Geology in British Columbia

1976

Province of British Columbia
Ministry of
Energy, Mines and
Petroleum Resources

VICTORIA
BRITISH COLUMBIA
CANADA

MAY 1983

British Columbia Cataloguing in Publication Data
Main entry under title:
Geology in British Columbia. -- 1975-1977/81.

Irregular.
With: Exploration in British Columbia; and, Mining in British Columbia, ISSN 0823-1265, continues: Geology, exploration and mining in British Columbia, ISSN 0085-1027.
1976 published in 1983.
1977/81 published as a 1 volume cummulation.
Issuing body varies: 1975, Ministry of Mines and Petroleum Resources; 1976-1977/81, Ministry of Energy, Mines and Petroleum Resources.
ISSN 0823-1257 = Geology in British Columbia

1. Geology - British Columbia - Periodicals. 2. Geology, Economic - British Columbia - Periodicals. 3. Mines and mineral resources - British Columbia - Periodicals. I. British Columbia. Ministry of Mines and Petroleum Resources. II. British Columbia. Ministry of Energy, Mines and Petroleum Resources.

QE187.G46 557.1105

PREFACE

The first Minister of Mines of the Province of British Columbia was appointed in 1874. One of his responsibilities was "the duty of collecting information on the subject of the mining industries of the Province." This material, which consisted of reports by the Gold Commissioners and Mining Recorders of the Province, was published in the Annual Report of the Minister of Mines.

A Bureau of Mines was established by Parliamentary authority in 1895 and in 1896 was staffed by a Provincial Mineralogist and an assayer and chemist. Technical reports on mines and mining activities were prepared by them and published in the Annual Report, together with reports contributed by the Mining Recorders and Gold Commissioners.

Over the years with the expansion of the mining industry, the staff of the Department of Mines grew, as did the number and size of the technical reports on geology and mining that were still published in the Annual Report of the Minister of Mines. Over a period of nearly 75 years the Annual Report became known as the authoritative record of mining in the Province.

However, in 1969 because of the size to which the Annual Report had grown, it was decided to publish all geological and technical reports dealing with solid minerals in a separate volume entitled *Geology, Exploration and Mining in British Columbia.* Thus a new annual publication was initiated with chapters on exploration and mining related to metals, placer, structural materials and industrial minerals, and coal. *Geology, Exploration and Mining in British Columbia, 1975* introduced a revised format to allow the three main sections to be released as soon as prepared. The separate sections are: *Geology in British Columbia*—a record of the mapping and research of the Geological Branch; *Exploration in British Columbia*—a record of the performance of the industry in exploration; and *Mining in British Columbia*—a record of mining in British Columbia and incorporating the Chief Inspector's report.

Starting in 1974 a new yearly volume *Geological Fieldwork* was initiated to bring to the interested public results of the work of the Geological Branch (then called 'Division') as soon as possible after the field season. This publication did not have the benefit of extensive laboratory or office research but its timeliness was such that it prospered and *Geology,* the more complete record, lost priority. The Advisory Committee to the Geological Branch recommended that the completed studies normally published in *Geology* should be published as soon as possible. Hence this volume for 1976, which will be followed by a consolidated volume for 1977 to 1981.

GEOLOGY

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INTRODUCTION

Geology in British Columbia, 1976 is comprised of reports on mineralized areas and mineral deposits based on fieldwork carried out by staff geologists of the Geological Branch, Mineral Resources Division. These reports are concerned either with areas and properties under active exploration, recent mineral discoveries of importance, or are part of a more general study of mineralized areas which will form the body of a subsequent bulletin. Some studies, in part financed by the Ministry, are carried out by graduate students in geology at various universities.

The geological reports contained in this section are arranged sequentially by National Topographic System map designations, beginning with Southeast British Columbia (NTS Division 82).

Draughting of diagrams in this section was done by D. Armitage (nee Dorrington).

PUBLICATIONS

Geology in British Columbia, in its revised format, continues to be the main vehicle for publication of result studies on mineral and coal deposits by the Geological Branch. *Geological Fieldwork,* an annual publication initiated in 1974, gives a summary review of field results of the Geological Branch as soon as possible after the end of the field season.

No bulletins were published during the year.

The following lithographed geological maps were released in 1976:

Map A—*Generalized Geological Map of the Canadian Cordillera,* 48 degrees north to 65 degrees north, by E. V. Jackson (1:2 500 000).

Map B—*Faults, Porphyry Deposits and Showings, and Tectonic Belts of the Canadian Cordillera,* 48 degrees north to 65 degrees north, by R. H. Seraphim, V. F. Hollister, E. V. Jackson, S. H. Pilcher, J. J. McDougall, A. Sutherland Brown (1:2 500 000).

The following preliminary geological maps were released in 1976:

Map 20—*Morehead Lake Area* (92A/10E), by David G. Bailey.
Map 21—*Nicola Group South of Allison Lake* (92H/10E), by V. A. Preto.
Map 22—*Radioactive Occurrences in British Columbia,* by P. A. Christopher.
Map 23—*Toby Creek Area* (82K/8, 9), by Susan J. Atkinson.

Mineral Inventory Maps show locations and commodities of all known mineral deposits. In 1976 a complete set of revised maps was issued (89 in total), covering the Province except for some non-mineralized terrain in the Peace River area.

Mineral Deposit/Land Use Maps are interpretive maps that portray the varying mineral potential of terrain in a simple five-fold classification. In 1976, five maps at a scale of 1:250 000 were issued.

Aeromagnetic Maps of two series were issued, Federal/Provincial maps in 1:250 000 map sheets and more detailed Provincial maps. In 1976 no Federal/ Provincial maps were released from the current survey program. British Columbia issued a series of 17 maps at 1 inch to 2 640 plus interpretative notes of parts of Vancouver Island and adjacent Mainland.

Assessment Report Index Maps are available which show the location and number of reports accepted for assessment credit by the Ministry. These maps, at various scales, cover the mineralized terrain of the Province. They are regularly updated.

The following external publication activities were undertaken and the following papers were published outside by the Ministry geological staff.

A. Sutherland Brown, N. C. Carter, W. J. McMillan, and E. W. Grove were members of the editorial board for *Porphyry Deposits of the Canadian Cordillera,* the Canadian Institute and Mining and Metallurgy Special Volume 15.

The following papers were published in Special Volume 15:

- *A Perspective of Porphyry Deposits,* by A. Sutherland Brown and R. J. Cathro.
- *Morphology and Classification,* by A. Sutherland Brown.
- *Metallogeny and Metallogenic Epochs for Porphyry Mineral Deposits,* by P. A. Christopher and N. C. Carter.
- *Supergene Copper Mineralization,* by C. S. Ney, R. J. Cathro, A. Panteleyev, and D. D. Rotherham.
- *Geology and Genesis of the Highland Valley Ore Deposits and the Guichon Creek Batholith,* by W. J. McMillan.
- *J.A.,* by W. J. McMillan.
- *Gibraltar: Regional Metamorphism, Mineralization, Hydrothermal Alteration and Structural Development,* by A. D. Drummond, A. Sutherland Brown, R. J. Young, and S. J. Tennant.
- *Schaft Creek,* by P. E. Fox, E. W. Grove, R. H. Seraphim, and A. Sutherland Brown.
- *Regional Setting or Porphyry Deposits in West-Central British Columbia,* by N. C. Carter.
- *Granisle,* by K. C. Fahrni, H. Kim, G. H. Klein and N. C. Carter.
- *Berg,* by A. Panteleyev, A. D. Drummond and P. G. Beaudoin.
- *The Alkaline Suite Porphyry Deposits: A Summary,* by D. A. Barr, P. E. Fox, K. E. Northcote and V. A. Preto.
- *Copper Mountain and Ingerbelle,* by K. C. Fahrni, T. N. Macauley and V. A. Preto.
- *Lorraine,* by W. J. Wilkinson, R. W. Stevenson and J. A. Garnett.
- *Galore Creek,* by D. G. Allen, A. Panteleyev and A. T. Armstrong.
- *Characteristics of Canadian Cordilleran Molybdenum Deposits,* by A. E. Soregaroli and A. Sutherland Brown.
- *Geology and Geochemistry of the Alice Arm Molybdenum Deposits,* by J. R. Woodcock and N. C. Carter.

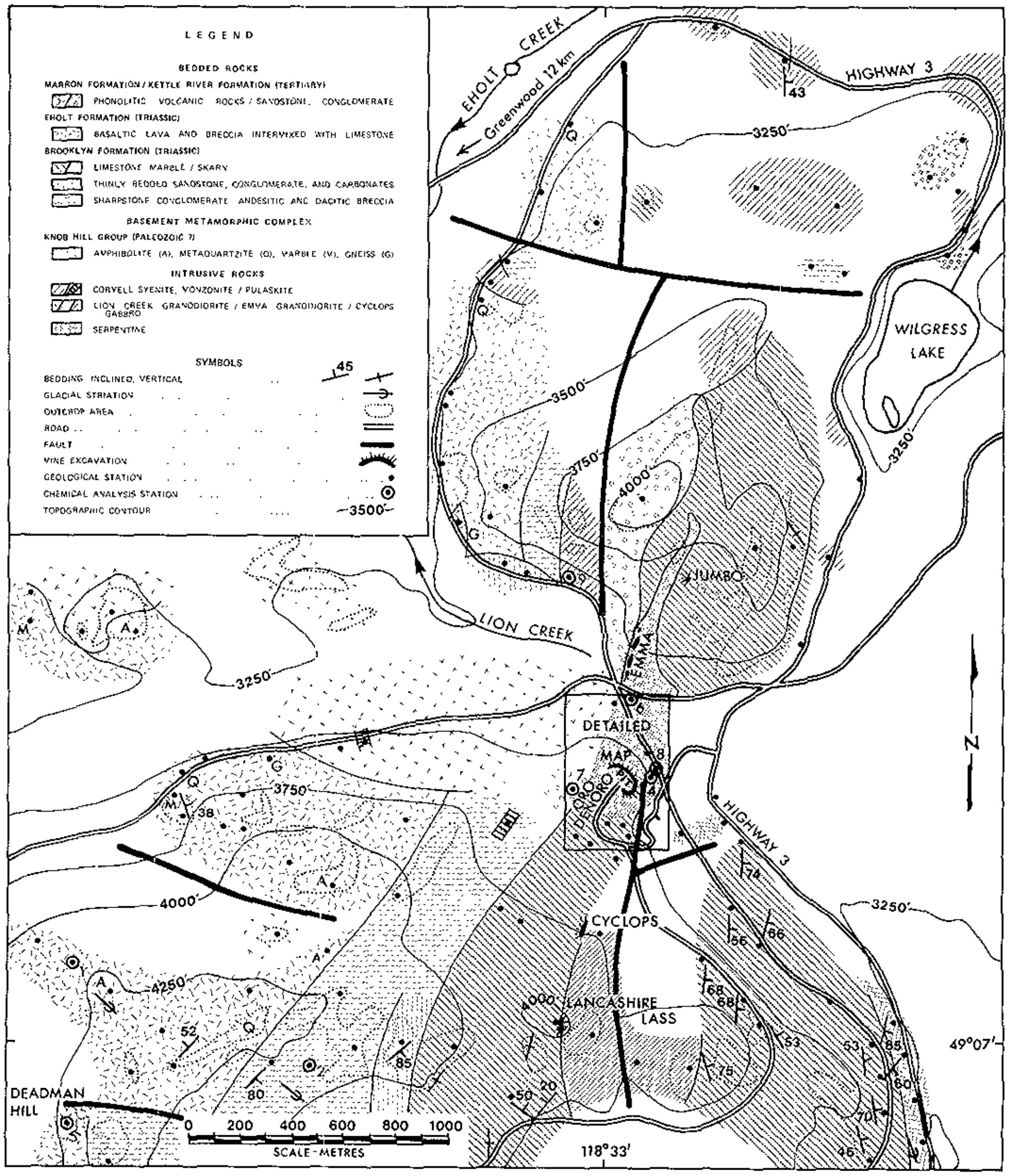

Figure 1. Geology of the Oro Denoro property, Wilgress Lake area, Greenwood Mining Division.

SOUTHEAST BRITISH COLUMBIA

GEOLOGY IN VICINITY OF THE ORO DENORO MINE (82E/2E)

By B. N. Church

INTRODUCTION: Detailed mapping was initiated following renewed exploration and mining in the vicinity of the old Oro Denoro workings, 9.7 kilometres northeast of Greenwood. Early in 1975 Granby Mining Corporation began a test operation to prove an orebody estimated by previous work to contain about one million tonnes grading slightly less than 1 per cent copper. When the property was visited in June 1975, excavation had advanced to the third bench in the open pit, and approximately 135 000 tonnes of bedrock has been removed. Subsequently mining ceased pending the results of a percussion drilling program. In 1976 stockpiled ore at the pit site was transported to the Phoenix mill.

The history of Oro Denoro can be traced to the original discovery of copper in the so-called 'Summit Camp' in 1891. Beginning in 1903 the property became an important local mine producing 136 447 tonnes of ore grading 1.37 per cent copper, 0.027 ounce per ton gold, and 0.225 ounce per ton silver. By 1910 accessible ore had been extracted from five open stopes and 1,800 feet of underground drifts. After many years of inactivity, prospecting was revived in response to increases in the price of copper. Between 1951 and 1953, Attwood Copper Mines Ltd. carried out a number of geological, geophysical, and geochemical surveys. Later the property was drilled by Noranda Mines, Limited (1955 to 1957) and again by West Coast Resources Ltd. (1965 to 1970). Testing by Granby Mining Corporation in the area continued through 1976.

PHYSIOGRAPHY: The topography in the vicinity of the Oro Denoro mine is relatively subdued, the hills in this region having been smoothed by southeasterly moving Pleistocene glaciers. The mine site, at 3,500 feet elevation, occupies a low point on the ridge dividing the Boundary Creek and Granby River drainage systems. Slopes rise to the southwest in the direction of the Phoenix mine, attaining a maximum elevation of 4,500 feet m.s.l. on Deadman Hill. Low points in the area near Eholt Creek on the north, Lion Creek on the west, and Wilgress Lake on the northeast are characteristically well vegetated and drift covered, bedrock being exposed mostly in road cuts.

Access is from a number of old railway grades, now converted to logging roads, and Highway 3 which bounds the map-area on the north and east.

GENERAL GEOLOGY: The Oro Denoro region is underlain mostly by Mesozoic beds east of the drainage divide and an older basement complex of resistant metamorphic rocks to the west (Fig. 1). These units are intruded by an assortment of plutonic rocks ranging from granodiorite to gabbro, serpentine, and smaller dykes and sills of mostly diorite and pulaskite composition.

The relative age of formations is judged from metamorphism and the cutting relationship of intrusions. Fossil evidence and a few radiometric determinations provide some specific control.

Metamorphic Basement Complex: The basement rocks comprising an assemblage of amphibolites, quartzites, marble bands, gneiss, and schist are collectively referred to as the 'Knob Hill Group'. The age range of the constituent formations is unknown although they are certainly pre-Mesozoic.

Amphibolites predominate in the southwest part of the map-area. These are dark-coloured and generally massive, medium to fine-grained rocks of probable basic volcanic derivation. In thin section there is little evidence of primary textures or mineralogy, these features having been largely obliterated by cataclasis and regional metamorphism. Fresh samples consist of fine-grained aggregates of pleochroic green and yellow amphibole accompanied by thin discontinuous bands and lenses enriched in magnetite dust or plagioclase. Retrograde effects have commonly reduced the rocks to a mixture of chlorite, carbonates, and clay minerals. Chemical analysis is the main vestigial evidence proving the basaltic nature of the rocks (*see* analysis No. 1, Table 1).

The most prominent outcrops of metaquartzite are near the southwest corner of the map-area on the crest of the ridge leading to Deadman Hill. Characteristically the rock is competent and ranges from dark grey to light cream coloured. In thin section samples are commonly very fine-grained and cherty except for numerous veinlets of coarser quartz.

The amphibolites and metaquartzite are accompanied by an older complex of gneiss and schist. This basal assemblage is exposed on the hillside northeast of Lion Creek. Generally the rocks are well foliated having thin alternating bands of felsic and mafic minerals. In thin section a sample displays a mixture of small grains, averaging about 0.1 millimetre in diameter, of quartz 25 per cent and biotite 40 per cent, interspersed with composite granules of muscovite and quartz 35 per cent, and accessory magnetite.

The structural fabric of the basement complex is often difficult to identify owing to the massive habit of the major units, such as the amphibolites, contortion of the gneiss and schist formations, and paucity of marker beds.

BEDDED ROCKS: Mesozoic and Tertiary strata rest unconformably on the basement complex. The Triassic Brooklyn Formation, lowermost in the cover assemblage, consists mostly of limestone and clastic sedimentary rocks and is overlain by the slightly younger predominantly volcanic Eholt Formation. The Tertiary beds, consisting of two formations, the Marron volcanic rocks and Kettle River sedimentary rocks, are of minor importance occurring only as small outliers.

Brooklyn Formation: Two members constitute the Brooklyn Formation— at the base, a widely distributed 'sharpstone conglomerate' and, uppermost, a thick limestone deposit.

The sharpstone member forms a narrow belt-trending subparallel to the crest of the northeast ridge of Deadman Hill. It is a thickness of about 1,500 feet of well indurated and often massive pebble conglomerate. Detailed examination of the constituent fragments indicates a diverse provenance. Chert and greenstone are most abundant, comprising about 80 per cent of the clasts with carbonate, schist, and gneiss fragments being accessory. Modal analysis of the sandy matrix shows an average of chert and quartz grains, 40 per cent; amphibolite and porphyritic clasts, 25 per cent; schist and chlorite hash, 15 per cent; carbonates, 15 per cent; and minor feldspar and iron oxides. Calculations based on chemical analysis of a sample of carbonate-poor sharpstone conglomerate (analysis No. 2, Table 1) gives 47 per cent normative quartz.

Contact relations of the sharpstone member are displayed on the slopes of Deadman Hill. At the lower contact the conglomerate directly overlies Knob Hill quartzites, and at one point, a thin wedge of felsic tuff breccia. The upper contact, exposed further east on the main ridge, passes transitionally into the limestone member through several hundred feet of intercalated sandstone, conglomerate, and carbonate beds.

The limestone member, estimated to be about 2,000 feet thick, is exposed extensively in the eastern section of the map-area. This is a light blue-grey rock of variable structure consisting of massive relatively pure calcium carbonate phases and thinly bedded zones enriched in clay and chert impurities. Above the sharpstone contact in the area southwest of Wilgress Lake and the Oro Denoro mine, the member is commonly massive, and in places resembles a coarse breccia. To the east, the upper half of the limestone section is generally well-bedded with frequent shaly partings. Cherty sand is concentrated at several horizons in calcarenite zones. A thin section of this peculiar sedimentary rock shows mostly rounded carbonate clasts and fine-grained carbonate mud matrix, 55 per cent; subangular to well-rounded chert grains, 35 per cent; and accessory quartz, feldspar, porphyritic rock fragments, and amphibolite.

The age has been determined as Middle Triassic by the discovery of *Daonella* sp. in the limestone near the Phoenix mine (H. W. Little, personal communication).

TABLE 1. CHEMICAL ANALYSES

	1	2	3	4	5	6	7	8	9
Oxides Recalculated to 100—									
SiO_2	49.66	75.60	52.28	36.71	56.21	66.44	65.71	60.07	59.95
TiO_2	1.05	0.52	0.96	0.11	0.97	0.42	0.47	0.90	1.13
Al_2O_3	17.21	9.98	17.83	5.69	19.41	16.22	16.12	15.84	14.84
Fe_2O_3	3.11	1.33	9.31	23.09	4.85	2.00	1.02	2.58	2.31
FeO	8.83	3.30	1.36	1.16	1.94	2.25	3.89	3.66	4.22
MnO	0.22	0.12	0.15	0.39	0.08	0.06	0.14	0.12	0.22
MgO	7.07	2.94	8.17	0.64	2.24	2.00	2.52	5.12	4.53
CaO	8.51	3.86	4.85	32.20	4.37	4.46	4.49	4.12	5.33
Na_2O	2.17	1.42	4.80	0.01	5.61	3.46	4.19	4.73	3.03
K_2O	2.17	0.93	0.29	—	4.32	2.69	1.44	2.67	4.55
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Oxides as Determined—									
$+H_2O$	2.11	1.14	3.49	0.28	2.77	0.87	1.21	1.98	1.27
$-H_2O$	0.24	0.27	0.35	0.11	1.25	0.24	0.19	0.78	0.79
CO_2	0.60	0.15	0.87	1.67	1.35	0.45	1.19	0.91	1.21
P_2O_5	0.18	0.32	0.39	0.48	0.71	0.18	0.30	0.28	0.41
S	0.01	0.02	0.01	0.11	0.01	0.02	0.06	0.02	0.02
SrO	0.03	0.02	0.09	0.006	0.30	0.08	0.09	0.13	0.12
BaO	0.08	0.06	0.02	0.001	0.21	0.12	0.11	0.11	0.09

1—Amphibolite, Knob Hill Group, Deadman Hill area.
2—Sharpstone conglomerate, Brooklyn Formation, Deadman Hill area.
3—Basalt lava, Eholt Formation, near the junction of the Phoenix road and Highway 3 just beyond the southeast corner of the map-area.
4—Skarn from No. 1 quarry of the Oro Denoro mine.
5—Mafic phonolite, Marron Formation, Deadman Hill area.
6—Lion Creek granodiorite, just south of the Emma mine.
7—Emma porphyry, west of the Oro Denoro pit.
8—Pulaskite dyke, No. 1 quarry of the Oro Denoro mine.
9—Coryell monzodiorite, northwest of the Emma mine.

Eholt Formation: The Eholt Formation, described by Carswell (1957), is little known in the map-area. The only exposures are near the Phoenix road turnoff and rock cuts along Highway 3. The formation consists of intercalated limestone and dark green and purple lavas and breccia. A peculiar breccia facies of mixed chert, greenstone, and limestone blocks (similar to the Brooklyn sharpstone conglomerate) has been included in the formation. Chemical analysis of a samply of Eholt lava gives a basaltic composition (analysis No. 3, Table 1).

The Eholt rocks are believed to unconformably overlie Brooklyn Formation. The age has been determined as probable Late Triassic from an assemblage of fossil corals, which includes *Thecosmilia* sp. (H. W. Little, personal communication), obtained from an outcrop of Eholt limestone north of the Phoenix road.

Kettle River Formation: The basal Tertiary assemblage represented by the Kettle River Formation is found only in a small area north of Wilgress Lake. This is a channel deposit of light-coloured sandstone and pebble conglomerate. A thin section of the sandstone shows the following modal composition: quartz, 15 per cent; chert, 5 per cent; feldspar, 40 per cent; volcanic rock, 10 per cent; mica and opaque minerals, accessory; matrix, 30 per cent. It is estimated that more than 75 per cent of the clasts were derived from a fresh felsic volcanic source rocks, the remainder having a metamorphic provenance.

Marron Formation: The Marron volcanic rocks are found in two places, a small area of exposure on Deadman Hill and north of Wilgress Lake. At the latter locality Marron rocks directly overlie the Kettle River beds.

The volcanic rocks are medium to dark grey lavas and breccia characterized by scattered tabular or rhomb-shaped anorthoclase and anhedral pyroxene phenocrysts. In thin section the matrix is commonly charged with randomly arranged feldspar microlites, rounded analcite crystals, and interstitial pyroxene, magnetite, abundant apatite, and glass. Chemical analysis of the rock suggests a mafic phonolite composition (*see* analysis No. 5, Table 1).

IGNEOUS INTRUSIONS: The Lion Creek granodiorite, the main intrusion in the area, is accompanied by smaller satellitic bodies, the Emma porphyry and related dykes, and the Cyclops gabbro. Other intrusions include a small serpentine body and some young Coryell-related monzonite sills and pulaskite dykes.

Lion Creek Granodiorite: The Lion Creek granodiorite is thought to be an appendage of the Wallace Creek batholith. The intrusion enters the map-area from the west penetrating the Triassic beds and basement complex and extends eastward to the Oro Denoro workings. This is a light grey massive granoblastic rock having the following approximate modal composition: feldspar, about 65 per cent (mostly plagioclase); quartz, 25 per cent; and accessory amphibole, biotite, and magnetite. The plagioclase occurs as rectangular oscillatory-zoned plates, intermixed with subhedral quartz, 1 to 4 millimetres across, with slightly smaller interstitial quartz and feldspar and magnetite grains associated with patches of pale yellow-green amphibole and scattered biotite books. Some garnet, sphene, and diopside are reported near the contaminated borders of the intrusion.

The Emma intrusion is an elongated northerly trending offshoot of the Lion Creek body. It is well exposed in a small area west of the Oro Denoro pit and on the slopes to the north in the vicinity of the Emma mine. This is a distinctive porphyritic phase consisting of about 8 per cent subhedral plagioclase, individual and clusters, and 1 per cent partly resorbed amphibole phenocrysts, ½ to 4 millimetres in length, suspended in a fine-grained quartzofeldspathic matrix. According to normative calculations the rock contains a total of 20 per cent quartz and about 70 per cent feldspar (An_{30}), the chemical composition of the Emma phase being very similar to the Lion Creek intrusion (*see* analyses Nos. 6 and 7, Table 1).

The age of the Lion Creek intrusion has been determined as Cretaceous, 140±5 Ma, based on K/Ar analysis of biotite obtained from a sample of granodiorite taken near the Emma mine.

Cyclops Gabbro: The Cyclops gabbro occurs in the area south and southeast of the Cyclops prospect as a large partly concordant body and a number of small dyke-like offshoots in the vicinity of the Oro Denoro and Emma workings. The rock is commonly dark greenish grey and rather uniform, fine grained, consisting of subhedral plagioclase plates, about 55 per cent, interspersed with equant pyroxene grains, 20 per cent (measuring to 1.5 millimetres in diameter) set in a matrix of chlorite and disseminated magnetite. Conversion of some of the pyroxene to blue-green amphibole locally is viewed as a retrograde metamorphic effect.

The age of the gabbro certainly post-dates the Middle Triassic Brooklyn Formation which it intrudes, however, its relation to other igneous rocks in the area is uncertain.

Ultramafic Rocks: A small lens of serpentinized peridotite occurring in basement gneisses north of Lion Creek constitutes the only ultramafic body in the map-area. This rock is generally brittle and mottled light grey, dark greenish grey on fresh surfaces and rust brown where weathered. In thin section, a typical sample is comprised of a cataclastic aggregation of serpentine, talc, and minor carbonates interspersed with ragged pyroxene remnants and associated with magnetite.

Coryell Intrusions: The Coryell intrusions are exposed mostly in the northern part of the map-area. These include an assemblage of syenite, monzonite, and shonkinitic bodies, and their finer-grained equivalents—a variety of pulaskite and lamprophyre dykes. The most common rock in this suite is a mottled pink and grey feldspar porphyry consisting of glomerophenocrystic plagioclase-sanidine clots, measuring to 6 millimetres in diameter, and smaller solitary feldspar crystals suspended in a finer-grained matrix of interlocking feldspars and biotite, and a small amount of interstitial quartz, disseminated magnetite, and apatite. Clinopyroxene is also present as an additional mineral in the more basic phases.

A sample of pyroxene monzodiorite obtained northwest of the Emma mine shows the following normative mineralogy: quartz, 6.5 per cent; potassium feldspar, 27.2 per cent; plagioclase (An_{33}), 41.1 per cent; clinopyroxene, 22.8 per cent; magnetite, 2.4 per cent. The chemical analysis of this rock is similar to the composition of a post-mineralization pulaskite dyke exposed in the No. 1 quarry at the Oro Denoro mine (*see* analyses Nos. 8 and 9, Table 1).

The age of Coryell batholith, recently established by Fyles *et al* (1973) in the Rossland area, is Middle Eocene.

STRUCTURE: The general pattern of folding, faulting, and intrusion seems to have a north-south and east-west control. In detail, the structures are intricate and often difficult to unravel because of the scarcity of marker horizons and imperfect exposure.

The trend of the Brooklyn and Eholt Formations is mostly northerly, bedding strikes averaging 005 degrees. The Mesozoic section is tilted easterly about 50 degrees forming a monocline. Local reversals and deflections of beds give evidence of the presence of northeasterly plunging minor folds (Fig. 2).

The structure of the basement complex is more difficult to determine because of the massive character of the rocks, particularly the amphibolite formation which covers a wide area. An exception is a band of marble, traced for about 2 kilometres striking from the west boundary of the map-area to the north slope of Deadman Hill, following near the base of the amphibolite formation. Metaquartzite with an average bedding attitude of 060°/50° northwest overlies the amphibolite near the crest of Deadman Hill.

The main fractures trend easterly coincident with major draws and valleys, and northerly subparallel to the principal strike direction of the Mesozoic beds (Fig. 1). Specific measurements of numerous minor fractures illustrates this bimodal distribution showing a development of strong joint sets at approximately 110°/85° southwest and 005°/82° east (Fig. 3). That the fracture system pre-dates the major igneous intrusions and was probably advantageous to the emplacement of these rocks is suggested by the east-west elongation of the Lion Creek pluton and the north-south orientation of the Emma and Cyclops bodies.

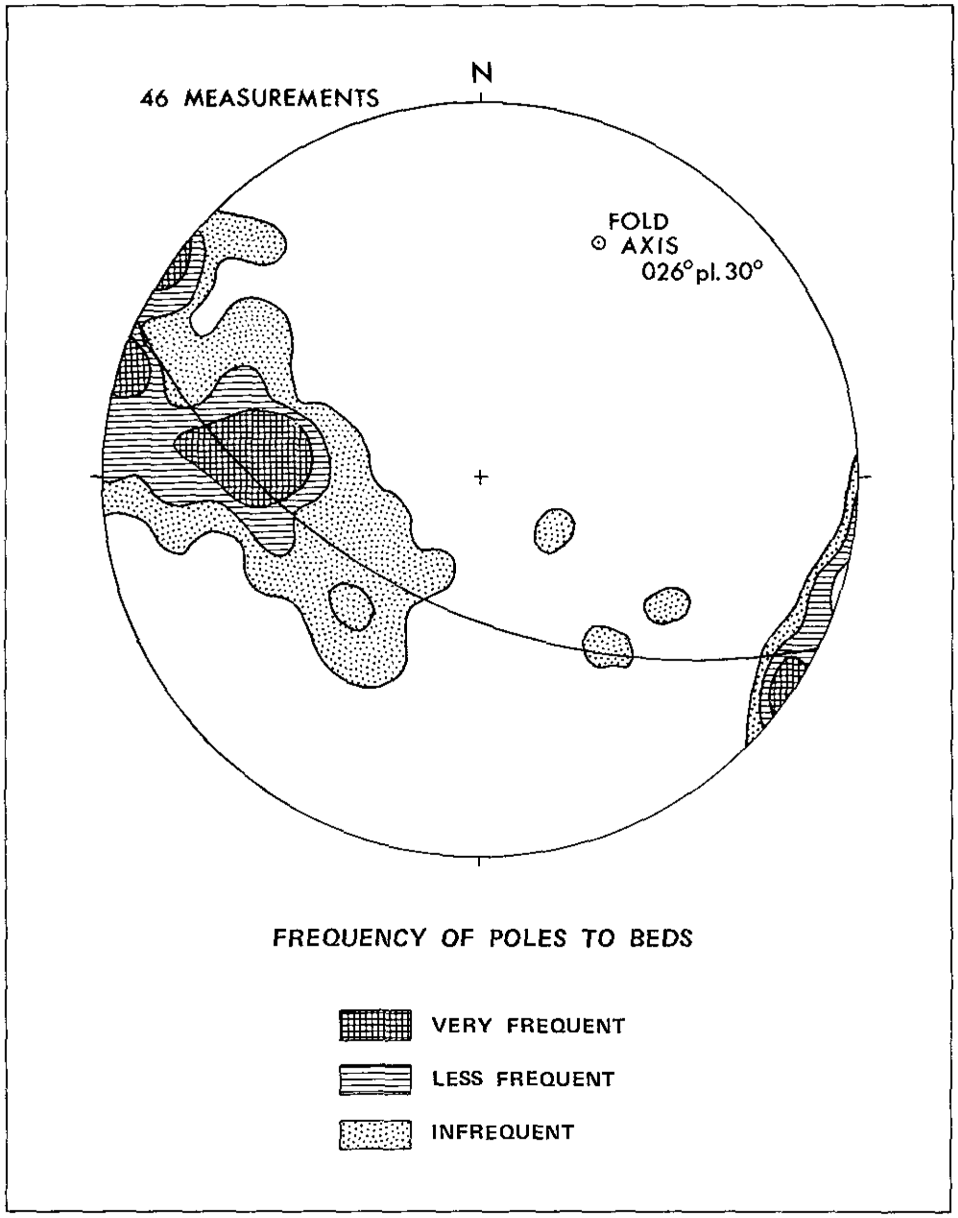

Figure 2. Equal area plot of poles to bedding for Mesozoic rocks, Oro Denoro area.

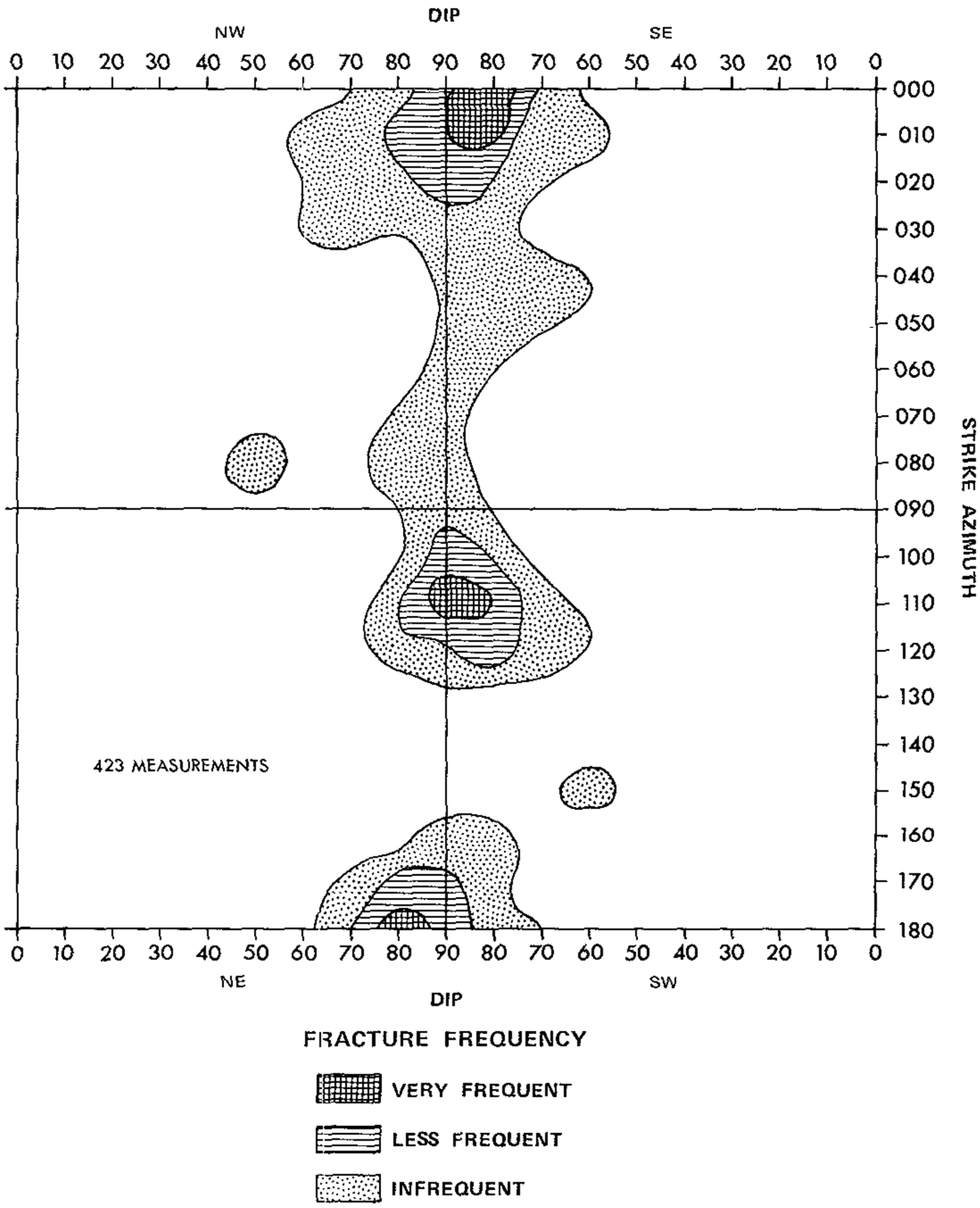

Figure 3. Fracture frequency plot for the Oro Denoro area.

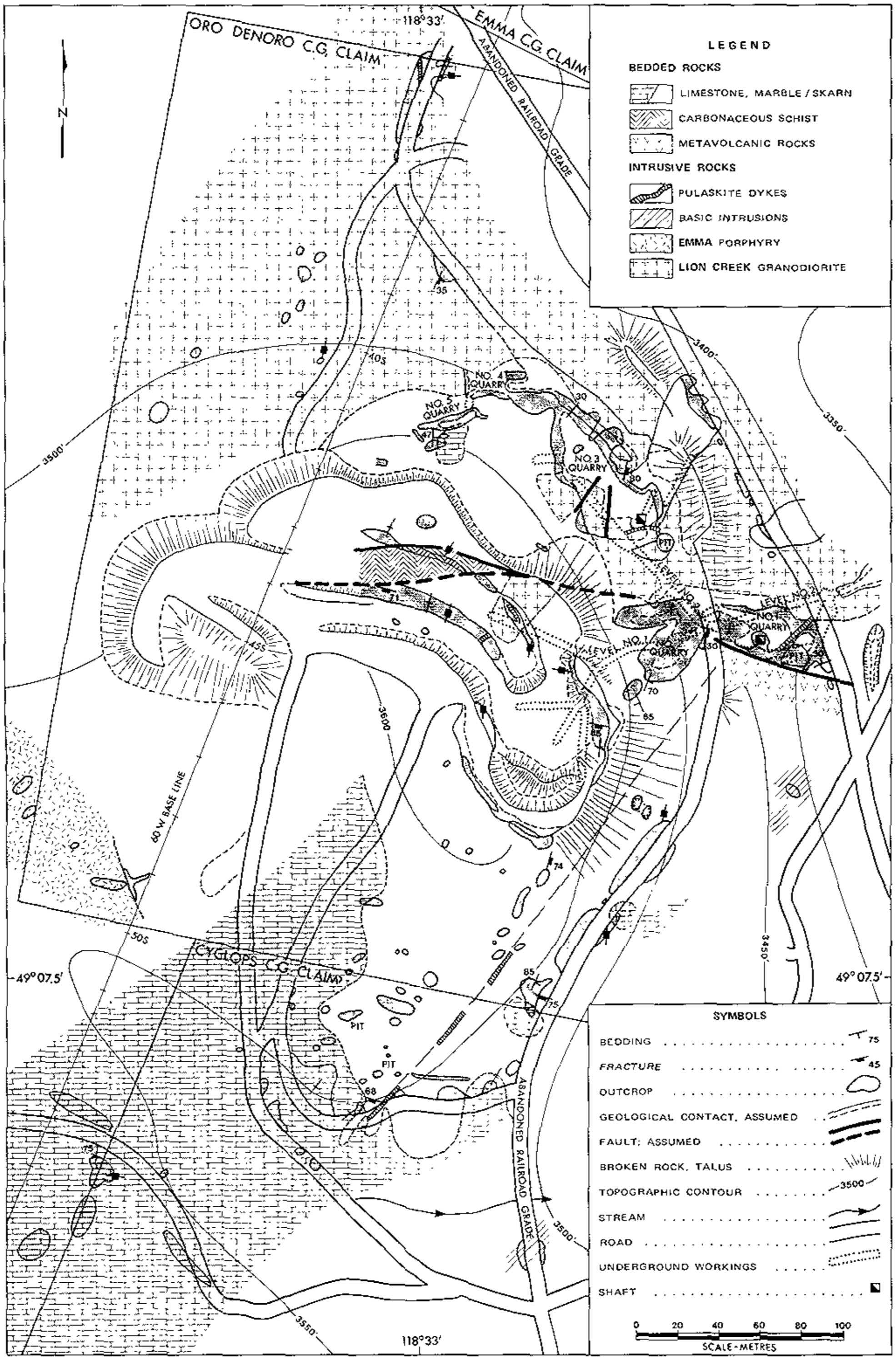

Figure 4. Detailed geology in the vicinity of the Oro Denoro mine.

Plate I. Oro Denoro, view of open pit and looking south.

MINERALIZATION: The Oro Denoro mine is centrally located within a 2.4-kilometre-long meridianal alignment of skarn deposits which includes the Emma and Jumbo on the north and the Cyclops and Lancashire Lass on the south. The host rock for all of these, and many other deposits in the Greenwood area, is the Brooklyn limestone member (Fig. 1).

The geology of the Oro Denoro is relatively straightforward. Mineralization consists of pockets of pryrite, chalcopyrite, and magnetite in a garnetite skarn. This is mostly a replacement of limestone intruded by an apophysis of the Lion Creek granodiorite stock (Fig. 4).

The mine workings cover an area of about 10 acres in the central part of the Oro Denoro Crown-granted claim. In the early period of mining between 1903 and 1910 ore was drawn from five quarries and a number of open stopes which were serviced by two underground levels. This mine and the Phoenix operation several miles to the southwest were among the earliest attempts at open-pit mining in the Province.

In the old workings of Oro Denoro the southernmost quarries, Nos. 1 and 2, were the principal source of copper ore. These are interconnected and have a general east-west elongation. The trend of the excavations appears to follow the course of a number of large steeply dipping calcite lenses in the skarn along the granodiorite contact which is near the north wall. Quarry No. 3, centred about 200 feet north of Nos. 1 and 2, is the second largest pit. Here the mineralization was concentrated in a tongue of skarn rock projecting deep into the granodiorite mass. Quarries Nos. 4 and 5, centred about 150 feet northwest of No. 3, are relatively small. The magnetite-rich ore was situated between a small remnant of limestone in the skarn rocks and the granodiorite. Control of the mineralization appears to be east-west crossfractures cutting approximately perpendicular to bedding in the limestone.

The new excavation which is located immediately west and south of the old quarries is a large-benched open pit about 500 feet long and 150 feet wide in mainly garnetite skarn which forms the core and summit of Oro Denoro's 'mine hill'. The target of this development was a mineralized zone near the south end of the pit.

The mine area is traversed by a number of faults of ore control significance. The most important is a pronounced shear zone striking about 120 degrees from the north end of the main pit through No. 1 quarry. Profound movement on this zone has resulted in the emplacement of exotic formations in the skarn such as a wedge of carbonaceous schist in the main pit and epidotized volcanic breccia along the south wall of No. 1 quarry. Of less importance are two minor faults 045°/75° southeast and 015°/80° east causing local displacements in the skarn-granodiorite contact in No. 3 quarry and a weaker fracture 150°/45° southwest observed in No. 5 quarry.

