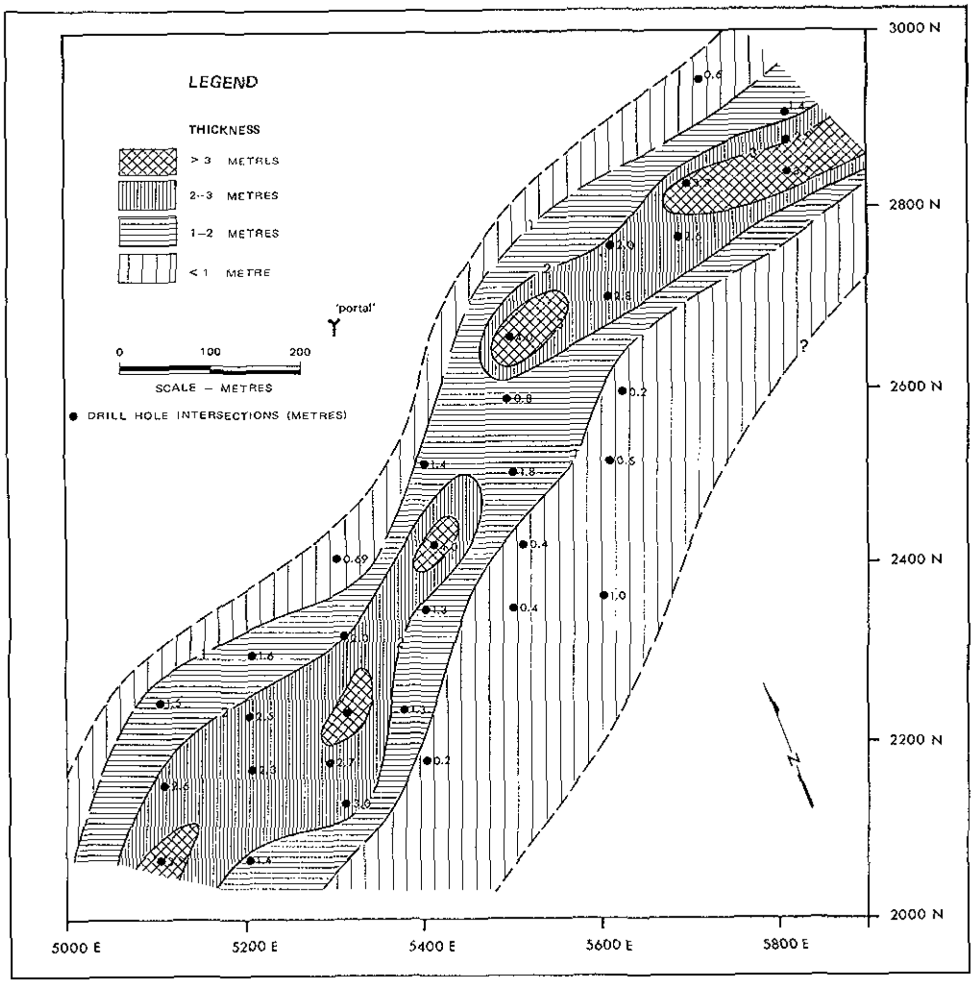


Figure 10. Isopach map of massive sulphide (>40 per cent sulphides) layer, showing drill-hole intersections.

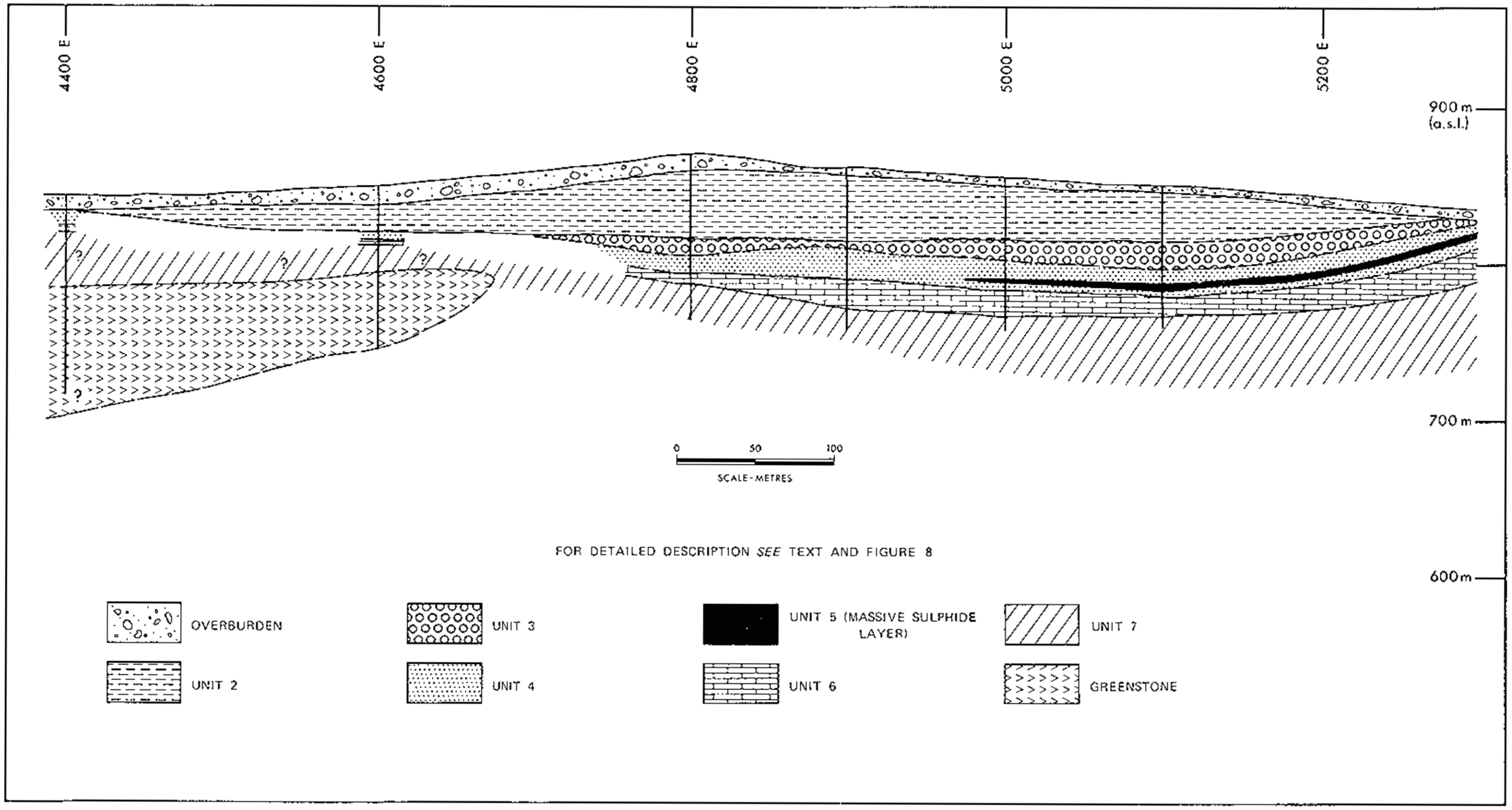


Figure 11. East/west vertical section (2100 N) through Goldstream deposit.

The massive sulphide layer is enclosed within light green to brown, very siliceous chlorite and sericite phyllite (unit 4) that grades to fine-grained sericite-chlorite quartzite (Plate XIX). A grey limestone layer, 1 to 2 metres thick, occurs within unit 4 above the sulphide layer. Pyrrhotite, chalcopyrite, and minor sphalerite, generally uncommon within the unit, increase substantially just above the sulphide layer (Plate XXII). Here they occur as fine disseminations, discontinuous blebs, and as layer-parallel streaks. Sulphides are less common below the massive sulphide layer, occurring primarily as discontinuous layers in a dark, layered siliceous rock.

A light grey banded limestone (unit 6), averaging 10 to 20 metres in thickness, occurs below the phyllites of unit 4. The limestone is underlain by siliceous sericite-biotite-chlorite phyllite, schist, minor quartzite, and limestone of unit 7 (Plates XX and XXI).

Greenstone was encountered in three drill holes west of the deposit (Fig. 11). The greenstone is believed to lie structurally below the mineralized horizon as a grey limestone lying above it is tentatively correlated with the footwall limestone (unit 6). The greenstone varies from fine-grained, massive varieties to chloritic phyllite. In thin section, it is composed dominantly of actinolite, chlorite, epidote, and albite.