Mineralization and the development of a skarn at Oro Denoro is evidently the result of intrusion of the Lion Creek granodiorite stock. An exchange of chemical components between the granodiorite and Brooklyn limestone is apparent. A determination of the mineralogy of the skarn is provided by Carswell (1957): garnet grossularite$_{10}$, andradite$_{90}$, 85 per cent; and 5 per cent for each of clinozoisite, diopside, and quartz (in weight per cent). In terms of estimated chemical composition this mineralogy reduces to: SiO_2, 39.6 per cent; Al_2O_3, 3.9 per cent; Fe_2O_3, 24.7 per cent; MgO, 0.9 per cent; CaO, 30.9 per cent on an anhydrous base—a calculation which compares closely with the actual chemistry of a sample of skarn rock (analysis No. 4, Table 1). The gain of large amount of iron oxide and silica by the limestone is matched by an equally large loss of lime to the granodiorite. Source of the iron oxide and silica appears to result from calcification of iron-bearing silicates and plagioclase feldspar in the granodiorite.

Mineral paragenesis begins with the skarn silicates which are partly overlapped by magnetite and succeeded by sulphides. Magnetite commonly occurs interbanded with the skarn silicates, the banding generally having the same trend as bedding in the nearby limestone (Plate II). In contrast, the sulphides are present as disseminated grains, individual large crystals or masses associated with calcite in seams and pods (Plate III). Also, mixtures of sulphides, mostly pyrite and chalcopyrite, with garnet and calcite may display a crude planar fabric or banding of coarse and fine grains betraying a suggestion of relict bedding (Plate IV). The final generation of sulphides is reposed in interstices and cracks crossing the skarn silicates, magnetite, and older sulphides (Plate V).

Formation of the skarn and emplacement of the sulphide and magnetite ores involved high temperature interaction between the limestone and granodiorite—high temperatures being implied by the extensive development of garnetite. Marked irregularity and variation in the width of the skarn zone from a few metres to many tens of metres suggests that the reactions occurred only at places where ascending solutions were active. These solutions, enriched in carbon dioxide, silica, and iron, rose along the fissure system. At first the interaction of invading solutions on the host rocks was intensified along fissures forming metasomatic veins, with later infiltration of the limestone mass-soaking rock pores and ultimately achieving wholesale replacement.

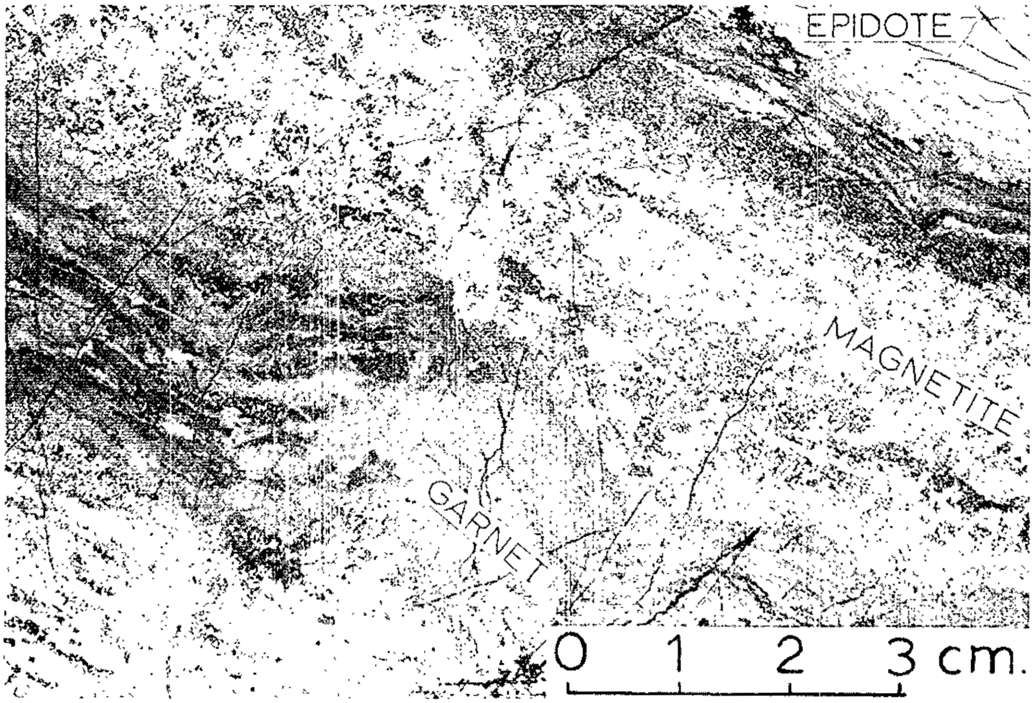

Plate II. Oro Denoro, banded garnet-magnetite-epidote skarn.

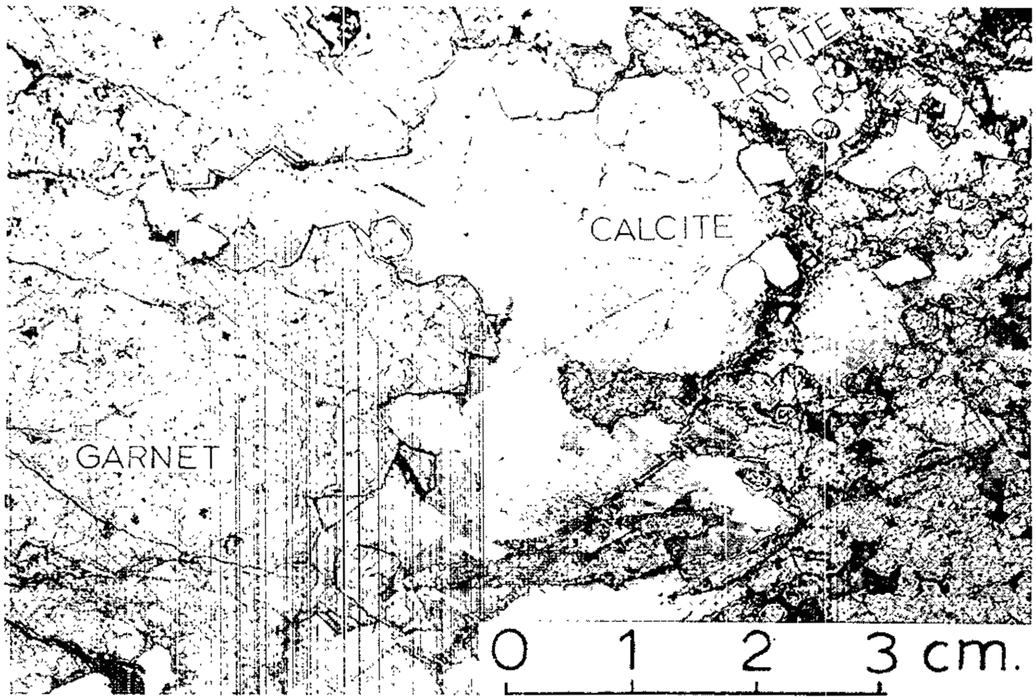

Plate III. Oro Denoro, garnetite with calcite and pyrite fillings.

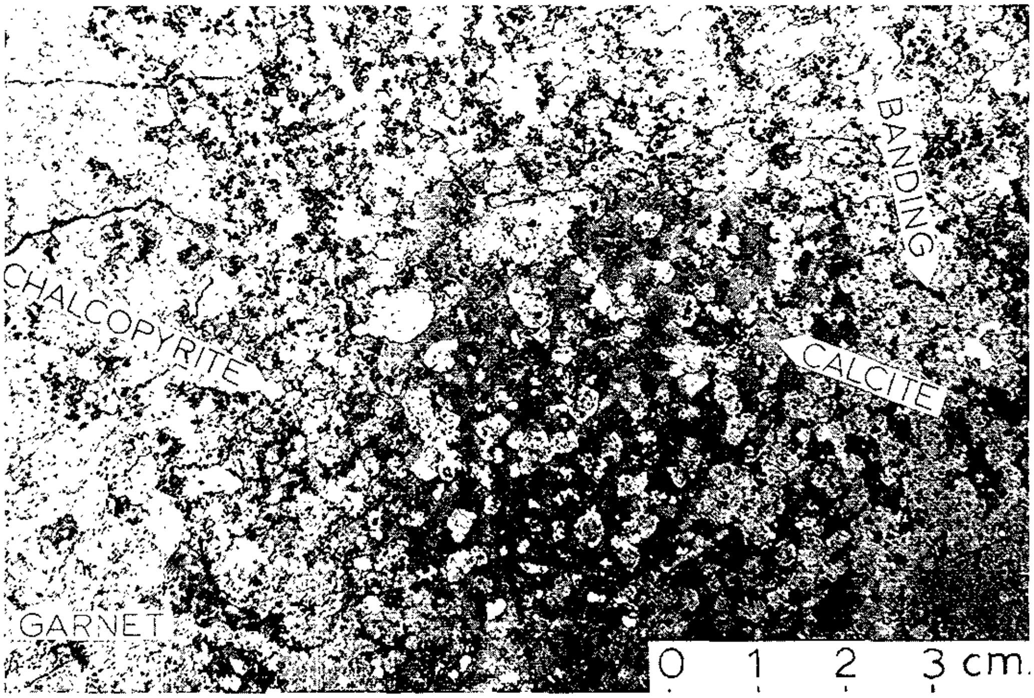

Plate IV. Oro Denoro, garnetite with relict carbonate-rich bands and disseminated pyrite and chalcopyrite.

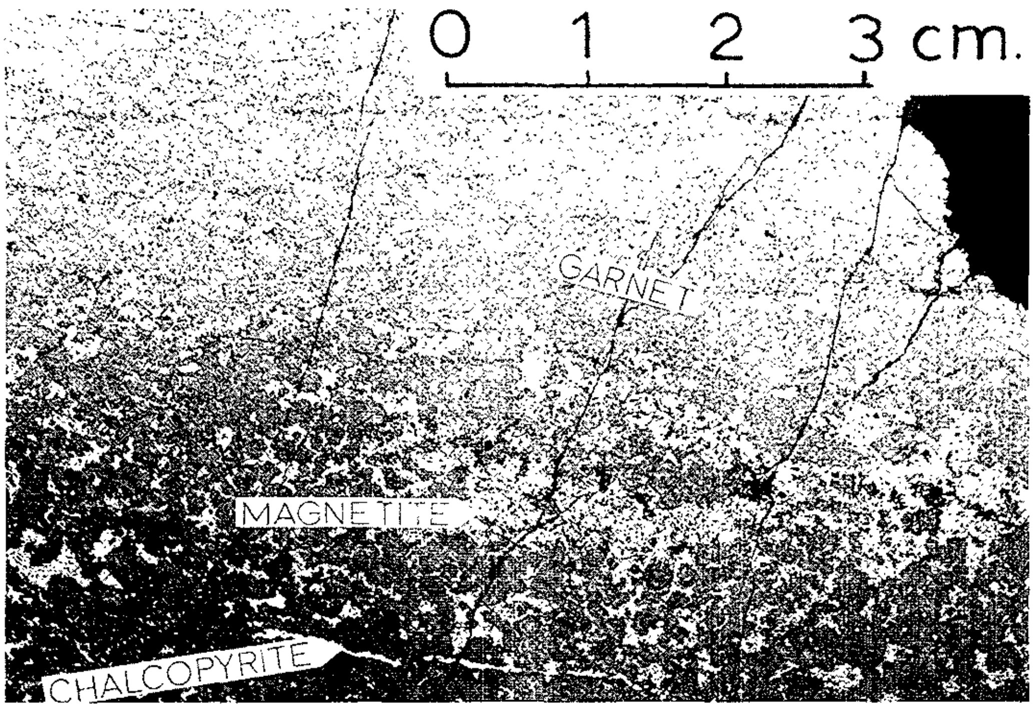

Plate V. Oro Denoro, magnetite-rich garnetite with pyrite and chalcopyrite on cracks.

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PB, KETTLE, URANUS, URANIUM CLAIMS (82E/11E, 14E)

By P. A. Christopher

LOCATION: The Pb claims are divided into three groups;

(1) Pb 189 to 214, 217 to 259
Lat. 49°49′ Long. 119°12′ (82E/14E)
Osoyoos and Vernon M.D. Twenty-one kilometres east-southeast of Kelowna, covering Browne and Fish Lakes and the headwaters of Grouse Creek.

(2) Pb 81 to 148, 152, 154 to 179
Lat. 49°45′ Long. 119°08′ (82E/11E, 14E)
Greenwood M.D. Twenty-seven kilometres southeast of Kelowna, on Kallis Creek, east of Hydraulic and Haynes Lakes.

(3) Pb 260 to 289
Lat. 49°47′ Long. 119°03′ (82E/14E)
Greenwood M.D. Thirty-two kilometres east-southeast of Kelowna, extending along the northwest side of the West Kettle River, opposite the mouth of Champion Creek.

Uranus 1–13 claims (approximately 190 units) and Kettle 1–23 (approximately 180 units)
Lat. 49°49′ Long. 119°12′ (82E/14E, 14W)
Staked around Pb claims 189 to 214 and 217 to 259.

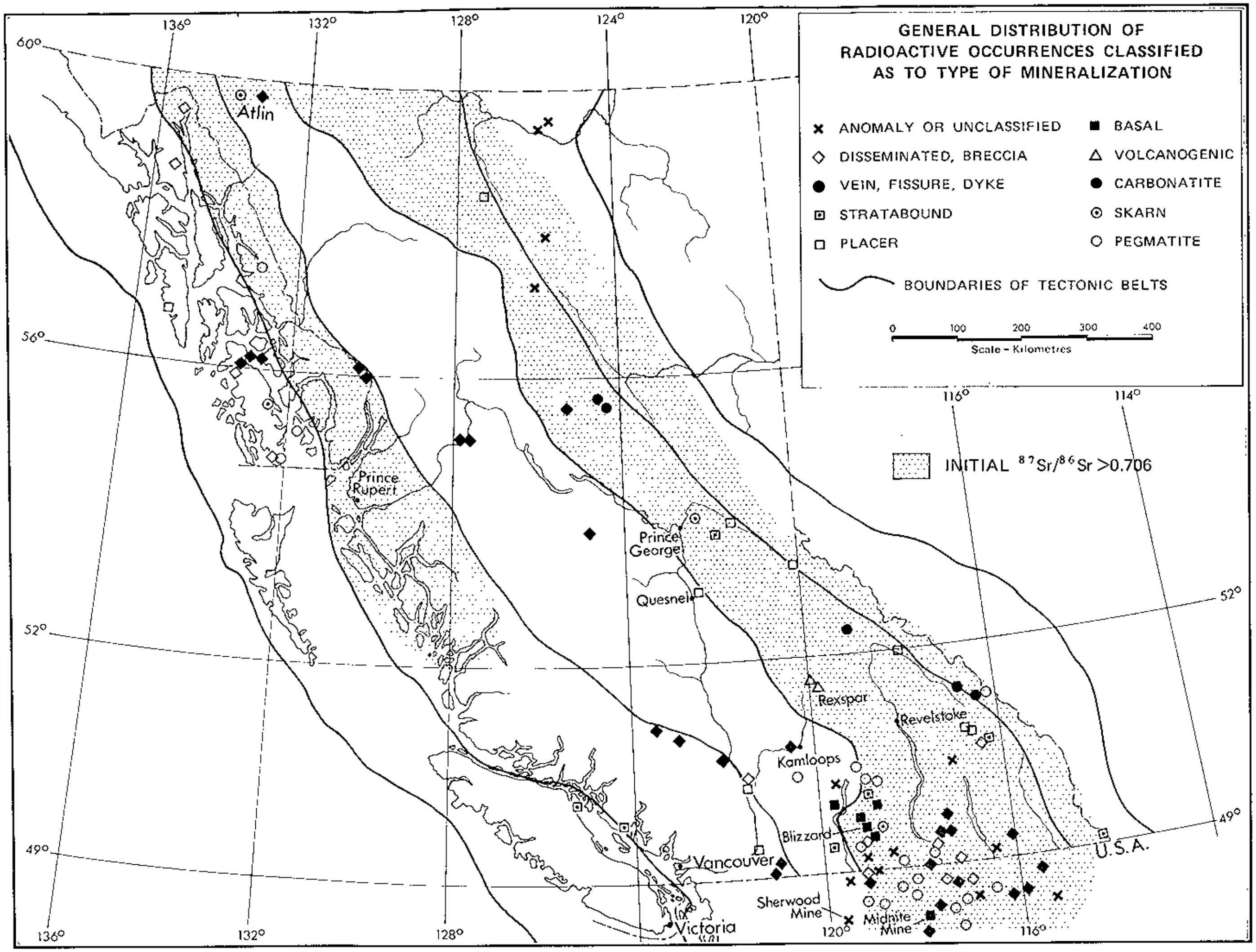

Figure 5. General distribution of radioactive occurrences in British Columbia classified as to type of mineralization.

Goat 1–8 (approximately 140 units), Tab 1 and 2 (approximately 35 units), Freedom 1–3 (approximately 44 units), Cookson 1–3 (approximately 40 units), and Hayes 1–7 (approximately 103 units).
Lat. 49°45′ Long. 119°08′ (82E/11E, 14E)
Staked around Pb claims 81 to 148, 152, and 154–179.

OWNERS: The PB claims are owned by Nissho-Iwai Canada Ltd., the Kettle and Uranus claims are owned by Tyee Lake Resources Ltd., and the Goat, Haynes, Freedom, and Tab claims are owned by Peregrine Petroleum Ltd.

HISTORY: The PB claims were staked for Nissho-Iwai Canada Ltd. in 1972, 1973, and 1974 to cover geological settings similar to the settings of mineralized areas on the Fuki-Donen property (*see* Geology in British Columbia, 1975, pp. G 35, G 36). The Kettle and Uranus claims were staked in 1976 for Tyee Lake Resources Ltd. to cover possible extensions of the mineralized channel on the PB 180–214 and PB 217–249 claims. The Goat, Haynes, Cookson, Freedom, and Tab claims were staked in 1976 for Peregrine Petroleum Ltd. to cover the possibility of favourable ground around the PB 81–148, PB 152, and PB 154–179 claims. From 1973 through 1976 approximately 4 000 metres of drilling has been completed. Geological, geochemical, and geophysical surveys have also been completed in the area but drilling appears to be the most reliable exploration tool.

REGIONAL SETTING: Basal-type uranium deposits have been found at several locations in the Kelowna area in south-central British Columbia (Fig. 5). Uranium occurs in unconsolidated fluvial sediments that are capped by an impermeable horizon, usually Pliocene or Miocene (?) plateau basalts. The uranium-bearing sediments unconformably overlie metamorphic rocks (Monashee Group), Nelson, Valhalla, and Coryell intrusive rocks (Kettle River or Marron Formations), and early Tertiary sedimentary and volcanic rocks. Strong faults occur near mineral deposits but their relationship to the mineralization has not been determined.

Secondary uranium minerals occur as films on pebbles and in the matrix of unconsolidated or loosely consolidated conglomerate and carbonaceous sediments in paleo-stream channels. Meta-autunite from the Dear Creek area is the only uranium mineral that has been identified. The name gummite has been applied to a black, sooty alteration product of uranium minerals that occur with massive iron sulphide in the deposit near Hydraulic Lake.

Figure 6 is an idealized section showing typical settings for basal-type deposits in south-central British Columbia. Uranium mineralization occurs in groundwater traps at several horizons within basal sediments that underlie an impermeable capping. Uranium minerals are generally found at or near an unconformity.

LOCAL GEOLOGY: The general geology of the Hydraulic Lake area is shown on Figure 7. Plateau basalt occurs in three separate areas and in each area unconsolidated, mineralized sediments are situated below the plateau basalts. The mineral deposit northwest of Hydraulic Lake is partly capped by basalt and partly by clay-rich, metamorphic rocks (Monashee Group), Nelson, Valhalla, and Coryell intrusive rocks (Kettle River Formation), and early Tertiary sedimentary and volcanic rocks. The average thickness of the plateau basalt unit is about 50 metres (164 feet) and up to 74 metres (242.8 feet) of underlying sediments occurring in paleo-stream channels. The maximum thickness of reported mineralization is 25.9 metres (85 feet) in diamond-drill hole 76–22 (110.1 to 195.1 feet at 1.1 pounds U_3O_8 per ton; George Cross Newsletter, 1976, No. 216).

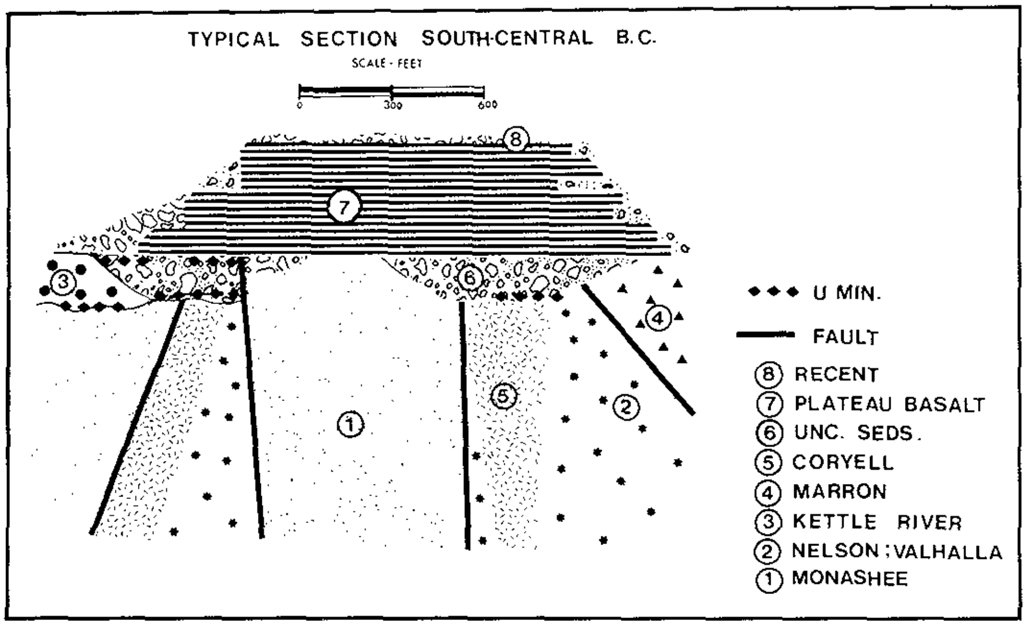

Figure 6. Favourable environments for uranium deposition in south-central British Columbia.

Prominent, steeply dipping northwesterly and northeasterly trending faults occur in the vicinity of the mineral deposits but their role in directing and locating uranium-bearing groundwater has not been determined. Deeply weathered basement rocks encountered in drilling could be related either to faults or to a mid-Tertiary episode of weathering and erosion. Oxidation and weathering of basement rocks play a major role in making uranium leachable by groundwater.

MINERALIZATION: Secondary uranium minerals occur in unconsolidated or loosely consolidated carbonaceous sediments. The term gummite is used for alteration products containing uranium and no specific uranium minerals have been identified. Massive iron sulphide cements sediments near the unconformity with basement rocks. Because higher grade uranium sections often have significant iron sulphide content, geophysical methods have been used in an attempt to locate sulphide accumulations.

The distribution of uranium deposits in the Hydraulic Lake-Haynes Lake area is mainly controlled by paleo-stream channels. Uranium mineralization occurs in fluvial sediments deposited near the heads of paleo-streams in their tributaries.

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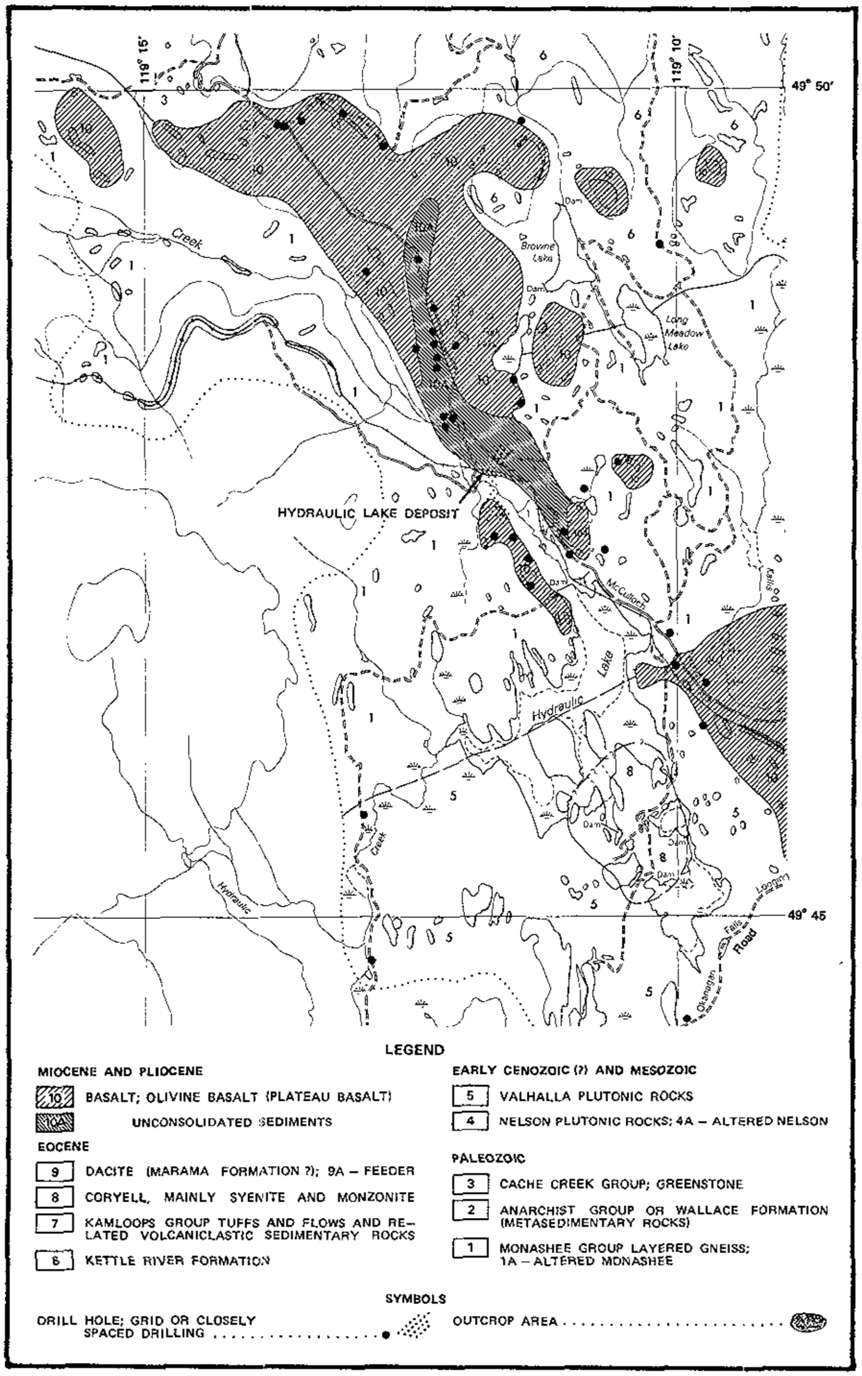

Figure 7. Geological setting of the Hydraulic Lake uranium deposit (modified from company assessment reports).

GOLDSTREAM DEPOSIT (82M/9W)

By Trygve Höy

INTRODUCTION: The Goldstream deposit is a stratabound massive sulphide layer in metasedimentary rocks of probable Late Proterozoic age (Brown, Höy, and Lane, 1977). It is located at an elevation of 700 metres just south of Goldstream River in the Selkirk Mountains in southern British Columbia. The deposit is accessible by road from Revelstoke, 90 kilometres 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; rock exposures are rare. Above treeline, at 1 800 and 1 950 metres elevation, exposures are abundant although precipitous cliffs, névé, 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 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, 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 per cent copper, 3.123 per cent zinc, and 20 grams per tonne silver. In 1976 an adit was driven south to the mineralized zone, and an east-west drift developed along the zone (Plate VI).

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

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 Brown, Höy and Lane (1977).*

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.

Tight to isoclinal north-trending folds with nearly horizontal to steeply east-dipping axial surfaces dominate the structure of the Goldstream area. 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 rocks in the Goldstream area were divided into five major lithologic packages. These include dominantly pelitic and calcareous schists and marble exposed east of the Goldstream deposit (Fig. 8) that are tentatively correlated with the Late Proterozoic Horsethief Creek Group (Brown, Höy, and Lane, 1977). They are overlain by a succession of rocks that has been split 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.

Based on a number of stratigraphic tops recognized in the Goldstream area, the sequence of rock units outlined above is believed to represent an original stratigraphic succession, with rocks correlated with the Horsethief Creek Group being the oldest, and the dominantly calcareous rocks of the carbonate-phyllite division, the youngest.

Metasedimentary rocks of the quartzite-schist division south of the Goldstream pluton (Fig. 8) comprise at least several thousand metres of pelitic schist interlayered with micaceous quartzite, massive thick-bedded pure to micaceous quartzite, and thin-bedded interlayered pelitic schist, rusty weathering hornblende gneiss, and calcareous phyllite.

Thin-bedded, rusty weathering calcareous phyllite and quartzite, pure to siliceous marble, and biotite gneiss of the calc-silicate gneiss division overlie the dominantly siliceous rocks of the quartzite schist division. These are exposed along the southern margin of the Goldstream pluton.

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 is a massive, fine to medium-grained greenstone that is composed primarily of chlorite, actinolite, epidote, plagicoclase, and minor carbonate. Analysed samples from within the Goldstream area and to the east are within or along the edge of the "basalt" field of Church's (1975) triaxial oxide plot (Lane 1977; sample H76 G19-1, Table 2). 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 VII). The massive greenstone is

* Bulletin 71 (Höy, 1979) describes in more detail the regional geology of the Goldstream area, as well as the geology of the Goldstream deposit and other deposits in the area.

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 chlorite phyllite that may originally have been pyroclastic or volcaniclastic rocks.

In the Standard area (Fig. 8) coarse-grained ultramafic talc-chlorite-serpentine dolomite pods overlie grey limestone and are overlain by a coarse-grained intrusive diorite and *massive greenstone.*

Dark grey to black calcareous phyllite is common in the 'metavolcanic-phyllite' division (Plate VIII). It has a well-defined foliation outlined by micaceous minerals, dark carbonaceous material (graphite?), and the alignment of clear quartz eyes. Grey limestone and discontinuous thin chlorite phyllite layers are common in the calcareous phyllite unit.

Dolomite, limestone, and calcareous phyllite of the carbonate-phyllite division overlie rocks of the metavolcanic-phyllite division. The carbonates are typically grey to buff-coloured, thin-bedded limestone or dolomite interlayered with less pure rusty weathering calcareous schist, biotite schist, and less commonly chlorite schist. Both Keystone and Downie Peaks (Fig. 8) are composed of massive limestone, considerably thickened in the fold cores.

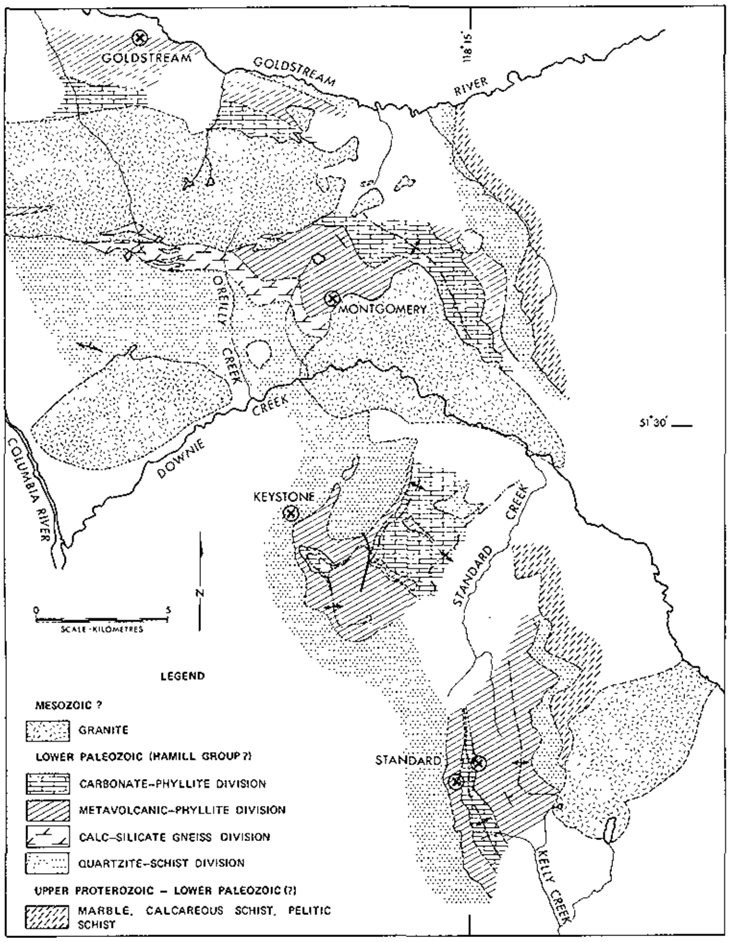

Figure 8. Regional geology of the Goldstream area showing location of important mineral deposits (after Brown, Höy, and Lane, 1977).

Plate VII. Pillows (outlined by felt pen) in basalt on ridge northeast of Keystone Peak.

Plate VIII. Dark calcareous phyllite from core of Standard antiform showing style of late folds.

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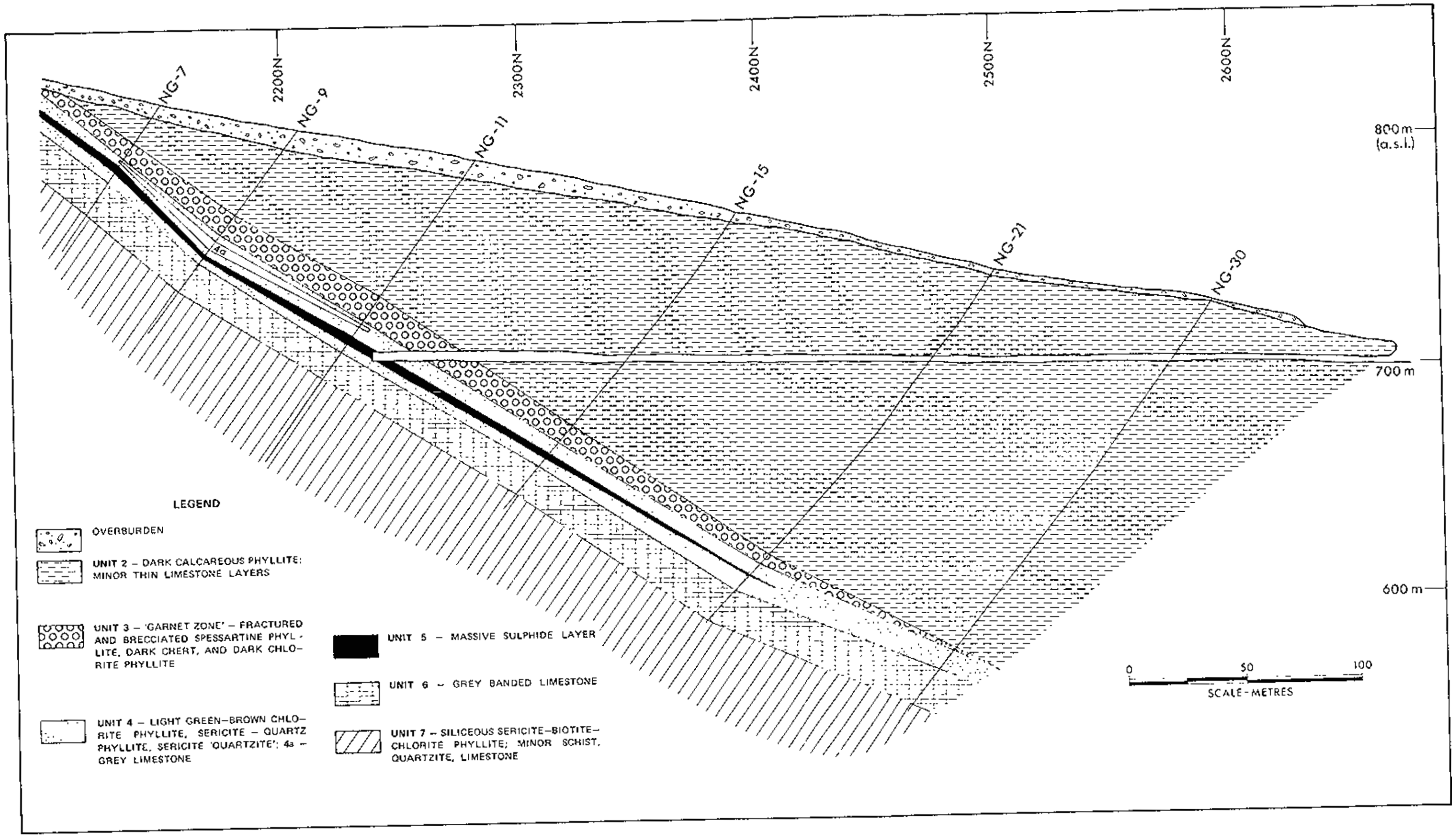

Figure 9. North-south vertical section (5300 E) through the Goldstream deposit.

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 have been correlated with a more calcareous western facies of the upper part of the Proterozoic Horsethief Creek Group of Hadrynain age (Brown, Höy, and Lane, 1977) and the overlying package of psammites, grits, pelites, and metavolcanic rocks are tentatively correlated with the Eocambrian Hamill Group. Rocks of the metavolcanic-phyllite division and the bulk of the overlying carbonate-phyllite succession may correlate with the upper part of the Hamill Group or the Mohican Formation, and the thick carbonate that is exposed in the core of the Downie and Keystone antiforms may be the Badshot Formation.

STRUCTURE: Tight to isoclinal east-dipping to recumbent folds dominate the structure of the Goldstream area. They have well-developed axial plane schistosities and variable, but generally northeast trending fold axes. A number of stratigraphic top determinations in graded grit beds indicate that younger metasedimentary rocks are exposed in the cores of large antiformal structures in the Downie Peak area (just northwest of the Montgomery occurrence, Fig. 8 and Plate IX), and in the Keystone and Standard areas. This suggests (Lane, 1977; Brown Höy, and Lane, 1977) that these folds developed in an inverted stratigraphic panel, believed to be the underlimb of an earlier (Phase 1) recumbent nappe. Minor structures that can be related to Phase 1 deformation are not obvious; it was not possible to assign many rootless, isoclinal fold hinges to Phase 1 or Phase 2.

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

GOLDSTREAM DEPOSIT: The Goldstream deposit is a sheet of massive sulphides in calcareous and chloritic phyllite that ranges to 4 metres in thickness, is 400 metres wide, and at least 1 200 metres long. Surface exposures are restricted to a number of weathered pits where the south end of the deposit subcrops. A pronounced mineral foliation, crenulation cleavage, small-scale late folds, and brecciation, quartz-carbonate veining, and fault gouge in the hangingwall phyllite are the obvious structures observed underground.

Rock Units: The Goldstream deposit is within the metavolcanic-phyllite division described above. Figure 9, a north-south vertical section through the deposit, illustrates the sequence of metasedimentary rocks above and below the deposit. Unit 1 (structurally above the section of Fig. 9) includes siliceous chlorite-biotite phyllite, phyllitic quartzite, calcareous and graphitic phyllite and a few impure limestone layers.

Unit 2 includes approximately 220 metres of dark carbonaceous 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 produce a well-defined foliation, and augens of quartz and carbonate and the abundant limy partings give this rock a distinctive layered appearance (Plate X). Chemical analyses of a number of samples of unit 2 are given in Table 2.

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 (Plate XI). 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 (Plate XII). Pyrrhotite may be very abundant, concentrated in layers or in discontinuous streaks, and grunerite occurs in some dark siliceous layers. Chemical analyses of unit 3 show an abnormally high manganese content and only trace copper and zinc (samples NG-D, NG-E, 17099M, Table 2).

TABLE 2

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	0.36±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*	67ppm*	<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	0.57±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).

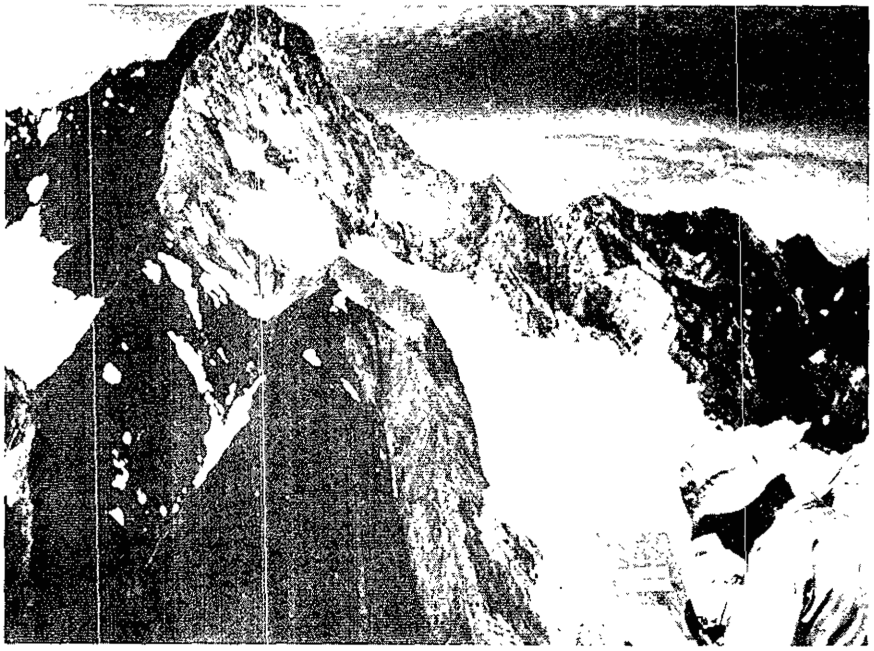

Plate IX. Limestone in the core of the Downie antiform in Downie Peak, viewed toward the northeast (courtesy of R. L. Brown, Carleton University).