MINERALIZATION

MASSIVE SULPHIDE LAYER

The massive sulphide layer (unit 5) averages from 1 to 3 metres in thickness, has a strike length of at least 500 metres, and a plunge length of at least 1 200 metres (Fig. 10). Underground drilling by Noranda indicates that the massive sulphide layer splits into two layers in the western part of the deposit (Fig. 13). Only its western and truncated southern boundaries are defined. Its northern boundary is open, although at 3000 N is approximately 350 metres below Goldstream River. Its eastern boundary is restricted by a barren hole (at 25 + 62 N, 59 + 00 E) approximately 300 metres east of the last known sulphide mineralization.

The sulphide layer (Plates XXIII, XXIV, and XXV) consists largely of pyrrhotite, chalcopyrite, and sphalerite. Galena, although uncommon and not identified in core, was observed in a number of specimens from the adit dump. Pyrite is rare, occurring primarily in fractures or shears that cut the massive sulphide. The sulphides are generally medium to coarse grained and intimately mixed. They generally have a granular texture, although streaking and shearing is fairly common, particularly toward the boundaries of the sulphide layer and there the grain size is commonly much finer. Layering, defined by alternation of the various sulphides, is not present (or at best, very rare).

Numerous rounded clear quartz fragments, darker 'chert' fragments, and dark siliceous chlorite-phyllite fragments are scattered through the massive sulphides. These may contain hairline fractures filled with chalcopyrite, inclusions of chalcopyrite, sphalerite,

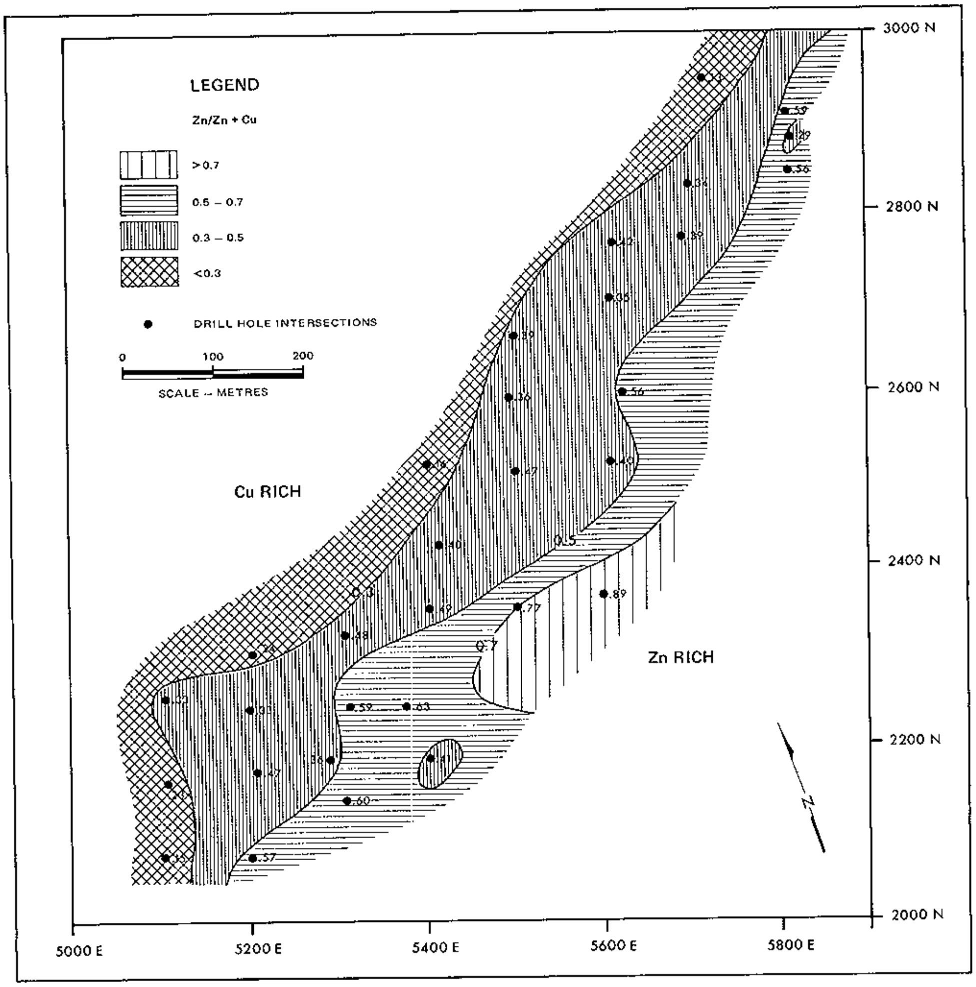


Figure 12. Weighted Zn/Zn + Cu ratios, massive sulphide layer.

TABLE 5. COMPARISON OF HANGINGWALL, MASSIVE SULPHIDE, AND FOOTWALL MINERALIZATION

(Cut-off grade arbitrarily chosen at 0.1 per cent Cu; standard deviation, in brackets)

	MAXIMUM THICKNESS	AVERAGE THICKNESS		AVERAGE COPPER GRADE		$\frac{Zn}{Zn + Cu}$	
HANGINGWALL	~9 metres	2.28	(2.3)	.62%	(.71)	0.47	(0.24)
MASSIVE SULPHIDE	~5.5 metres	2.00	(1.38)	5.23%	(2.42)	0.32	(0.17)
FOOTWALL	~5 metres	1.72	(1.58)	.58%	(.46)	0.33	(0.23)

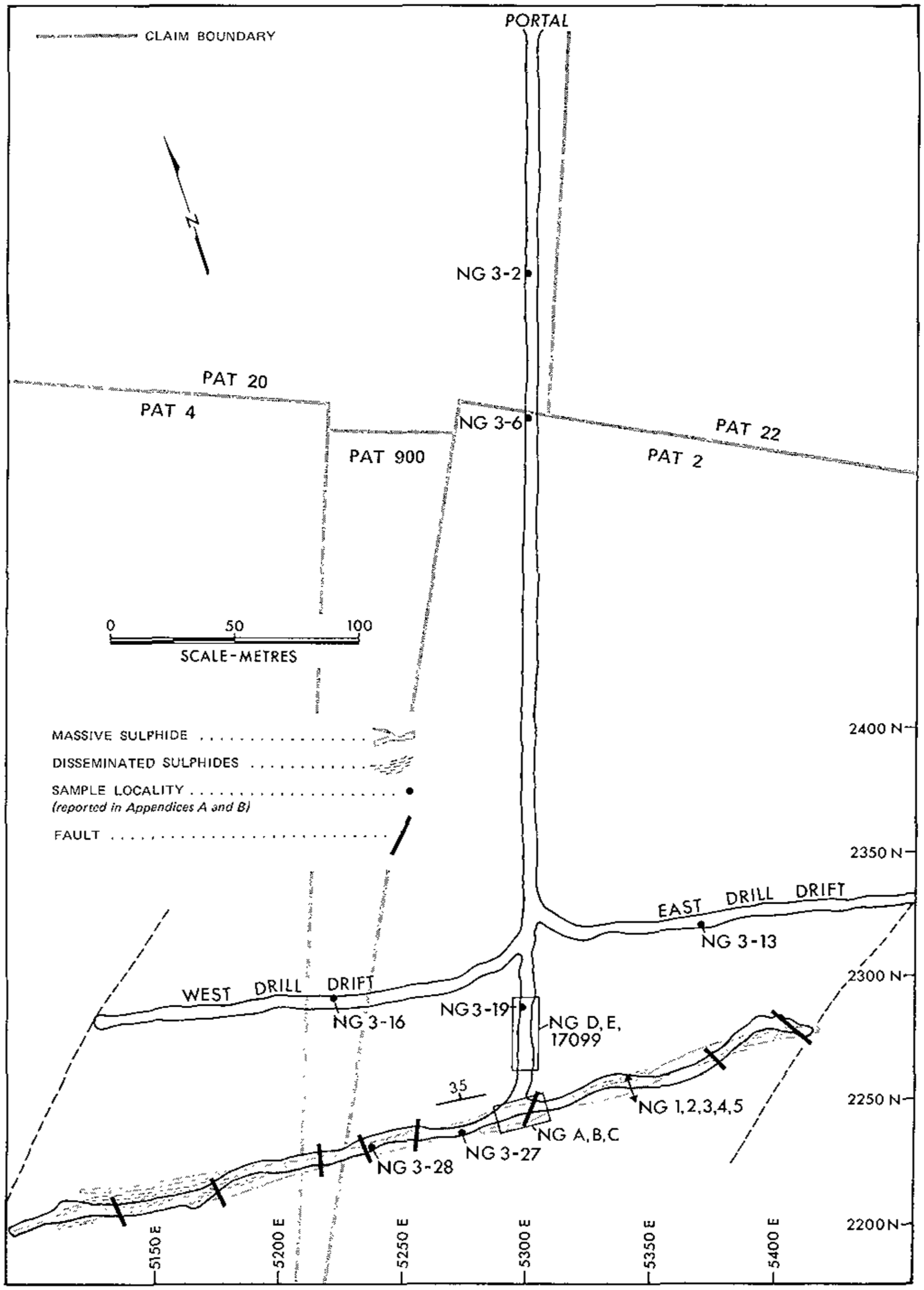


Figure 13. Plan view of underground workings.

or pyrrhotite, or may be free of sulphides. They resemble the mineralized and non-mineralized siliceous metasediments in the country rock.

In general, the lower (footwall) contact of the massive sulphides is fairly sharp, whereas the upper contact may be more gradational with the mineralization in the hangingwall.

HANGINGWALL AND FOOTWALL MINERALIZATION

Sulphides in the country rock above the sulphide layer (the hangingwall) are in the form of fine disseminations, discontinuous blebs, and layer-parallel streaks in quartzites and siliceous phyllites (Plate XXII). They also occur in bull quartz veins and in a complex network of thin, interconnected, generally layer-parallel fractures. Dark grey to black, 'greasy' lustered chlorite alteration may be associated with hangingwall sulphides.

Sulphides are less common below the massive sulphide layer, occurring primarily as discontinuous layers in a dark, layered siliceous rock.

METAL ZONING

Zn/Zn + Cu ratios in the massive sulphide layer generally increase toward the east (Fig. 12). This tendency for decreasing relative abundance of copper to the east is not apparent in either the hangingwall or footwall where higher ratios occur in central zones that parallel the northeast trend of the deposit. There is not a consistent vertical zonation in the deposit. The Zn/Zn + Cu ratios in the hangingwall and massive sulphides are very similar, and in the footwall, slightly less (Table 5). The 2-foot chip samples from the hangingwall through to the base of the massive sulphide layer (Appendix B, samples NG-1 to NG-5 and Fig. 13) demonstrate a general tendency toward higher metal values toward the base with a corresponding decrease in silica. Obviously this trend does not necessarily represent the deposit as a whole. It merely reflects increased sulphide content at the expense of quartz at this particular locality.

CONCLUSIONS

A number of features of the hangingwall may be contrasted with those in the footwall. These include:

(1) a generally more gradational contact of the hangingwall mineralization with the massive sulphide layer contrasted with a sharper massive sulphide footwall contact;
(2) a relatively higher abundance of sulphides in structural hangingwall rocks than in footwall rocks;
(3) a greater maximum thickness and average thickness of mineralized hangingwall than footwall rocks (Table 5);

(4) the more common occurrence of disseminated and fracture-controlled sulphides in the hangingwall as opposed to layered sulphides in the footwall;
(5) more noticeable 'greasy-lustered, dark chlorite' alteration in hangingwall than footwall; and
(6) a slightly higher average Zn/Zn + Cu ratio in the hangingwall than footwall (Table 5).

The more gradational contact with the massive sulphides, greater abundance of sulphides, greater thickness of mineralization, and nature of mineralization and alteration in the structural hangingwall are generally more typical of stratigraphic footwall characteristics (the 'stringer ore') of Precambrian massive sulphide deposits (Sangster, 1972) than of stratigraphic hangingwall characteristics. This suggests that the Goldstream deposit may be overturned.

Consideration of regional structures in the Goldstream area (*see* chapter on structural geology) also suggests that the sequence of rocks in the immediate vicinity of the deposit may be inverted. At Downie Peak, 10 kilometres to the southeast, graded grit beds indicate that rocks young toward the core of the Downie antiform. The axial trace and younger core rocks of this antiform swings east/west just northwest of Downie Peak and are probably located south of the deposit in the Goldstream area.

However, the higher Zn/Zn + Cu ratio in the structural hangingwall does not support an inverted deposit. Generally, hangingwall rocks of massive sulphides are enriched in zinc relative to copper, and footwall rocks, depleted in zinc. Hence, a definitive determination of stratigraphic tops in the deposit must await more detailed work.

Goldstream is interpreted to be in the north limb of a major Phase 2 antiform. Rock units in the limbs of Phase 2 structures are very attenuated as indicated by the pronounced Phase 2 foliation and boudinaging of more competent units. Hence, the form of the Goldstream deposit must be fairly substantially modified by this deformation. Its pronounced northeast trend is probably due to structural elongation in the direction of plunge of Phase 2 structures and its thin-layered form due to flattening in the plane of the foliation.

An attempt to recognize an alteration 'pipe' may be futile due to the intense regional deformation in the area. An alteration pipe, if it existed in the deposit, may be so attenuated as to be no longer recognizable.

SUMMARY AND CONCLUSIONS REGARDING THE GOLDSTREAM, MONTGOMERY, AND STANDARD DEPOSITS

These deposits are stratabound massive copper-zinc deposits. They are hosted by either basic volcanic rocks (Standard) or metasedimentary rocks spatially associated with basic metavolcanic rocks. A common association, and one that should be the guide for future exploration for similar deposits in the Selkirk Mountains, includes the greenstones, dark carbonaceous and calcareous shales, and thin to relatively thick limestone.

A number of features of the deposits indicate that they have been subjected to the intense regional deformation. Some of these features include the obvious folding and shearing of some of the massive sulphides, gneissic textures, and the rounded silicate inclusions ('Durchbewegung' fabric described by Vokes, 1969). Regional and contact metamorphism has partially recrystallized some of the massive sulphides, resulting in medium-grained, granoblastic textures and secondary growth of euhedral pyrites in gneissic pyrrhotite. Remobilization of sulphides, particularly chalcopyrite, into pressure shadows and fractures in silicate inclusions is very common.

The deposits compare closely with the 'bedded cupriferous iron sulphide' or 'Besshi' type deposits in Japan (Kanehira, *et al.,* 1970). These are both bed-like or lenticular in form, are composed primarily of massive compact pyrite- (pyrrhotite at Goldstream) chalcopyrite ore, and occur in geosynclinal crystalline schists associated with submarine basic volcanism. In contrast, some of the typical features of Kuroko deposits are absent: the association with acid volcanism, the obvious metal and ore-type zoning, the alteration pipe, and the association with sulphates (barite, gypsum, and anhydrite).

APPENDICES

APPENDIX A. CHEMICAL ANALYSES OF METASEDIMENTARY AND METAVOLCANIC ROCKS OF THE GOLDSTREAM AREA (ATOMIC ABSORPTION; *EMISSION SPECTROGRAPHIC)

PER CENT (%)