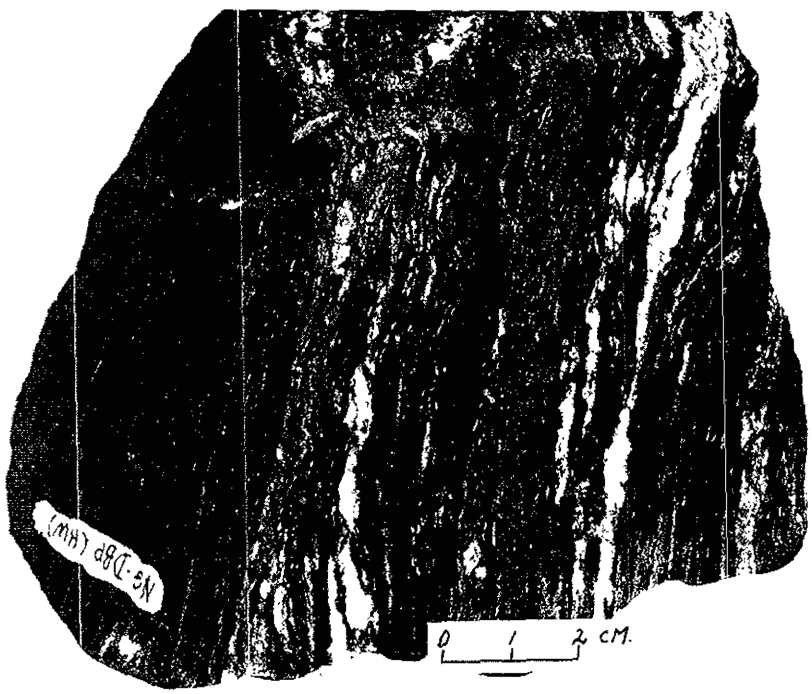

Plate X. Unit 2, Goldstream deposit. Dark calcareous phyllite, light bands are quartz and reflecting grains are pyrrhotite.

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

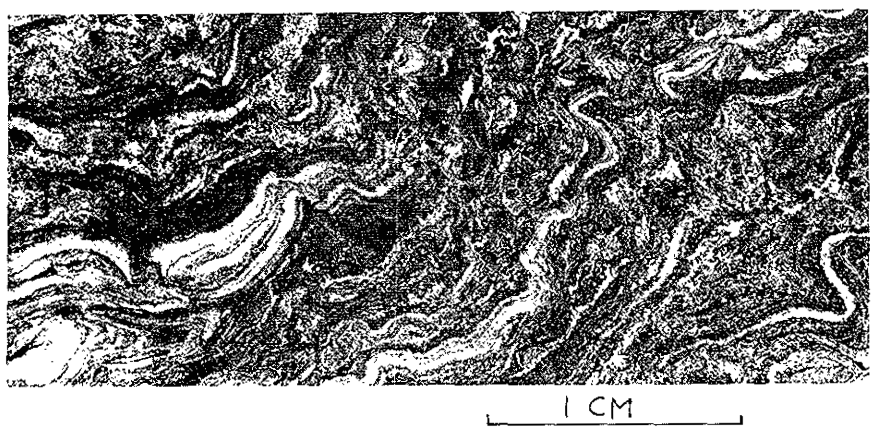

Plate XII. Unit 3, Goldstream deposit (diamond-drill hole NG 14, 427 feet). Folded chert-spessartine garnet layers; light mineral is pyrrhotite (sample width, 3.5 centimetres).

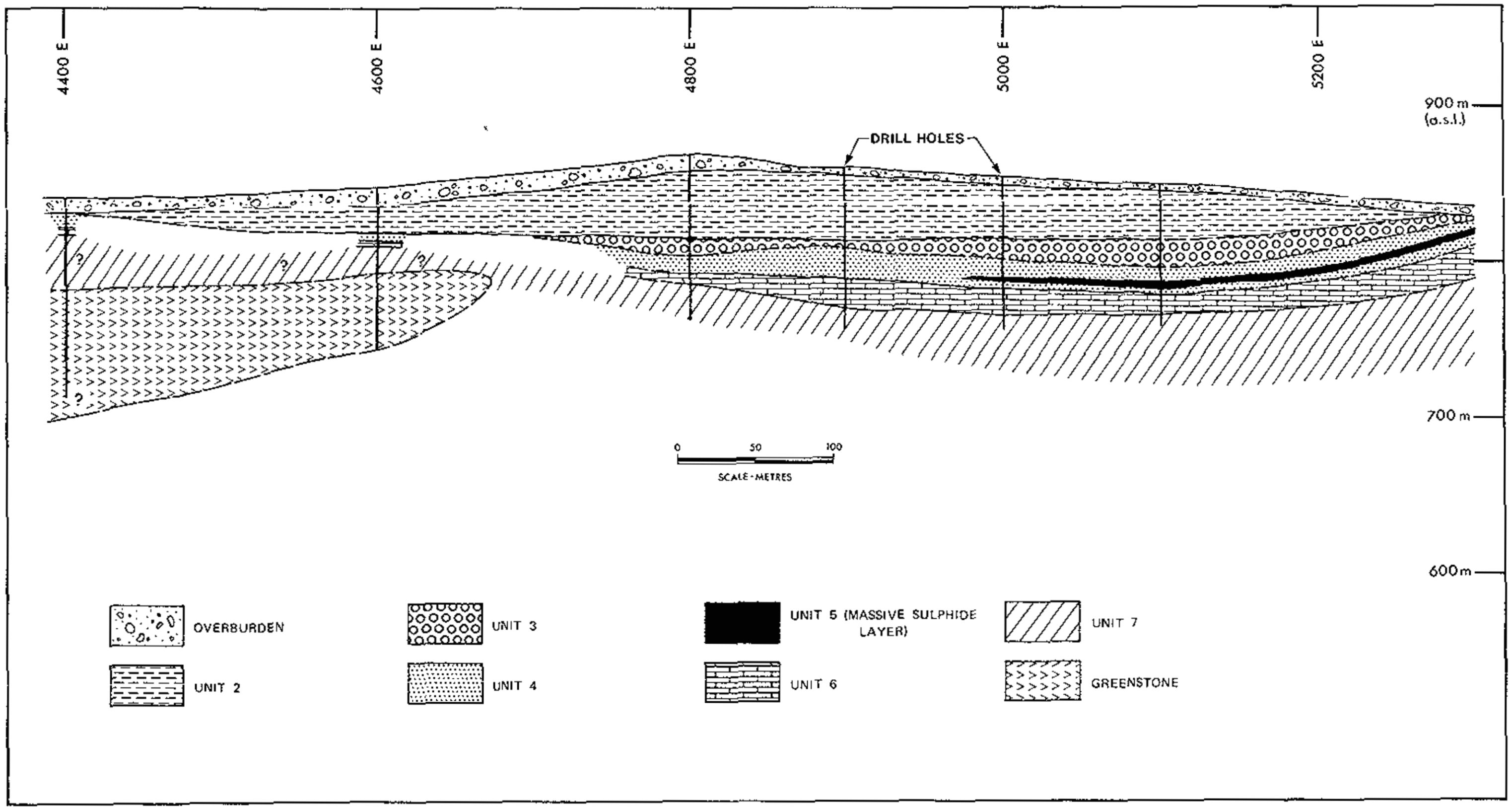

Figure 10. East-west vertical section (2100 N) through the Goldstream deposit.

TABLE 3. 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	10.8±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).

The garnet zone is sheared and broken, and cut by numerous quartz-carbonate layers. The garnets predate 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.

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 XIII). 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. 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 dark, layered siliceous rocks.

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.

Greenstone was encountered in three drill holes west of the deposit (Fig. 10). The author believes that the greenstone lies structurally below the mineralized horizon as a grey limestone lying above it is tentatively correlated with the footwall limestone (unit 6). However, Noranda geologists correlate the grey limestone with unit 4 implying that greenstone is approximately stratigraphically equivalent to the massive sulphide layer. 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: The massive sulphide-layer (unit 5) averages from 1 to 3 metres in thickness, has a strike length of at least 400 metres, and a plunge length of at least 1 200 metres (Fig. 11a). Underground drilling by Noranda indicates that the massive sulphide layer splits into two layers in the western part of the deposit (Fig. 12). Only its western and truncated southern boundaries are defined. Its northern boundary is open, although it continues at least as far as the Goldstream River where it is 350 metres below surface. Its eastern boundary is restricted by a barren hole (at 25+62N, 59+00E) approximately 300 metres east of the last known sulphide mineralization. Analyses of massive sulphide ore and hangingwall and footwall mineralization are presented in Table 3.

The sulphide layer consists largely of pyrrhotite, chalcopyrite, sphalerite, and trace galena. Pyrite is rare, occurring primarily in fractures or shears that cut the massive sulphides. The sulphides are generally medium to coarse grained and intimately mixed (Plates XIV, XV, XVI). However, finely recrystallized (<0.004 millimetres) admixtures of pyrrhotite and sphalerite are noted in thin section. Sulphides generally have a granular texture, although streaking and shearing is fairly common, particularly toward the boundaries of the sulphide layer and there the finer grain size is more common. 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, 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.

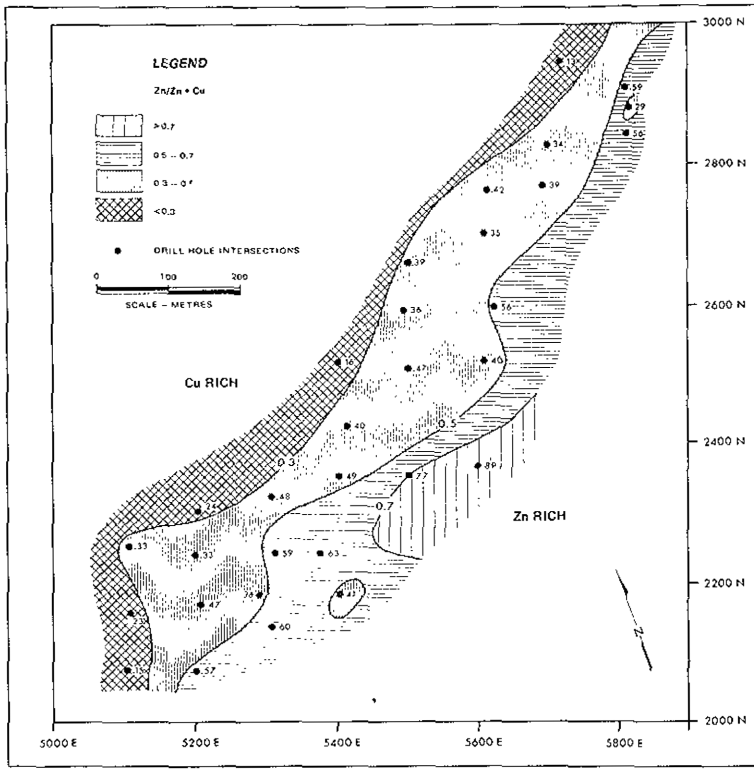

Figure 11a. Weighted Zn/Zn + Cu ratios, massive sulphide layer, Goldstream deposit.

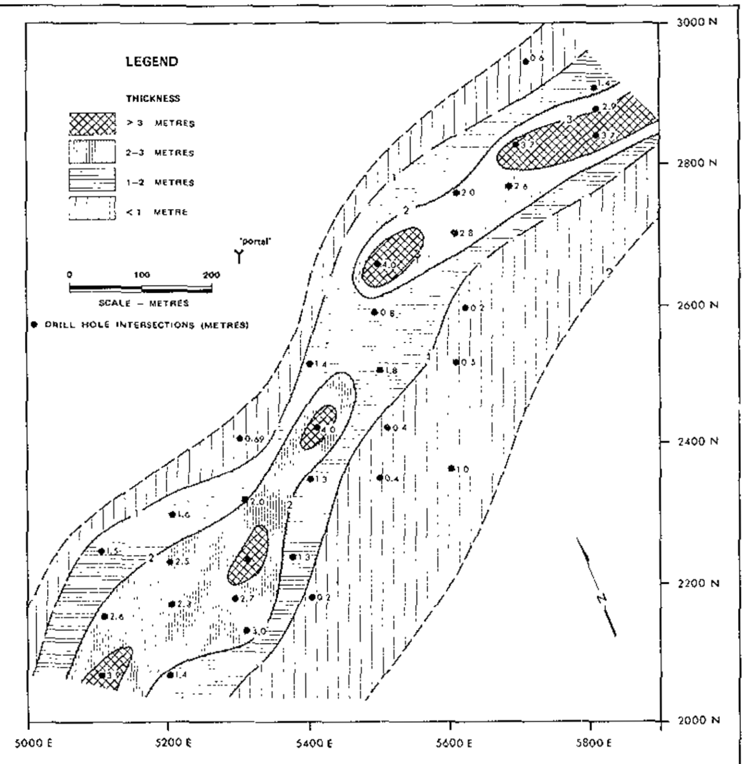

Figure 11b. Isopach map of massive sulphide layer (>40 per cent sulphides), Goldstream deposit.

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 XVII). 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 and restricted to a considerably lesser stratigraphic interval below the massive sulphide layer. They occur 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. 11b). This tendency for increasing relative abundance of copper to the west is not apparent in either the hangingwall or footwall mineralization 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 average of Zn/Zn + Cu ratios in the hangingwall and massive sulphides are very similar, and in the footwall, slightly less (Table 4). Chip samples 0.65 metres in length (see Fig. 12 for location) from the hangingwall through to the base of the massive sulphide layer (Table 3, samples NG-1 to NG-5) show a general tendency toward higher metal values toward the base with a corresponding decrease in silica. This is not a general trend throughout the deposit.

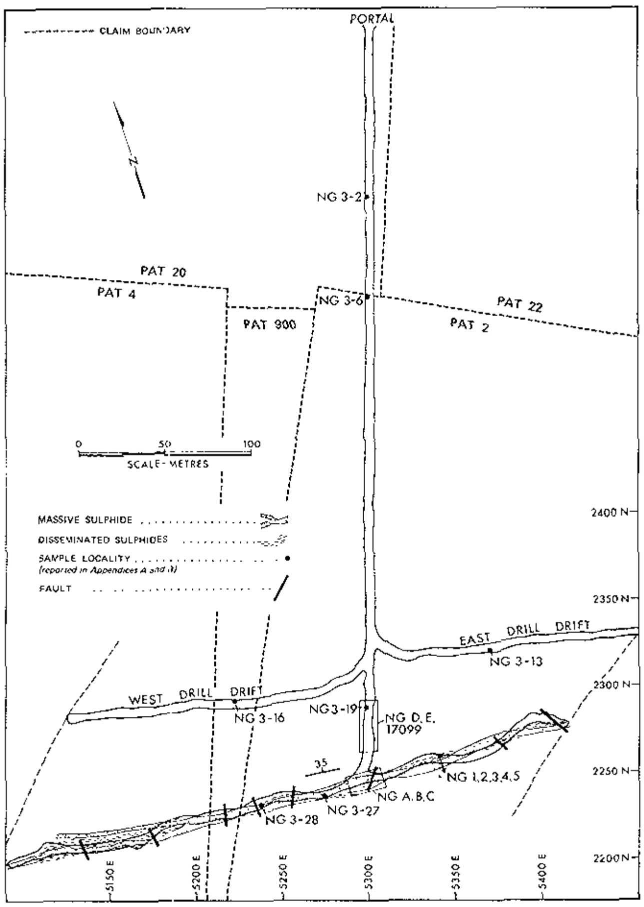

Figure 12. Plan view of underground workings, Goldstream deposit (after Noranda Exploration Company, Limited's plans) and locations of analysed rock samples.

TABLE 4. COMPARISON OF HANGINGWALL, MASSIVE SULPHIDE AND FOOTWALL MINERALIZATION

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

	Maximum Tickness	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%	F(.46)	0.33	(0.23)

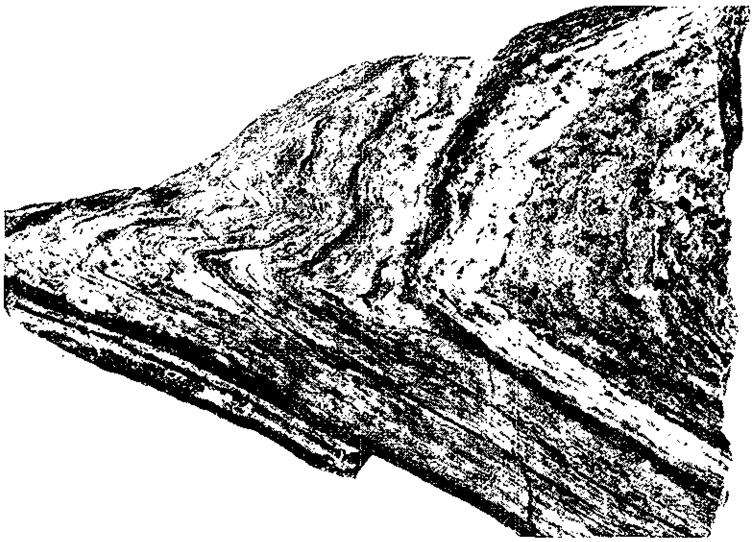

Plate XIII. Unit 4, Goldstream deposit. Fold in fine-grained sericite quartzite. Chalcopyrite and pyrrhotite are disseminated through the sample.

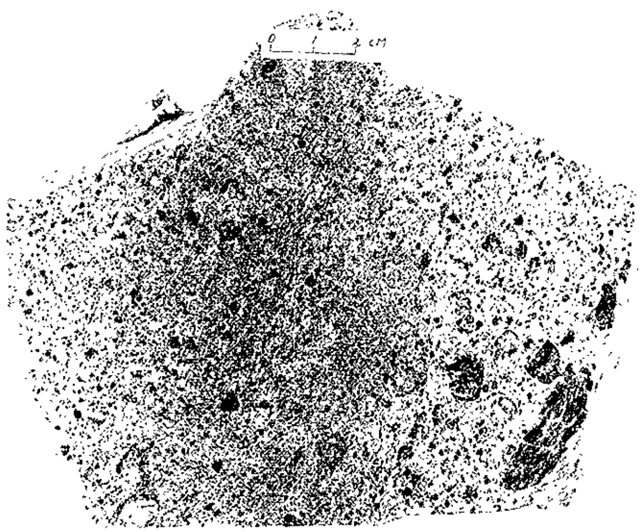

Plate XIV. Massive sulphides (unit 5), Goldstream deposit. Note gneissic texture of sulphides, intimate intermixing of chalcopyrite (lighter coloured) and pyrrhotite, and preferential concentration of chalcopyrite in pressure shadows of dark siliceous fragments.

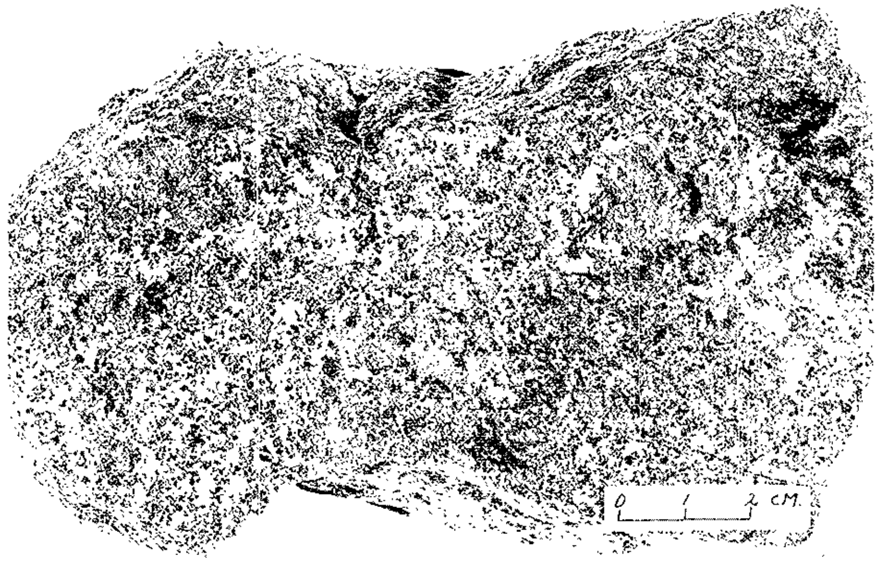

Plate XV. Equigranular chalcopyrite, sphalerite, and pyrrhotite in a fine-grained, light grey quartzite matrix, Goldstream deposit.

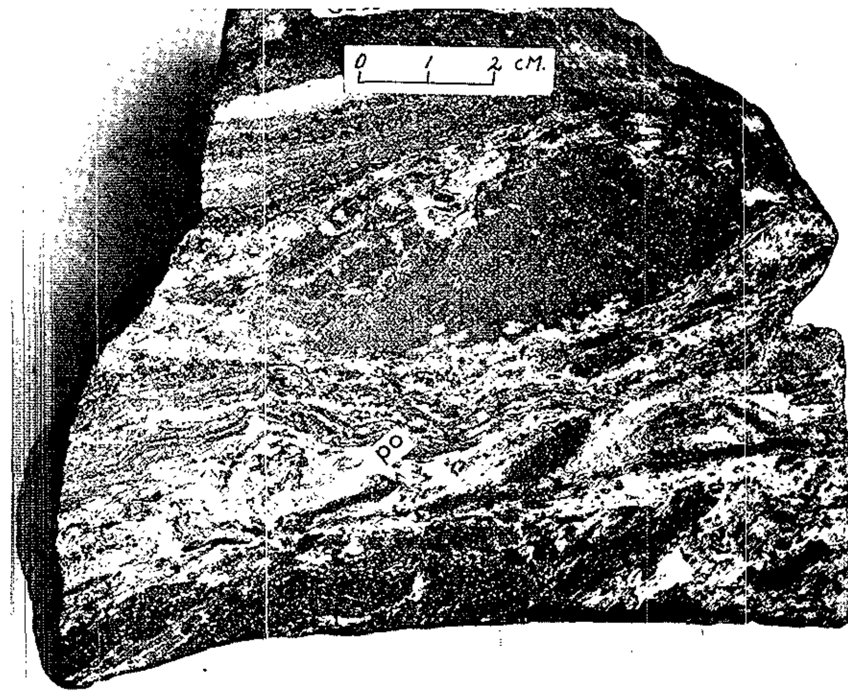

Plate XVI. Siliceous ore, Goldstream deposit. Fine-grained, light grey sericite quartzite intimately interlayered and swirled with gneissic pyrrhotite-chalcopyrite. Large augens of quartzite and pure quartzite layers (near top of specimen) contain abundant finely disseminated pyrrhotite (po = pyrrhotite).

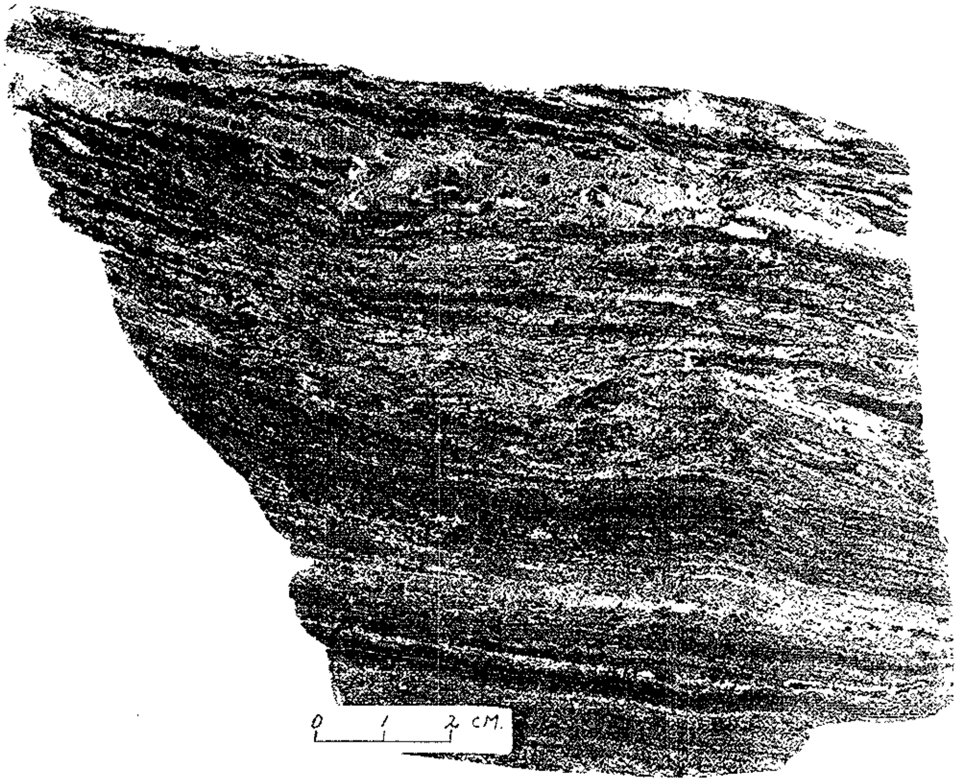

Plate XVII. Disseminated and layered chalcopyrite and pyrrhotite in dark grey chlorite-quartz rock immediately above massive sulphide layer, Goldstream deposit.

CONCLUSIONS: The Goldstream deposit 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 modified (fairly substantially) 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.

A number of features of the hangingwall may be contrasted with the footwall to suggest that the Goldstream deposit is inverted. 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.

Consideration of regional structures in the Goldstream area also suggests that the sequence of rocks in the immediate vicinity of the deposit is 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 swing east/west just northwest of Downie Peak and are located south of the deposit in the Goldstream area.

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.

A number of features of the deposit indicates that it has been intensely deformed and metamorphosed along with the country rocks. These include the common gneissic textures of sulphides, locally contorted and brecciated sulphide wall-rock contacts, rounded gangue inclusions ("Durchbewequng" fabric described by Vokes, 1969) and the overall geometry of the deposit. 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 Goldstream deposit is one of a number of stratabound massive copper-zinc deposits in the area. They are hosted by either basic volcanic rocks (Standard) or metasedimentary rocks spatially associated with basic metavolcanic rocks. They 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).

ACKNOWLEDGMENTS: Discussion with Noranda geologists, Gordon Gibson, Brian Hughes, Laurie Reinertson, and the late Walter Nelson, and with Don F. Sangster of the Geological Survey of Canada regarding the geology of the Goldstream deposit and other massive sulphide deposits were most helpful. Field assistance by A. Doherty is gratefully acknowledged.

R. L. Brown of Carleton University introduced me to the geology of the Northern Selkirk Mountains, and regional mapping by him, L. Lane also of Carleton University, and myself were combined and published as a Ministry preliminary map (Brown, Höy, and Lane, 1977). This mapping forms the basis of Figure 8 in this paper and the discussion on regional geology.

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STANDARD (82M/8E)

By Trygve Höy

The Standard property is located in the Goldstream area (*see* Fig. 8, Goldstream report) at the headwaters of Standard Creek near Standard Peak. It 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 XVIII and XIX). Three of the holes, centred at approximately 95E – 95 + 00N (Fig. 13), 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. 13). Limestone and dark graphitic and calcareous phyllite of the carbonate-phyllite division (*see* Goldstream report) 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 5.

Massive sulphide mineralization on the Standard property is most dominant within a distinct stratigraphic interval in the greenstones (unit 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 and zinc, from 0.3 to 1 per cent. Analyses of two grab samples of sulphide mineralization are given below:

Sample Number	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

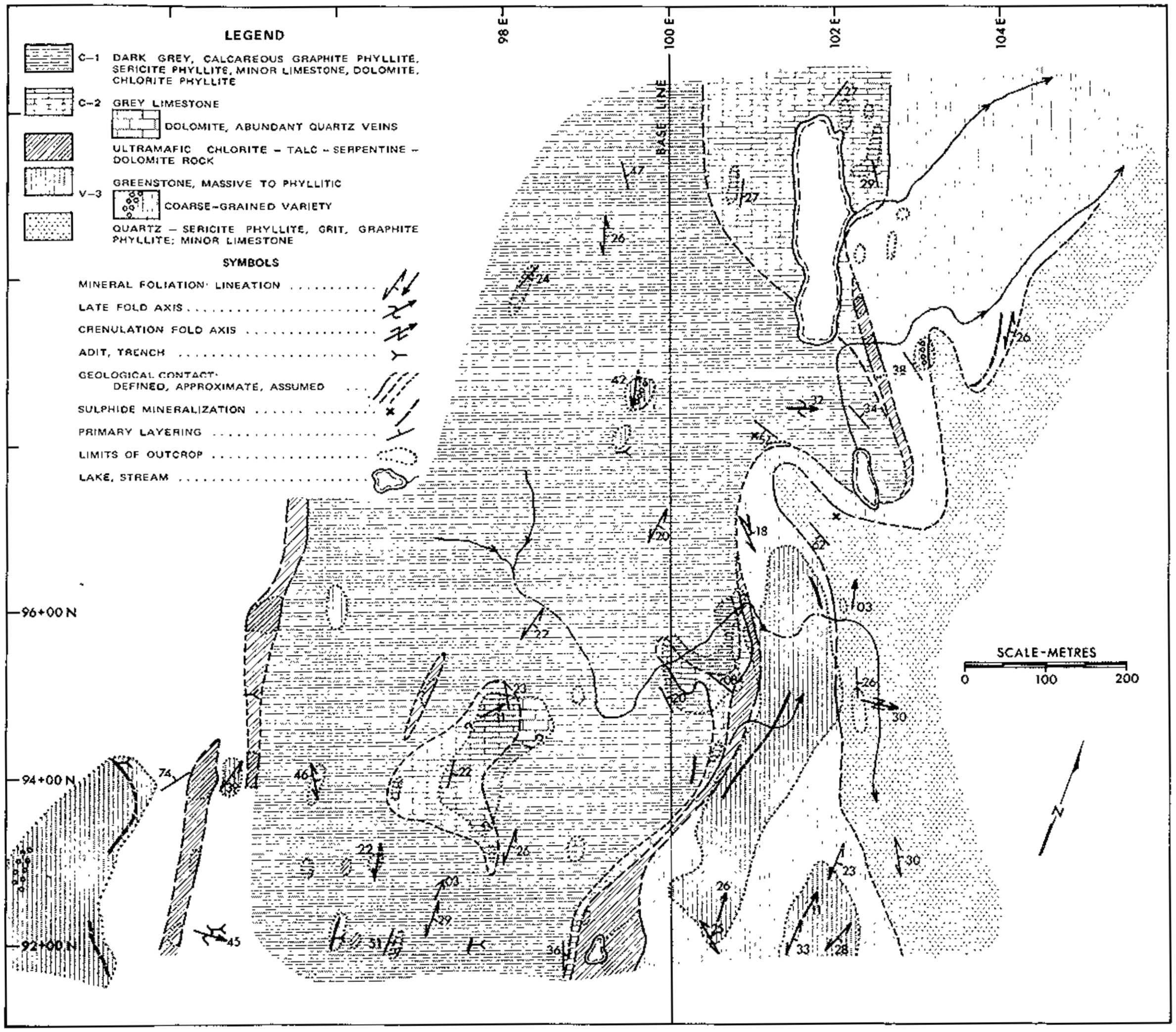

Figure 13. Detailed geology of the Standard basin.

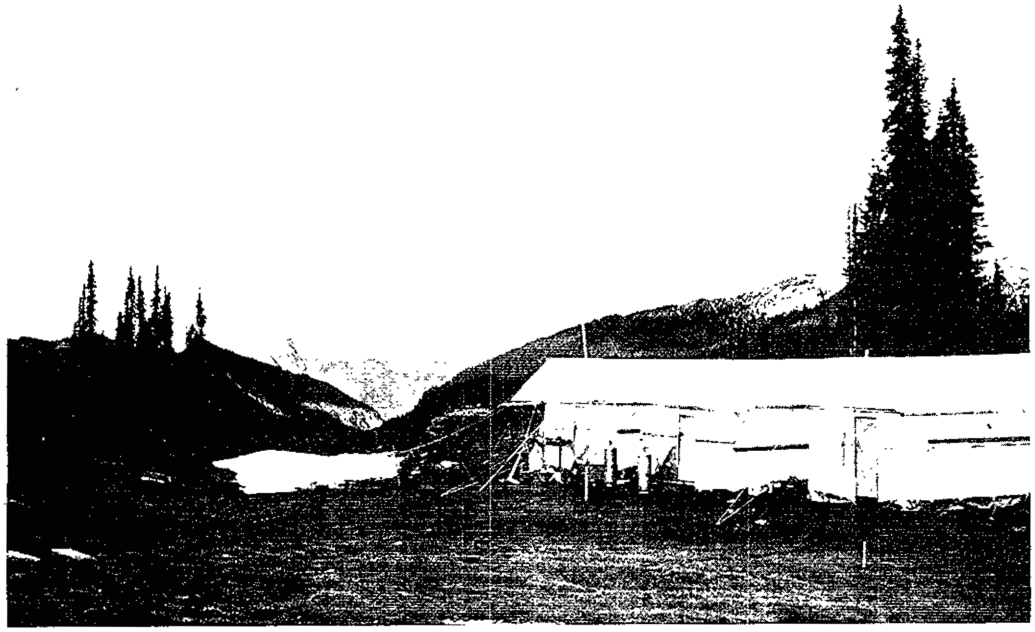

Plate XVIII. Base camp at Standard, August 1976; view looking northward across Downie Creek.

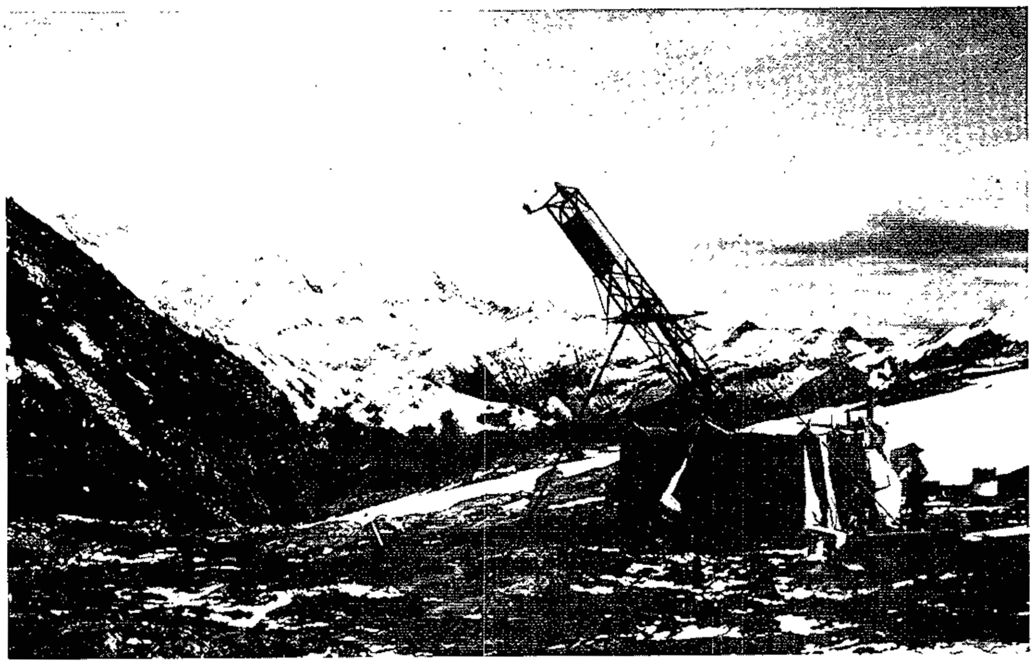

Plate XIX. Drilling at the Standard property in September 1976; Carnes Peak is in the background.

TABLE 5. 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
	C-1	>150	Dark-banded calcareous phyllite; carbonaceous phyllite; minor limestone and chlorite phyllite.
CARBONATE-PHYLLITE	C-2	30	Dominantly grey limestone, minor quartz-rich phyllite, grit, and chlorite phyllite.
		0–15	'Ultramatic layer'—coarse-grained talc-chlorite-serpentine-carbonate unit; rusty weathering.
		~10–100	'Diorite layer'—coarse-grained chlorite-hornblende-plagioclase unit.
METAVOLCANIC-PHYLLITE	V-3	150–200	'Greenhouse'—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.

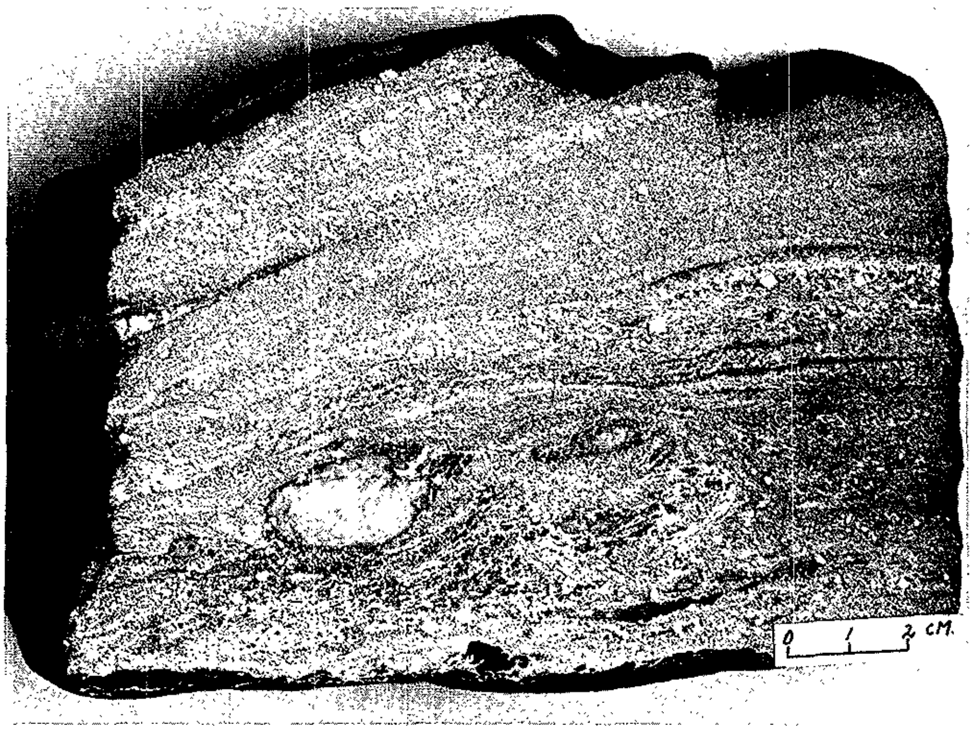

Plate XX. Gneissic sulphide sample from Standard. Fine-grained sulphides are predominantly pyrrhotite with minor chalcopyrite; light-coloured (more highly reflecting) subhedral porphyroblasts are pyrite and silicate fragments are quartz.

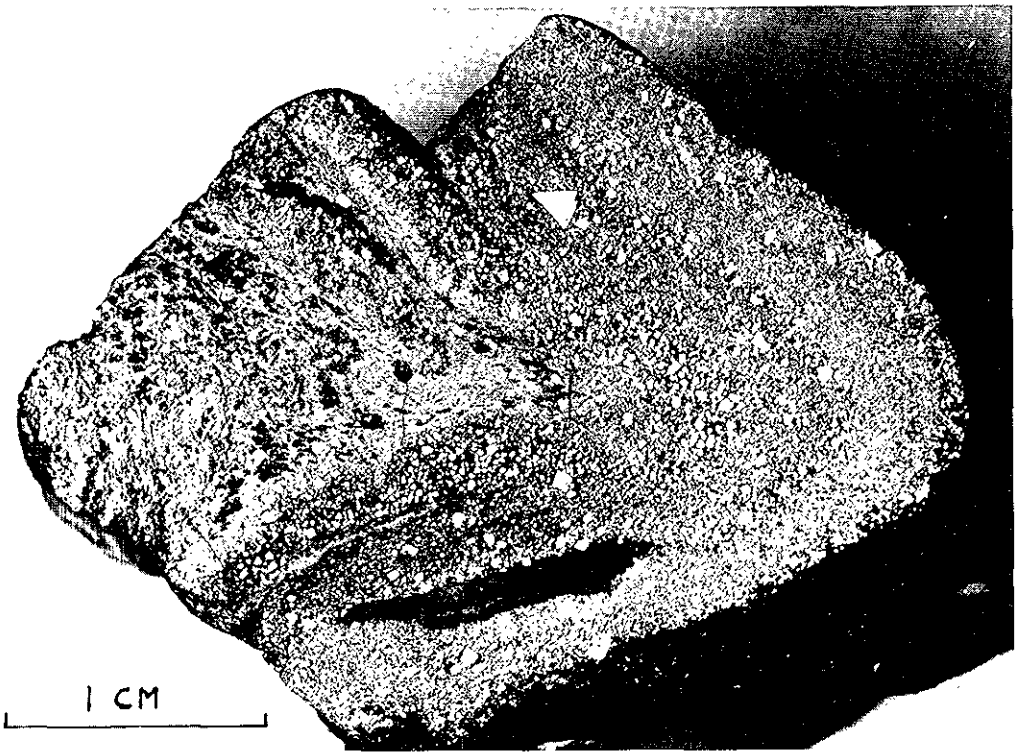

Plate XXI. Small fold in sulphide sample from the Standard property; dominantly pyrrhotite and subhedral to euhedral light-coloured pyrite (sample width, 4 centimetres).

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 XX). 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 XXI).

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

ACKNOWLEDGMENTS: Discussions with Larry Lane of Carleton University and Brian Hughes of Noranda Exploration are gratefully acknowledged. A. Doherty assisted in the field.

References:

B.C. Ministry of Mines & Pet. Res., Assessment Report 5070.

SOUTHWEST BRITISH COLUMBIA

VANCOUVER AND TEXADA ISLANDS

By G. E. P. Eastwood

SR (WET) (92C/15W)

The SR molybdenum prospect is in Alberni Mining Division on the east side of the South Sarita River. It can be reached via Branch 139 and the Sarita access road of MacMillan Bloedel Ltd. from their Franklin camp, which is connected with both Port Alberni and Lake Cowichan.

The SR property was held by J. Sirola in 1963, and was explored by Marshall Creek Copper Co. Ltd. between 1965 and 1968. In 1974 and 1975 it was relocated by Amax Exploration, Inc. as the WET claims, and a geochemical survey was carried out. In 1976 the geology was mapped by D. G. Allen, and 13 line-kilometres of magnetometer and induced polarization surveying was done. The writer visited the property while the mapping was being completed.

Figure 14 is a reduction of D. G. Allen's map, with outcrops, topography, and roads omitted for clarity. In general the area slopes moderately northwest down to the South Sarita River, but some tributaries have cut fairly deep canyons. The country rock has been assigned to the Bonanza Group by J. E. Muller of the Geological Survey of Canada. The predominant rock type is medium to dark grey andesite and possibly latite. In addition to the porphyritic unit shown, the writer observed porphyritic phases in the rocks along the north edge of the area. In the west part of the area a dense white to light grey rock is probably rhyodacite or rhyolite. In places it is laminated and may be bedded tuff. In the central part of the area the volcanic rocks are highly siliceous and may be rhyolites, but in large part they are clearly products of silicification.

Intruding the country rock are two differentiated stocks and a series of dykes. The most extensive intrusive phase is medium to coarse-grained and medium grey or greenish grey in colour; in thin section Allen found sufficient interstitial quartz to classify the rock as quartz diorite. This phase grades to a coarse-grained or porphyritic, light grey rock speckled with ferromagnesian minerals. A pink cast is imparted by interstitial orthoclase, and Allen classified the rock as quartz monzonite. It is also present in the hybrid contact area, where crystals of pink orthoclase are visible in hand specimen. A group of northeast trending feldspar porphyry dykes intrude quartz monzonite and silicified volcanic rocks near the centre of the area. The dykes contain some epidote and chlorite, but otherwise are fresh and probably of post-mineral age. The unit 7 dykes were not seen by the writer. Unit 8 dykes vary from dark greenish grey andesite to a feldspar-poor, greenish black rock. The writer saw two narrow peridotite dykes transecting an andesite dyke which had in turn intruded quartz diorite.