	H76G19–1	NG3–2	NG3–6	NG3–13	NG3–16	NG3–19	NG–D	NG–E	17099M
Si	21.17±0.2	23.6±0.2	24.8±0.2	9.25±0.05	24.07±0.2	13.4±0.1	19.3±0.1	34.1±0.3	22.57±0.2
Al	7.04±0.2	6.0±0.2	6.0±0.2	2.43±0.05	9.10±0.3	3.00±0.05	1.86±0.04	.79±0.02	1.83±0.04
Fe(T)	9.30±0.05	5.16±0.02	4.63±0.02	3.22±0.02	4.48±0.02	2.62±0.02	18.67±0.08	10.28±0.07	16.58±0.07
Mg	5.43±0.04	2.62±0.02	2.44±0.02	2.10±0.01	2.43±0.02	2.43±0.02	1.39±0.01	0.77±0.01	1.63±0.01
Ca	6.25±0.05	9.1±0.07	8.15±0.07	>18.0	7.22±0.07	>18.0	8.39±0.07	2.72±0.02	6.81±0.06
Na	2.49±0.04	0.81±0.01	1.06±0.01	0.55±0.01	0.93±0.01	0.18±0.07	0.01±0.003	<0.01	0.01±0.004
K	0.02±0.001	2.00±0.02	1.95±0.02	0.83±0.01	2.33±0.03	1.17±0.01	0.01±0.003	0.03±0.001	0.02±0.001
Ti	0.75±0.05	0.83±0.05	0.76±0.04	0.16±0.02	0.37±0.02	0.25±0.02	0.08±0.01	0.04±0.01	0.08±0.01
Mn	0.16±0.01	0.12±0.01	0.07±0.001	0.05±0.003	0.07±0.001	0.06±0.001	2.92±0.03	1.28±0.01	2.36±0.02
Cu	0.029±0.001	0.015±0.001	0.05±.001	0.018±0.001	0.006±0.001	0.012±0.001	0.016±0.001	0.021±0.001	0.032±0.001
Pb	20 ppm*	38 ppm*	44 ppm*	67 ppm*	<0.005	53 ppm*	23 ppm*	<0.005	<0.005
Zn	0.014±0.003	0.017±0.002	0.010±0.002	0.011±0.002	0.013±0.003	0.010±0.002	0.057±0.002	0.022±0.002	0.052±0.003
Co	<0.005	18 ppm*	14 ppm*	12 ppm*	0.006±0.001	11 ppm*	15 ppm*	10 ppm*	<0.005
Ni	0.006±0.002	47 ppm*	40 ppm*	33 ppm*	0.006±0.001	23 ppm*	75 ppm*	63 ppm*	0.011±0.002
Cr	0.009±0.001	0.014±0.001	0.013±0.001	0.006±0.001	0.010±0.001	<0.005	0.009	<0.005	0.008±0.001
S	0.05	1.42	1.36	0.15	0.64	0.18	1.39	1.74	3.67
P_2O_5	<.2	0.21	0.24	<.2	<0.18	<.2	0.37	0.30	0.48
BaO*	0.0018	0.12	0.17	0.10	0.14	0.06	0.0006	0.0016	0.0012
SrO*	0.017	0.06	0.06	0.10	0.06	0.10	0.03	0.01	0.015
Au (ppm)*	-----	-----	-----	-----	-----	-----	<1	<1	-----
Ag (ppm)*	-----	-----	-----	-----	-----	-----	<10	<10	-----
Ba (ppm)*	-----	-----	-----	-----	-----	-----	5	14	-----
Cr (ppm)*	-----	140	140	70	-----	40	75	45	-----
V (ppm)*	-----	-----	-----	-----	-----	-----	120	100	-----

H76G19–1: basic schist from Standard area (for location *see* Fig. 2).
HG3–2: dark banded phyllite (unit 2), Goldstream adit (*see* Fig. 13).
NG3–6, NG3–13, NG3–16, NG3–19: *see* NG3–2.
NG–D, NG–E, 17099M: garnet zone (unit 3).

APPENDIX B. CHEMICAL ANALYSES OF MINERALIZED SAMPLES FROM GOLDSTREAM (ATOMIC ABSORPTION; *EMISSION SPECTROGRAPHIC)

PER CENT (%)

	NG–1	NG–2	NG–3	NG–4	NG–5	NG–B	NG–C	NG–A	NG3–28b	NG3–27
Si	32.18±0.3	10.20±0.05	15.52±0.1	13.69±0.1	4.39±0.05	20.94±0.2	19.6±0.2	3.50±0.05	11.5±0.1	6.03±0.04
Al	2.18±0.04	0.71±0.02	0.64±0.02	1.22±0.03	0.75±0.02	1.93±0.05	2.59±0.05	0.75±0.02	1.00±0.03	2.50±0.05
Fe(T)	6.03±0.03	17.76±0.07	16.7±0.07	22.10±0.08	32.73±0.2	16.09±0.07	23.64±0.08	35.04±0.2	22.4±0.1	33.7±0.2
Mg	1.62±0.01	3.02±0.02	1.42±0.01	1.39±0.01	0.80±0.01	0.61±0.01	1.01±0.01	0.49±0.01	2.12±0.02	4.06±0.03
Ca	3.30±0.02	10.43±0.07	8.86±0.07	5.31±0.05	5.59±0.05	4.84±0.05	3.17±0.02	4.95±0.04	7.43±0.07	5.00±0.04
Na	*0.93±0.01*	*0.04±0.004*	*0.06±0.004*	*0.10±0.004*	*0.04±0.004*	*0.05±0.004*	*0.09±0.004*	*0.07±0.004*	*0.09±0.004*	0.05±0.003
K	0.36±0.01	0.08±0.001	0.12±0.002	0.42±0.01	0.18±0.01	0.79±0.01	1.05±0.01	0.22±0.01	0.15±0.002	0.56±0.01
Ti	0.20±0.01	0.04±0.01	<0.03	0.05±0.1	<0.03	0.11±0.01	0.13±0.01	<0.03	0.04±0.01	0.10±0.01
Mn	0.15±0.003	0.50±0.01	0.44±0.01	0.33±0.01	0.39±0.01	0.33±0.01	0.23±0.01	0.33±0.01	0.33±0.01	0.29±0.01
Cu	1.96±0.01	4.53±0.03	4.07±0.03	5.20±0.04	5.52±0.04	3.71±0.03	0.231±0.002	5.21±0.04	5.13±0.04	2.69±0.02
Pb	0.104±0.003	0.725±0.005	0.566±0.005	0.73±0.005	0.887±0.006	0.038±0.003	0.018±0.003	1.03±0.01	0.523±0.005	0.025±0.003
Zn	*1.08±0.01*	*5.98±0.08*	*4.97±0.06*	*5.10±0.06*	*7.10±0.10*	*0.217±0.003*	0.023±0.013	7.95±0.12	4.53±0.05	2.39±0.03
Co (ppm)*	28	86	78	96	144	30	34	76	53	100
Ni (ppm)*	32	71	70	85	133	40	100	60	20	45
Cr	<0.005	<0.005	<0.005	<0.005	<0.005	0.016±0.001	0.016±0.001	<0.005	<0.005	<0.005
S	4.66	16.4	15.0	18.8	27.3	11.7	15.1	28.8	18.7	23.1
P_2O_5*	0.18	0.18	0.18	0.21	0.18	0.41	1.05	0.25	0.2	0.2
BaO*	0.02	0.006	0.01	0.03	0.04	0.02	0.025	0.02	0.003	0.015
SrO	0.015	0.02	0.017	0.016	0.016	0.02	0.016	0.01	0.016	0.015
Au (ppm)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Ag (ppm)	14	48	19	24	19	<10	<10	<10	<10	<10

NG–1, NG–2, NG–3, NG–4, NG–5: successive 21 chip samples from hangingwall to structural base of massive sulphide layer (for location *see* Fig. 13).
NG–B, NG–C: layered silicate ore.
NG–A: massive sulphide.
NG3–28b, NG3–27: massive sulphide (for location *see* Fig. 13).

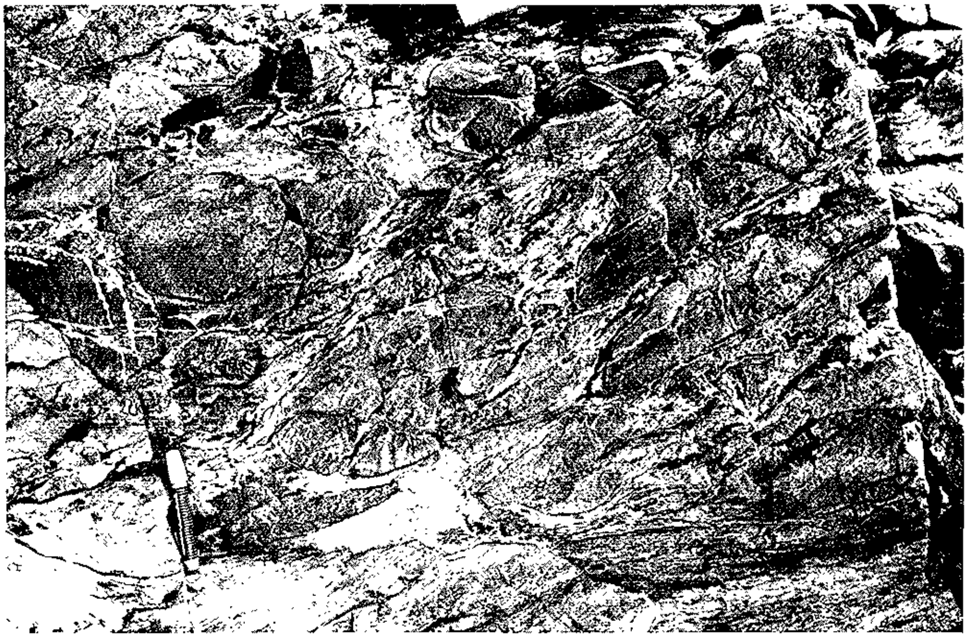


Plate I. Pillows, outlined by felt pen, in basalt on ridge northeast of Keystone Peak.

Plate II. Dark, calcareous phyllite from core of Standard antiform showing style of Phase 3 folding.

Plate III. Limestone in the core of the Downie antiform, viewed toward the northwest.

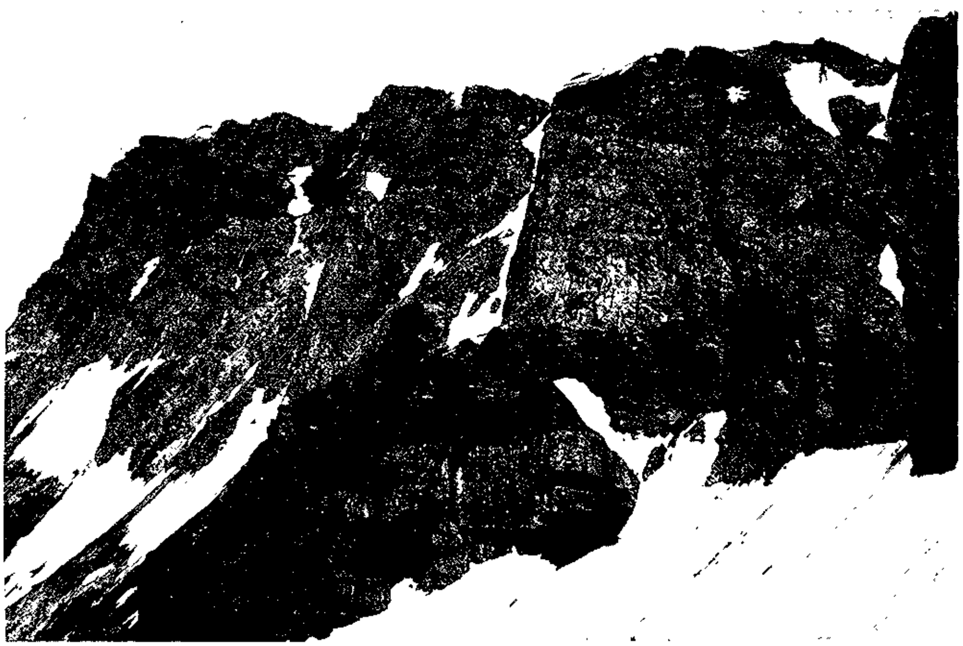


Plate IV. The core of the recumbent Keystone fold; view looking southeast. The actual core is in the top left-hand corner of the photograph; note vergence of folds in the lower limit of the Keystone fold, just above the snow slope.

Plate V. Detail of minor folds on lower limb of Keystone fold, due east of Keystone Peak. Competent grey limestone is surrounded by phyllitic greenstone.

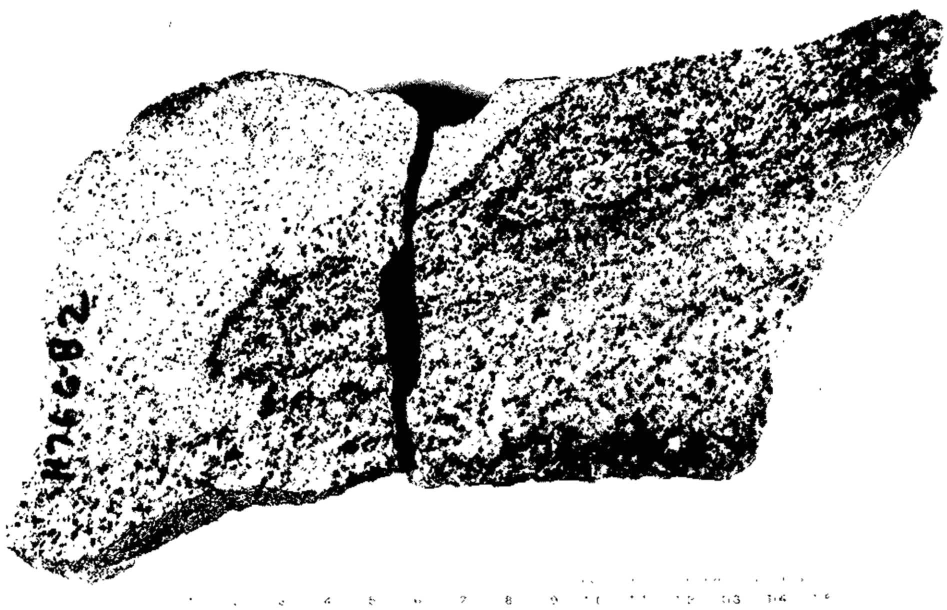


Plate VI. Foliation in the Goldstream pluton, deformed by Phase 2 folding.

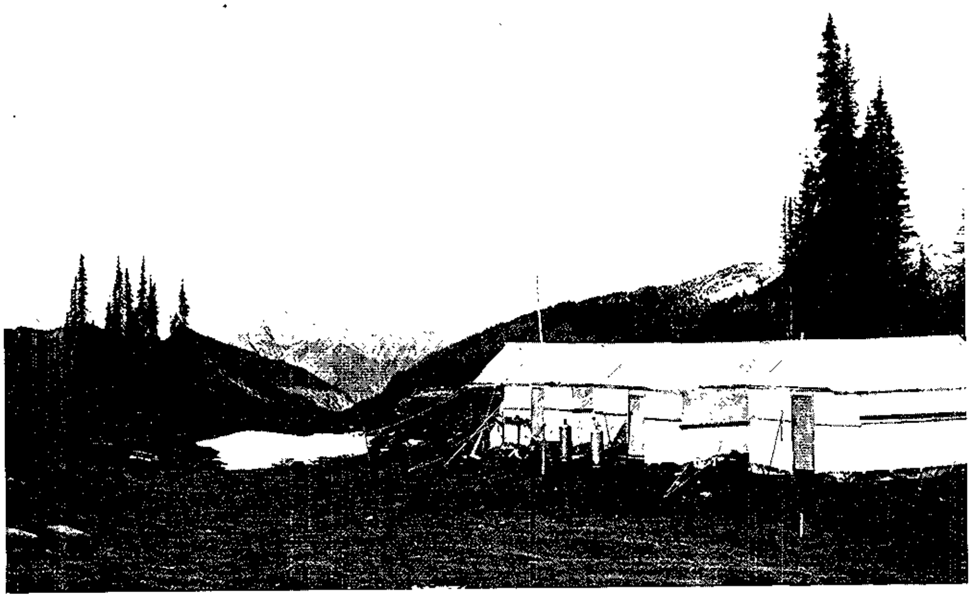


Plate VII. Base camp at Standard, August 1976; view looking northward across Downie Creek.

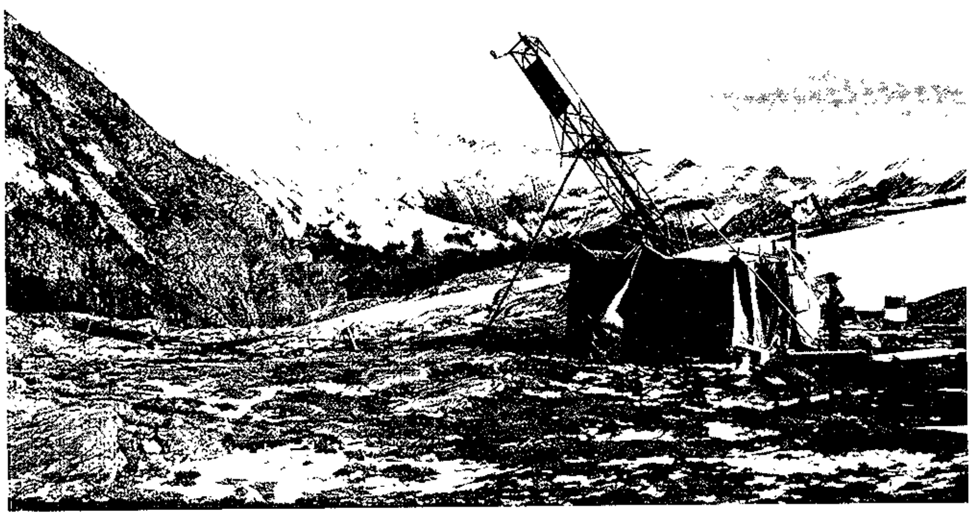


Plate VIII. Drilling at the Standard property in September 1976; Carnes Peak is in the background.