Most of the rocks are cut by northwest and northeast trending faults. One fault appears to have dropped quartz monzonite, quartz diorite, and silicified volcanic rocks down on the southwest and to have offset the feldspar porphyry and porphyritic monzonite dykes to the right. The L-shaped fault in the east part of the area appears to have dropped the southeast side down (Fig. 14).

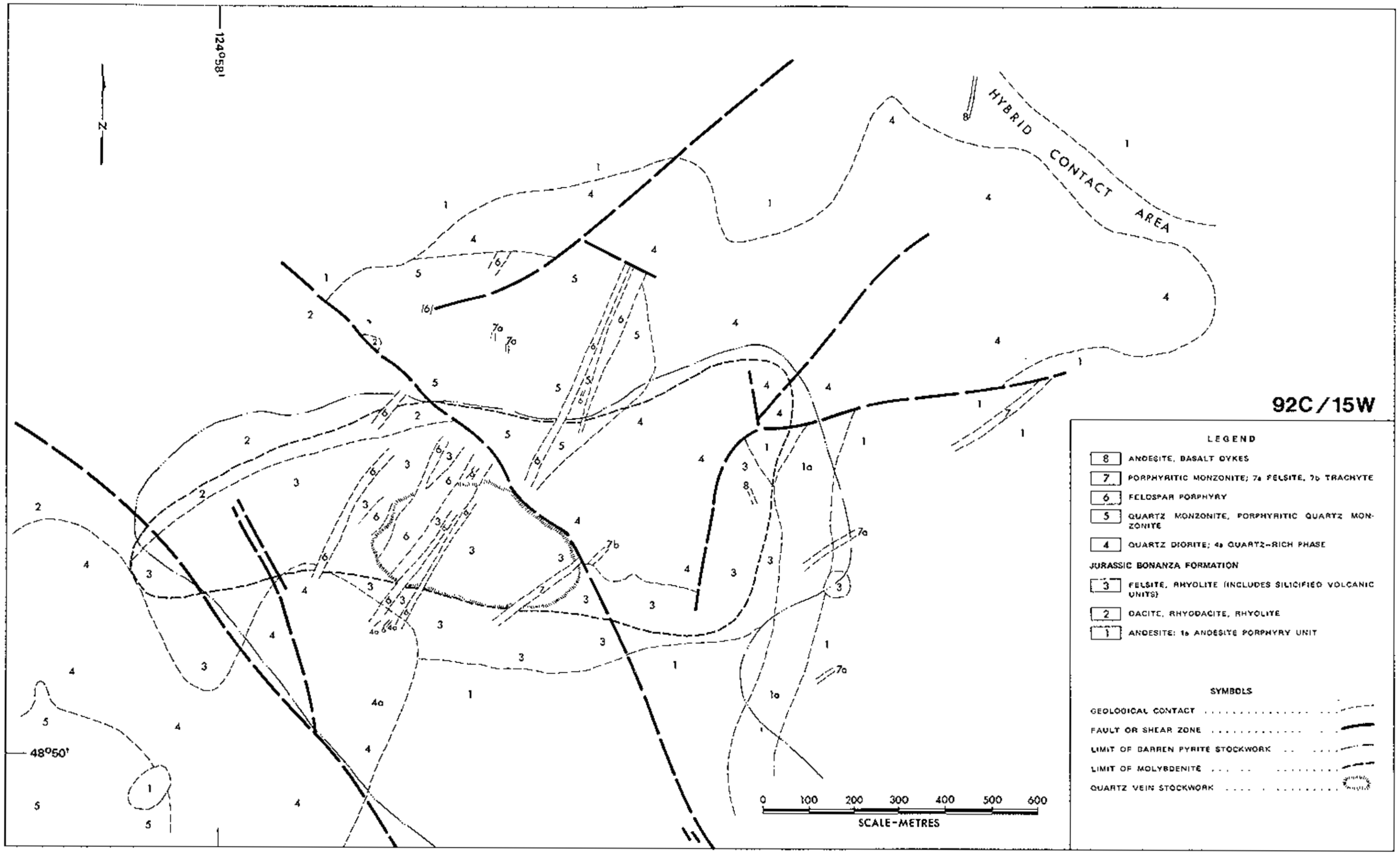

Figure 14. Geological map of the SR (Wet) property (after D. G. Allen, Amax Exploration, Inc.).

In the centre of the area a stockwork of quartz veinlets is developed within the siliceous unit, and forms the core of a much larger stockwork of pyrite veinlets. Molybdenite occurs as fine disseminations in quartz veinlets of the stockwork and as fillings of dry fractures associated with the pyrite veinlets. The pyrite veinlets themselves appear barren of molybdenite. Both the pyrite veinlets and the molybdenite seams continue into quartz monzonite and quartz diorite. Specimens of good grade may be obtained, but the overall grade of the outlined molybdenite-bearing area appears low.

REFERENCES:

Minister of Mines, B.C., Ann. Rept., 1966, p. 77; 1968, p. 104; *B.C. Ministry of Mines & Pet. Res.,* GEM, 1975, p. E.93; Assessment Reports 5772, 6129.

A (92F/2W)

The A claims are west of Port Alberni and south of Sproat Lake. Access is via the Summit Road of MacMillan Bloedel Ltd. from Port Alberni. Copper and iron occurrences are in a broad saddle between the heads of two tributaries of Cous Creek and on a low ridge to the east. They were discovered by the owner, Lawrence Vezina, in 1974 and opened up to varying degrees by trenching and blasting in 1974 and 1975. They were examined and roughly mapped by the writer in 1975, and remapped by planetable in June 1976. Craigmont Mines Limited subsequently optioned the property and did geological mapping and magnetometer and geochemical surveys.

Figure 15 is derived mainly from the planetable survey, with additions from a 1975 tape and compass survey and from part of an enlarged aerial photograph. The Karmutsen Formation is well exposed in the east part of the map-area, and most of the showings occur in it. The Karmutsen rocks are dark greyish green andesite or basalt and are mostly amygdaloidal. The Quatsino limestone is medium grey to white, crystalline, and massive. Caves and sink holes are common. The rocks provisionally assigned to the Parson Bay Formation are black and range from limestone to calcareous argillite. Generally deformed bedding is evident in some exposures. The west side of the map-area is underlain by grey pyroclastic rocks, which are common in the Bonanza Formation. The contact is exposed only in the road cut in the north part of the map-area where carbonaceous limestone is separated from pyroclastic rocks by a few feet of thin-bedded white quartzite interbedded with pale green chert and possibly cherty tuff. A large dyke or small stock of diabase has been intruded along the Karmutsen-Quatsino contact in the south part of the area and forms the host rock of the No. 1 showing. Its age is unknown.

The layered rocks evidently lie in a west-dipping panel which has been broken by at least one fault. Northward from the middle cross-road the course of the fault is marked by a shallow draw and by several caves and sink holes along the edge of the limestone outcrop. However the rock in the nearby outcrops is not markedly sheared and the necessary extension of the fault into the Karmutsen area has no topographic expression. A deep draw extending south-southwest from the middle of the south cross-road may mark the continuation of the fault. Additional structures are suggested by the outcrop of black calcareous argillite in the middle cross-road: the long swamp may mark a fault with downthrow on the west, though folding is also possible. The overburden around and north of the swamps is littered with Bonanza rubble which has probably been transported, and there is no indication of the bedrock.

The nine showings depicted have been described in the 1975 reports. The only additional exposure was at Nos. 1 and 2, and served to confirm the irregular nature of the alteration and chalcopyrite-bornite mineralization and the low overall grade. The best showings are Nos. 4 (magnetite-chalcopyrite) and 7 (chalcopyrite), which have been subjected to limited exploration.

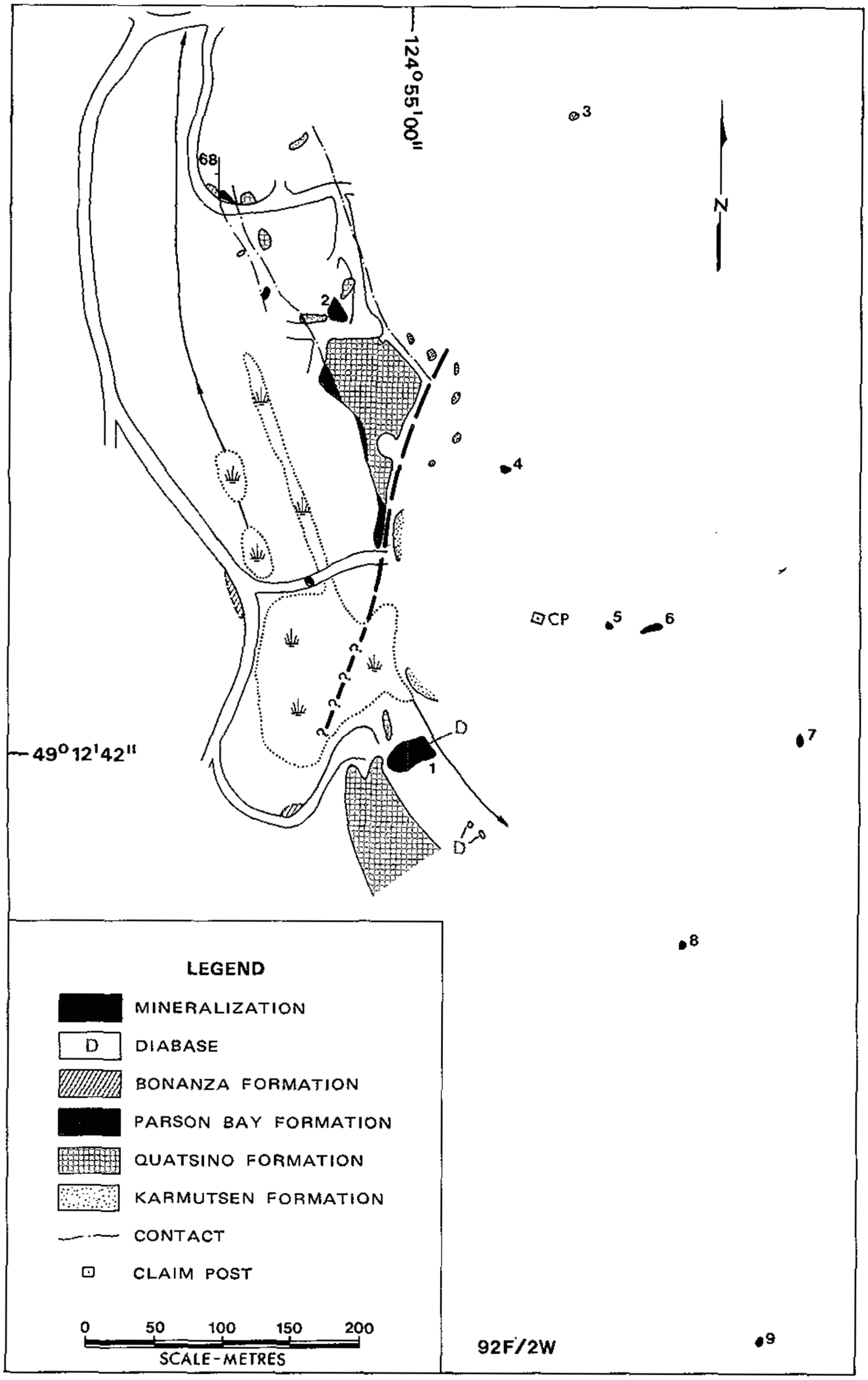

Figure 15. Geology of the A showing.

REFERENCES:

B.C. Ministry of Mines & Pet. Res., Geological Fieldwork, 1975, p. 41; *B.C. Ministry of Mines & Pet. Res.,* GEM, 1974, p. 173; 1974, pp. G44–G46; Assessment Report 5981.

MORNING (92F/6W)

The Moshing property is on the north side of the Taylor River, 4.8 kilometres west of Taylor Arm on Sproat Lake. Access is by 3.9 kilometres of rough road, designated Branch 500, which leaves Highway 4 at 32.5 kilometres from the bridge and marina at the head of Alberni Inlet. A tractor road climbs steeply from Branch 500 to the portal of the main adit at 180 metres elevation.

Exploration may have begun as early as 1907, under the name Silver Star. In 1916 the principal claim was the Columbia, and by 1922 it was relocated as the Morning, which was subsequently Crown granted. Eleven veins were exposed by open cuts and short adits, but the later work was concentrated on the No. 1 vein. An adit was driven in stages, many years apart. In the latest stage in 1975/76, the adit was enlarged and extended 41-metres and a crosscut driven. The work was done under option from Lou-Mex Mines Limited to Highland Mercury Mines Limited. When the property was visited in June, a contractor, Don Amyotte, was diamond drilling three holes from the crosscut to test the vein below adit level. There appears to have been some stoping from the back of the adit, but the only recorded shipment is of 25 pounds for metallurgical testing. The writer mapped the adit by Brunton compass and polychain at 1:480, and it is shown in Figure 16.

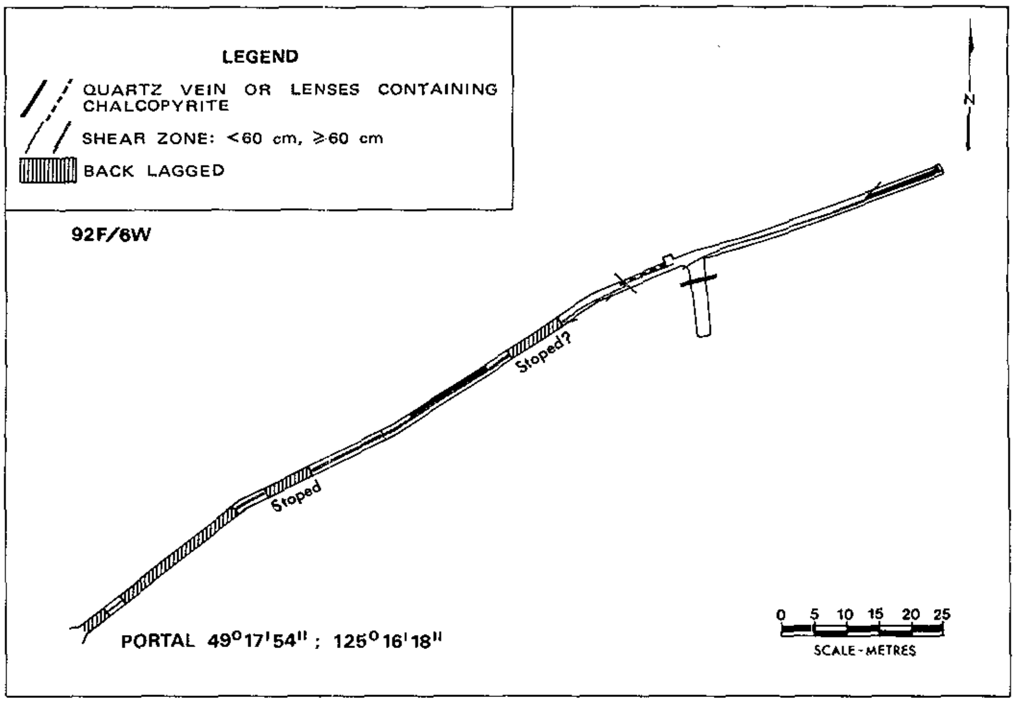

Figure 16. Plan view of the Morning adit.

For most of its length the adit follows a persistent shear zone which has an overall strike of 244 degrees and a northwest dip of 75 to 80 degrees. The wallrock is massive andesite or basalt of the Karmutsen Formation. The outer part of the adit follows a branch which strikes more southerly, and several other branches are shown. It is not clear what happens to the shear zone near the crosscut. The branch followed by the adit pinches out just before the crosscut, but two other branches or shear zones appear in the footwall, one of which is followed by the adit. It may be a continuation of the branch extending into the footwall at the inner end of the lagged section. The main shear zone is generally 60 to 300 centimetres wide, though narrower sections are present; typically its core consists of 20 to 30 centimetres of rusty, strongly sheared, non-gougy rock, which makes a moderate amount of water. Adjacent to it, the wallrock has been variably sheared, bleached, altered, and pyritized.

Lenses and small veins of white quartz are common along both walls of the main shear zone, and are somewhat less common in the Karmutsen rocks away from the shear zone. They are either entirely barren or contain only disseminated pyrite. Chalcopyrite is largely restricted to a series of larger quartz veins along the northwest side of the main shear zone, though near the crosscut some lenses in the hangingwall contain sparsely disseminated chalcopyrite and malachite. Observed chalcopyrite-bearing veins are shown on Figure 16. In addition, chalcopyrite-bearing veins are inferred above the two inner lagged sections. Of the two veins shown, the one closest to the portal is 30 to 90 centimetres wide and contains some disseminated chalcopyrite. The other is initially 30 centimetres wide, but is 60 centimetres wide for the last 8 metres to the face, and well mineralized with chalcopyrite, malachite, sphalerite, and pyrite. A footwall quartz vein, 90 centimetres wide, is exposed in the crosscut 3 metres from the centre of the main shear zone and is well mineralized with disseminated chalcopyrite. It was intersected by the first drill hole from the crosscut, but this hole failed to intersect the main shear zone, suggesting a possible vertical *en echelon* relationship. The central part of the main shear zone appears barren save for a little malachite deposited by the circulating water.

Modest gold values were obtained in the past from samples from the adit, and metallurgical tests in 1927 showed that it is contained in both the pyrite and chalcopyrite. A grab sample from the new face of the adit assayed: gold, 3.5 ppm; silver, 14 ppm; copper, 0.35 per cent.

SELECTED REFERENCES:

Minister of Mines, B.C., Ann. Rept., 1934, p. F4; 1960, p. 110; 1961, p. 103; 1963, p. 121; *B.C. Ministry of Mines & Pet. Res.,* GEM, 1974, p. 176.

SANDY (92F/10E)

This 2-unit claim is on Texada Island, in Nanaimo Mining Division, 500 metres west-northwest of the north end of Paxton Lake. It is reached by a dirt road which branches off the highway to Gillies Bay on Crown-granted Lot 79. The owner, E. T. Johanson of Vananda, prospected the central part of the claim with the aid of a magnetometer and a self-potential instrument, and sank seven test pits in bedrock. Two blind mineralized zones were found.

Figure 17 is based on part of a 1:4 800 topographic map prepared for Texada Mines Ltd. Mr. Johanson located the test pits and intersecting dykes on it, and the writer has sketched in the other dykes and the quarry. The country rock is limestone of the Marble Bay (Quatsino Formation, which is described in some detail by Mathews and McCammon). On the Sandy claim it is generally dark grey in colour, but is locally bleached white. Adjacent to the quarry it is cut by two sets of altered dykes and by a small stock of altered quartz diorite

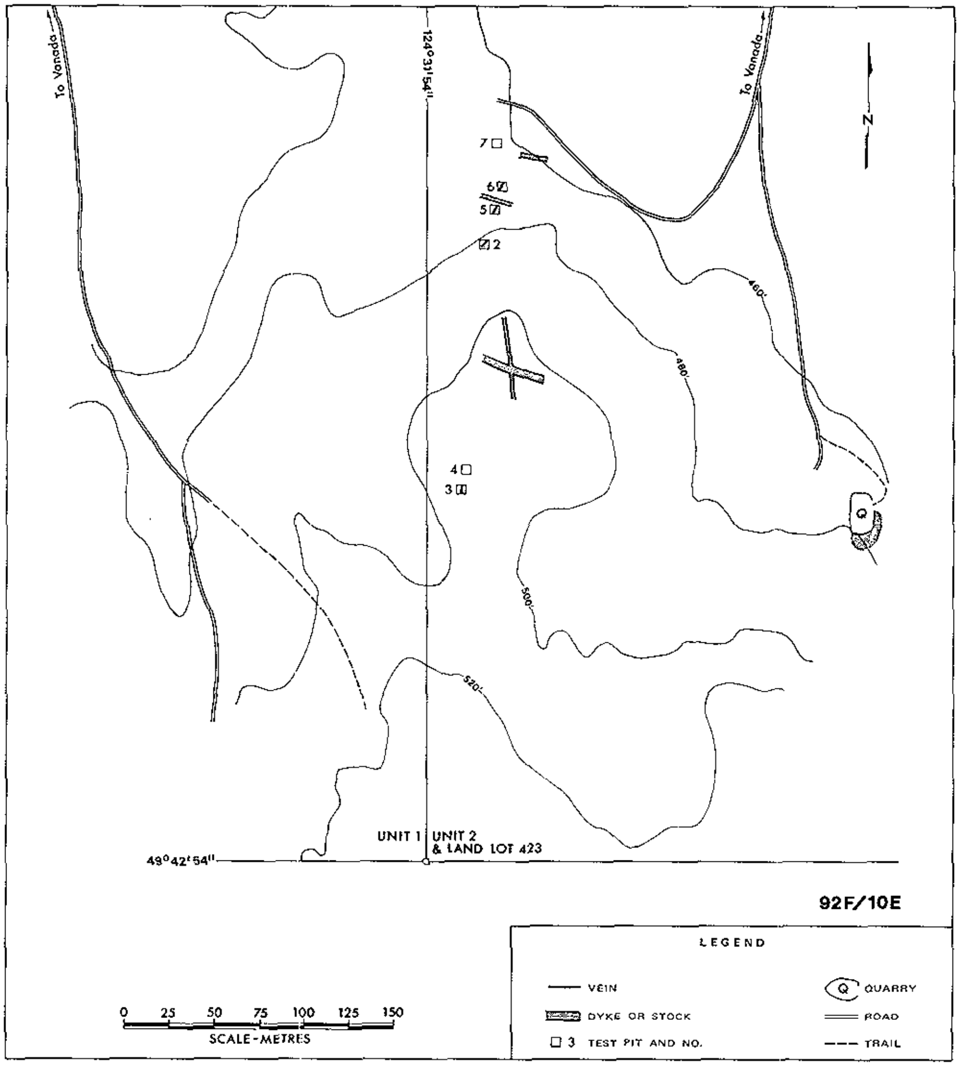

Figure 17. Geology of the Sandy showings.

porphyry. The intersecting dykes are both granite porphyry, but the dyke east of No. 7 pit is dacite porphyry. Considerable solution of the limestone has occurred along the north contact of the more westerly striking of the intersecting dykes.

A zone of bleaching and mineralization strikes 014 degrees through pits Nos. 2, 5, and 6. It attains a maximum width of 75 centimetres in No. 2 pit, but is mainly 30 centimetres wide, and narrows to 20 centimetres at the north end of No. 6 pit. It contains veins of galena, sphalerite, and pyrite. Both bleaching and mineralization die out upward, below the present bedrock surface. No controls are evident in Pits 2 and 5, but in 6 it is bounded on the east by a rusty vertical fracture. There too it is sliced by a 10-centimetre, barren gouge zone striking 029 degrees and dipping 85 degrees northwest. Between these structures and above the bleached zone grey limestone has been brecciated and healed with coarse white calcite.

A second zone of bleaching and mineralization is exposed in No. 3 pit, dying out 30 centimetres below the bedrock surface. It strikes 020 degrees and appears to terminate abruptly at the north end of the pit. The east side of the zone appears to dip east at 60 degrees, but veins on the west side are vertical. The maximum exposed width is 120 centimetres. The bleached limestone contains thickly disseminated pyrite and less sphalerite.

The limestone in the quarry is thoroughly bleached, saccharoidal, and rather friable. It contains a few small seams of pyrite, chalcopyrite, and sphalerite.

Pyrite and pyrrhotite are very finely disseminated in the north side of the dyke east of pit No. 7, and probably account for a broad self-potential anomaly.

REFERENCES:

Mathews, W. H. and McCammon, J. W. (1957), *B.C. Ministry of Mines & Pet. Res.,* Bull. 40, pp. 52–58.

FAITH LAKE (RIM) (92F/11W)

Faith Lake is a tarn at 1 200 metres elevation between Mount George V and an unnamed peak southeast of Mount Albert Edward. It is drained by Eric Creek, which descends very steeply to the end of the old road at 600 metres elevation. Access was made to the west end of the lake by helicopter from Campbell River.

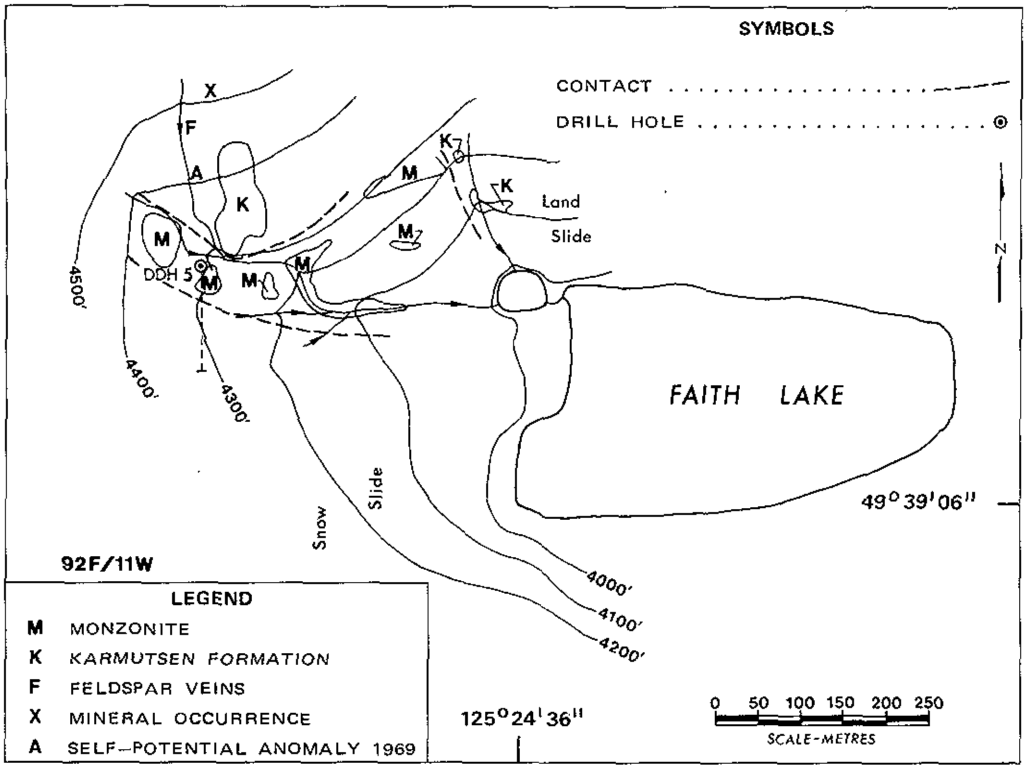

Figure 18. Geological sketch map of the area above Faith Lake.

Falconbridge Nickel Mines Limited explored the area in 1961 to 1964 and in 1969, and located 12 RIM claims covering Faith Lake and the valley slopes to the north, west, and south. J. J. McDougall did preliminary geological mapping, self-potential surveys were made, and several holes were diamond drilled. Mr. McDougall made his reports on this work available to the writer after the property was visited. The work was directed towards exploring a number of narrow gold-bearing quartz veins. In 1964 and 1965 D. J. T. Carson studied the metalliferous deposits of Vancouver Island as a thesis project, and suggested that a small Tertiary stock west of Faith Lake is a low-grade porphyry copper deposit. Despite these indications of mineralization, and without reference to the Ministry of Mines and Petroleum Resources, this area was included with Forbidden Plateau in a tract of land added to Strathcona Park in 1968.

Figure 18 is modified from a 1964 Falconbridge map. Massive andesite and basalt of the Karmutsen Formation are intruded by a small stock and associated dykes of granodiorite, which grades to silexite at the west end of the stock. The stock contacts are only partly defined. The south contact was covered by the toe of a snowslide, but had been intersected by Falconbridge's drill hole AX-5. Some magnetite, a little pyrite, and some rusty sections were note in the core. Three traverses were made over the length of the stock; no chalcopyrite and only very minor, sporadic pyrite were found. The large Karmutsen outcrop northeast of the drill hole contains sporadic disseminated pyrite and rare grains of chalcopyrite. The mineral occurrence is a skarn lens in Karmutsen rocks, 25 centimetres wide and about 2 metres long, well mineralized with chalcopyrite. One small Karmutsen outcrop is injected by many narrow, barren feldspar veins. Such mineralization as exists appear to be related to minor shearing along the south-flowing creek, and lines up with a rusty chasm high on the south face of the mountain. Falconbridge obtained anomalous self-potential readings across the lower course of this creek, but their significance is questionable; most of this anomalous area is covered with overburden which appears to be frozen or waterlogged most of the year.

None of the gold-quartz veins were seen, partly due to the late persistence of the snow slides. According to company maps, few of the veins exceed 13 centimetres in width.

REFERENCE:

Muller, J. E. and Carson, D. J. T. (1969), Geology and Mineral Deposits of Alberni Map-Area, *Geol. Surv., Canada,* Paper 68-50.

GEM LAKE (MEG) (92F/11W)

Gem Lake lies at 1 040 metres elevation in a deep valley between Mounts Regan and Albert Edward on the southwest and Jutland Mountain on the north. At the time of the visit in August, slide snow still filled the valley bottom between the lake and the headwall cliffs to the south, but the steep rocky walls were largely bare. Access was by helicopter from Campbell River.

Copper mineralization 300 metres southeast of Gem Lake was examined in 1930 by H. C. Gunning. It was rediscovered by Ventures Ltd. personnel on a helicopter reconnaissance in 1960, and 24 claims were located. A 12-metre rock cut was excavated on the west side of Gem Lake. In 1961 the main mineralized zone southeast of the lake was topographically and geologically mapped, a magnetometer survey was made, and six holes totalling 300 metres were diamond drilled. In 1963 an inclined hole was diamond drilled 190 metres and a rapid self-potential survey was made. The key claims were retained in the name of Falconbridge Nickel Mines Limited, but no further work was done. In 1968 the Gem Lake area was included with the Forbidden Plateau in a tract of land added to

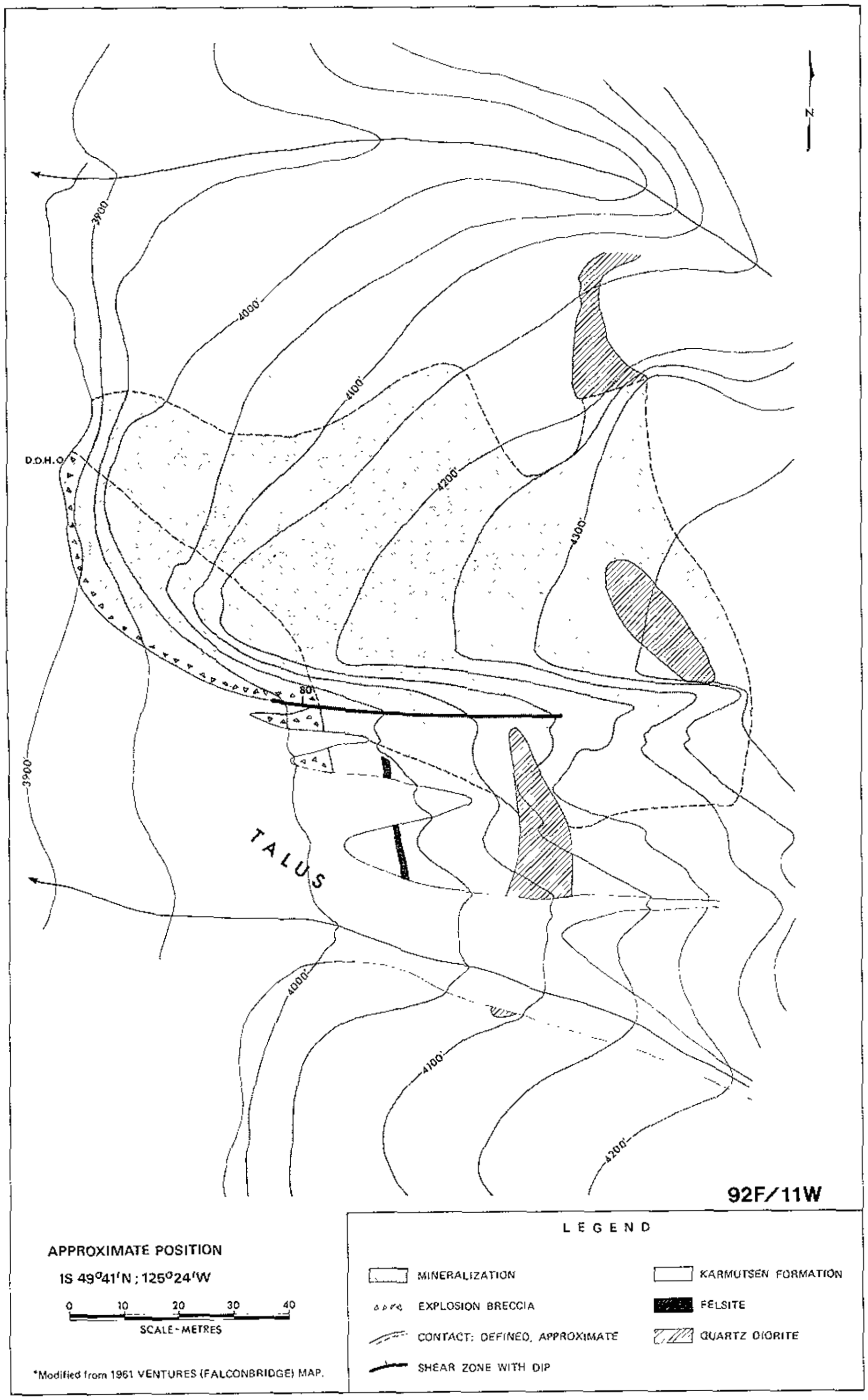

Figure 19. Geology of the area of the main mineralized zone, near Gem Lake.

Strathcona Park. The writer spent one day on the property in 1976, examining the base of outcrop on the east side, and subsequently obtained copies of reports from J. J. McDougall.

Figure 19 is modified from the Ventures 1961 map; locations of the modifications are approximate. The country rock is dark grey and greenish grey basalt and andesite typical of the Karmutsen Formation. It is intruded by several small bodies of medium-grained quartz diorite, and narrow felsite dykes. The quartz diorite is massive where observed at the edge of outcrop. Some 200 metres south of the map-area a 6-metre felsite dyke that strikes 350 degrees may be an extension of the one shown. In thin section, rock consists mostly of untwinned, anhedral plagioclase, with refractive indices between those of quartz and clinochlore; it is probably a basic andesite.

A breccia consists of fragments of these three rock types in an intrusive matrix. The proportions of the fragments vary from wholly Karmutsen to predominantly felsite, but the matrix is fairly constant at 35 per cent. This matrix consists of medium to coarse crystals of plagioclase and quartz, medium crystals of amphibole, and interstitial magnetite and fine-grained groundmass. The plagioclase and quartz crystals are mostly euhedral, both intact and broken, but a few quartz crystals are rounded. Most plagioclase crystals show interpenetrating twins and/or strong oscillatory zoning. Two medium crystals showing combined Carlsbad-albite twinning and only weak normal zoning gave compositions of An49 and An53. The groundmass comprises 15 to 20 per cent of the matrix and consists of amphibole needles, poorly defined felsic grains, probably mostly feldspar, and minor chlorite. The magnetite has partly replaced the groundmass and some Karmutsen fragments, and has penetrated some Karmutsen fragments as veinlets, with and without quartz. The groundmass is slightly altered, but the plagioclase and amphibole crystals are fresh.

The breccia body is evidently a diatreme, and resembles the Washington breccia on Mount Washington, 13 kilometres to the northeast. The fragments are mostly angular and do not appear to have been mobilized significantly. Toward the east boundary they are entirely of Karmutsen rocks and are not obvious, therefore this boundary may lie farther east than shown. At the north boundary there is a sharp transition from multifragment breccia to massive Karmutsen. The breccia body coincides with the southeast end of a magnetic high, and may continue northwest under talus. However it was apparently not intersected by the 1963 diamond drillhole, which was drilled from the bank of the north creek south along the west edge of the map-area.

A west-striking shear zone near the middle of the map-area is responsible for a spectacular south-facing bluff. The dip is steeply north, and the bluff is in places overhanging. Two holes drilled west of the south quartz diorite body passed through breccia and should also have intersected the shear zone. It is possible that the diatreme has been faulted to the right on the shear zone, and that the east boundary on the north side is considerably to the east of the position shown. Right hand offset is also suggested by the pattern of quartz diorite bodies mapped by Ventures geologists.

The Karmutsen rocks are coarsely sheeted south of the map-area, weathering to slabs 30 to 45 centimetres thick. The average attitude is 350 degrees and vertical. The felsite dykes have been injected along these sheeting planes.

Chalcopyrite occurs in the matrix of the breccia with the magnetite, as veinlets and disseminations in the volcanic rocks, and apparently as scattered veinlets in quartz diorite. The quartz diorite is barren where seen on the edge of outcrop, but a piece of talus contained a veinlet of massive chalcopyrite 3 centimetres long and 1 millimetre thick. Pyrite or pyrrhotite accompany the chalcopyrite both in the breccia matrix and in the disseminations in volcanic rock. Traces of molybdenite are reported to occur with the other sulphides in the disseminations. The bluff face is spectacularly stained with malachite.

South of the south creek (Figure 19) Karmutsen rocks appear to be barren. About 150 metres south of the breccia body they contain a little disseminated pyrite and sporadic small seams of chalcopyrite. This mineralization which extends at least 150 metres farther south, is slightly concentrated in and along the felsite dyke.

There is a substantial tonnage of mineralized rock in the east side of the valley, in the main zone, and along the felsite dyke, but the overall grade would be submarginal. Pockets within the diatreme are of ore grade, but they appear to be small and scattered. It is possible that an orebody could be outlined by additional drilling, but results thus far obtained are not encouraging.

REFERENCES:

Gunning, H. C., *Geol. Surv., Canada,* Summ. Rept., 1930, Pt. A, p. 74; Carson, D. J. T., *Geol. Surv., Canada,* Paper 68–50, p. 45.

STURT BAY AREA (92F/15E)

Sturt Bay defines the north limit of the town of Vananda on Texada Island. The north side may be reached by a dirt road which leaves the main highway 2.5 kilometres northwest of the main public access to Vananda. (Fig. 20.)

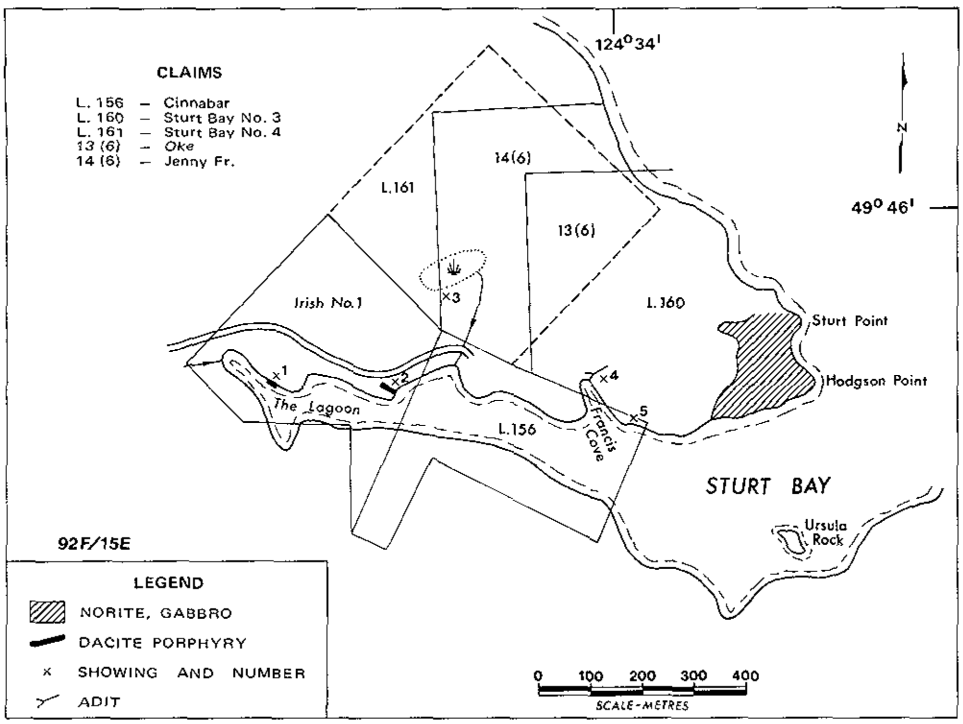

Figure 20. Geology of the Sturt Bay area.

Longbar Minerals Ltd. optioned the Irish No. 1 claim from Dave Murphy and in 1975 had a magnetometer and VLF EM survey made. Some lines were extended onto the former Lots

160 and 161. E. T. Johanson and Robert Duker used these lines as bases for a self-potential survey and located the Oke and Jenny Fr. claims. The area north of Sturt Bay was prospected, and some stripping and open cutting were done in the Oke and Jenny Frachon. Mr. Johanson guided the writer to the showings in September 1976.

Figure 20 is an enlargement from the claim map and a legal plan. Some geological features have been added from the writer's observations. The country rock is the Marble Bay (Quatsino) limestone, which is described in some detail by Mathews and McCammon. It is intruded by several small dykes of dacite porphyry and by a mafic stock. Two dykes are shown, and additional ones were seen at showings Nos. 4 and 5 and along the cut line. They are altered to varied degrees. The stock is coarse to very coarse grained, fresh, and dark grey in general aspect. In part it is banded light and dark and contains mafic segregations. It probably is mostly norite, but has been deuterically altered to diorite near the contact. A thin section from a specimen collected 25 metres southeast of the contact disclosed hypersthene more or less rimmed by deuteric hornblende and biotite and set in a framework of coarse plagioclase. The larger plagioclase crystals consist of fairly uniform labradorite (An_{64}) cores and zoned overgrowths of much more sodic plagioclase. Smaller crystals lack overgrowths. At the contact the ferromagnesian mineral is hornblende containing remnants of a clinopyroxene. Almost all the plagioclase crystals have sodic overgrowths. Alteration is slight, consisting of incipient sericite in the labradorite and, at the contact, the development of minor epidote. The freshness of the stock as compared with the dykes would suggest that it may be appreciably younger.

The limestone and dykes were apparently subjected to considerable stress. Healed shearing is apparent in some of the better limestone exposures, and some of the dykes have been sheared to chlorite schist and offset a metre or two on tight slips. A larger fault may underlie Francis Cove.

At showing No. 1 galena and chalcopyrite are sparsely disseminated in a resistant limestone bed, and galena veinlets feather out from it at 350 degrees. Blebs of massive chalcopyrite occur in the nearby dyke at about the mid-tide line. The enclosing limestone is bleached white. Showing No. 2 comprises veinlets and pockets of sphalerite and less pyrite in a 30-centimetre zone of bleached limestone centred on an open fracture that strikes 005 degrees and dips 80 degrees east.