Plate IX. Gneissic sulphide sample from Standard; fine-grained sulphides are predominantly pyrrhotite with minor chalcopyrite; light-coloured (more highly reflecting) subhedral porphyroblasts are pyrite, and silicate fragments are quartz.

Plate X. Small fold in sulphide sample from the Standard property; dominantly pyrrhotite and subhedral to euhedral light-coloured pyrite (sample width – 4 centimetres).

Plate XI. Setting of the Keystone showing.

Plate XII. Coarse-grained sphalerite (sl), pyrrhotite (po), and galena (gn) from the Keystone 1 showing. Chalcopyrite occurs in hairline fractures that cut the quartz (qz) fragments.

Plate XIII. Portal of the Goldstream adit (photograph courtesy of Noranda Exploration Company, Limited).

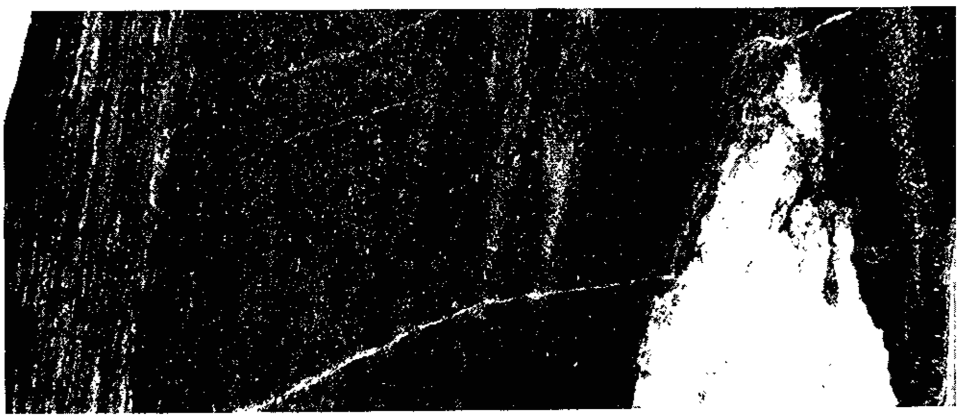


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Plate XIV. Unit 1, Goldstream deposit (DDH NG 43 – 262 feet). Chlorite-sercite-phlogopite phyllite that contains abundant quartz and limestone augens and lenses. Finely disseminated pyrrhotite occurs throughout this specimen (sample width – 3.5 centimetres).

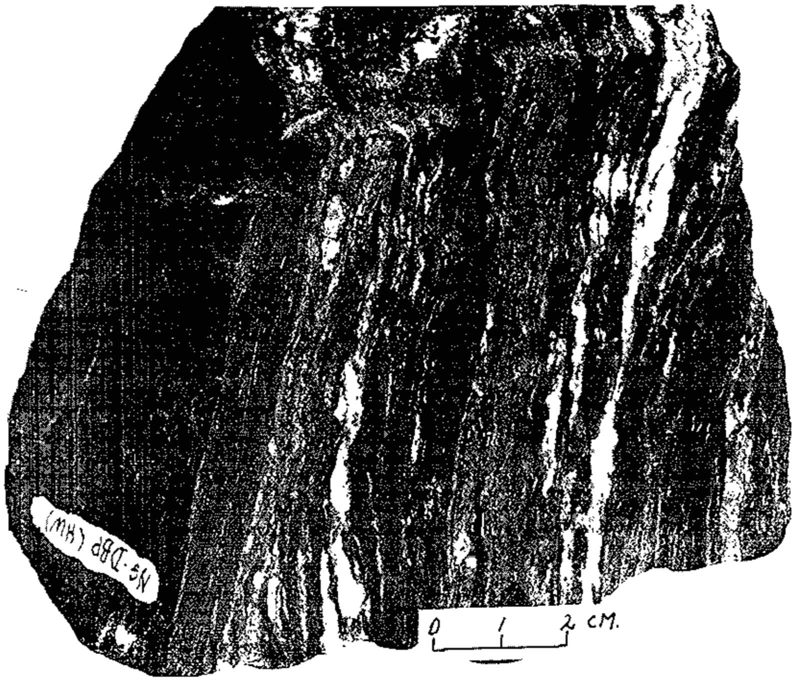


Plate XV. Unit 2, Goldstream deposit. Dark calcareous phyllite; light bands are quartz, and reflecting grains, pyrrhotite.

Plate XVI. Unit 3, garnet zone, Goldstream deposit. Note numerous spherical spessartine garnets, folded chert layer, and streaks and disseminations of pyrrhotite.

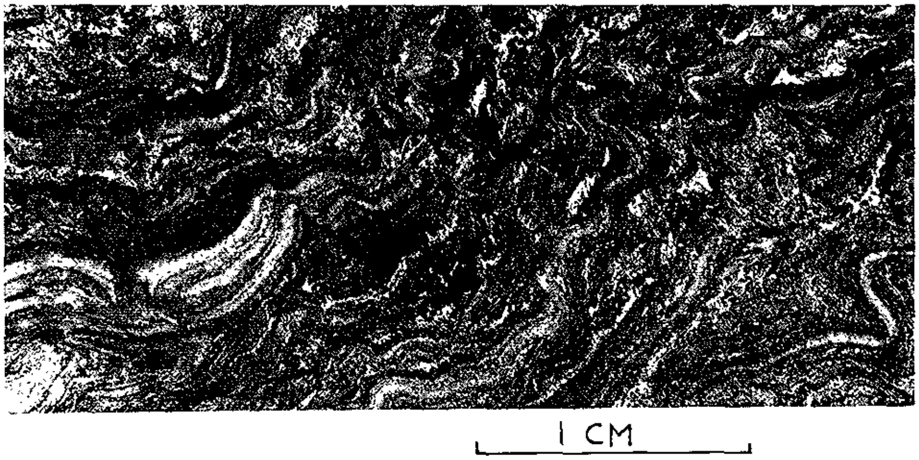


Plate XVII. Unit 3, Goldstream deposit (DDH NG 14 – 427 feet). Folded chert-spessartine garnet layers; light mineral is pyrrhotite (sample width – 3.5 centimetres).

Plate XVIII. Unit 3, Goldstream deposit. Folded and brecciated chert layers.

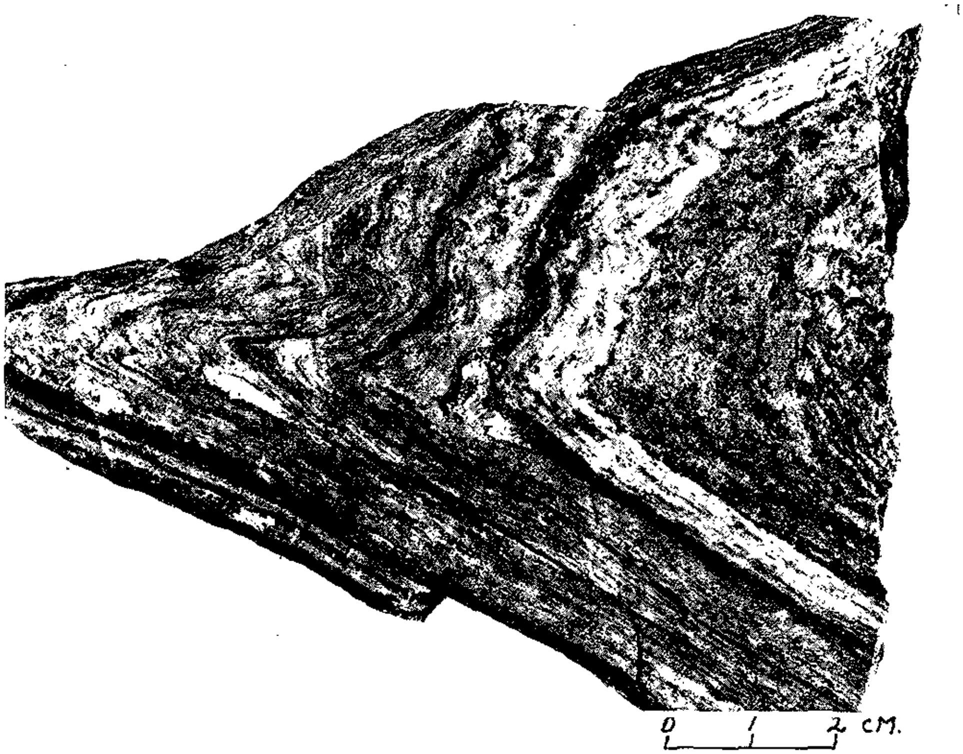


Plate XIX. Unit 4, Goldstream deposit. Fold in fine-grained sericite 'quartzite.' Chalcopyrite and pyrrhotite are disseminated through the sample.