Showing No. 3 is an open cut in bleached limestone. Pyrite and sphalerite are fairly abundant in the bottom of the cut but die out upward. No trend could be determined.

The old adit was driven 18 metres into the base of a small bluff of white limestone, apparently for the purpose of sampling the limestone. It does not appear to have intersected mineralization. No. 4 showing is in a recess in the upper part of this bluff, and had been partly exposed by stripping and blasting. A complex array of dykes has in part been sheared to chlorite schist and crossfaulted. Chalcopyrite and sphalerite occur in quartz veinlets in dyke rock, and with pyrite and a little galena in chlorite schist and adjacent limestone.

The mineralization of No. 5 showing is mainly in dyke rock. A boudinaged narrow dyke in white limestone extends 14 metres at 340 degrees back from the beach, then either turns abruptly or is cut off by another dyke striking 080 degrees. The first segment and flanking limestone are mineralized with chalcopyrite, and the second segment with chalcopyrite, sphalerite, and tetrahedrite.

REFERENCES:

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IRON MASK BATHOLITH (92I/10E, 9W)

By K. E. Northcote

REGIONAL SETTING: The Iron Mask batholith is a multi-unit intrusion composed of *Iron Mask Hybrid, Pothook, Sugarloaf, and Cherry Creek units, each of which has several* varieties. The rocks are fine grained and porphyritic to coarse grained and are silica-poor ranging from gabbro to syenite with diorite-monzodiorite-monzonite compositions predominating.

Major systems of northwesterly and northeasterly trending recurring fractures or faults controlled emplacement of various units of the Iron Mask batholith. The batholith was emplaced in a high level volcanic to subvolcanic environment and is comagmatic with Nicola volcanic rocks and coeval with part of the upper Nicola succession. The batholith intruded volcanic and sedimentary rocks of the lower Nicola, but the Cherry Creek unit both occurs as fragments in and is in intrusive contact with Nicola rocks.

The Nicola and Iron Mask rocks are unconformably overlain by Tertiary Sedimentary and volcanic rocks of the Kamloops Group. In many places along the flanks of the batholith the pre-Tertiary erosion surface seems nearly to coincide with the present-day erosion surface. Erosional remnants of Tertiary volcanic rocks cap the higher hills and occur in places along their flanks. This pre-Tertiary erosional surface appears to have been very irregular although post-Tertiary faulting may have accentuated this apparent irregularity and resulted in local preservation of post-batholithic rocks within the batholith.

The distribution of the rock units and linears from air photographs are shown on Figure 21.

GEOLOGY: Rock descriptions are based on field observations of texture, composition, and kind and intensity of alteration.

NICOLA GROUP: The Iron Mask batholith is flanked on both sides by Nicola volcanic and volcaniclastic sedimentary rocks which are lithologically dissimilar to overlying Tertiary volcanic and volcaniclastic rocks.

Nicola rocks on the southwestern flank consist predominantly of well-indurated, weakly metamorphosed, massive and bedded tuffs, breccias (some of which are probably lahars), and interbedded flows and monomictic flow breccias. Most of these rocks are of a fairly uniform green-grey colour. A well-indurated exposure of bedded tuff and breccia similar to those on the southwestern flank crops out between Knutsford and Knutsford Hill.

Nicola rocks on the northeast flank are mainly tuff and tuff breccia which are for the most part less well indurated and less altered than on the southwest flank. Adjacent to Iron Mask batholith contacts, however, the Nicola rocks are well indurated, altered mainly by epidotization and locally contain mineralization. The tuff breccias contain fragments of many colours which locally are commonly intrusive Cherry Creek unit and Cherry Creek-like fragments. In some places these tuff breccias are abundantly hematitic.

Refractive indices of 90 samples of Nicola volcanic rocks taken from the north side of the *batholith are shown on Figure 22. Composition ranges from basalt through trachyandesite* to trachyte-dacite fields. The distribution pattern of refractive indices for these Nicola rocks corresponds closely to that of the Central and Eastern Belt Nicola volcanic rocks for which silicate analyses indicate compositions for basalt through trachy-andesite showing high $Na_2O + K_2$ content and widely ranging Al_2O_3/SiO_2 ratios (Preto, personal communication).

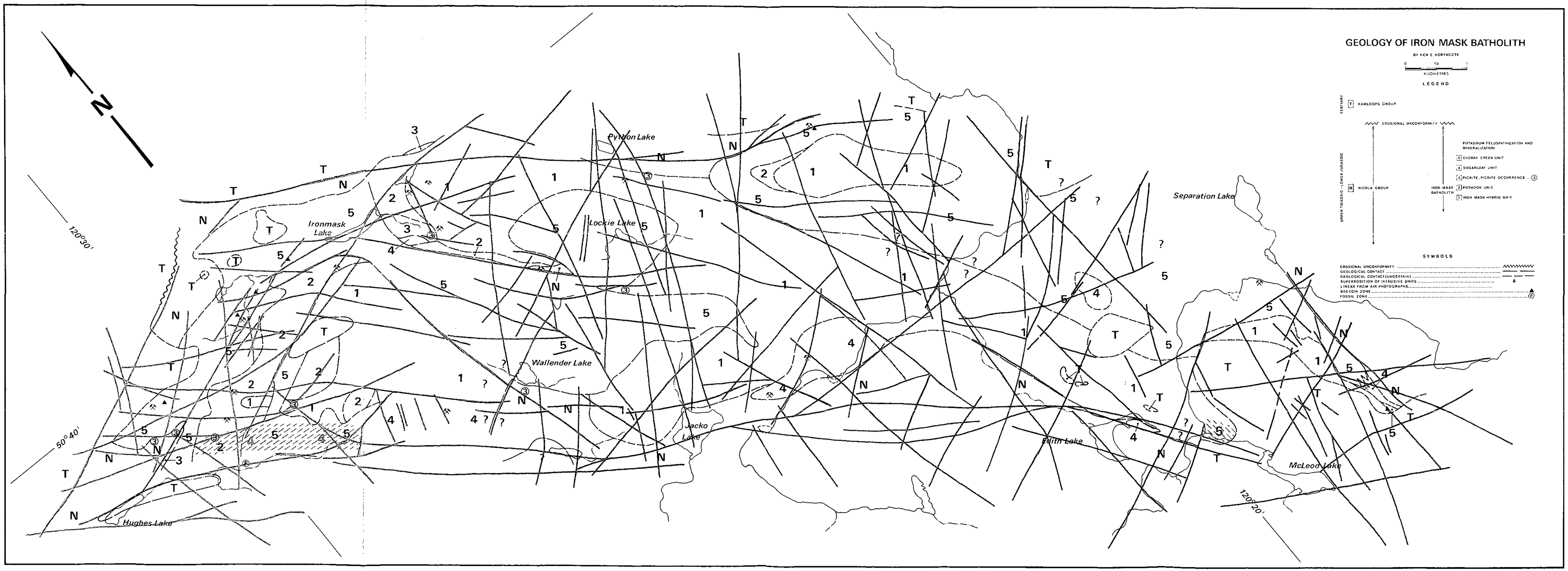

Figure 21. Geology and patterns of linear features in the Iron Mask batholith.

The unaltered tuffs and tuff breccias containing fragments of Cherry Creek and Cherry Creek-like rocks that occur along the northeast flank of the batholith have been previously mapped by others variously as Cretaceous Kingsvale or Tertiary Kamloops Groups to explain the presence of batholithic fragments and lack of alteration which would be expected to result from intrusion by the batholith. An increasing amount of evidence suggests that these unaltered, volcanic rocks containing batholith fragments may be the volcanic equivalent of some of the batholithic rocks and therefore the two are probably comagmatic and coeval.

The Nicola rocks on both flanks of the batholith contain augite porphyry and augite porphyry breccia which, on the north side of Jacko Lake, has been metamorphosed along the intrusive contact. Nicola rocks along the southwestern flank and at the southeast tip of the batholith contain distinctive augite-hornblende porphyries which are identical to varieties of the Sugarloaf unit which also occurs predominantly along the southwest flank of the batholith.

INTRUSIVE ROCKS OF THE IRON MASK BATHOLITH: All intrusive units of the Iron Mask batholith with the exception of Picrite unit are thought to be genetically related. However, the relationship between Sugarloaf unit and other units is not clear. Most units everywhere show some degree of alteration and/or contamination which may be intense in some places. In most cases, however, original textures are still visible and are used as the main criteria for distinguishing among units and varieties.

Index of refraction (Fig. 22) of selected samples of fine-grained Iron Mask batholithic rocks indicate that their composition range from gabbro to monzonite and syenite. Frequencies of indices on this diagram, however, are not indicative of overall composition of the batholith. Silicate analyses of samples collected by Preto in 1967 of Cherry Creek and Hybrid rocks range in composition in terms of volcanic rocks from basalt and andesite to trachyandesite as compared to more basic basalts, basaltic andesites, and $Na_2O + K_2O$-rich andesites or trachyandesites of the Central Nicola Belt (Preto, personal communication).

IRON MASK HYBRID UNIT: The Iron Mask Hybrid unit occurs in the central and eastern part of the northwest half of the batholith and forms a margin about 1.2 kilometres wide along the southwest side of the southeast half. An elongate pendant or screen of Iron Mask Hybrid rocks approximately 3.2 kilometres long occurs in Cherry Creek rocks and extends from east of Coal Hill southeasterly toward Knutsford Hill.

Most outcrops of the Iron Mask unit can best be described as a mixture of intrusive rock varieties. The rocks range from fine to coarse melanocratic and mesocratic diorite, fine to coarse-grained hornblendite, coarse-grained magnetite-rich gabbro, and xenoliths of recrystallized Nicola. All of the Iron Mask Hybrid varieties contain magnetite and, with the exception of the obvious xenoliths of recrystallized Nicola, none of the Hybrid varieties bear any physical resemblance to the surrounding Nicola (Plates XXII, XXIII). The mixture of Hybrid varieties appears to have been emplaced as intrusive breccias cut by and healed by interstitial mesocratic to leucocratic diorite. Some of the crosscutting rocks are recognizable as Cherry Creek varieties, particularly near Iron Mask Hybrid and Cherry Creek contacts.

Mineralization is fairly ubiquitous in Iron Mask rocks with notable concentrations of magnetite and copper. The Iron Mask mine is located in the rock unit and is in association with picrite.

POTHOOK UNIT: The Pothook unit occurs mainly in the northwest half of the batholith and is less prevalent than in the southeast half. This unit appears as narrow, mafic-rich, gradational zones between Iron Mask Hybrid and Cherry Creek units. The rock is more uniform in texture and composition than Iron Mask Hybrid rocks. At the northwest end of

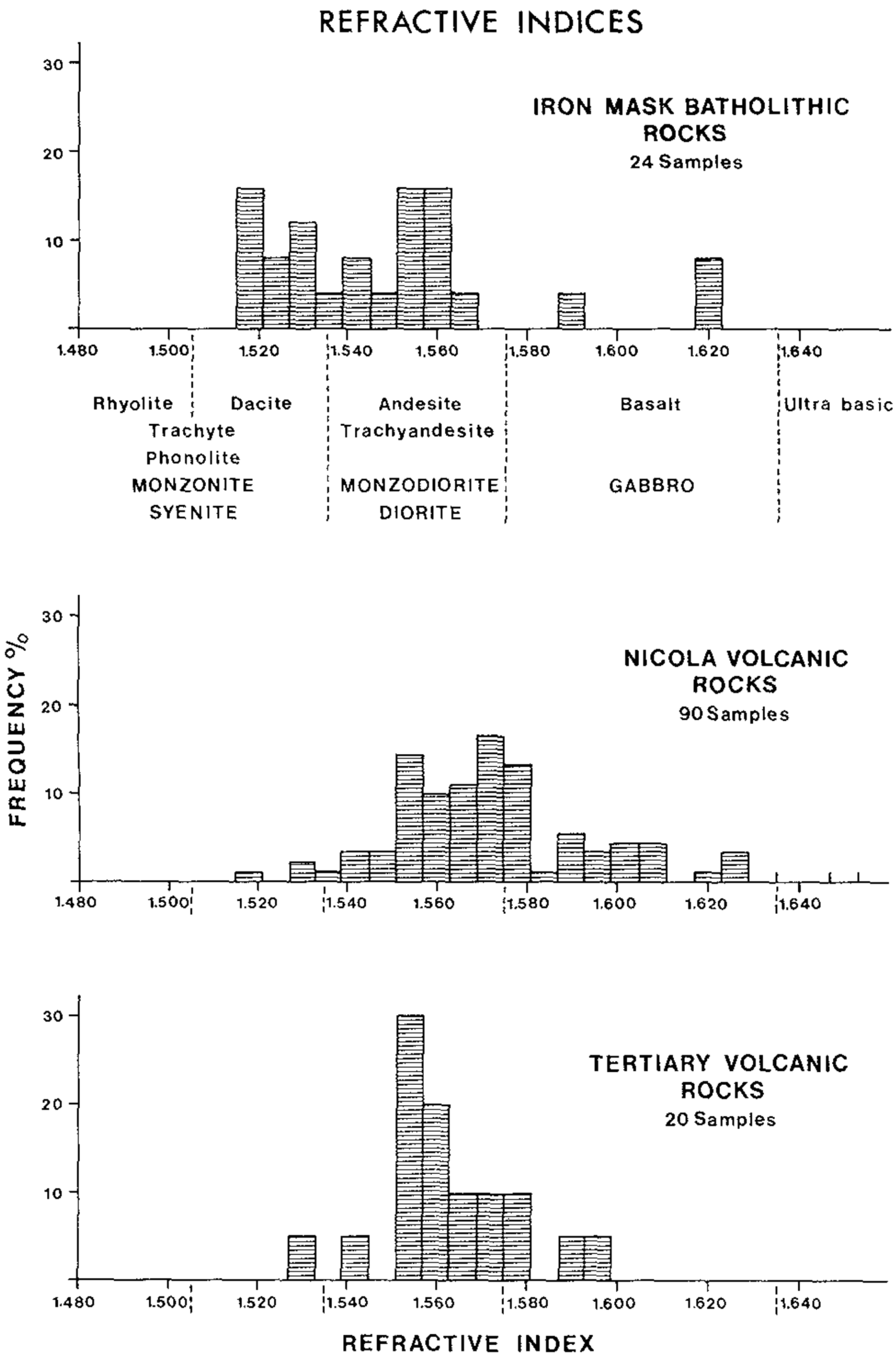

Figure 22. Refractive indices of fused powdered Nicola volcanic rocks from the *north side of the Iron Mask batholith.*

the batholith where the Pothook unit is most extensive it is of dioritic composition except near Cherry Creek contacts, is medium to coarse grained, and is mafic rich. Commonly coarse interstitial masses of biotite 2 or 3 centimetres across are visible in this unit. Near Cherry Creek contacts the Pothook unit commonly shows an increase in K-feldspar content (Plate XXIV).

Copper and iron mineralization is prevalent in many places in the Pothook unit with notable magnetite occurring in uniformly dipping veins south and southeast of Afton.

There appears to be a gradation from the mixture of Iron Mask varieties through mafic-rich Pothook varieties to the Cherry Creek unit showing an increasing degree of differentiation to more K-spar-rich varieties. Intrusive contacts between these units are also evident.

PICRITE UNIT: The problem of the origin and age of the Picrite unit remains unresolved. The picrite is of basaltic composition with serpentinized olivine reported by Carr (1956), Preto (1967), and Carr and Reed (1976) (Plate XXV). Picrite bodies appear to be associated with recurring, northwesterly trending fracture systems and are found in many parts of the batholith commonly in association with mineralization (Carr, 1956; Carr and Reed, 1976). The unit is cut by clean fine-grained rocks akin to the Cherry Creek unit. Inclusions of picrite are reported in the Iron Mask unit (C. Godwin, personal communication).

CHERRY CREEK UNIT: The name Cherry Creek is retained for the unit of rocks which extends along the north margin of the batholith (Preto, 1967) and is applied to equivalent rocks underlying Iron Mask Hill and brecciated, ankeritic rocks east of Galaxy. Mapping during the 1976 field season has shown that this same unit of Cherry Creek rocks forms the eastern half of the southeastern part of the batholith. A pendant or screen of Iron Mask Hybrid unit occurs within it extending from east of Coal Hill and projecting southeasterly toward Knutsford Hill. A body of Sugarloaf-like rocks extends up the north side of the Knutsford ski hill and heals brecciated fragments of Cherry Creek rocks.

There is a wide variety of Cherry Creek rocks which retain a characteristic speckled texture resulting from a clustering of fine-grained mafic minerals with indistinct outline. The rocks are commonly weakly porphyritic to porphyritic, fine grained, and range in composition from diorite to syenite. They include varieties which can be termed macrodiorite, microdiorite, micromonzonite, microsyenite, and Cherry Creek porphyry (Carr, 1956; Preto, 1967, 1973) (Plates XXVI to XXX). The wide variety of Cherry Creek rock types may be the result of tapping of magma of different stages of differentiation, with emplacement and crystallization occurring under varied pressure-temperature-volatile content conditions existing in an intermittently venting subvolcanic to volcanic environment.

Copper and lesser iron mineralization are prevalent in the Cherry Creek unit particularly in zones of intense brecciation and K-feldspathization. Preto (1967) points out the significance of the brecciation and K-feldspathization. Similar brecciation to that reported by Preto (1967) and Northcote (1974) in Cherry Creek rocks along the north side of the batholith occurs in Cherry Creek rocks on the Kimberly copper property northwest of Knutsford (Preto, 1967). A breccia consisting largely of Cherry Creek fragments also occurs on the extreme southeast tip of the batholith.

SUGARLOAF UNIT: The Sugarloaf unit occurs mainly along the southwest flank of the batholith and as small bodies within the batholith such as on the north flank of Knutsford ski hill and at the southeast tip of the batholith. Several varieties were noted which are mainly the result of differences in grain size. Almost everywhere the unit is of fairly uniform andesitic composition and is medium green in colour. The distinguishing characteristic of this unit is the presistent presence of hornblende and/or augite phenocrysts (Plate XXXI).

Identical rocks were observed in the Nicola. Their relationship to Nicola rocks was not determined but probably form dykes or sills.

Conflicting age relationships were observed where Cherry Creek rocks appeared to cut rocks of the Sugarloaf unit in one area and breccia fragments of Cherry Creek rocks were healed by a matrix of Sugarloaf-like rocks in another area.

Copper mineralization occurs within Sugarloaf rocks in several localities; notably at the Ajax property east of Jacko Lake where Sugarloaf rocks are brecciated and albitized (Preto, 1967).

KAMLOOPS VOLCANIC AND SEDIMENTARY ROCKS: Early Tertiary volcanic and sedimentary rocks unconformably overlie the batholith and Nicola rocks. The Kamloops volcanic rocks in the Iron Mask area are mainly andesitic composition (Figure 22) and occur as vesicular flows, flow breccias, and vent breccias. The present erosion surface fairly closely approximates the pre-Tertiary erosion surface so that erosional remnants of Tertiary rocks are prevalent capping the tops of some of the higher hills on the batholith, in former depressions on the pre-Tertiary erosion surface, and in downfaulted blocks both within and flanking the batholith.

ALTERATION: Most of the batholithic rocks show some degree of saussuritization which locally may be very intense. Some K-feldspathization is evident locally in most rock units but is most abundant in Cherry Creek rocks where the relatively high K-feldspar was introduced into the rocks through processes of normal crystallization of potassium-rich magma and by alteration of previously crystallized dioritic to monzonitic rocks by introduction of potassium-rich solutions.

ENVIRONMENT OF EMPLACEMENT OF BATHOLITH: An increasing amount of evidence suggests a shallow volcanic to subvolcanic environment of emplacement especially for Cherry Creek varieties and a comagmatic and partly coeval relationship between Nicola volcanic rocks and units of the Iron Mask batholith.

Cherry Creek rocks at the north end of the batholith occur as criss-crossing dyke-like bodies of varied grain size and composition. Their fine-grained texture suggests near surface conditions and, as noted by Carr (1957), the Cherry Creek unit had previously been mapped as volcanic rocks. Intrusive brecciation associated with K-feldspathization is prevalent in many places, particularly in a narrow zone extending westerly from a point near Iron Mask Lake to the Afton orebody. This brecciation appears to involve mainly varieties of Cherry Creek although fragments of Iron Mask Hybrid or Pothook are also visible in drill core. The brecciation may have been the result of venting at a slightly higher level. Fragments of Cherry Creek rocks and other Cherry Creek-like rocks occur in tuff breccia of the Nicola which indicates that some of the Cherry Creek rocks are older than some of the Nicola (Plate XXXII and XXXIII). However, intrusive contacts between these same Nicola volcanic rocks and Cherry Creek rocks indicate the opposite relationship; some Cherry Creek rocks are younger than some of the Nicola rocks they intrude. Intense epidotization of Nicola rocks which contained Cherry Creek fragments and some mineralization were noted at the north edge of the batholith which suggests that volcanic-plutonic processes were going on simultaneously.

It is unnecessary to postulate three separate magmatic events; one for Nicola volcanism, a second to emplace the Iron Mask batholith, and a third for later volcanism to explain Cherry Creek fragments in volcanic rock described as being identical to Nicola (Cockfield, 1948). The observed geologic features and relationships would be consistent with a single but pulsating comagmatic and partly coeval volcanic-plutonic system operating in a subvolcanic to shallow volcanic environment.

IRON MASK AGE DETERMINATIONS: K/Ar age determinations on samples collected by Preto in 1967 and analysed for K/Ar isotopes by J. Harakal, University of British Columbia, indicate Cherry Creek, Pothook, and Iron Mask Hybrid rocks are isotopically the same age.

TABLE 6. POTASSIUM—ARGON AGE DETERMINATIONS

Sample No.	Age	Rock Type	Location
VP 72 KA-3	197 ± 6 Ma	Cherry Creek Micromonzonite porphyry	Near east end Iron Mask Lake.
VP 72 KA-5	190 ± 6 Ma	Pothook	Afton.
VP 72 KA-4	205 ± 6 Ma	Cherry Creek Micromonzonite porphyry	Near Iron Mask Lake.
VP 72 KA-1	201 ± 6 Ma	Iron Mask Hybrid	Gas pipeline near Ajax property.
VP 72 KA-2	198 ± 6 Ma	Hydrothermal Biotite Cherry Creek Microdiorite	Near Iron Mask Lake.

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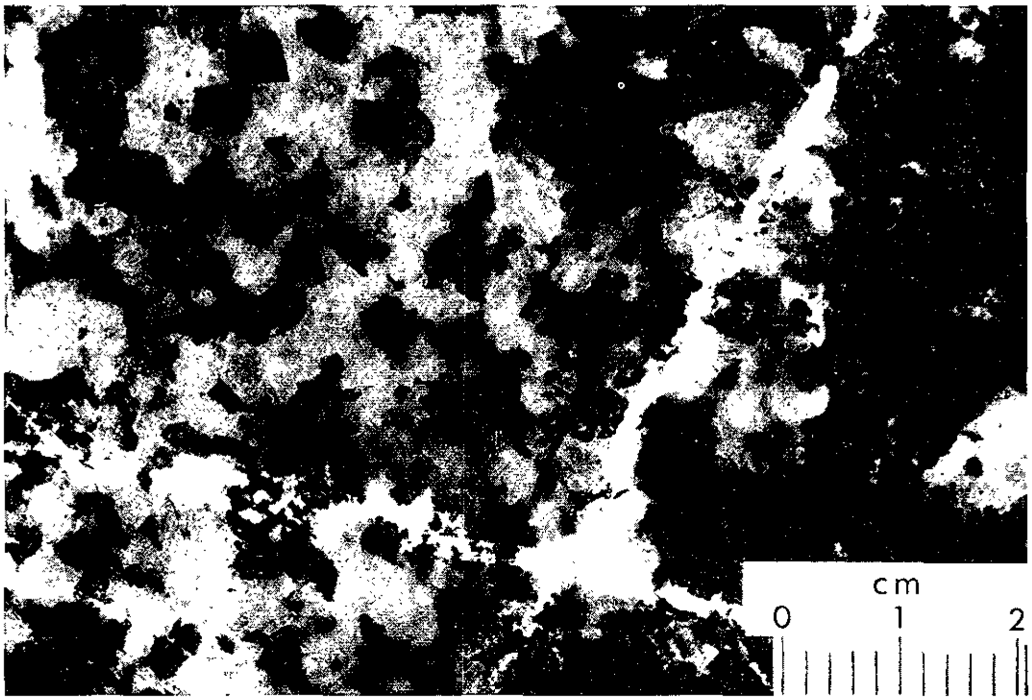

Plate XXII. Iron Mask hybrid unit.

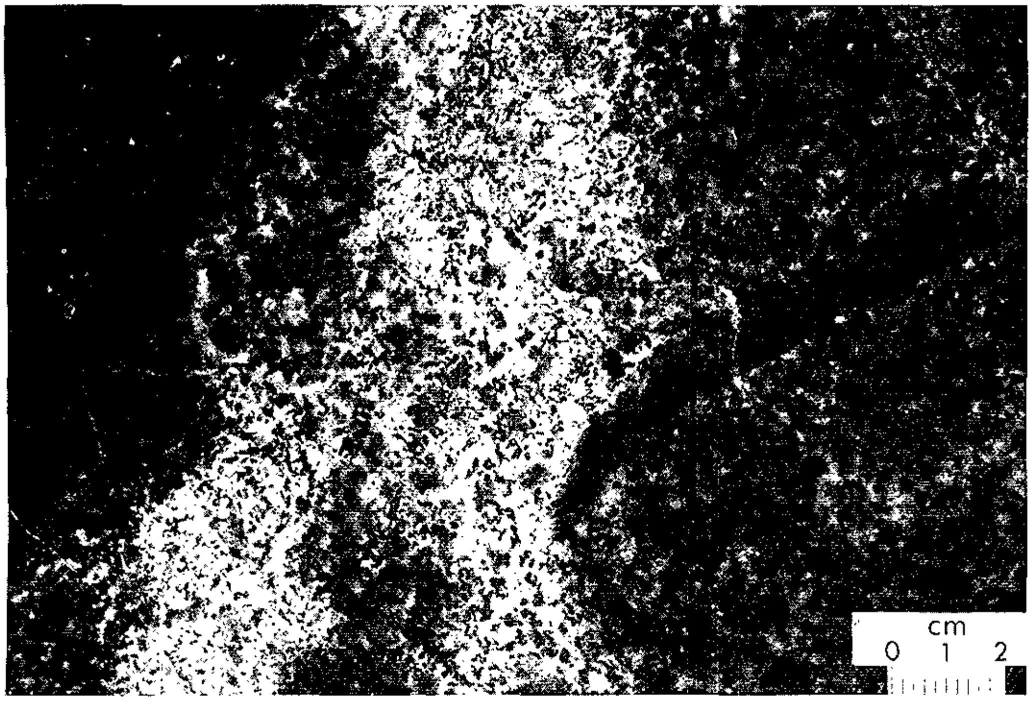

Plate XXIII. Iron Mask hybrid unit.

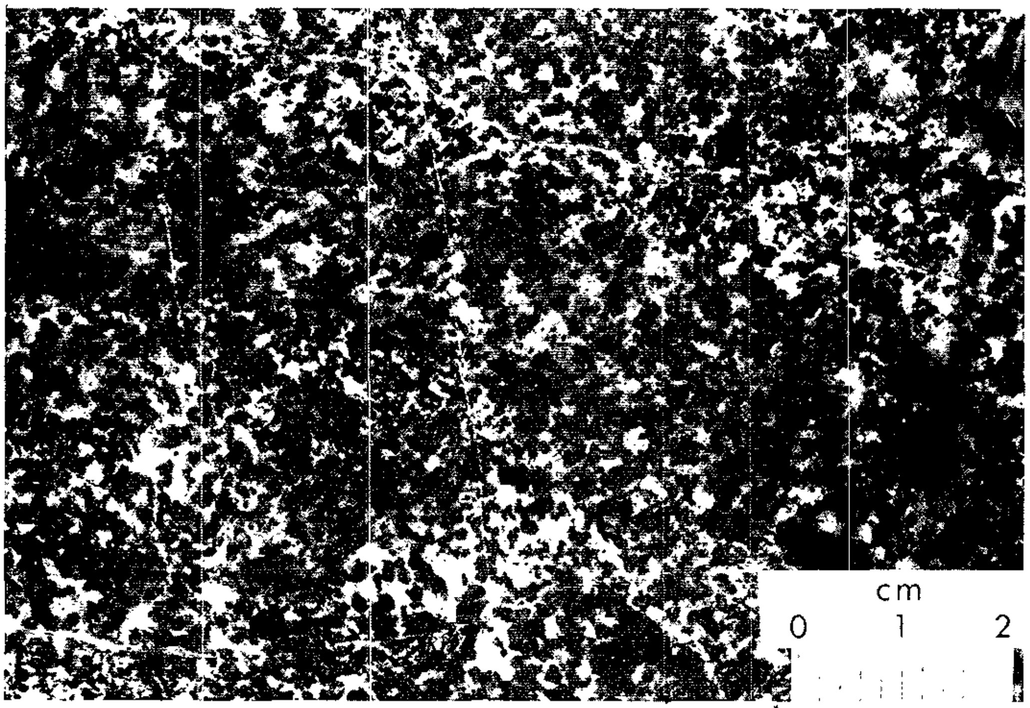

Plate XXIV. Pothook unit.

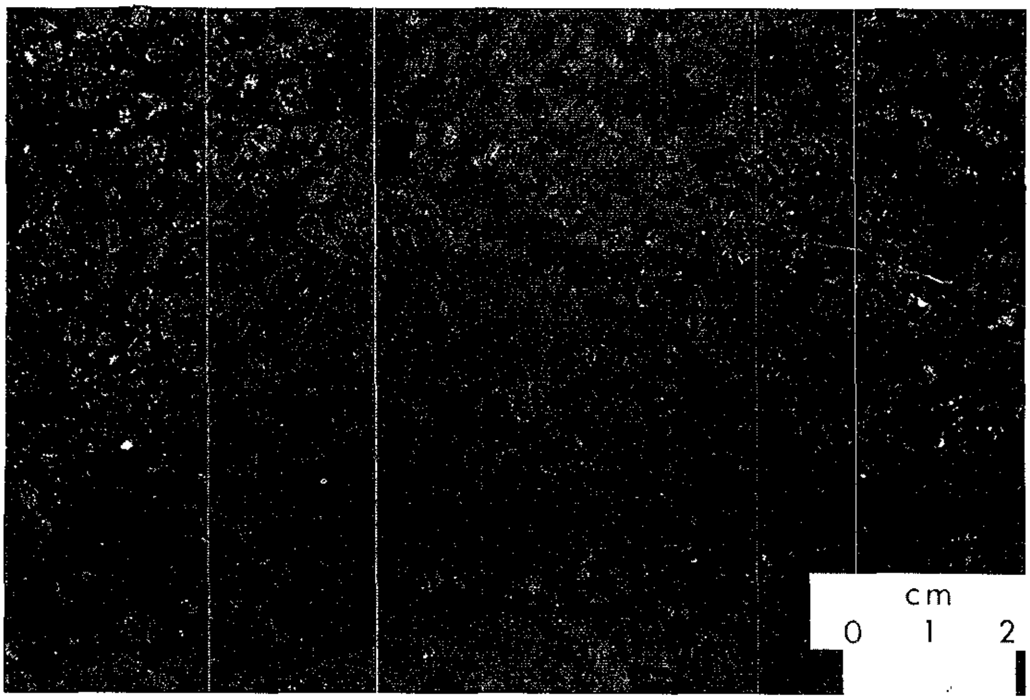

Plate XXV. Cherry Creek macrodiorite.

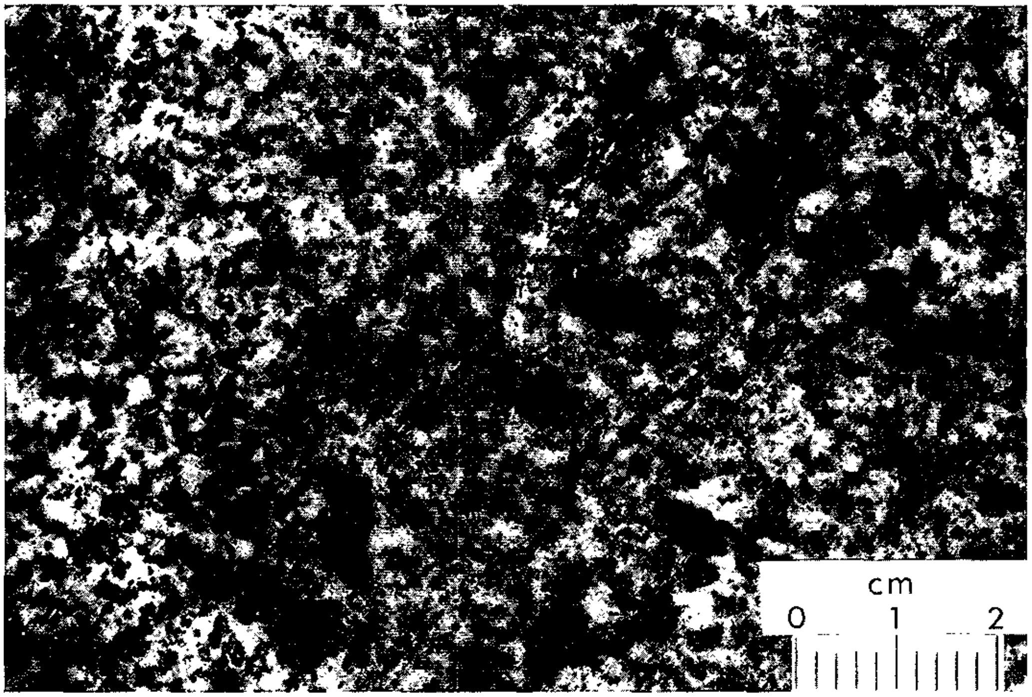

Plate XXVI. Cherry Creek microdiorite.

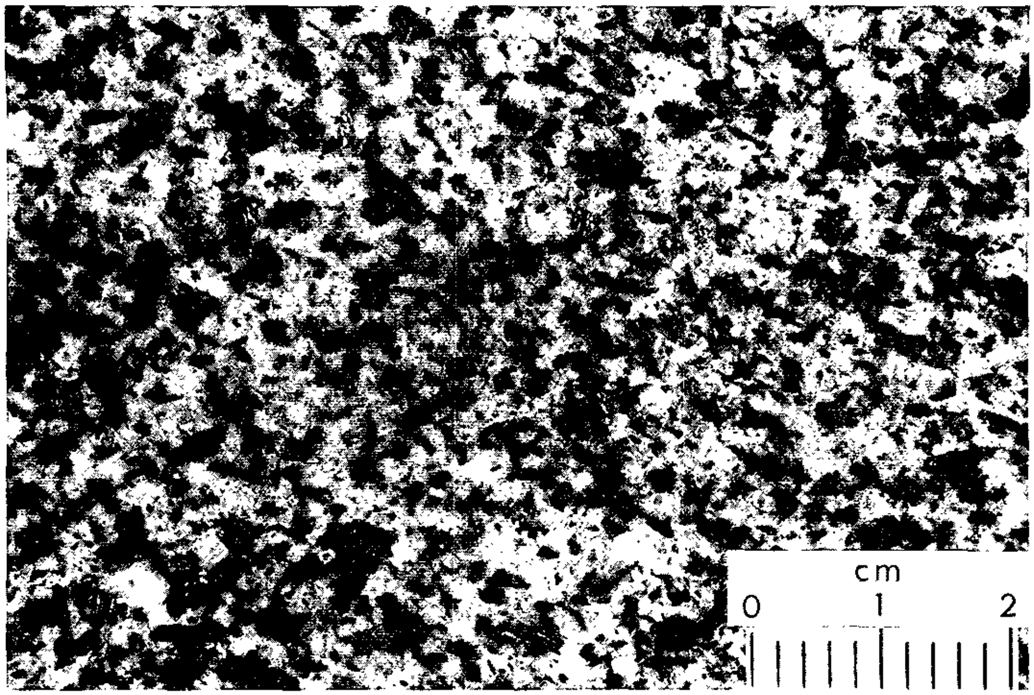

Plate XXVII. Cherry Creek micromonzonite.

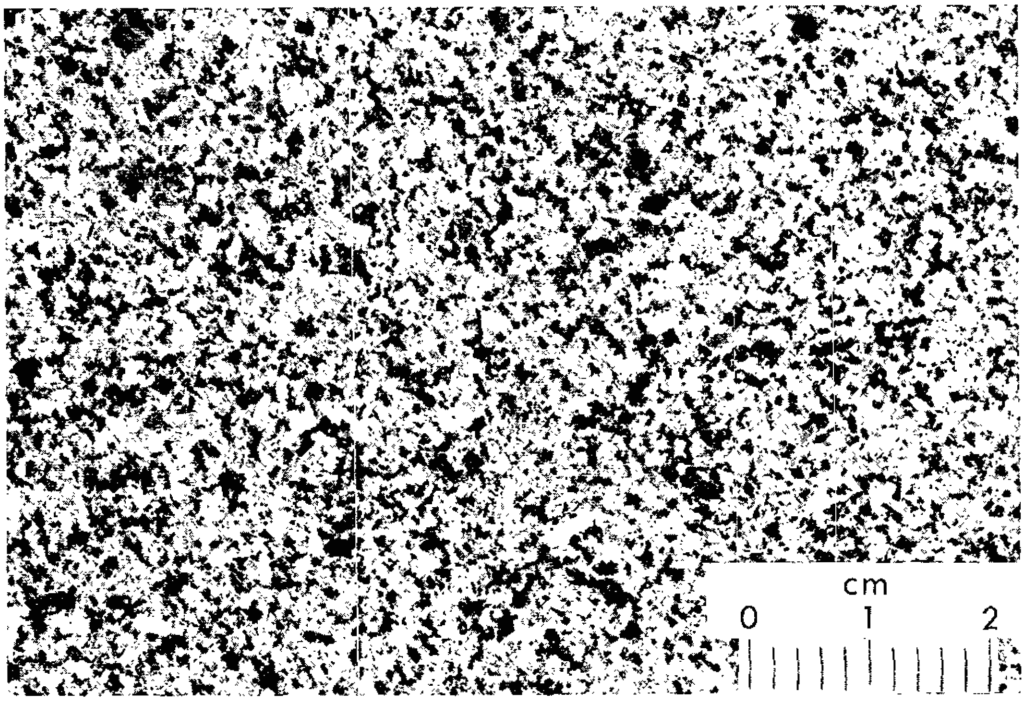

Plate XXVIII. Cherry Creek porphyritic microsyenite.

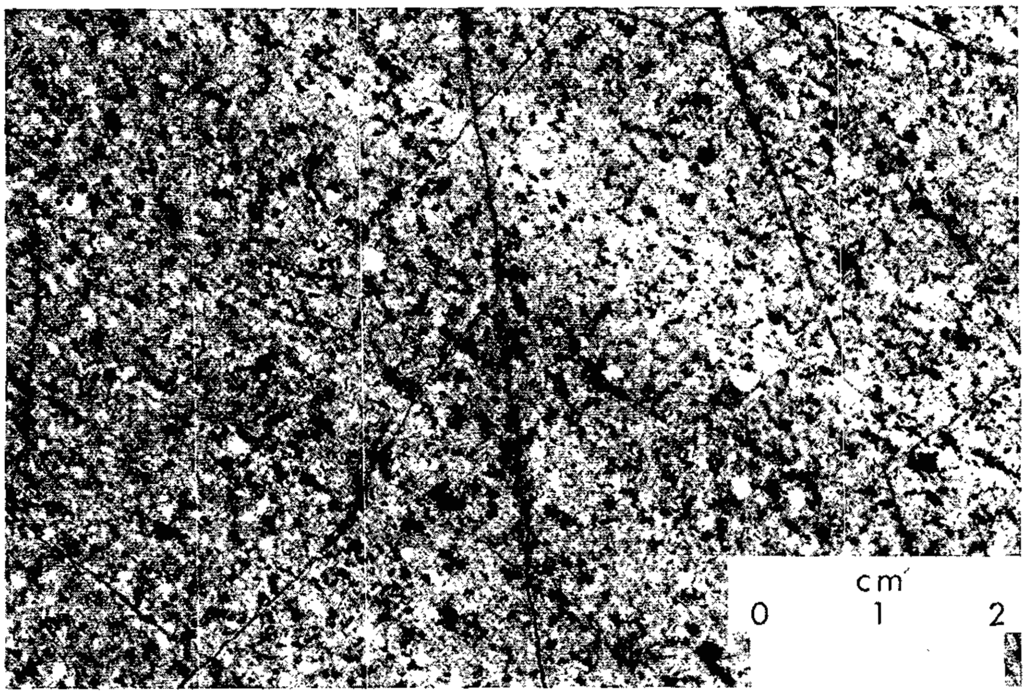

Plate XXIX. Cherry Creek porphyritic microsyenite.

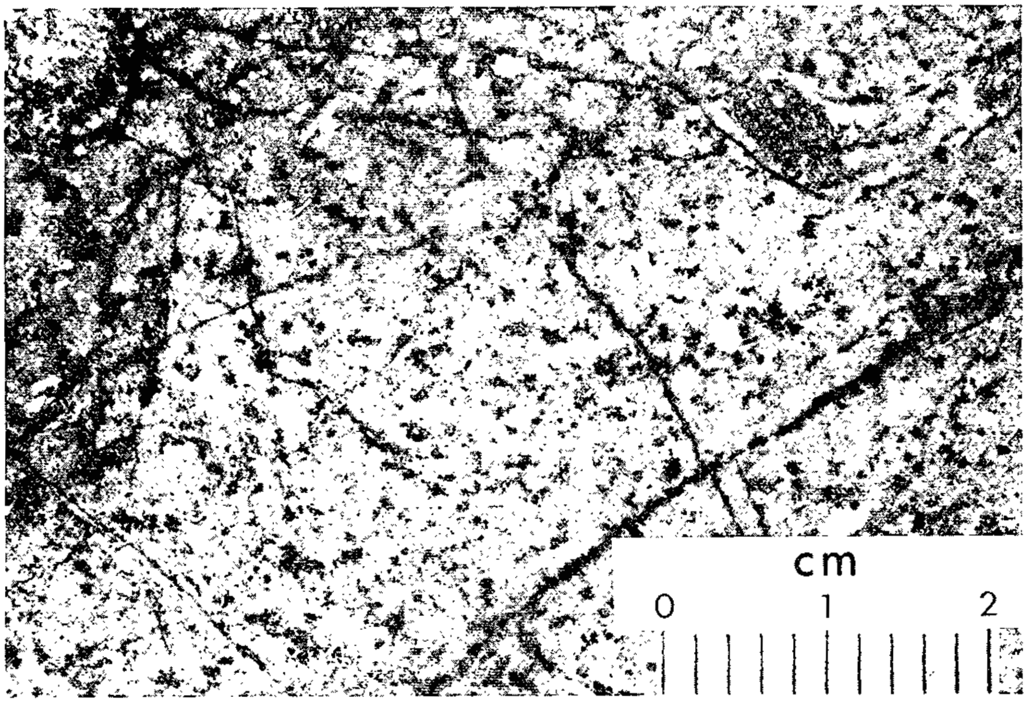

Plate XXX. Cherry Creek porphyry breccia.