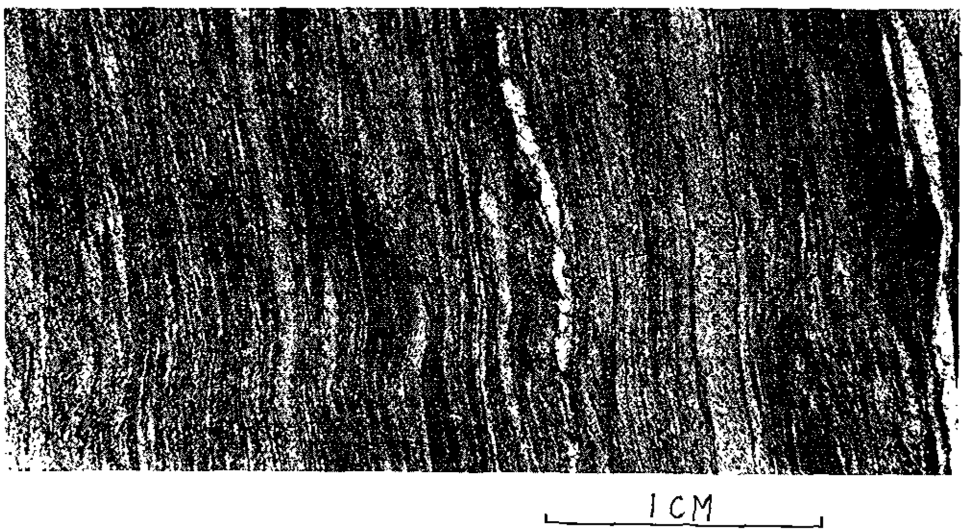


Plate XX. Unit 7, Goldstream deposit (DDH NG 34 – 137 feet). Sericite-phlogopite-chlorite schist (sample width – 3.5 centimetres).

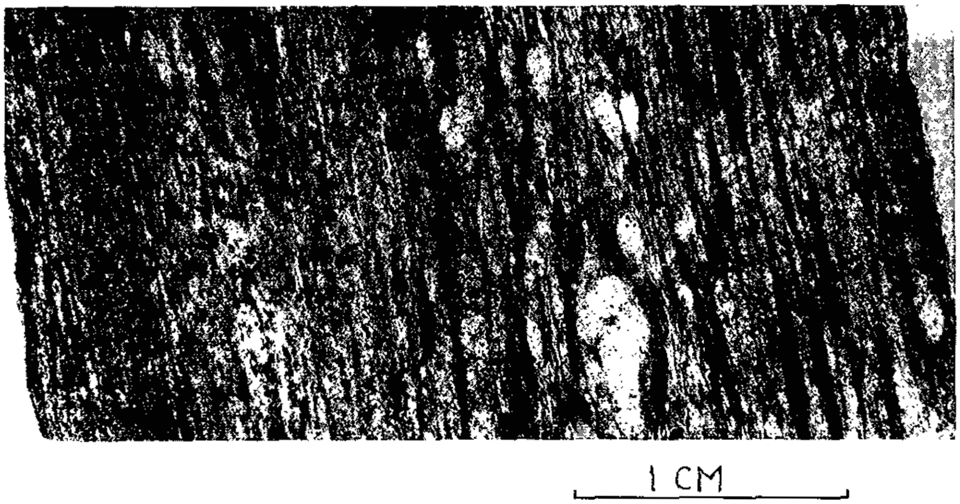


Plate XXI. Unit 7, Goldstream deposit (DDH NG 44 – 485 feet). Biotite (chlorite) gneiss (sample width – 3.5 centimetres).

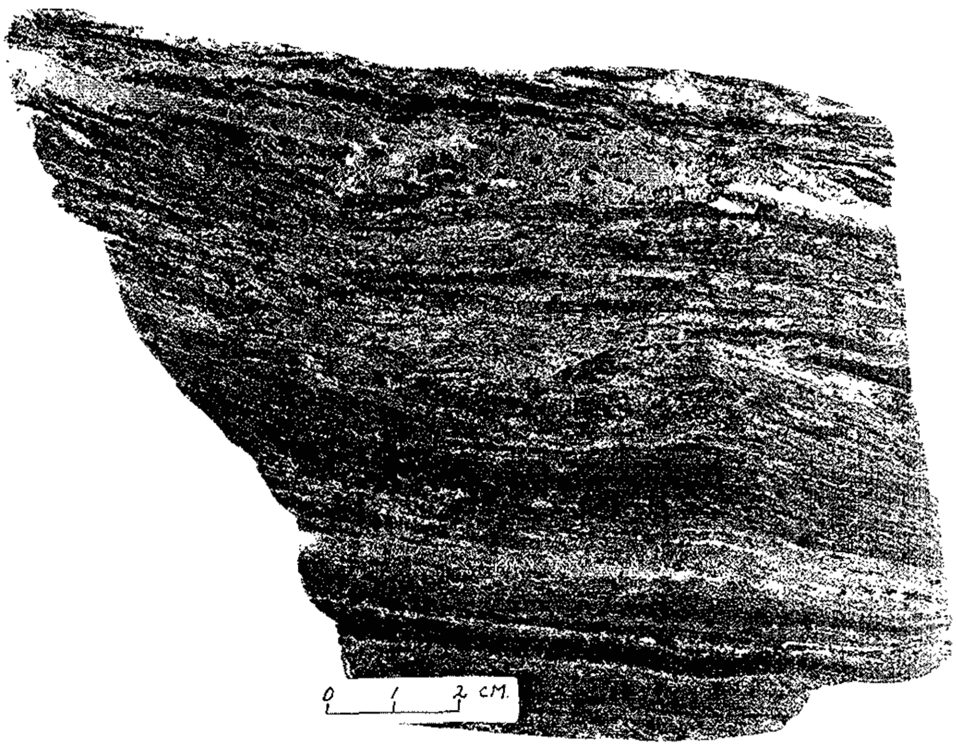


Plate XXII. Disseminated and layered chalcopyrite and pyrrhotite in dark grey chlorite-quartz rock immediately above massive sulphide layer, Goldstream deposit.

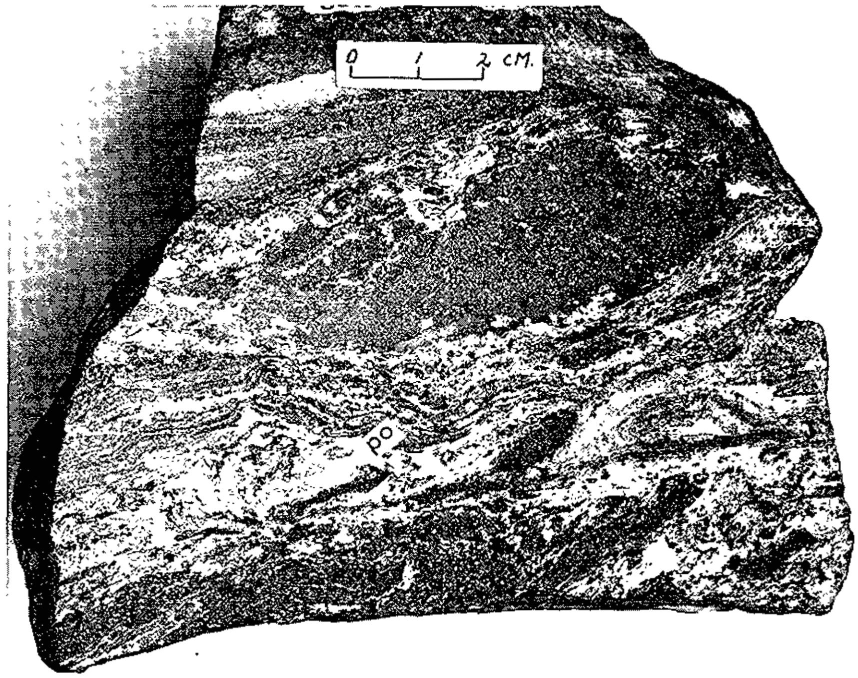


Plate XXIII. Siliceous ore, Goldstream deposit. Fine-grained, light grey sericite quartzite intimately interlayered and swirled with gneissic pyrrhotite-chalcopyrite. Large augens of quartzite and pure quartzite layers (near top of specimen) contain abundant finely disseminated pyrrhotite (po — pyrrhotite).