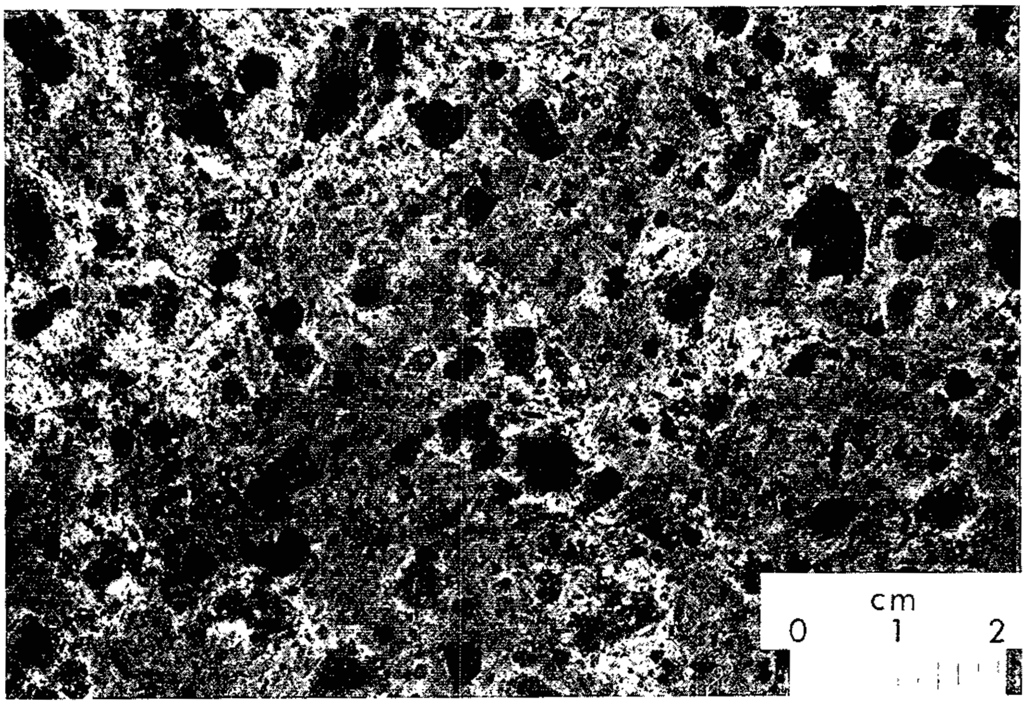

Plate XXXI. Sugarloaf unit.

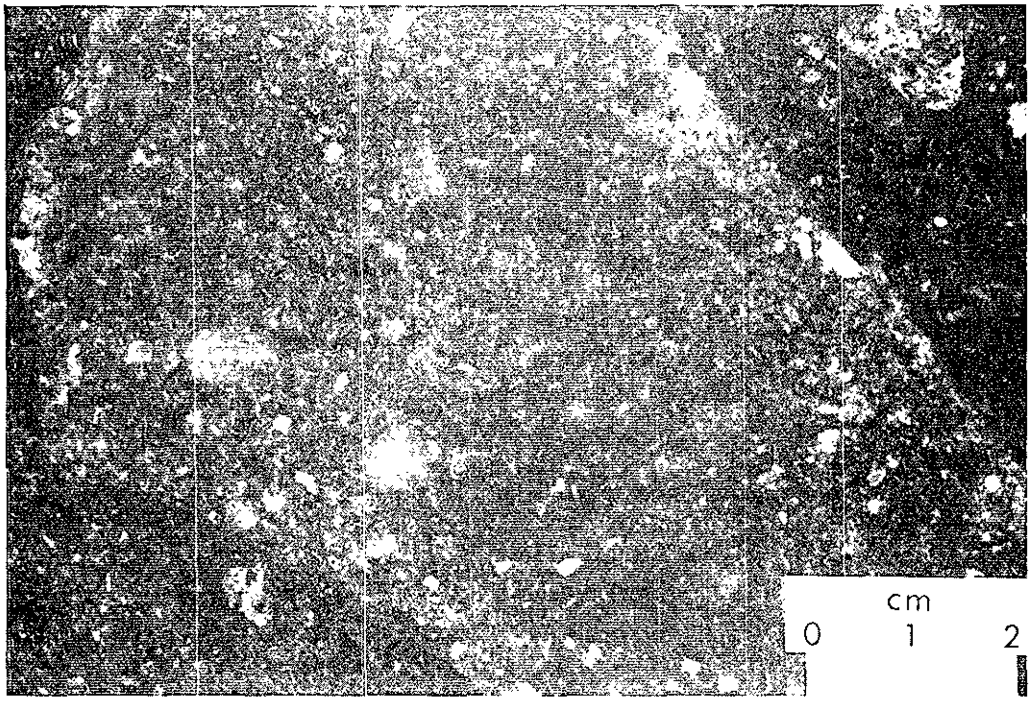

Plate XXXII. Nicola breccia.

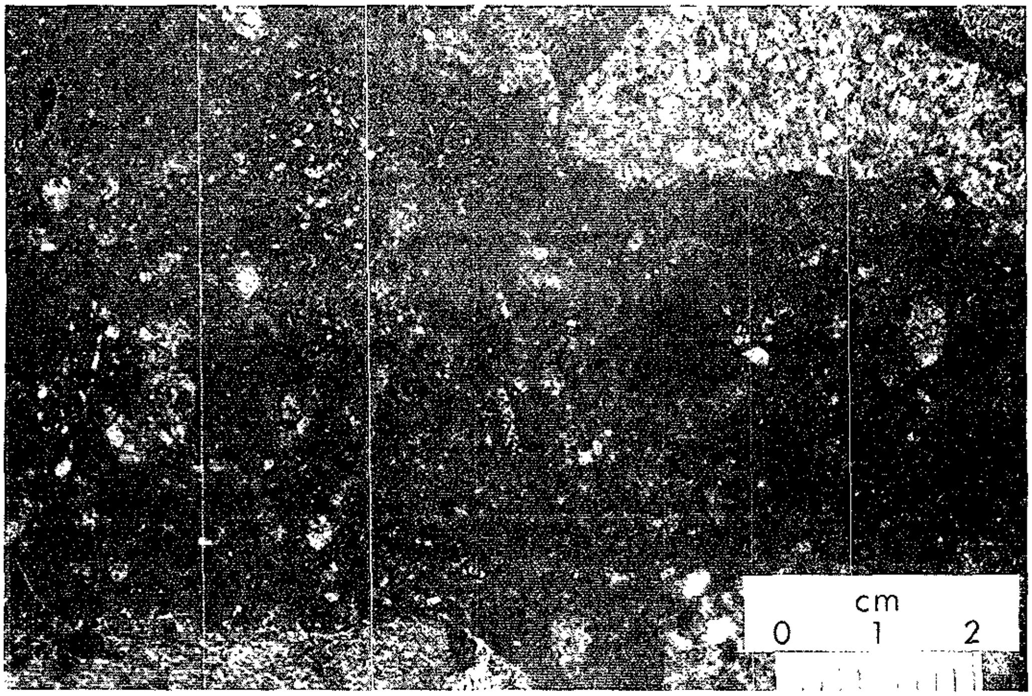

Plate XXXIII. Nicola breccia.

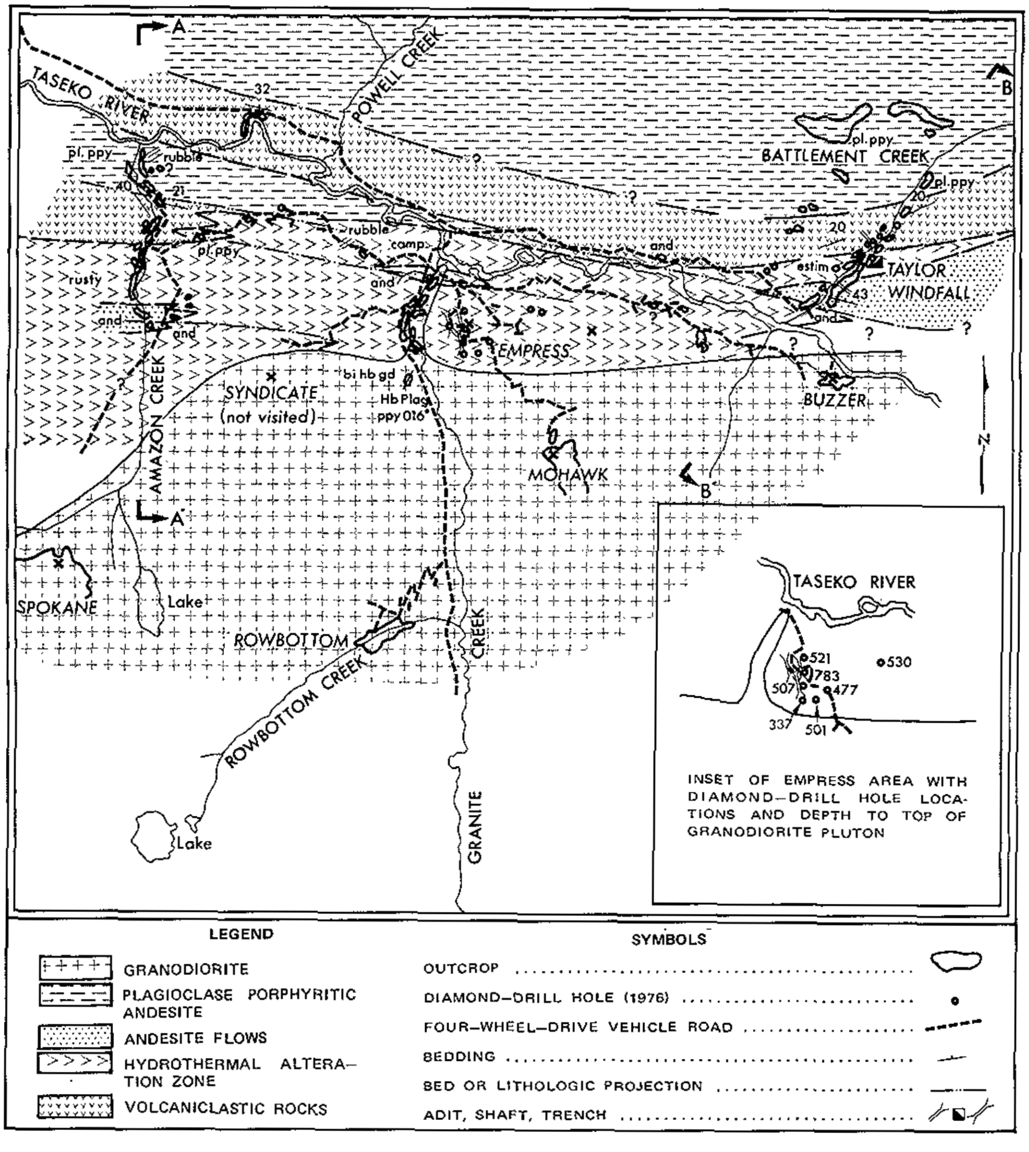

Figure 23. General geology of Granite Creek area.

GRANITE CREEK PROPERTY 920/3W

By W. J. McMillan

INTRODUCTION: Eight holes were diamond drilled by Quintana Minerals Limited in 1976. Work was directed by K. W. Livingstone and W. A. Howell. Most of the diamond drilling was done in the vicinity of the Empress showing (Fig. 23). The work was a follow up to earlier diamond and percussion drilling by Quintana and other companies. Granite Creek is a tributary of Taseko River southeast of the south end of Upper Taseko Lake.

Mineralization occurs in fractured and brecciated zones in the granitic rocks, as disseminations in the granitic rocks and in pyritic, phyllic, or siliceous alteration zones in adjoining volcanic country rock. Mapping and K/Ar age dating were conducted to learn the age of the mineralization and to see if mineralization in the granitic and volcanic host rocks are related.

GENERAL GEOLOGY: Tipper (1963) described rocks along Taseko River as varicoloured andesitic pyroclastic rocks with intercalated grey, grey-green, and mauve massive to porphyritic flows and local interbeds of shale and conglomerate. Sparse plant fossil remains on Mount Tatlow indicated an early Late Cretaceous age. These rocks are apparently correlatives of rocks called the Taylor Creek Group to the south. In Tyaughton Lake area, the unit is predominantly shale with interbeds of chert pebble conglomerate, volcanic breccia, and lavas. Marine fossils in the shale have an Albian age (Roddick and Hutchison, 1973). In the Shulaps Range lavas are rare and conglomerate and grit predominate (Leech, 1953). To the west in Mount Waddington area, volcanic members in the Taylor Creek Group are uncommon. Apparently, although sedimentation in the Taylor Creek Group was not controlled by the Tyaughton Trough, it is thickest in it. At that time, the axis of the trough trended southeastward, roughly through the middle of Lower Taseko Lake (Tipper, 1969).

LOCAL GEOLOGY: In the Granite Creek area, moderately dipping volcanic and volcaniclastic rocks are intruded by a large granitic pluton of Cretaceous age (Fig. 23). Within the pluton, deposits include those in which mineralization is disseminated (Buzzer, Rowbottom), vein and fracture controlled (Spokane), or in intrusive breccia (Mohawk). The predominant metals present are copper and gold with minor molybdenite and some silver. Adjacent to the pluton on the north, rocks of the volcanic pile are variably altered and mineralized. The altered rocks form striking gossans. Mineralization in the volcanic rocks is dominated by copper sulphides, gold, and secondary iron. Limonite deposits along the altered belt were derived from pyritized lavas.

VOLCANIC AND VOLCANICLASTIC ROCKS: To try to decipher the volcanic stratigraphy traverses were made along Amazon and Battlement Creeks where alteration is less pervasive than that near Granite Creek (Plate XXXIV). Judging from these traverses, the pluton cuts across the lithology; the contact is at a low angle to the strike between Battlement and Amazon Creeks but is more discordant west of Amazon Creek. Bedding trends generally east-southeast near Amazon Creek and east-southeast to northeast in Battlement Creek; dips are gentle to moderate toward the north. In areas to the southeast (Woodsworth, personal communication) the granite-volcanic contact is faulted. According to Dolmage (1928), the granodiorite contact also dips northward but more steeply than layering in the volcanic rocks. Drilling by Quintana suggests that the surface of the granite is uneven but dips about 20 degrees northward near Empress showing. No evidence was found to support or deny the fault postulated by Tipper (1969) along Taseko River.

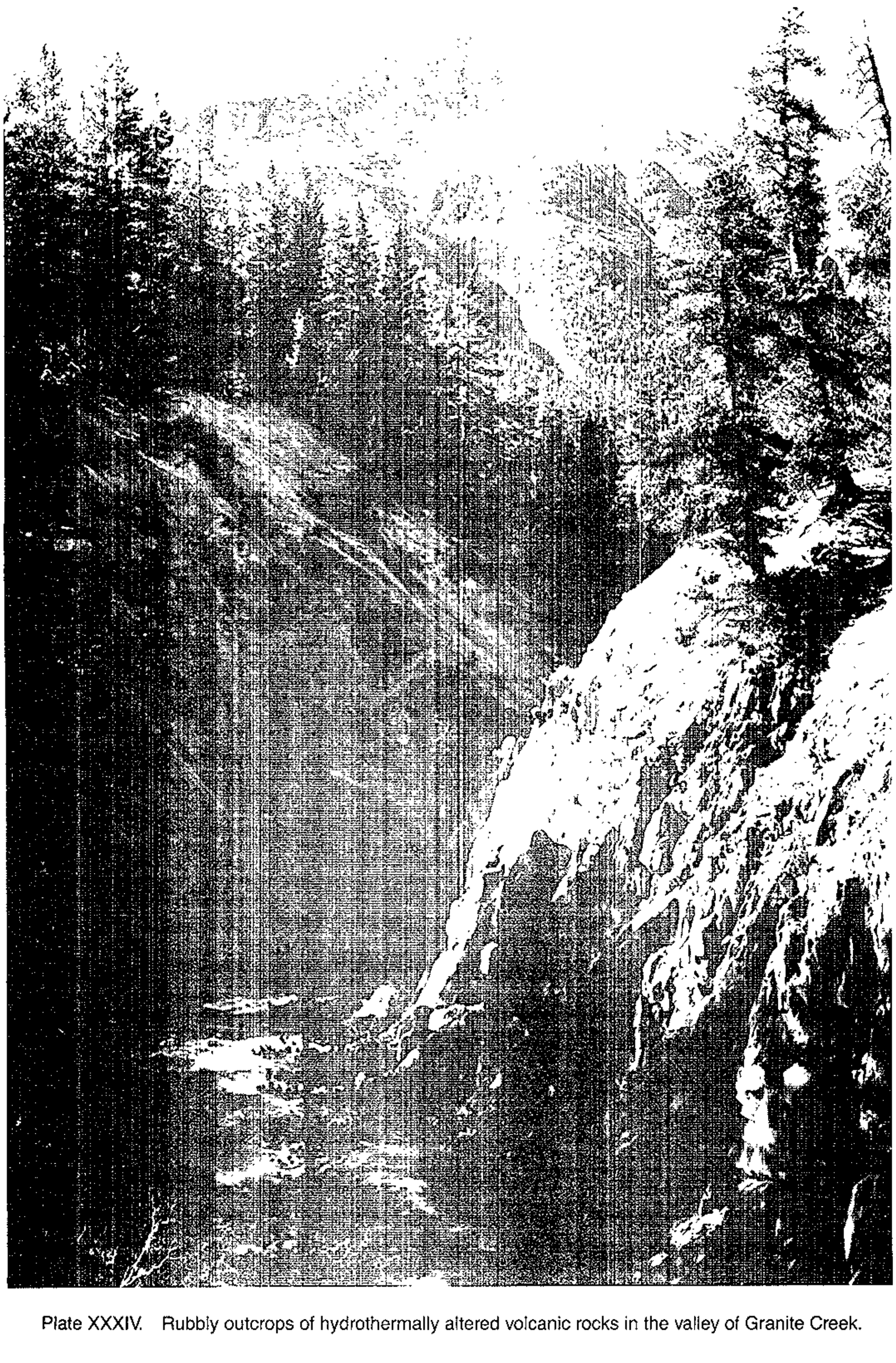

Plate XXXIV. Rubbly outcrops of hydrothermally altered volcanic rocks in the valley of Granite Creek.

Sections along Battlement and Amazon Creeks illustrate the volcanic stratigraphy (Fig. 24), unfortunately, there is no outcrop adjacent to the pluton in either area. The lowermost member seen in each section consists of a few hundred metres of dark green andesite. At Battlement Creek the andesite is overlain by about 450 metres of thick-bedded very fine-grained to coarsely fragmental volcaniclastic rocks which give way upward to a thick section of porphyritic andesite with occasional thin volcaniclastic layers. At Amazon Creek the lower andesite is overlain by a variably altered zone of mixed basic flow and volcaniclastic rocks which grade (?) upward into 150 metres of volcaniclastic rocks similar to those in Battlement Creek. These are overlain by about 180 metres of porphyritic andesite then apparently by another 450 metres of volcaniclastic rocks before the upper porphyritic andesite unit begins.

The lower andesite is dark green, chloritized, and variably massive to porphyritic. Local areas contain small volcanic rock fragments (flow breccia ?). The rock contains accessory pyrite and is cut by chlorite-epidote-magnetite-bearing fractures. Where it is porphyritic the rock has up to 30 per cent medium-grained plagioclase phenocrysts. In thin section alteration was found to be fairly pervasive. Mafic phenocrysts and the feldspathic matrix were partly altered to biotite and chlorite, plagioclase (An_{35}) phenocrysts were epidotized and sericitized. Etching and staining suggest that very fine K-feldspar occurs in the matrix. Crystal outlines suggest that the altered mafic crystals were pyroxene.

In Amazon Creek the rocks overlying the andesite are weakly to strongly hydrothermally altered. Hydrothermal alteration zones often cross lithological boundaries and locally are obviously fracture controlled. Altered zones are typically rusty weathering because the country rock is pyritic as well as variably sericitized, bleached, and silicified. Chlorite, epidote, and possibly some alunite (Livingstone, personal communication) alteration and specularite mineralization accompanied the alteration. The altered zone affects roughly 150 metres of section. Where they are recognizable, rocks in this zone are massive to porphyritic andesitic flows and fine to coarse volcaniclastic rocks. A dark grey basaltic dyke like that at the Spokane showing and a foliated tan-weathering rhyolite dyke crosscut the volcanic sedimentary rocks in this zone. The overlying unit is primarily thickly bedded volcanic sedimentary rocks but there are some intercalated flows. The sedimentary rocks are generally purplish to green and grain size varies from silty to coarsely fragmental in various layers.

Weathering of hydrothermally altered rocks in the Amazon Creek to Granite Creek zone has produced colourful yellow, brown, and red gossans (Plate XXXIV). In detail, the rocks have been moderately to strongly silicified; plagioclase has been variably albitized; mafic minerals have been chloritized, sericitized, and epidotized; and feldspars have been partly altered to sericite, dolomite, epidote, kaolinite, and other (?) clay minerals. Silicification results in quartz infilling in vugs and high siliceous zones in which the host rock has been replaced pervasively by a mosaic of fine quartz crystals. Flaky sericite formed after feldspars and locally as patches of pervasive alteration. In local areas, alteration minerals are quartz, kaolinite, what appears to be pyrophyllite, possibly andalusite (from X-ray analysis), and accessory tourmaline with abundant pyrite. Alunite also has been identified in these altered rocks. Pyrite with minor amounts of specularite in areas of moderate alteration gives way to pyrite and magnetite in intensely altered areas. The end product of alteration is a quartz-magnetite-albite-sericite-pyrite $\pm$ chlorite $\pm$ carbonate rock. Intensely silicified areas often carry chalcopyrite and are of potential economic interest.

In Battlement Creek, volcaniclastic rocks overlie andesitic flows. Beds in this unit pinch and swell and one distinctive zone has a spotted appearance caused by disseminated dark green chlorite-magnetite knots. The rock, which may be a hornfelsed tuff, has secondary biotite and chlorite in the groundmass. Clasts in the coarser zones are mostly volcanic rocks but there are also plagioclase crystal fragments. Pockets and veins of

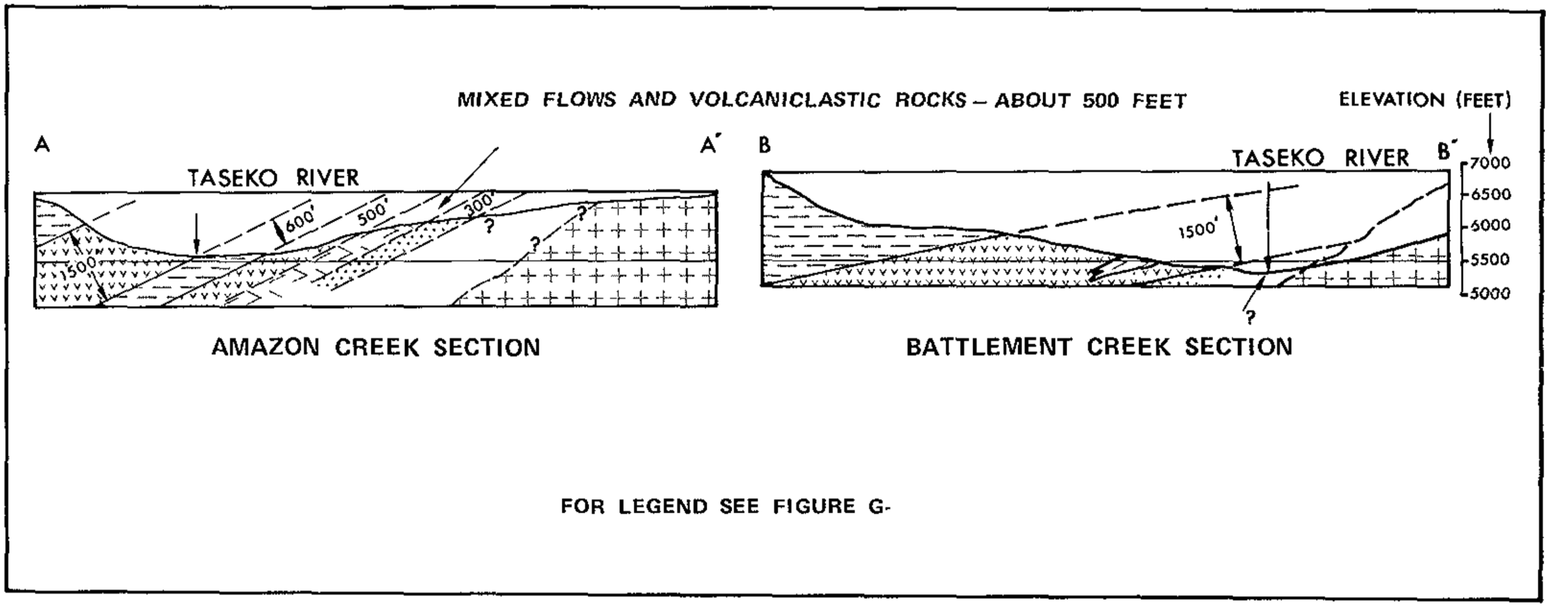

Figure 24. Geological sections in Granite Creek area.

quartz, tourmaline, and pyrite occur in the vicinity of the Taylor-Windfall workings. Taylor-Windfall was not mapped for this report but is well described in the Annual Report of the Minister of Mines for 1935. Apparently very fine to sponge gold was recovered with quartz, tourmaline, rutile, and pyrite gangue in fracture-controlled pockets. Other fine gold occurred in shoots which carried pyrite, tennantite, and chalcopyrite along with some sphalerite, galena, and barite in a gangue of chlorite with some sericite. Much of the gold was apparently disseminated in the chloritic gangue.

Overlying porphyritic andesites have dark grey to purplish matrices and abundant plagioclase phenocrysts. Mafic phenocrysts, either augite or hornblende, occur in small amounts but 20 to 40 per cent medium to coarse-grained plagioclase characterizes the rock. Volcaniclastic layers consist of porphyritic andesite and other fine-grained volcanic fragments. Most clasts are less than 5 centimetres across but a few range to 20 centimetres. Veinlets of celadonite and jasper cut one brecciated outcrop with pervasive carbonate and hematite alteration.

GRANITIC ROCKS: Granitic rocks associated with mineral showings in Granite Creek area are quartz diorites to quartz monzonites. Often they are slightly porphyritic and there are many crosscutting porphyry dykes. Partially chloritized subhedral biotite is the predominant mafic mineral but subhedral hornblende occurs locally. Quartz forms phenocrysts and is intergrown with feldspars in the matrices. K-feldspar is present in varying amounts in matrices where it is often clouded with clay (?) alteration. It is generally slightly perthitic. Plagioclase forms subhedral often eroded laths which are typically partially altered to sericite and carbonate. Most is oligoclase to andesite (An_{25} to An_{35}) with simple normal zoning but some has complex oscillatory zoning.

DATING AT GRANITE CREEK: Age dates from granodiorite, from an alteration zone in the granodiorite, and from a post-mineral dyke have been obtained. Biotite was separated from the granodiorite and the dyke and sericite from the alteration zone (Mohawk showing). As indicated in Table 7, all results were the same within limits of measurement error at 84.7 to 86.7 Ma. These results give the age of the stock, mineralization in it, and post-mineral dyking as mid-Lake Cretaceous.

TABLE 7

Sample	Mesh Size	Material Analysed	$\frac{Ar^{40}}{Total\ Ar^{40}}$	$\frac{Ar^{*40}}{10^{-5}\ cc\ STP/g}$	$\frac{Ar^{*40}}{K^{40}}$	Apparent Age (m.y.)
Granodiorite	$(-40+60)$	biotite	93.7	2.599	5.191×10^{-3}	86.7 ± 2.6
Alteration Zone	$(-60+80)$	sericite	95.3	2.938	5.081×10^{-3}	84.9 ± 2.5
Post-ore Dyke	$(-60+80)$	biotite	89.3	2.475	5.067×10^{-3}	84.7 ± 2.5

GEOCHEMISTRY OF GRANITE CREEK ROCKS

INTRODUCTION: Silicate analysis were made of 19 samples of various intrusive rocks, fresh volcanic rocks, and altered volcanic rocks. (Tables 8 and 9). The intent of the work was to define the chemical nature of the granitic and volcanic rocks and to see what changes occurred during the process of hydrothermal alteration.

TABLE 8. GRANITE CREEK ANALYSES

Sample No.	Granitic Rocks						"Fresh" Volcanic Rocks		
	76-WJ-2	76-WJ-121	76-WJ-13	76-WJ-224	76-WJ-232	76-WJ-239	76-WJ-241	76-WJ-242	76-WJ-262
SiO_2	69.12	67.58 (68.06)*	67.00	65.51	71.40	63.27	58.38	57.41	63.76
Al_2O_3	15.17	16.02 (15.96)	15.54	15.31	14.44	16.12	15.53	16.92	14.71
$(Fe_2O_3)T$	2.54	2.55 (2.60)	3.71	4.61	1.79	4.68	7.64	6.78	4.74
MgO	0.91	2.31 (2.34)	2.07	1.99	1.26	2.41	4.54	3.47	3.45
CaO	1.90	1.97 (1.98)	3.01	2.01	1.13	4.25	3.81	5.28	1.69
Na_2O	4.195	3.883 (3.901)	3.521	3.058	3.646	3.740	4.558	3.657	4.868
K_2O	3.433	1.558 (1.545)	3.165	4.084	4.306	2.827	0.269	1.549	0.663
TiO_2	0.341	0.556 (0.537)	0.569	0.524	0.356	0.557	0.797	0.824	0.665
MnO	0.058	0.038 (0.038)	0.060	0.063	0.032	0.078	0.147	0.107	0.151
H_2O+	1.23	1.90 (2.14)	1.14	1.67	0.99	0.87	1.99	1.27	2.50
H_2O-	0.18	0.22 (0.16)	0.17	0.09	0.18	0.10	0.16	0.15	0.15
CO_2	1.15	0.56 (0.21)	0.20	0.53	0.27	0.20	0.99	0.51	0.78
P_2O_5	0.15	0.28 (0.19)	0.15	0.18	0.07	0.10	0.11	0.08	0.14
S	0.04	0.14 (0.15)	0.01	0.27	0.04	0.02	0.01	0.02	0.05
FeO	1.52	1.87 (1.92)	1.82	3.67	1.12	2.75	3.68	3.16	2.99
Fe_2O_3	0.85	0.47 (0.46)	1.69	0.53	0.55	1.62	3.55	3.27	1.42
TOTAL	100.25	99.34 (99.59)	100.11	99.49	99.81	98.92	98.52	97.68	97.99

TABLE 8. GRANITE CREEK ANALYSES—*Continued*

Sample No.	"Fresh" Volcanic Rocks			Volcaniclastic Rocks		Altered Volcanic Rocks				
	76-WJ-46	76-WJ-55	76-WJ-63	76-WJ-37	76-WJ-571	76-WJ-171	76-WJ-19	76-WJ-281	76-WJ-42	76-WJ-587
SiO_2	59.64	55.21	54.17	71.43	54.91	57.67	62.22	75.87	74.11	50.72
Al_2O_3	16.06	19.96	16.99	19.21	19.31	19.63	11.56	13.39	17.50	31.42
$(Fe_2O_3)_T$	5.92	6.44	7.51	0.39	8.07	6.42	19.73	1.81	0.92	1.12
MgO	2.63	2.90	5.09	0.03	2.84	3.87	0.09	0.93	0.02	0.23
CaO	3.82	7.43	8.46	0.05	3.89	0.28	0.88	0.10	0.04	<0.02
Na_2O	4.767	3.740	3.209	0.120	3.797	0.674	0.957	0.266	0.082	0.424
K_2O	2.500	0.583	0.936	0.075	0.859	3.472	1.278	2.954	0.034	8.838
TiO_2	0.765	0.839	1.003	0.923	1.154	0.846	0.940	0.299	0.876	1.158
MnO	0.095	0.109	0.178	<0.003	0.078	0.019	0.056	0.004	0.003	0.010
H_2O+	1.68	1.03	1.58	6.24	2.52	3.66	1.39	1.74	2.42	3.16
H_2O-	0.13	0.16	0.14	0.20	0.38	0.21	0.21	0.17	0.13	0.16
CO_2	0.55	0.27	0.20	0.20	0.20	0.20	0.32	0.20	0.20	0.20
P_2O_5	0.07	0.15	0.21	0.13	0.22	0.07	0.07	0.09	0.40	0.17
S	0.03	0.01	0.01	0.10	0.02	2.44	0.43	0.10	0.90	0.04
FeO	2.25	2.92	3.36	0.10	3.45	2.66	7.85	0.80	0.22	0.17
Fe_2O_3	3.42	3.20	3.78	0.28	4.24	3.46	11.00	0.92	0.67	0.93
TOTAL	98.41	98.52	99.32	99.08	97.87	99.16	99.25	97.84	97.61	97.65

TABLE 9. C.I.P.W. WEIGHT NORMS (WATER-FREE) FOR GRANITE CREEK ROCKS

	Granitic Rocks						"Fresh" Volcanic Rocks		
	76-WJ-2	76-WJ-121	76-WJ-13	76-WJ-224	76-WJ-232	76-WJ-239	76-WJ-241	76-WJ-242	76-WJ-262
Quartz	29.31	33.61	25.63	24.80	30.27	17.92	18.31	15.02	26.30
Corundum	4.17	6.51	1.69	3.95	2.56	—	3.50	1.04	5.30
Orthoclase	20.53	9.47	18.93	24.70	25.80	17.06	1.65	9.51	4.11
Albite	35.91	33.79	30.15	26.48	31.28	32.31	40.02	32.15	43.21
Anorthite	1.19	4.53	12.84	5.57	3.49	19.24	12.37	23.32	2.66
Clinopyroxene	—	—	—	—	—	0.23	—	—	—
Orthopyroxene	3.94	8.18	6.35	10.75	4.27	9.00	14.62	10.99	12.68
Magnetite	1.25	0.70	2.48	0.79	0.81	2.40	5.34	4.93	2.16
Ilmenite	0.66	1.09	1.09	1.02	0.69	1.08	1.57	1.63	1.32
Hematite	—	—	—	—	—	—	—	—	—
Rutile	—	—	—	—	—	—	—	—	—
Apatite	0.35	0.67	0.35	0.43	0.17	0.24	0.27	0.19	0.34
Calcite	2.65	1.31	0.46	1.23	0.62	0.46	2.34	1.20	1.86
Other (sulphur)	0.04	0.14	0.01	0.28	0.05	0.02	0.01	—	0.05

TABLE 9. C.I.P.W. WEIGHT NORMS (WATER-FREE) FOR GRANITE CREEK ROCKS—*Continued*

	"Fresh" Volcanic Rocks			Volcaniclastic Rocks		Altered Volcanic Rocks				
	76-WJ-46	76-WJ-55	76-WJ-63	76-WJ-37	76-WJ-571	76-WJ-171	76-WJ-19	76-WJ-281	76-WJ-42	76-WJ-587
				(altered)						
Quartz	12.25	11.73	8.97	75.98	18.58	36.09	50.22	64.14	77.29	14.93
Corundum	0.01	0.65	—	20.43	6.37	15.49	8.10	10.17	18.23	22.43
Orthoclase	15.29	3.54	5.67	0.48	5.35	21.53	7.73	18.20	0.21	55.37
Albite	41.76	32.52	27.82	1.10	33.83	5.98	8.29	2.35	0.73	3.80
Anorthite	15.55	35.17	29.91	—	17.48	—	1.93	—	—	—
Clinopyroxene	—	—	7.70	—	—	—	—	—	—	—
Orthopyroxene	7.01	9.00	10.07	0.08	8.58	10.81	4.20	2.64	0.05	0.61
Magnetite	5.13	4.77	5.61	—	6.47	5.26	16.33	1.39	—	—
Ilmenite	1.50	1.64	1.95	0.23	2.31	1.69	1.83	0.59	0.50	0.40
Hematite	—	—	—	0.30	—	—	—	—	0.70	0.99
Rutile	—	—	—	0.87	—	—	—	—	0.66	1.02
Apatite	0.17	0.50	0.36	0.33	0.54	0.17	0.17	0.22	0.98	0.42
Calcite	1.29	0.47	0.63	0.49	0.48	0.48	0.75	0.47	0.48	0.48
Other (sulphur)	0.03	0.01	0.01	—	0.02	2.44	0.43	0.10	0.90	0.04

NOTE: Normative Color Index = 100 (Corundum + acmite + clinopyroxene + orthopyroxene + olivine + wollastonite + magnetite + ilmenite + rutile + chromite) divided by sum of all normative minerals.

GRANITIC ROCKS: The granitic rocks are variably porphyritic to even-grained quartz monzonites (adamellites) and granodiorites. They are of calc-alkaline affinity but too few analyses were done to show overall differentiation trends. On an A-F-M plot (Fig. 25) the rocks analysed are generally slightly iron deficient compared to average adamellite and average granodiorite (Nockolds, 1954). Normative quartz versus orthoclase versus albite plotted for each sample (Fig. 26) are similar to adamellites and granodiorites of approximately the same age from northern British Columbia (Gabrielse and Reesor, 1974). The sample (121) which is relatively distant from the others on the normative quartz-orthoclase-albite plot, is a vuggy, altered porphyritic biotite quartz porphyry.

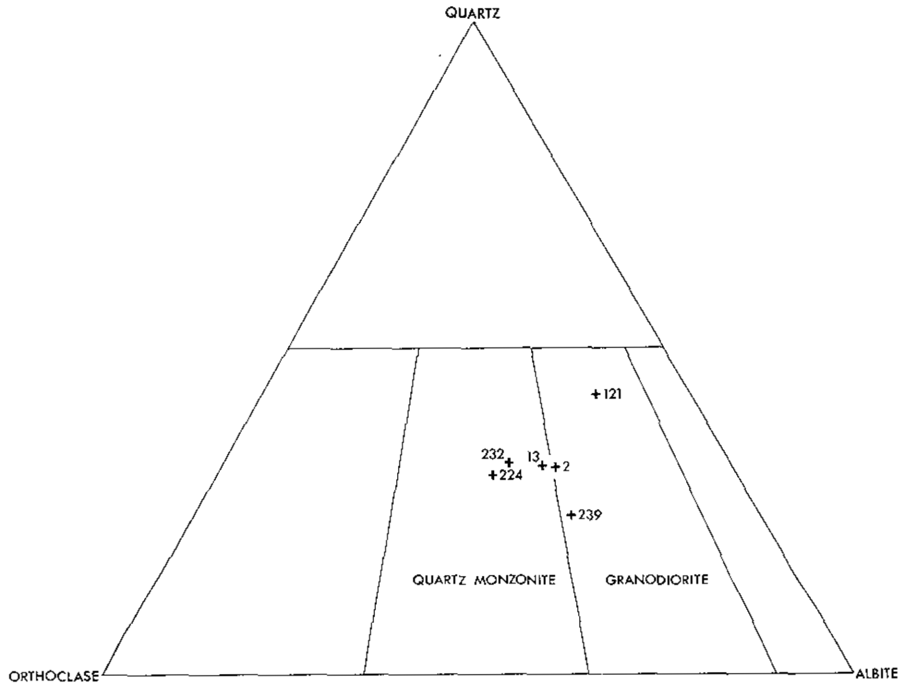

Figure 25. AFM diagram for analysed granitic and volcanic rocks from Granite Creek.

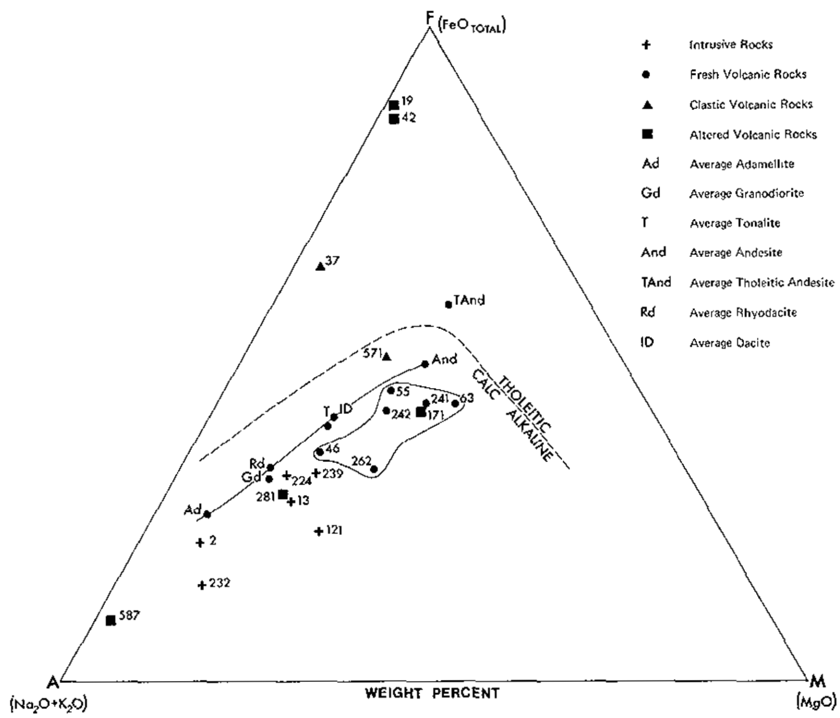

Figure 26. Plot of quartz-orthoclase-albite for granitic rocks from Granite Creek.

VOLCANIC AND VOLCANICLASTIC ROCKS: The rocks are classified according to the scheme of Irvine and Baragar (1971) by plotting A-F-M (Fig. 25) and normative plagioclase versus Al_2O_3 and normative colour index (Fig. 27). The plot show that the relatively unaltered volcanic flows are calc-alkaline and range from dacite to basalt in composition. According to the classification scheme of Church (1974), the rocks are dacitic andesites, andesites, and basalts (Fig. 28). Only one 'fresh' volcaniclastic sample was analysed and it is a calc-alkaline andesite according to both schemes. On a normative orthoclase-albite-anorthite plot (Fig. 29), most of these rocks fall in the average range but two are sodic. One, 241, is either tholeiitic andesite or sodic dacite (Irvine and Baragar, 1971), or basalt (Church, 1974); the other, 262, dacite, sodic rhyolite, or dacite andesite. It is probable that both these samples were hydrothermally altered. Classification according to normative plagioclase composition is too sensitive to changes in alkali ratios to be used in areas where hydrothermal alteration is suspected; alkalis and lime are too mobile. Changes in alkali content strongly influence nomenclature in the Irvine and Baragar scheme but, unless they are large, have lesser effects on nomenclature in the Church scheme where 241 is basalt and 262 is dacitic andesite.

ALTERED VOLCANIC AND VOLCANICLASTIC ROCKS: Alteration zones are generally pyritiferous and so form colourful rusty zones. In detail, the rock is variably bleached to a pale grey colour and altered to clay minerals, sericite, quartz, specularite, sodic plagioclase, some tourmaline, rare andalusite, and alunite. Other locally abundant secondary minerals are biotite, tourmaline, magnetite, and chalcopyrite.

Chemical analyses of altered volcanic rocks were compared to those of equivalent fresh volcanic rocks to see what changes in bulk chemistry occurred during hydrothermal alteration. There are too few samples to show regional changes or to do mass balance calculations, but several trends and variants are evident (Fig. 30). In general, SiO_2 was added but in one aluminum-rich, andalusite-bearing sample it was leached. Al_2O_3 tended to be reduced slightly during alteration. Surprisingly total iron was typically decreased although as expected it was markedly increased in one magnetite-rich sample. Some iron was undoubtedly lost because of weathering but presumably some was removed during hydrothermal alteration, despite formation of specularite and pyrite during the alteration. Sulphur was added to the system except in samples with abundant magnetite. Some water was introduced and there was slight oxidation. As was expected from the mineralogy, calcium, magnesium, and sodium were leached but potassium was added during alteration.

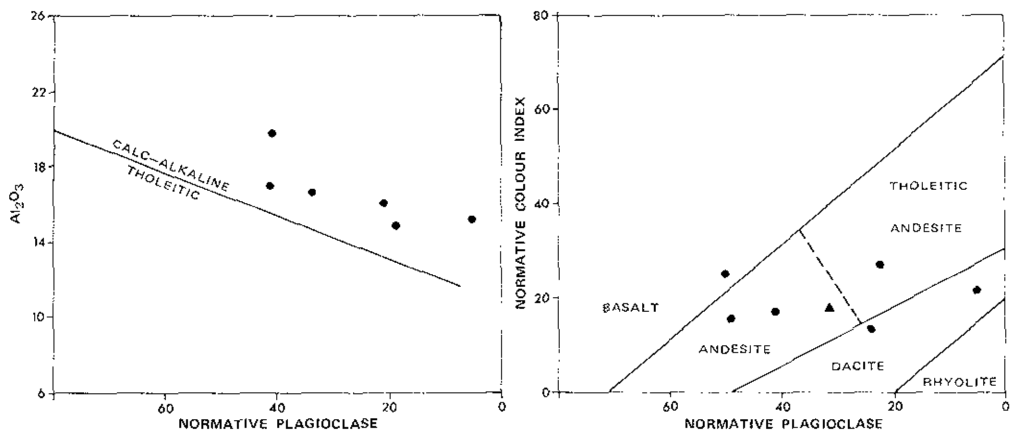

Figure 27. Normative plagioclase plotted against Al_2O_3/SiO_2 versus basicity index for 'fresh' volcanic rocks from Granite Creek.

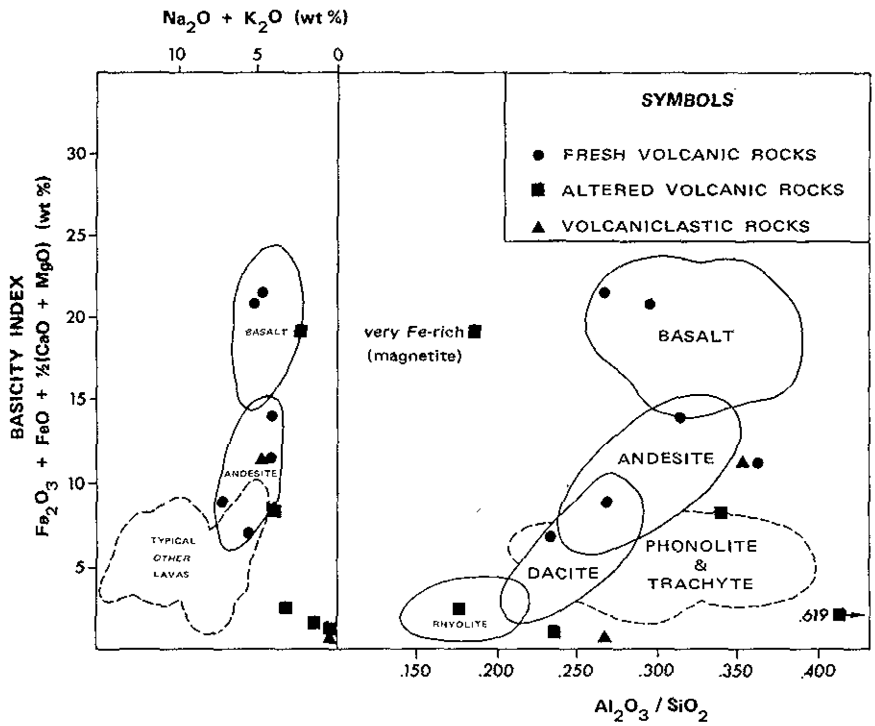

Figure 28. Plot after Church (1974) of Al_2O_3/SiO_2 versus basicity index for 'fresh' volcanic rocks from Granite Creek.

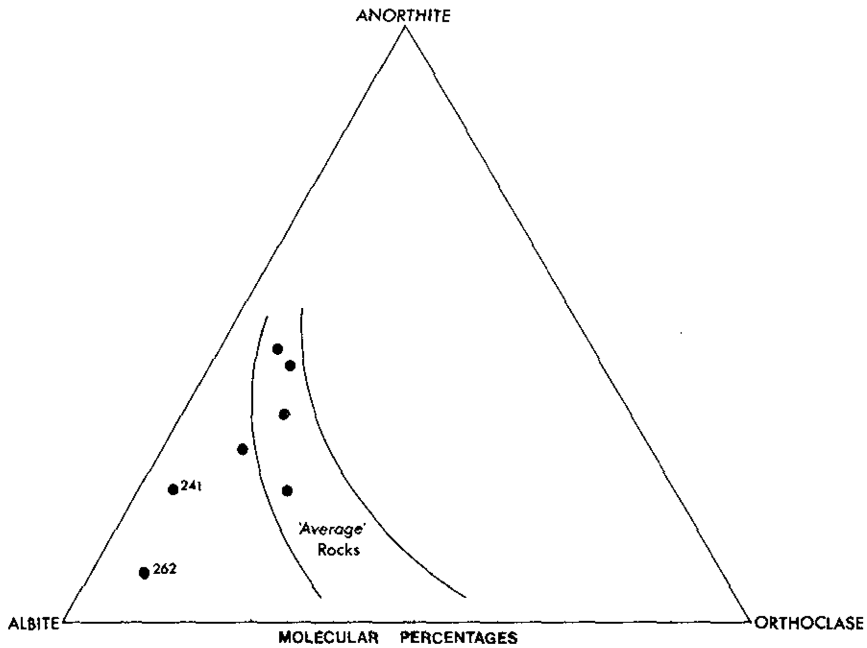

Figure 29. Plot of normative albite-orthoclase-anorthite for 'fresh' volcanic rocks, Granite Creek.

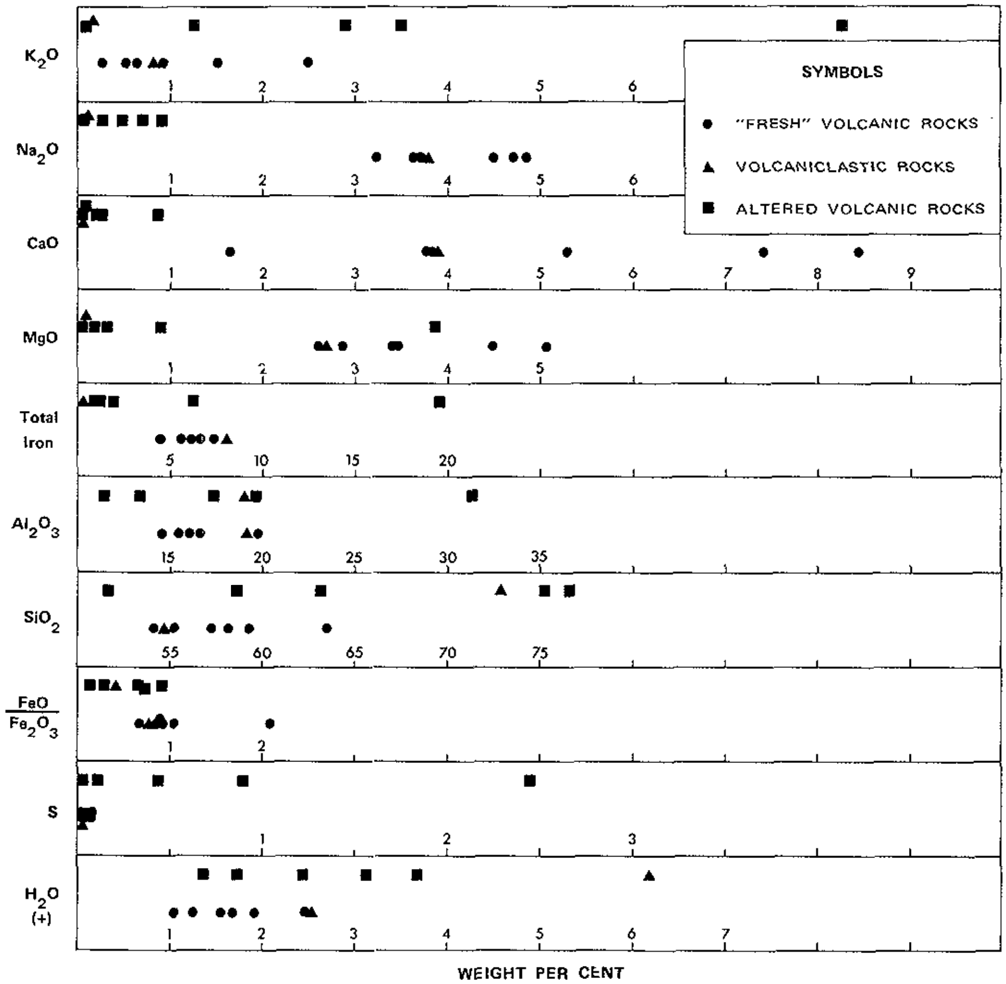

Figure 30. Plot of analysed oxides and sulphur for 'fresh' and altered volcanic rocks, Granite Creek.

DEPOSITS IN THE GRANODIORITE

BUZZER SHOWING: Mineralization at Buzzer forms a subcircular zone in variably altered porphyritic quartz diorite (Fig. 31). The country rock is vuggy and sulphides, quartz, flaky sericite, and rarely tremolite fill the vugs. The country rock is distinctly porphyritic at the main open cut but gradually gives way northward to grey, slightly porphyritic granodiorite. The size and percentage of phenocrysts in the rock vary. Consequently, unless there is an appropriate weathered face, the porphyritic nature of the rock is not always obvious.

In mineralized areas the country rocks are both relatively fresh and altered. Relatively fresh rocks look grey whereas the altered rocks are pink. Mafic minerals in both types are pervasively chloritized and plagioclase (An_{30}) is mildly to pervasively altered to sericite and carbonate. Mineralization occurs in vugs in the country rock but although the size and percentage of vugs increase in more altered zones grade is not necessarily better there.

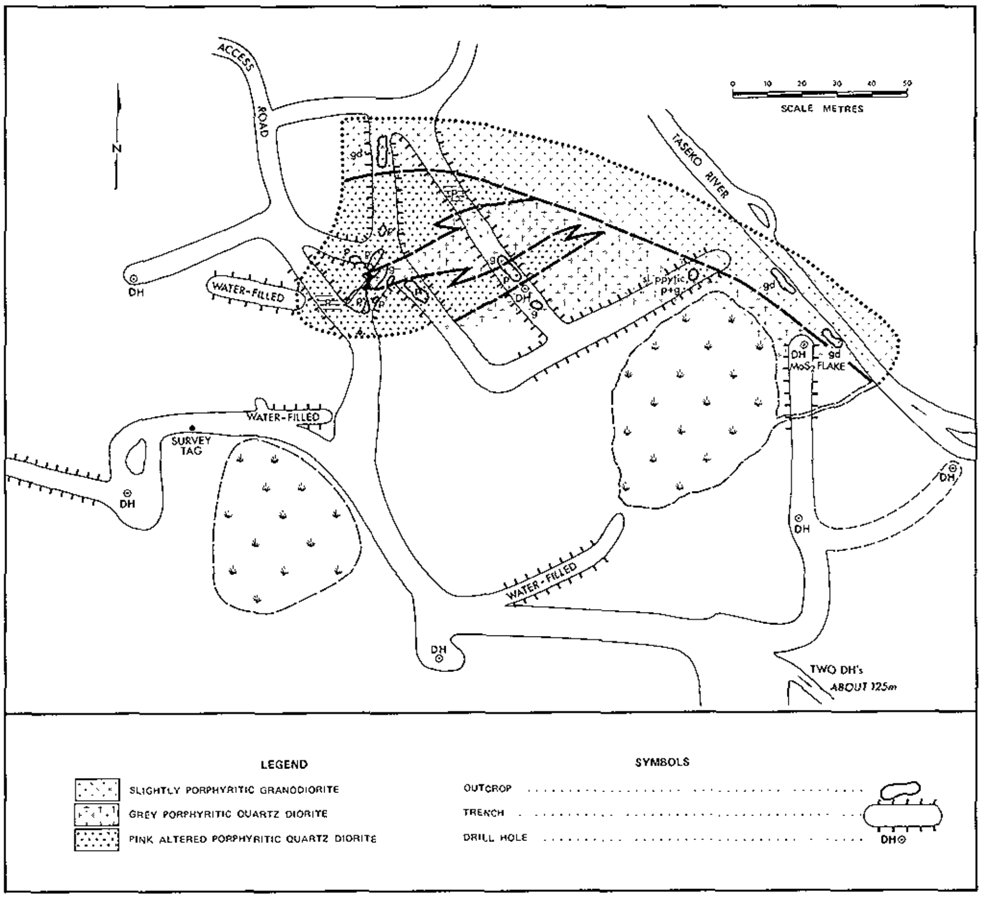

Figure 31. Buzzer showing, Taseko River.

Chalcopyrite is the predominant mineral in vugs in 'fresh' zones whereas flaky sericite and quartz are more abundant than chalcopyrite in vugs in 'altered' zones. Molybdenite occurs locally. Areas of pink alteration trend 060 to 070 degrees and are probably fracture controlled. Oxidation is minor but some malachite occurs. The overall control which localizes mineralization is obscure. It appears, however, that the granitic rocks were high level intrusions and that mineralization occurred in gas cavities in volatile-rich areas. Consequently, these areas of 'disseminated' mineralization may be embryonic shatter zones.

Reserve potential for the deposit cannot be estimated from surface exposures although the deposit has been outlined by drilling. Visual estimates suggest copper between 0.3 and 0.4 per cent and minor amounts of molybdenum; minor values in gold have been reported also. Depending on depth extent, reserves are likely to be between 1 and 10 millions tonnes.

ROWBOTTOM SHOWING: Mineralization in the Rowbottom showing (Fig. 23; Plate XXXV) closely resembles that at the Buzzer showing with the exceptions that the rock is quartz monzonite rather than quartz diorite and pyrrhotite is a minor accessory. Mineralization is in vugs and replaces chloritized mafic minerals in variably altered porphyritic granodiorite. At Rowbottom as at Buzzer copper abundance is not directly correlated with alteration intensity. In more altered zones at Rowbottom the rock is pinker, fractures are rusty, and vugs may comprise 10 per cent by volume. The vugs are rusty weathering, rounded to elliptical in outline, and range to 1 centimetre by 2.5 centimetres. Generally in the mineralized zone feldspar is mildly altered to sericite and carbonate and is pink to yellow-green in colour; mafic minerals are completely chloritized. Local epidote alteration was noted in drill core. In this deposit plagioclase phenocrysts are medium to coarse grained, mafic phenocrysts are coarse grained and range from 15 to 20 per cent, and there are several per cent medium-grained quartz phenocrysts. The matrix is a finely crystalline mixture of quartz, mafics, and feldspar.

Away from the main showing, the rock is less obviously porphyritic and alteration decreases. Mafic minerals are seen to be biotite and hornblende in roughly equal abundance. Sulphides continue to be present but pyrite rather than chalcopyrite predominates.

In drill core, the country rock granodiorite is cut by barren, locally epidotized, porphyritic dykes. The dykes have hornblende (8 per cent) and plagioclase (15 per cent) phenocrysts in a finely crystalline grey matrix. These dykes are probably of post-mineral age.

No estimates of tonnage potential are possible with available data but the zone is apparently smaller than the Buzzer showing with roughly the same grades.

MOHAWK SHOWING: Mineralization at Mohawk is largely confined to a zone of apparently monomictic breccia (Fig. 32; Plate XXXVI). Breccia fragments consist almost entirely of hematite-speckled, finely crystalline leucocratic 'aplite' although there are rare intrusive fragments (Wolfhard, personal communication). Most fragments are from fist to boulder size and many are rounded. The fragments do not appear to be strongly altered but the breccia matrix is veined by and infilled with quartz, flaky sericite, and sulphides. In thin section, the 'aplite' is seen to consist of iron oxide and flaky sericite in a fine mosaic of albite grains, consequently, it may be an alteration product rather than an intrusive body. Although the breccia body is irregular in detail, it can be traced northeasterly across the hillside (Fig. 32). An adit, which is now caved, was driven by Cominco in 1928 and extended by Motherlode Gold Mines Ltd. between 1933 and 1935 *(Minister of Mines, B.C.,* Ann. Rept., 1935). It intersected the breccia and confirmed that the body dips steeply southeastward. Along strike to the northeast, the breccia zone narrows rapidly, to the southwest there is no exposure. At its maximum, the zone is roughly 25 metres wide. In the underground working, where the footwall is reported to be marked by a 1-metre-wide gouge zone, mineralization is weak and confined to a 10-metre-wide zone adjacent to it (*Minister of Mines, B.C.,* Ann. Rept., 1935, p. F24).

Mineralization occurs as disseminations in the matrix of the breccia and with quartz in veinlets. Chalcopyrite is the predominant sulphide and is reported to carry significant gold and weak silver values. Lesser molybdenite and minor galena and sphalerite occur. Small amounts of tourmaline and rutile have been reported and calcite-apatite veinlets were found in the adit dump.

Quartz veins occur throughout the breccia but are most abundant adjacent to the hangingwall. They tend to be vuggy, locally have crystals to 3 centimetres in length, and may carry chalcopyrite, pyrite, disseminations or rosettes of molybdenite, galena, or sphalerite. Molybdenite and galena appear to be more abundant near the hangingwall. Some quartz veins have coarse-grained envelopes, some have flaky sericite in vugs. Molybdenite rosettes are usually rimmed by pale brown micaceous-looking powellite. Chalcopyrite also occurs as disseminations in the quartz-flaky sericite-rich breccia matric. In outcrop, oxidation has produced local malachite staining.

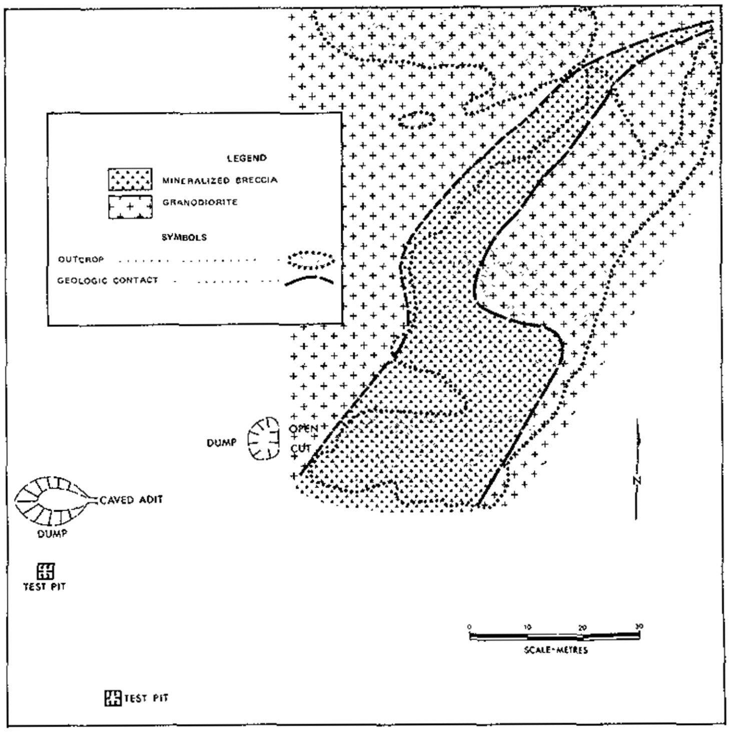

Figure 32. Mohawk showing, Granite Creek.

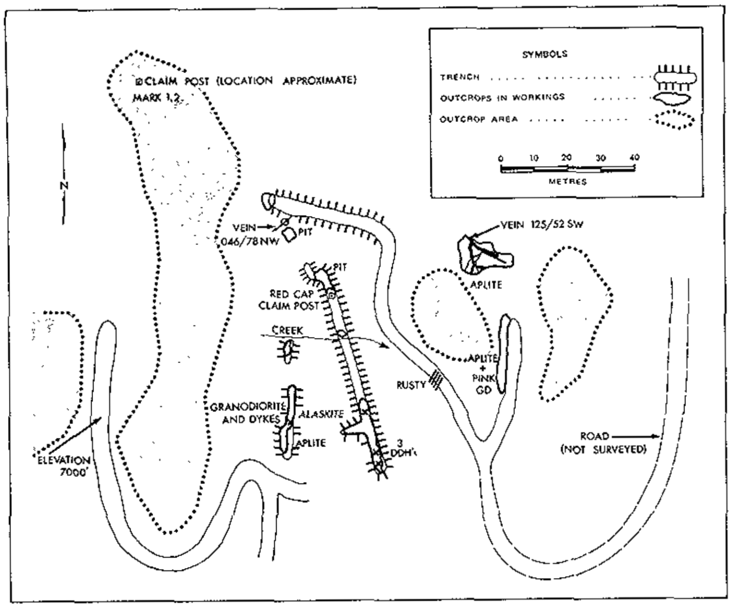

Figure 33. Spokane showing, Amazon Creek.

Adjacent to the mineralized zone, the footwall country rock has a narrow zone of weak argillic alteration of plagioclase and chloritization of biotite. The hangingwall alteration halo is also narrow but is more intense; in it, plagioclase is altered to a pink-coloured mixture of sericite, carbonate, and hematite (?) and biotite is sericitized. Pink rims also occur locally on altered plagioclase within a few feet of the zone in the footwall (Wolfhard, personal communication).

The country rock of the Mohawk showing is variably even-grained to porphyritic biotite granodiorite to quartz monzonite. The textural variations apparently reflect local conditions of crystallization rather than multiple intrusions because porphyritic and even-grained varieties seem to have gradational boundaries. Further, biotite and plagioclase which comprise phenocrysts in the porphyritic rocks are also early formed components in those which are even grained. K-feldspar and quartz are late interstitial components.

East of the showing the granitic country rock is cut by medium to dark grey, fine-grained to porphyritic dykes. Phenocrysts, where present, are biotite and plagioclase. One finely crystalline dyke had calcite amygdules.

RESERVE POTENTIAL: Insufficient data are available to estimate reserves for the showing. Assay results from the 1935 Annual Report of the Minister of Mines suggests that grades at surface will average about 0.15 ounce gold over 20 metres with copper near 0.75 per cent. Grades lessen and the zone narrows with depth. Reserves potential of the known zone to a depth of 30 metres is roughly 150 000 tonnes; grades will be less than the above estimates.

SPOKANE SHOWING: Mineralization at Spokane (Plate XXXVII) is in veins in shear zones and along altered fractures in biotite hornblende granodiorite (Fig. 33). In the area of the workings, the country rock is cut by pre-mineral aplite and alaskite dykes. Often the dykes are altered and locally are heavily pyritized. Basaltic post-mineral dykes have glassy quartz amygdules set in a finely crystalline matrix shot through with plagioclase microlites. Xenoliths are fairly common in the granodiorite. Most are medium grained, grey, and partly assimilated but some are amphibolites. Almost all the xenoliths are less than 15 centimetres across.

Sulphides occur both as disseminations in altered country rock and pre-mineral dykes and in veins. Most of the disseminated sulphide is pyrite but chalcopyrite and pyrite are prominent vein minerals. Usually granodiorite adjacent to veins is altered to a pink colour because plagioclase is hematized and mafic minerals are pervasively chloritized. Veins often have walls lined with quartz with well-developed crystal terminations and cores filled with sulphides. Chalcopyrite and pyrite predominate in the veins but arsenopyrite occurs locally. Along fractures with associated pink alteration, chalcopyrite and pyrite occur in pockets of quartz-sericite alteration. The best mineralized veins on the property strike northeast or southeast and are steeply inclined. In weathered surface exposures, primary sulphides have been partially altered to malachite and chrysocolla. Pyrite-rich areas are rusty weathering and in them the country rock tends to be bleached to a pale grey colour. Tan to green-coloured scheelite was an accessory in one vein.

It is difficult to assess the reserve potential of this deposit from surface exposures. According to early assay reports gold is present but best values were in leached, oxidized granodiorite rather than with chalcopyrite.

DEPOSITS IN THE VOLCANIC ROCKS

EMPRESS: Rocks at the Empress showing are pervasively altered. Judging from regional relationships the country rocks are a mixed assemblage of andesitic flows, porphyritic flows, and mixed fine to coarse, thickly bedded fragmental volcanic rocks. At

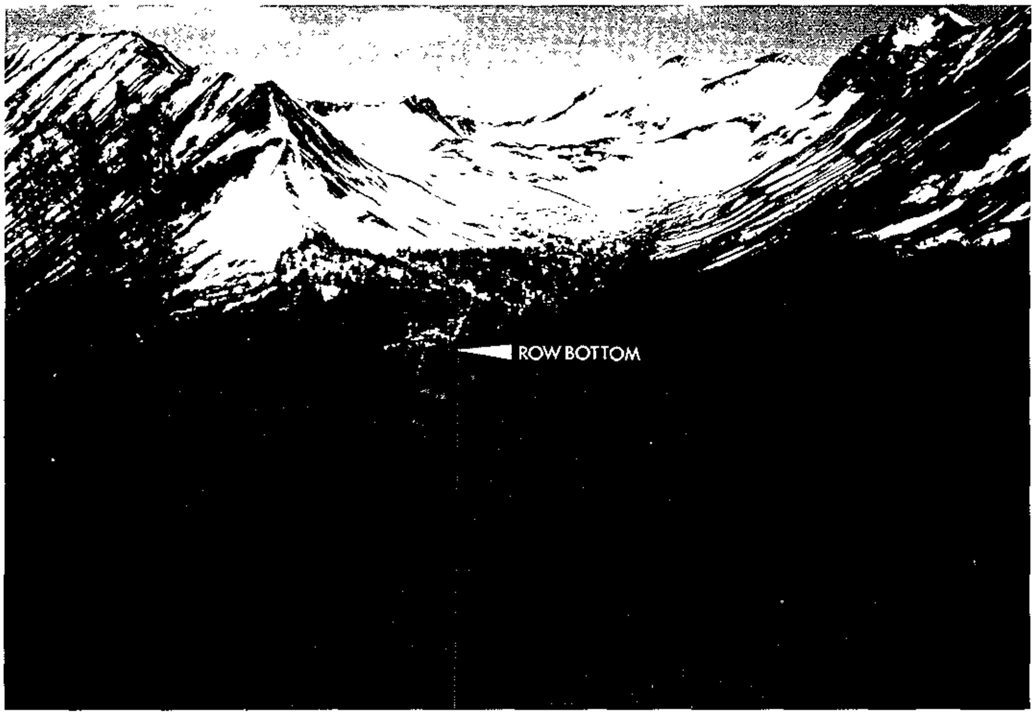

Plate XXXV. View looking west from the Mohawk showing to show the setting and access roads on the Rowbottom showing, Granite Creek area.

Empress, bleaching, sericitic alterations, and pervasive silicification were accompanied by formation of pyrite, chalcopyrite, and magnetite. Alteration intensity and type vary as do amounts and proportions of magnetite and sulphides. Both in trenches and in drill core, variations in magnetite content impart lighter and darker colour banding and a foliation to the rock. The foliation typically dips 40 to 50 degrees and may represent relict bedding.

Silicification is more intense at Empress than elsewhere in the hydrothermally altered area adjacent to the grandodiorite contact (Fig. 23) along Taseko River. In places the rock now consists primarily of granular quartz with disseminated magnetite and sulphides. Sericitic alteration is expressed as both pale pink or green alteration of feldspars and as flaky sericite which is disseminated, in pockets, and in veinlets. Where the flaky sericite is disseminated, it generally accompanies magnetite, quartz, sulphides, and often feldspar. In pockets and veinlets it is often joined by quartz and sulphides. Less commonly specularite rather than magnetite and chlorite may be present.

Magnetite is predominantly disseminated but at the original Empress showing it forms irregular patches and massive zones in a strongly silicified outcrop. Sulphides are mainly pyrite and chalcopyrite but there are minor amounts of molybdenite and pyrrhotite. Sulphides occur dominantly as disseminations with minor amounts present in fractures and in veins. Gangue minerals in fractures and veins include calcite, quartz, and chlorite. Gypsum-coated fractures occur locally and are associated with soft green montmorillonite alteration zones. Some fractures are coated with white kaolinite. Potential reserves for the showing are unknown but apparently small.

Plate XXXVI. Mineralized monomictic breccia comprises much of the Mohawk showing. Mineralization is largely in the sericitized matrix of the breccia.

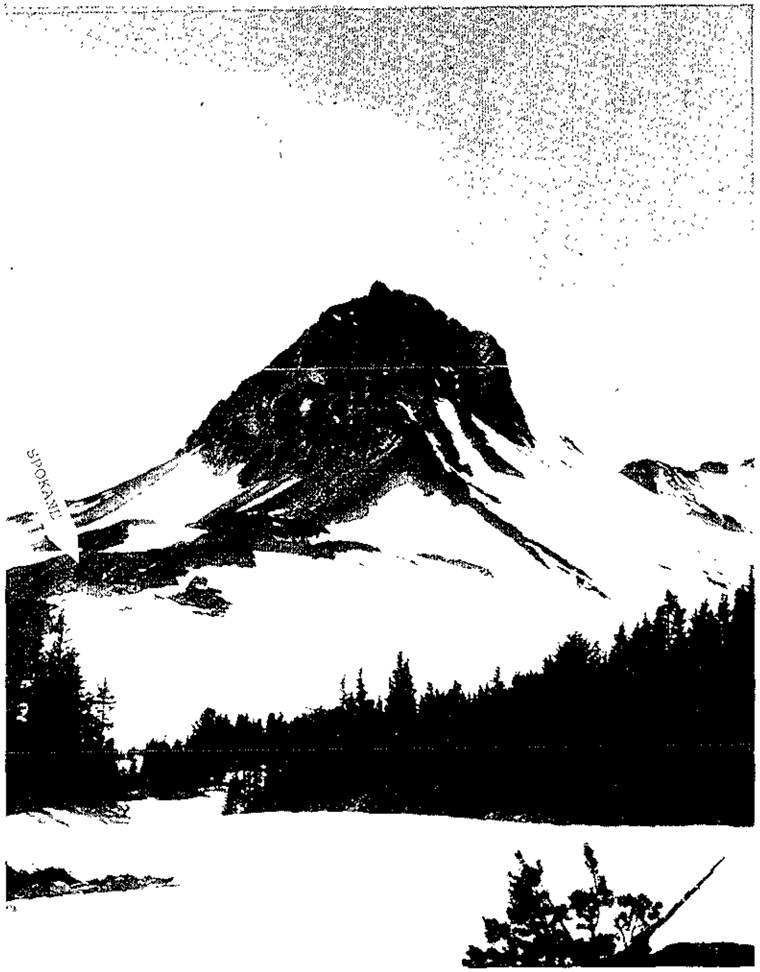

Plate XXXVII. View westward to Mount McClure with Spokane showing in the clear area immediately above the snowfield.

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FISH LAKE DEPOSIT (920/5E)

By W. J. McMillan

LOCATION AND ACCESS: The Fish Lake deposit is situated about 130 kilometres southwest of the city of Williams Lake and about 10 kilometres north of the north end of Taseko Lake. Access is via the Bella Coola Highway to Lee's Corners, roughly 100 kilometres from Williams Lake, then southward and westward across the Chilcotin River, through the Chilco Ranch and the Stoney Creek Indian Reserve and west to the White-water Bridge across the Taseko River. A branch road goes southward along the east side of the river and about 10 kilometres along it another branch road leads 6 kilometres eastward to the property and Fish Lake (Plate XXXVIII).

REGIONAL GEOLOGIC SETTING: The Fish Lake deposit (Fig. 34) lies within an embayment in the north contact of a northwest elongated, fine-grained, porphyritic quartz diorite stock. The stock was emplaced into marine Lower Cretaceous shale and greywacke and marine to non-marine Lower to Upper Cretaceous andesitic pyroclastic rocks with intercalated massive to porphyritic flows which occupy the Tyaughton Trough. The Tyaughton Trough is a successor basin infilled by both marine and non-marine sedimentary and volcanic rocks. Infilling of the trough occurred from mid-Jurassic to mid-Cretaceous time and the last marine transgression occurred in the Early Cretaceous. Swarms of east-trending feldspar porphyry dykes (Jeletzky and Tipper, 1968) north of the stock and northerly to northwesterly trending faults north and south of it disrupt the Cretaceous succession (Tipper, 1963). One of these, the Yalakom fault had significant transgressive movement during Late Cretaceous time accompanied by volcanism and continental sedimentation.

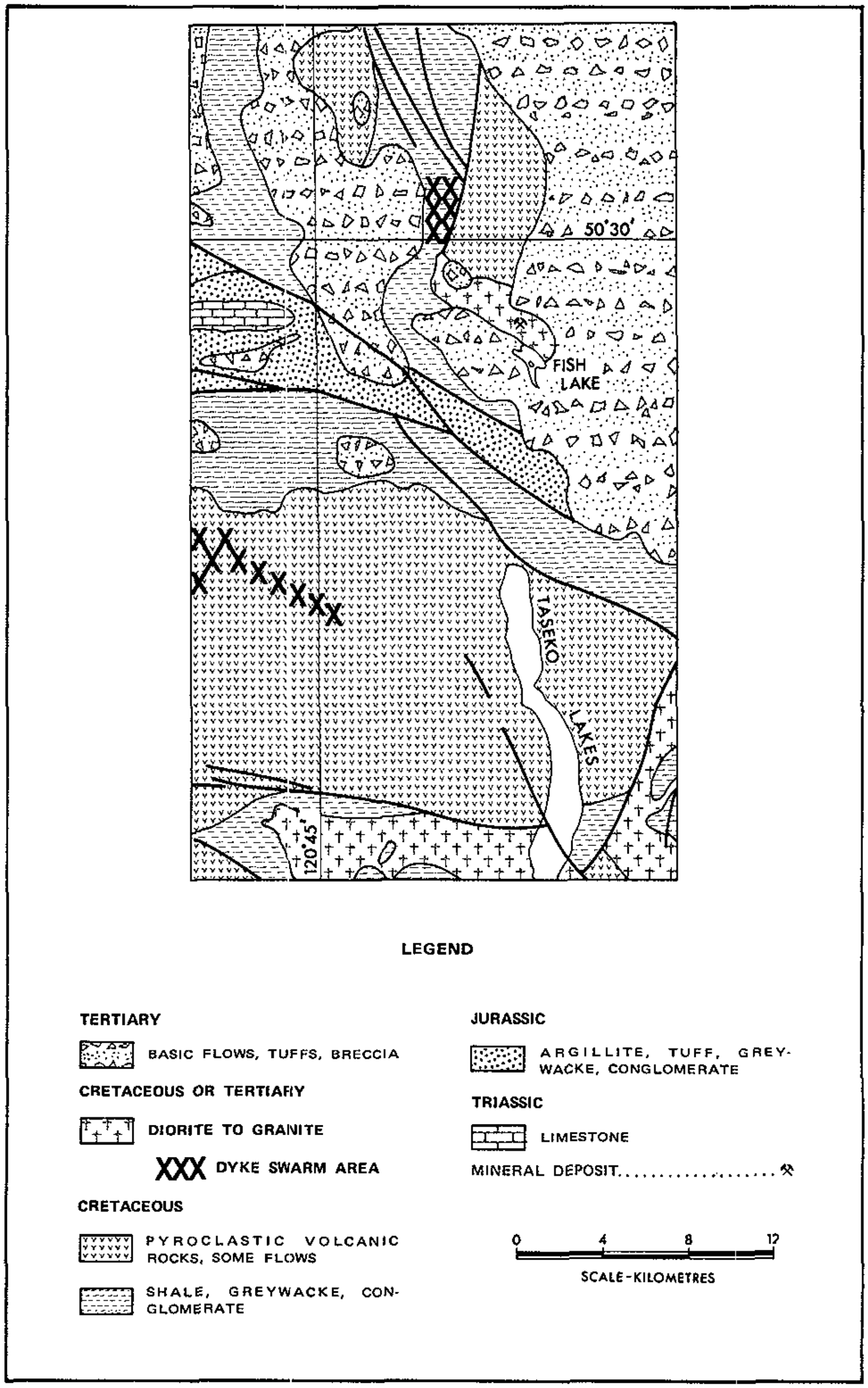

Figure 34. Regional geological setting of Fish Lake deposit.

Plate XXXVIII. View across Fish Lake toward Taseko Mountains.

In the embayment of the contact of the quartz diorite stock where the Fish Lake deposit lies, hornfelsed sedimentary, volcanic, and pyroclastic country rocks were intruded by a complex of post-diorite dykes and small stocks. Mineralization at Fish Lake occurred 77 Ma ago (Wolfhard, 1976) and may be genetically linked to later stages of this fault movement and volcanism. Subsequently, much of the area was covered by Miocene lavas or Pleistocene to Recent alluvial deposits. Erosion has opened windows in the Miocene lavas and Fish Lake deposit is exposed in one of these.

LOCAL GEOLOGIC SETTING: The Fish Lake porphyry system (Fig. 35a) occurs in an area of volcanic, sedimentary, and porphyritic intrusive rocks within a plication in the contact of a fine-grained porphyritic quartz diorite stock. As a result of contact metamorphism associated with the various intrusions, the country rocks were pervasively converted to biotite hornfels. As is discussed later, the distribution of biotite is complicated both by a superimposed wave of hydrothermal biotite alteration and by later overprinting of argillic-propylitic alteration assemblages.

The country rock was a mixed assemblage of massive to porphyritic volcanic and volcaniclastic rocks, greywackes, and shales. Few original textures have survived the overlapping effects of the thermal and hydrothermal events. In many instances, where alteration is strong, it is difficult to distinguish volcanic country rock from altered finely crystalline intrusive rocks in this subvolcanic regime.

Rocks of the large quartz diorite stock are not exposed on the property but have been described by Wolfhard (1976). They are finely crystalline, but porphyritic with 20 to 40 per cent, 1 to 2 millimetre euhedral plagioclase phenocrysts and 10 per cent hornblende phenocrysts in a matrix of plagioclase, quartz, and 1 to 5 per cent biotite.Plagioclase is typically reversely zoned An_{40-45} with some An_{50} overgrowths. Wolfhard also describes two younger pre-mineral porphyry phases and one post-mineral phase.

In this study, porphyries were grouped as pre-ore plagioclase porphyry and quartz plagioclase porphyry (QFP) and post-ore mafic plagioclase porphyry. In pre-ore porphyries mafic phenocrysts are often but not always present; in all types mafic minerals are pervasively altered. There is very sparse bedrock exposure and drill holes are widely spaced so relative age relationships are not clearly defined. Tentatively, however, there appears to be an area of younger plagioclase porphyry cut by QFP more or less centrally located in the 0.15 per cent copper contour (Figs. 35a and b). To the southwest and southeast are large and small bodies respectively of older (?) plagioclase porphyry in which the matrix has been biotitized. These probably correspond to Wolfhard's older porphyritic quartz diorite porphyry. An attempt was made to contour the upper surface of the QFP based on drill hole intersections. Too many interpretations were possible from the fragmentary data but generally it seems that there are several bodies of QFP with varying strikes, moderate to low dips, and varying thicknesses (Figs. 36 and 37). There does seem to be a body with northwesterly strike and perhaps one with northerly strike. These trends are speculative and at odds with those given by Wolfhard. He suggests easterly strikes and steep dips. Post-ore dykes appear to strike northeastward and dip moderately northwest (Figs. 36 and 37); the strike accords with Wolfhard but he indicates that the dykes dip steeply where seen on surface.

GEOMETRY AND RESERVES OF THE DEPOSIT: The portion of the Fish Lake deposit with grade exceeding 0.25 per cent copper (after Wolfhard, 1976) is ovaloid (Fig. 35a) with long and short axes about 450 metres and 250 metres respectively. The contacts of the zone are subvertical and the bottom has not been reached by drilling (Figs. 36a and b). Wolfhard gives a tonnage estimate of several tens of millions of tonnes with grades 0.3 per cent copper and 0.5 grams per tonne gold. No cutoff grade was quoted. A

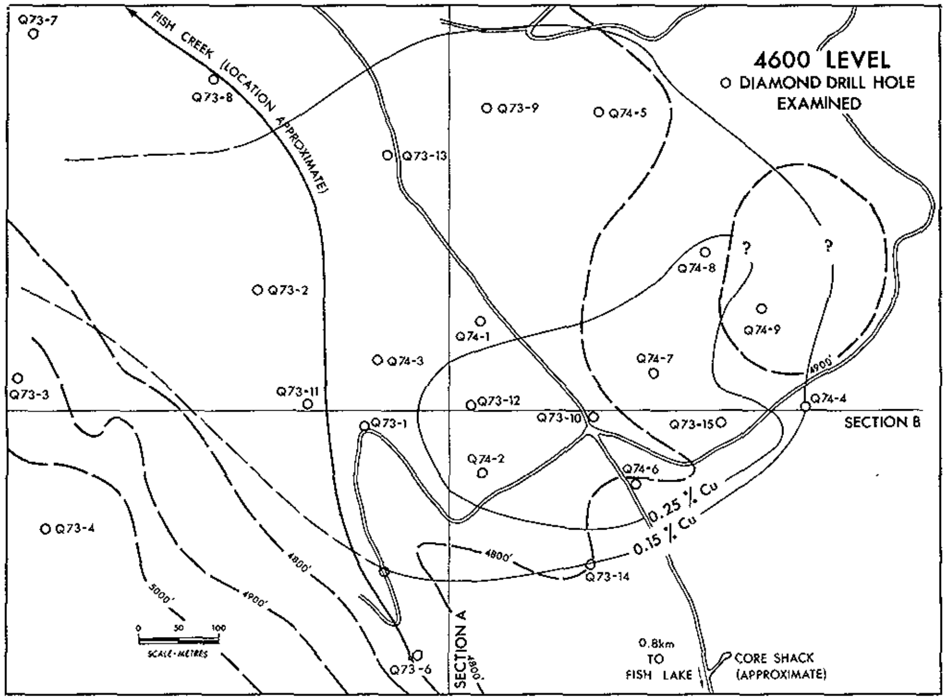

Figure 35a. Map showing topography and roads (only drill holes examined shown).