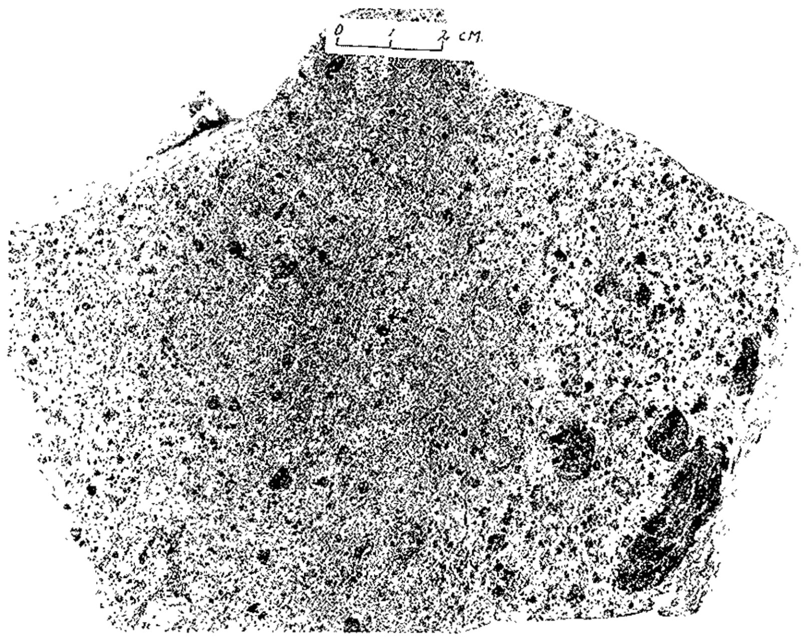


Plate XXIV. Massive sulphides (unit 5), Goldstream deposit. Note gneissic texture of sulphides, intimate intermixing of chalcopyrite (lighter coloured) and pyrrhotite, and preferential concentration of chalcopyrite in pressure shadows of dark siliceous fragments.

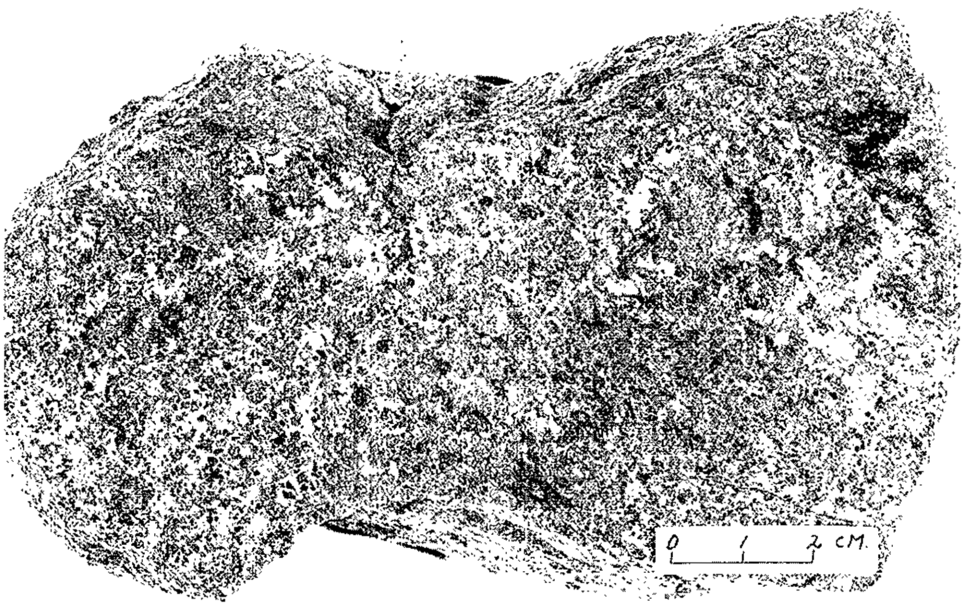
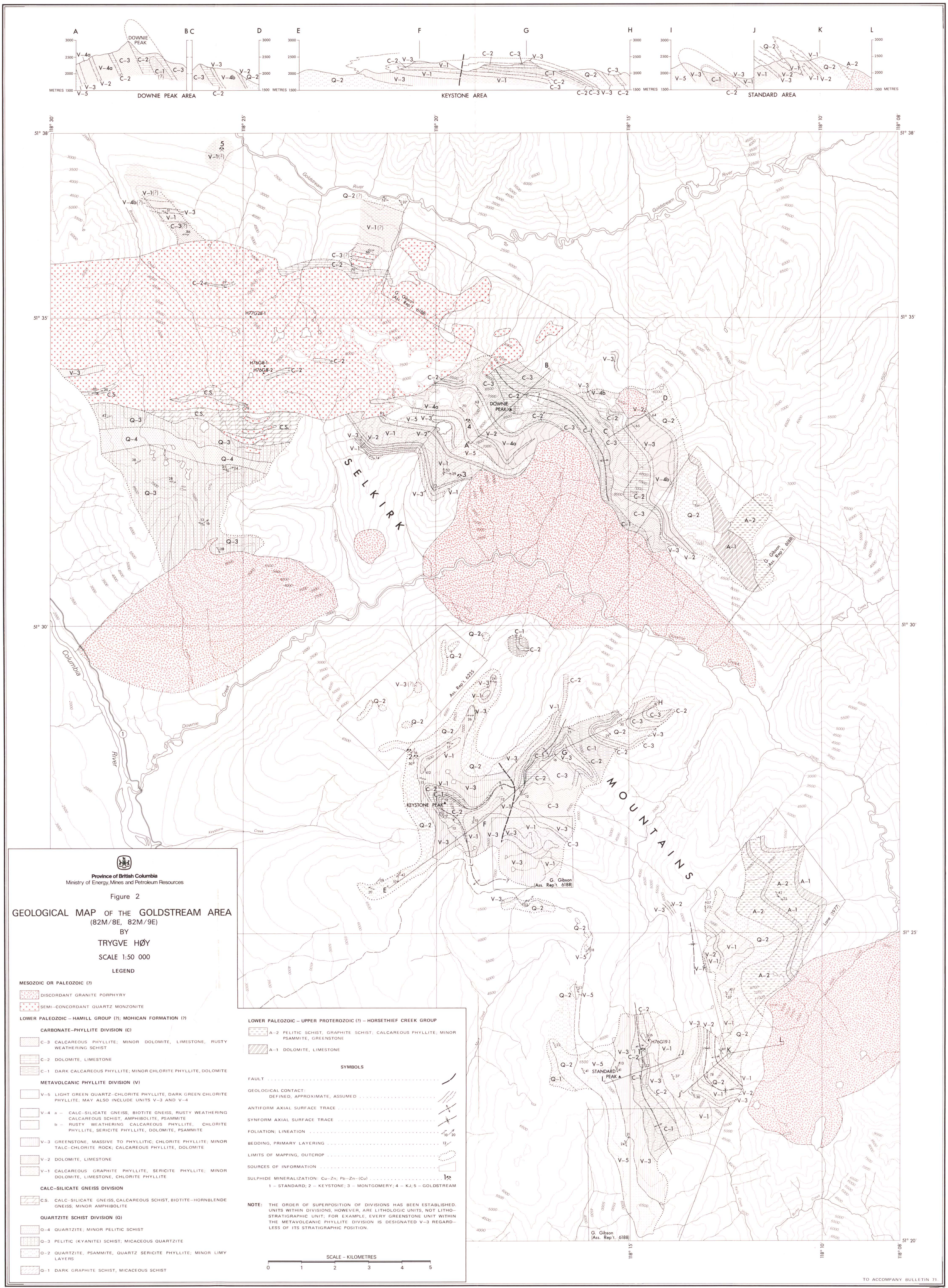


Plate XXV. Equigranular chalcopyrite, sphalerite, and pyrrhotite in a fine-grained, light grey 'quartzite' matrix, Goldstream deposit.



TO ACCOMPANY BULLETIN 71

#71