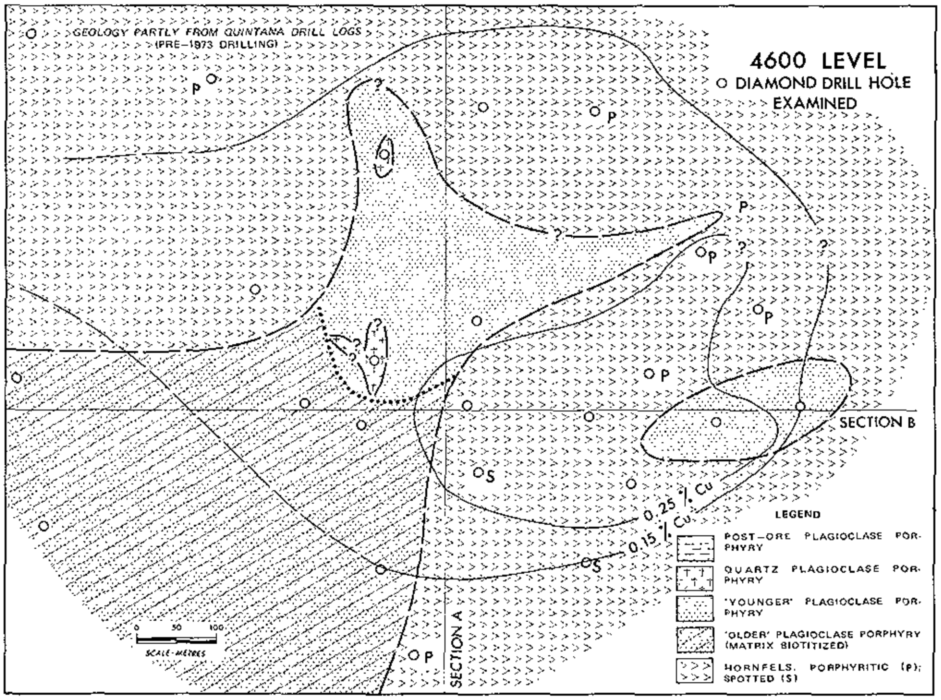

Figure 35b. Simplified geology of the 4600 level, Fish Lake deposit.

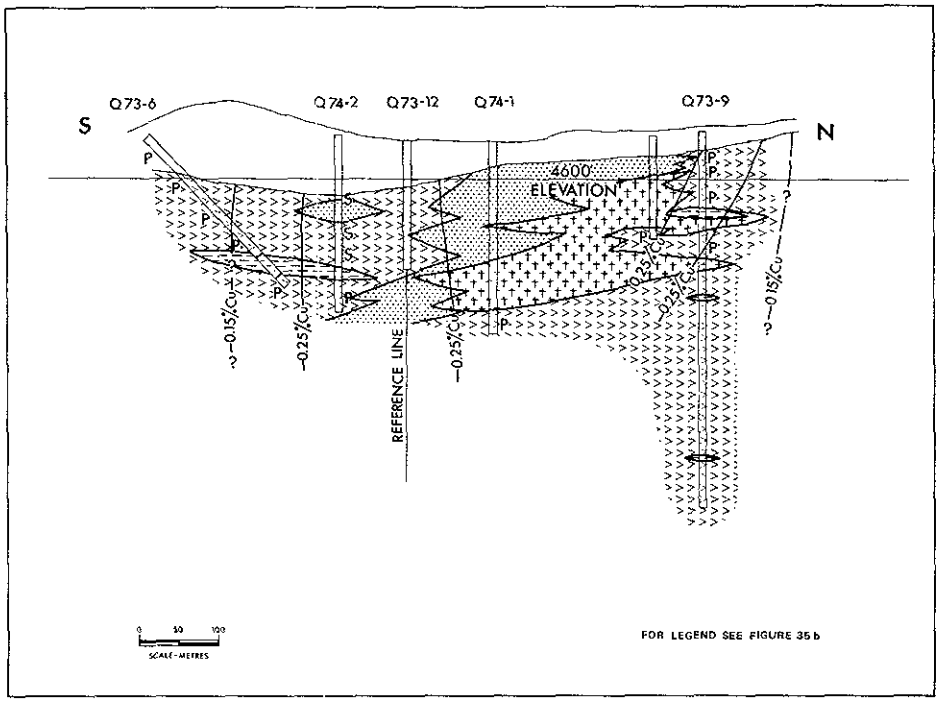

Figure 36a. Generalized geology of section A, Fish Lake deposit.

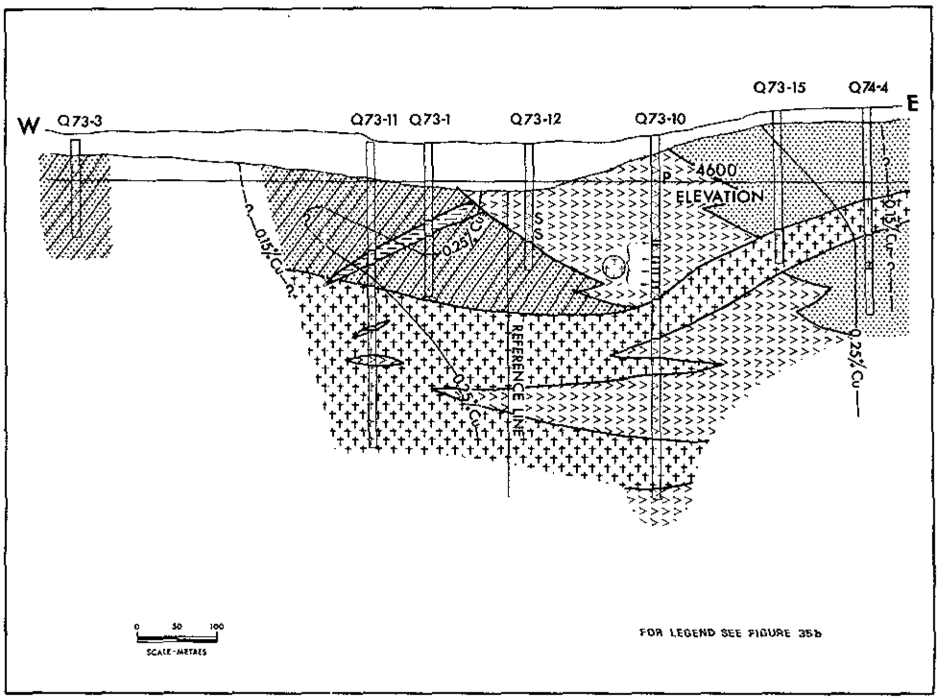

Figure 36b. Generalized geology of section B, Fish Lake deposit.

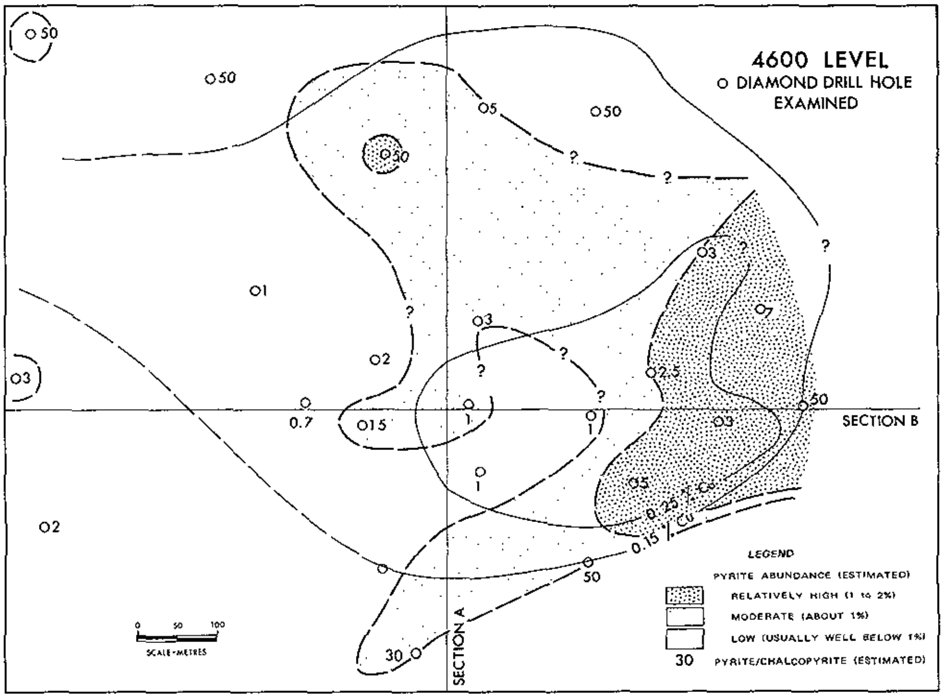

Figure 37. Plan showing relative abundance of pyrite and chalcopyrite on 4600 level, Fish Lake deposit.

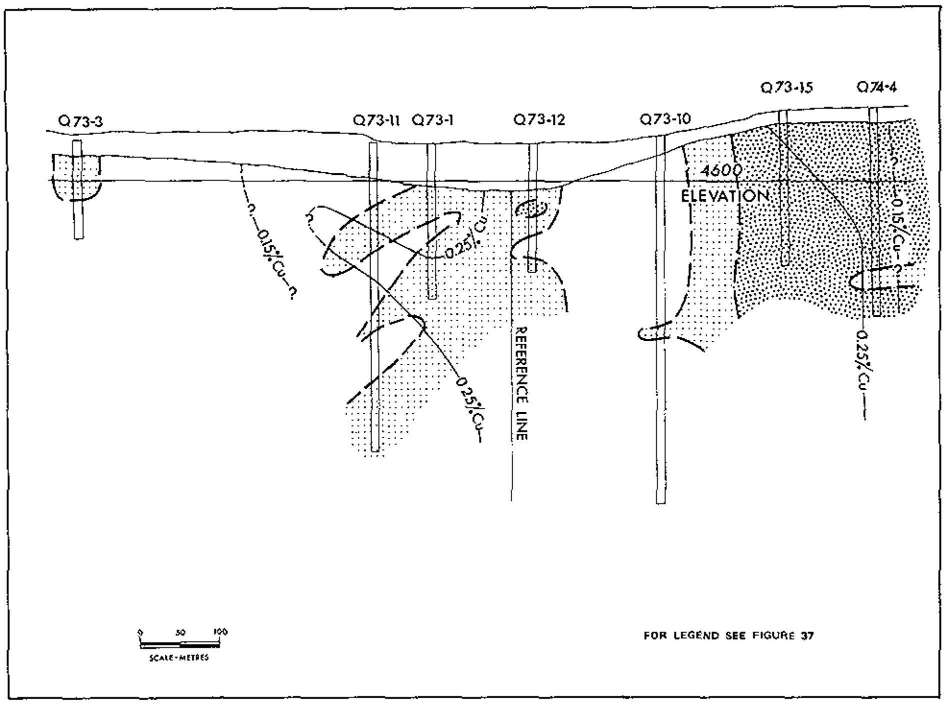

Figure 38a. Distribution of pyrite in section A, Fish Lake deposit.

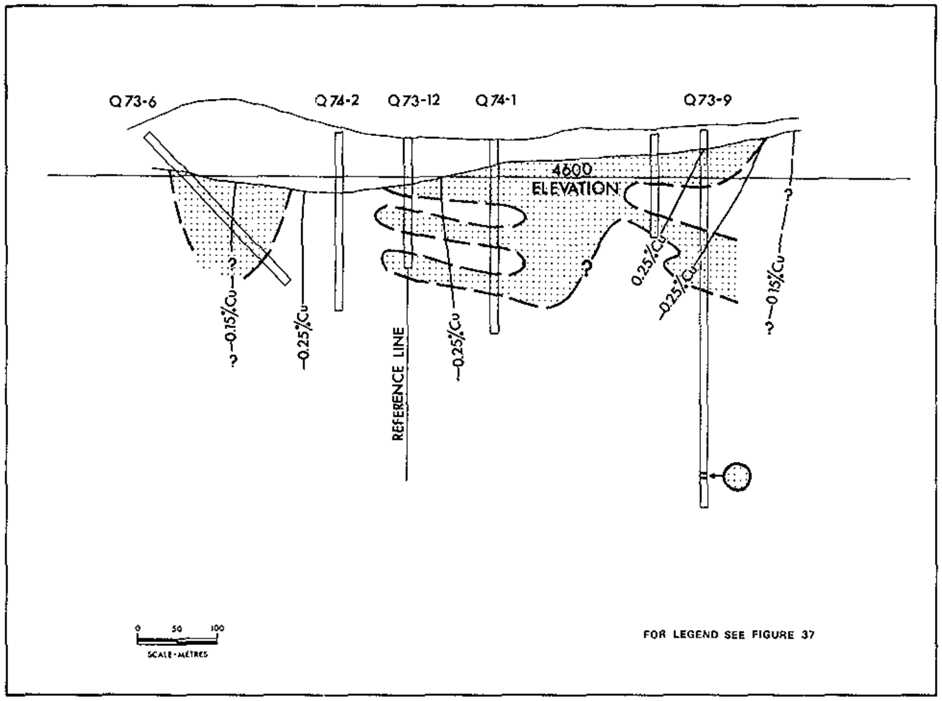

Figure 38b. Distribution of pyrite in section B, Fish Lake deposit.

rough calculation can be made from the dimensions of the deposit. Assuming the average specific gravity of mineralized material is 2.70, tonnage of material with ± 0.25 per cent copper is roughly 35 million tonnes to depth 150 metres or 48 million tonnes to depth 200 metres. These figures are very rough and do not consider pit design, consequently they do not represent mineable tonnages. Using the same calculation method, reserves of ± 0.15 per cent copper are 125 million tonnes to 150 metres and 170 million tonnes to 200 metres depth. The deposit is open at depth and has limited potential for expansion along its western border.

PETROLOGY OF THE PORPHYRY PHASES AND COUNTRY ROCK: Texturally, the porphyries are all similar. Distinctions between them are made on the basis of alteration and relative percentages of quartz. Relative amounts of plagioclase and mafic minerals change in an apparently unsystematic way. As far as alteration is concerned, only the presence or absence of pervasive biotite alteration is considered, all other alteration types seem to be ubiquitous.

The 'older' and 'younger' plagioclase porphyries are mineralogically similar but the matrix of the 'older' porphyry is biotitized. Phenocrysts in the rock comprise 20 to 40 per cent complex and oscillatory zoned plagioclase which varies from An_{37} to An_{43} in average composition; 0 to several per cent wispy clumps of chlorite, iron carbonate with or without quartz, sericite, and iron oxides or sulphides; and as much as 1 per cent quartz. The primary mafic mineral appears to have been largely pyroxene or hornblende. The quartzofeldspathic matrix is generally 50 to 80 per cent altered. Plagioclase phenocrysts are generally about 60 per cent altered. Phenocrysts average 2 to 3 millimetres but range from 1 to 5 millimetres across.

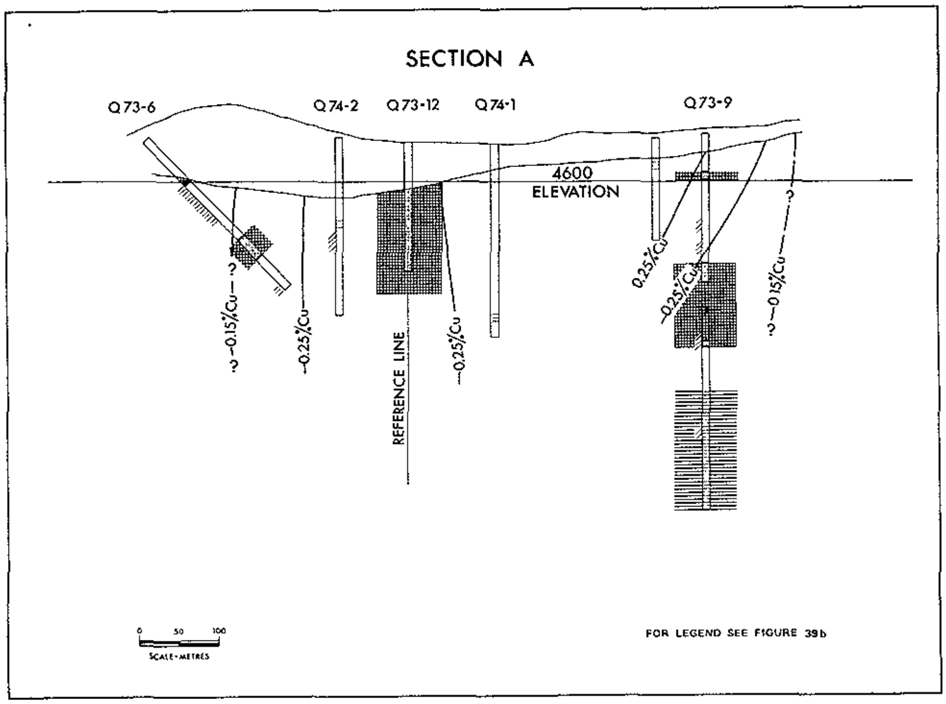

Figure 39a. Distribution of secondary biotite in section A.

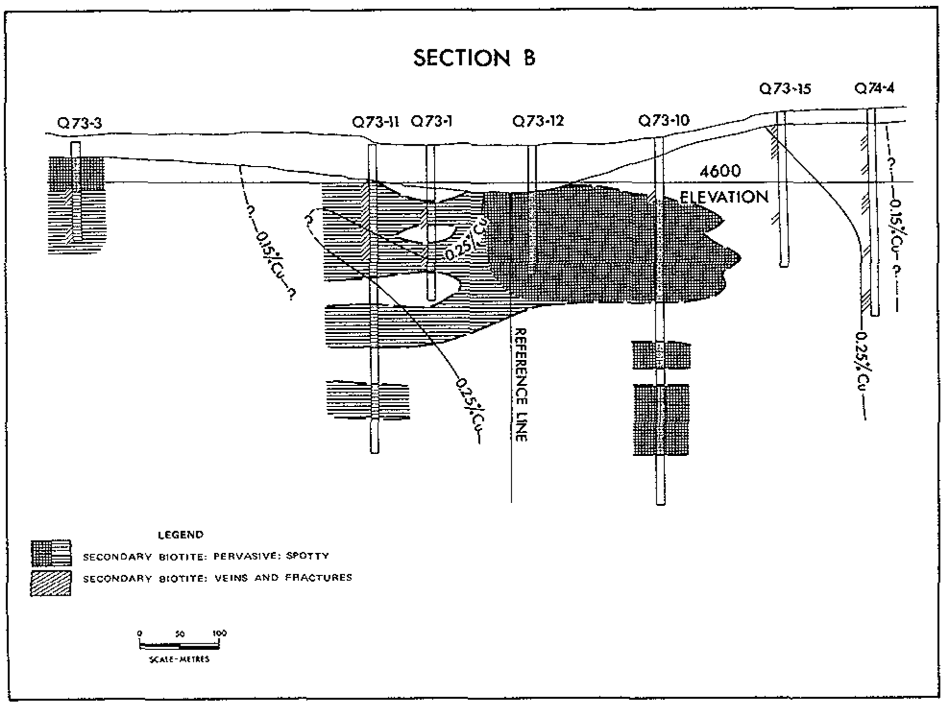

Figure 39b. Distribution of secondary biotite in Section B.

In hand specimen, quartz feldspar porphyries are distinguishable from younger plagioclase porphyry only because quartz is present in amounts from 2 to 5 per cent. Plagioclase phenocrysts range from 2 to 5 millimetres across and have complex oscillatory zoning with average compositions ranging from An_{28} to An_{37}. Most plagioclase is more than 60 per cent altered and much is totally replaced. Mafic phenocrysts are generally less abundant than in plagioclase porphyry and are similarly altered.Only locally has primary biotite escaped subsequent alteration. Quartz forms embayed, sometimes broken, usually rounded phenocrysts. Crystal borders are sometimes closely sutured and often have an external rim where overgrowths have incorporated matrix material. Crystals range from 2 to 5 millimetres across. The quartzofeldspathic matrix is often only 20 to 40 per cent altered, which contrasts with that of the plagioclase porphyries.

Post-ore dykes seen in drill core appear to be less altered and are characterized by chloritized, elongated mafic phenocrysts. Plagioclase phenocrysts are 2 to 4 millimetres across and generally comprise 20 to 30 per cent of the rock. Only one such dyke was thin sectioned. In it, plagioclase phenocrysts were 80 per cent altered to carbonate with lesser sericite, 10 per cent of the rock was chlorite and iron carbonate pseudomorphous after hornblende, and there were about 1 per cent rounded quartz phenocrysts. The quartzofeldspathic matrix was 70 per cent altered to carbonate, sericite, chlorite, and clay minerals (?). Plagioclase in this sample was oligoclase (An_{15}), but Wolfhard reports a mean composition of An_{50} for samples he examined.

Apatite is an accessory mineral in all the porphyry dykes. Magnetite is common in less altered areas and uncommon zircon was noted. Disseminated pyrite is common but is probably an alteration mineral.

There is little difference between degree of alteration, composition, and texture of plagioclase phenocrysts in the porphyries and those in rocks interpreted to be altered porphyritic volcanic rocks. This fact is not surprising because the porphyries are undoubtedly high level, subvolcanic intrusions. Matrices were pervasively biotitized early and later partly bleached or chloritized to varying degrees; in some cases later alteration has left only scattered remnants of earlier pervasive biotite alteration.

Porphyritic volcanic rocks are distinguishable from porphyries in two ways. First, clasts in volcaniclastic types are sometimes still recognizable; second, they are within and gradational into areas of non-porphyritic hornfels. Contacts of porphyry dykes in the country rock are generally sharp on centimetre-scale. With nebulous criteria such as these complicated by pervasive alteration, separation of porphyritic volcanic rocks and porphyritic intrusions becomes highly subjective. Consequently, only areas of spotted hornfels and fine-grained hornfels on Figures 35 and 36 can be confidently mapped as country rock.

METALLIC MINERAL, ALTERATION, AND VEIN DISTRIBUTION: Patterns of metal distribution and alteration types were defined by examining drill core from all the 1973 and younger drill holes along an east-west and a north-south section through the deposit (Figs. 35a and b). This data was supplemented by examining core from all available drill holes as close as possible to the 4 600 level across the deposit. Subsequently, 55 thin sections were cut from specimens across the east-west section to test visual interpretations and confirm alteration assemblages. From this work, annular zones of alteration and less well-defined sulphide zoning patterns emerged.

METAL ZONING: The relative abundance of pyrite and ratio of pyrite to chalcopyrite will be considered first. Subsequently, the abundance of copper sulphides, zinc sulphides, and gold will be discussed.

PYRITE DISTRIBUTION: Pyrite occurs both within and outside the 0.15 per cent copper contour on 4 600 level but is most abundant in an area which overlaps the +0.25

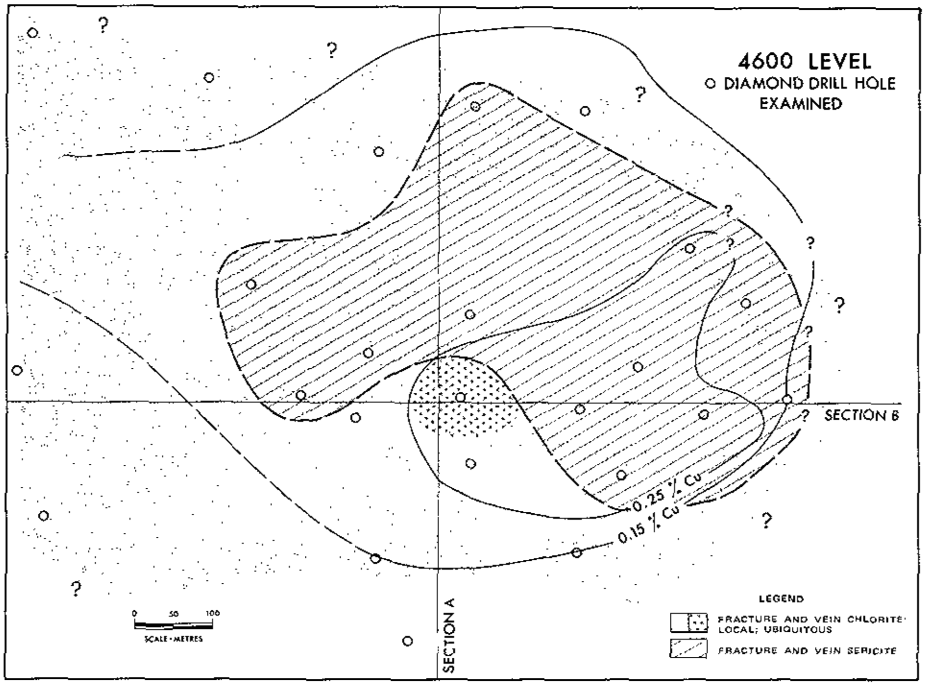

Figure 40. Distribution of fracture and vein sericite and chlorite on 4600 level, Fish Lake area.

per cent copper zone on the east and slightly more abundant than average in an arcuate area which partially envelopes the +0.25 per cent copper zone elsewhere (Fig. 37). Visually estimated pyrite to chalcopyrite ratios range from 1:0.7 to 5:1 in the +0.15 per cent copper zone but are generally 1:1 or 2:1; outside this area ratios range from 2:1 to 50:1 and are generally more than 20:1. These data are in reasonable accord with those reported by Wolfhard (1976). In section (Figs. 38a and b), pyrite distribution is also spotty but in a general way it forms overlapping halos in the better grade zone.

COPPER SULPHIDES, ZINC SULPHIDES, AND GOLD DISTRIBUTION: Chalcopyrite is the predominant copper mineral in the deposit. Wolfhard (1976) reports that bornite comprises 5 to 30 per cent of the copper present in the central part of the deposit but is absent in peripheral areas.

Sphalerite was encountered in quartz veins and in quartz-specularite veins with pyrite halos. It was seen once in each of two peripheral drill holes and in one hole within the +0.25 per cent copper zone so is of little practical use in defining a metal zoning scheme. In hole Q73-11 below the 0.25 per cent copper zone (Figs. 38 a and b), arsenopyrite and tetrahedrite occurred along with pyrite and chalcopyrite.

Gold is reported by Wolfhard to have a ratio of 1:4000 with copper in the central zone but only 1:6000 in the peripheral area. In the area averaging 0.3 per cent copper, he reports gold values are 0.5 ppm.

ALTERATION AND ASSOCIATED VEINING: In this section, a discussion of the relative timing and mineral assemblages related to hydrothermal alteration based on thin section analysis is followed by a discussion of the distributions of biotite, sericite, chlorite, epidote, and gypsum from drill core examination.

ALTERATION ASSEMBLAGES: Thin sections from 55 samples taken from drill holes in east-west section B were studied for petrologic data and alteration assemblages. Within the 0.15 copper contour, fine sericite occurs as a replacement of plagioclase feldspar, locally it also replaces mafic minerals. Almost invariably sericite is accomplished by carbonate, commonly by quartz, and less often by kaolinite, chlorite, clay, and hydromica. In fringing holes, carbonate tends to be more abundant than sericite. In one hole (73-3) fine sericite was absent. Mafic minerals in various porphyries are replaced by chlorite often accompanied by iron carbonate, sericite, and iron oxide or sulphide. In one fringing hole mafic minerals were replaced by actinolite. In areas of pervasive biotite alteration, biotite formation was early; all other alterations are superimposed on it, most are retrograde. The main components of the younger alteration assemblage are the same regardless of whether the altered rock was biotite hornfels, older plagioclase porphyry, younger plagioclase porphyry, or quartz feldspar porphyry. Minor components of the younger alteration vary somewhat across the section; for example, hydromica was noted in every hole but kaolinite, gypsum, and actinolite occurred only in holes outside the 0.25 per cent copper contour.

DISTRIBUTION OF SECONDARY BIOTITE: The distribution of biotite flooding associated with hornfelsing and the distribution of vein biotite associated with mineralization should give some insight into the relative importance of hydrothermal versus contact metamorphic biotite formation. Except for the younger plagioclase and quartz plagioclase porphyries, pervasive biotite alteration was ubiquitous (Fig. 35). It is unlikely that biotitized matrices in older porphyries are due to contact metamorphism. In some areas much of the early biotite has been destroyed but its former presence is indicated by biotite remnants and relict textures (Fig. 39). Vein biotite on the other hand, has a similar but more restricted distribution. Partly this is probably the results of later chloritization so vein and fracture biotite was likely more widespread than it is now. Veins and fractures carrying biotite typically have chlorite, often have sulphides, and less often have flaky sericite. Pervasive and fracture-controlled biotite are both widespread. It seems probable that contact metamorphic and hydrothermal influences were active, important, and operated together.Initial pervasive biotite formation probably occurred during emplacement of the quartz diorite stock and perhaps some of the younger porphyries whereas hydrothermal biotite formed as an alteration mineral and in veins in response to conditions in the hydrothermal system early in the mineralizing cycle (potassic alteration).

FLAKY SERICITE DISTRIBUTION: Flaky sericite occurs as fracture coatings, in veins, as vein halos, as zones of pervasive alteration, and replaces mafic minerals. Generally, where flaky sericite is found, grades exceed 0.15 per cent copper and it occurs more abundantly in and adjacent to areas where grades exceed 0.25 per cent (Figs. 40, 41 a and b). The zone with occurrences of pervasive flaky sericite mantles the biotitized core zone and extends somewhat beyond the 0.25 per cent copper contour. Vein and fracture-controlled flaky sericite occurs within the pervasive sericite zone and extends beyond it. Its approximate outer limit nearly coincides with the 0.15 per cent copper contour (*see also* Wolfhard, 1976, p. 321). There is an imperfect antithetic relationship between flaky sericite and areas of pervasive biotite alteration.

PERVASIVE AND FRACTURE-CONTROLLED CHLORITE DISTRIBUTION: Pervasive chloritization of mafic minerals is widespread and except in pervasively biotitized or sericitized zones alteration is generally complete. Fracture-controlled chlorite is best developed in the core of the +0.25 per cent zone in biotite hornfels and is spottily distributed in zones peripheral to it (Figs. 40 and 42). Wolfhard (1976) has also defined a second zone of fracture-controlled chlorite which lies generally outside but locally laps across the 0.15 per cent copper contour. Pervasive chlorite alteration extends at least 100

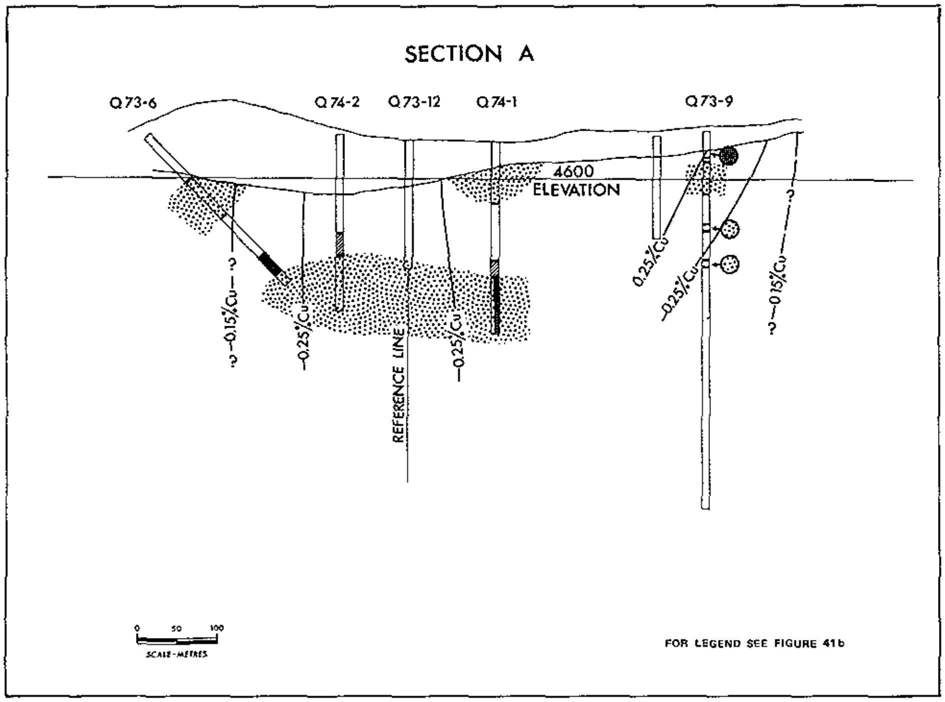

Figure 41a. Distribution of flaky sericite in section A.

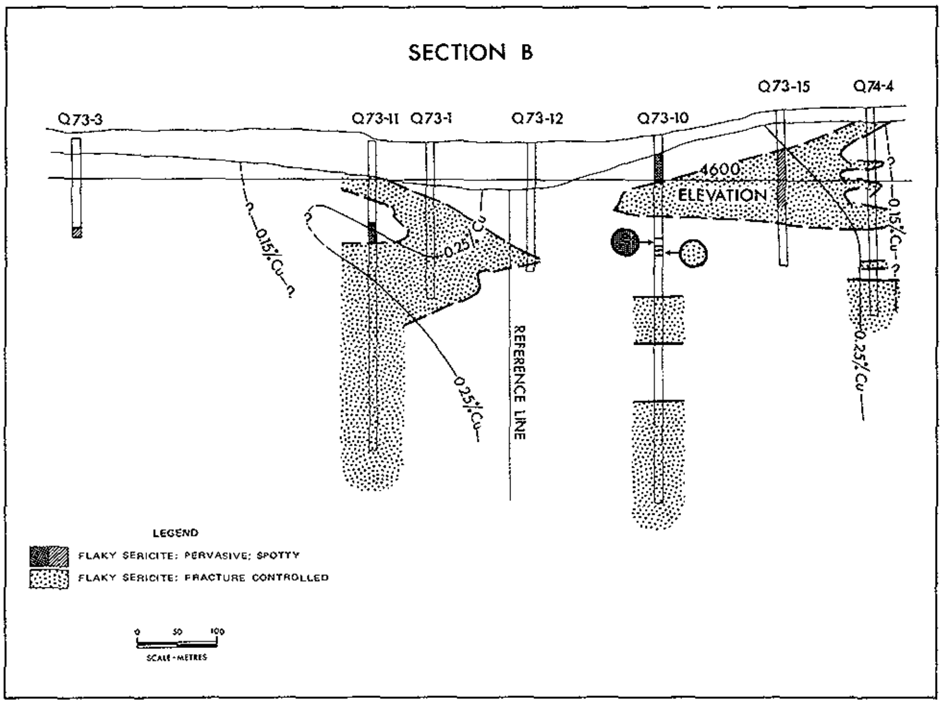

Figure 41b. Distribution of flaky sericite in section B.

metres beyond the 0.15 per cent contour in section A. Consequently, distribution of chlorite is a weak but potentially useful guide to exploration.

EPIDOTE DISTRIBUTION: Epidote was found in trace amounts in only one drill hole during this study but Wolfhard (1976) outlined a zone of epidote alteration external to the zone of pervasive chlorite alteration.

GYPSUM DISTRIBUTION: The elevation of the first appearance of gypsum veins was plotted on a plan of the deposit (Fig. 43). Data are partly from drill holes along sections A and B and partly from Quintana Minerals' drill logs. The contoured surface so defined consists of two *en echelon* west-northwest elongated domes. Data are too dispersed for detailed analysis but in general the surface is not obviously related to present topography and the generalized gypsum zone forms a northwest elongated dome. In section (Fig. 44 a and b), gypsum is generally fairly common below its level of first appearance. The exception is seen in section B where there is an isolated gypsum zone above the main zone in holes Q73-15 and Q74-4. If the 'perched' zone is a remnant which has escaped being removed by leaching then the original upper surface of the gypsum zone was higher than at present but has been lowered by groundwater action. A similar but much better documented model of gypsum leaching has been postulated for the Berg deposit (Panteleyev *et al.,* 1976). At Berg, the depth of leaching is more strongly influenced by the effects of fracture density on the groundwater table level than by topography. Therefore in spite of the poor correlation between the 'gypsum line' and topography at Fish Lake gypsum distribution is not inconsistent with a leaching model.

Gypsum at Fish Lake may have been derived from anhydrite (Wolfhard, 1976). Conversely, it may have been deposited directly from calcium and sulphate-rich hydrothermal fluids as they cooled. Alteration of plagioclase during main stage mineralization would be expected to generate suitable calcium-rich solutions and would account for the relative age of the gypsum and later, when sulphur was depleted, calcite veins. A similar model was postulated for Valley Copper (Jambor and McMillan, 1976).

AGE RELATIONSHIPS AND TYPICAL MINERALOGIES OF VEINS AND FRACTURE FILLINGS: Emplacement of porphyritic intrusive bodies at Fish Lake was accompanied by extensive biotite hornfelsing of the volcanic country rocks. The earliest vein and fracture filling minerals cut hornfelsed rocks but were probably deposited very shortly after their formation. These veins carry magnetite with quartz, hematite, some pyrite and chalcopyrite, and lesser chlorite. As the hydrothermal system became established and evolved, the mineralogy of fracture and vein fillings changed (Fig. 45). For example, carbonate joined magnetite and its associated minerals prior to main stage mineralization. During main stage mineralization chalcopyrite, pyrite, and molybdenite along with quartz, biotite, chlorite, and sericite were deposited. Pervasive country rock alteration of varying intensity also occurred during main stage mineralization. During this pervasive alteration, particularly in altered mafic minerals, disseminated magnetite, pyrite, chalcopyrite, and minor amounts of bornite were deposited. Magnetite in altered mafic minerals may be a simple byproduct of alteration but sulphides required addition of sulphur to the system.

Typical vein and fracture assemblages include:

quartz + pyrite (often with quartz + flaky sericite envelopes)
quartz ± pyrite ± chalcopyrite ± MoS_2 (mainly with quartz + flaky sericite envelopes)
chalcopyrite ± pyrite
pyrite ± chalcopyrite
biotite + chlorite ± pyrite ± chalcopyrite
sericite ± chlorite ± biotite ± pyrite ± chalcopyrite
sericite + quartz ± pyrite ± chalcopyrite ± carbonate

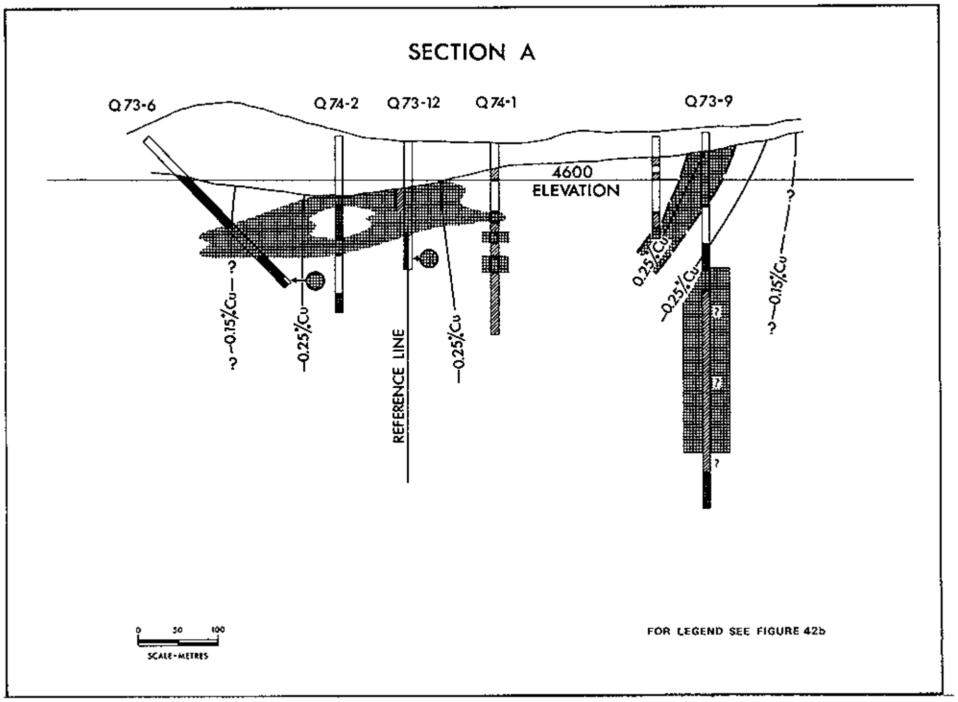

Figure 42a. Chlorite distribution on section A.

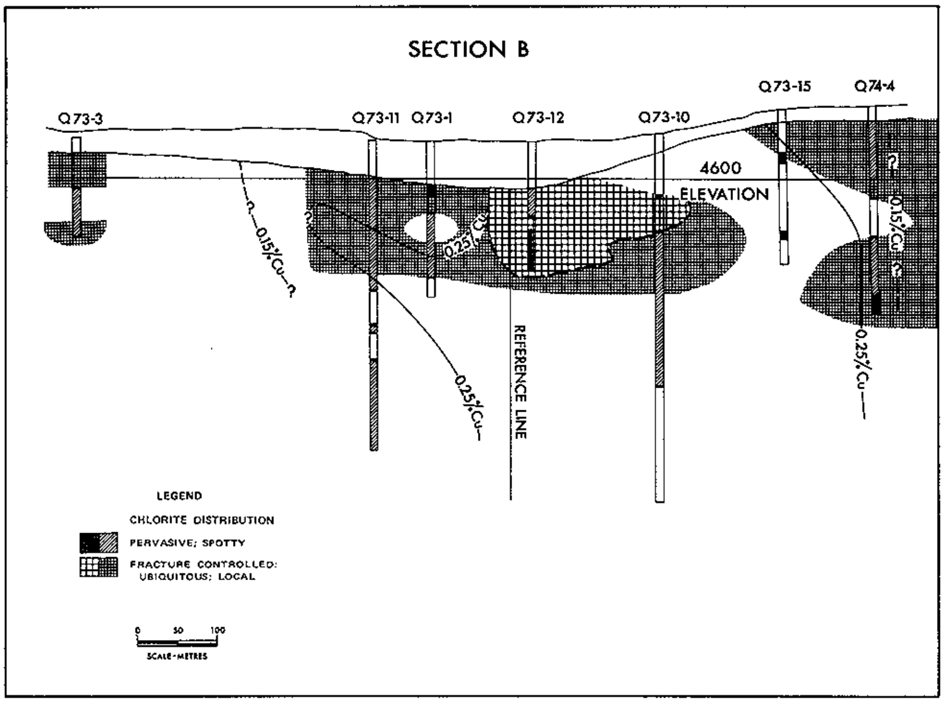

Figure 42b. Chlorite distribution on section B.

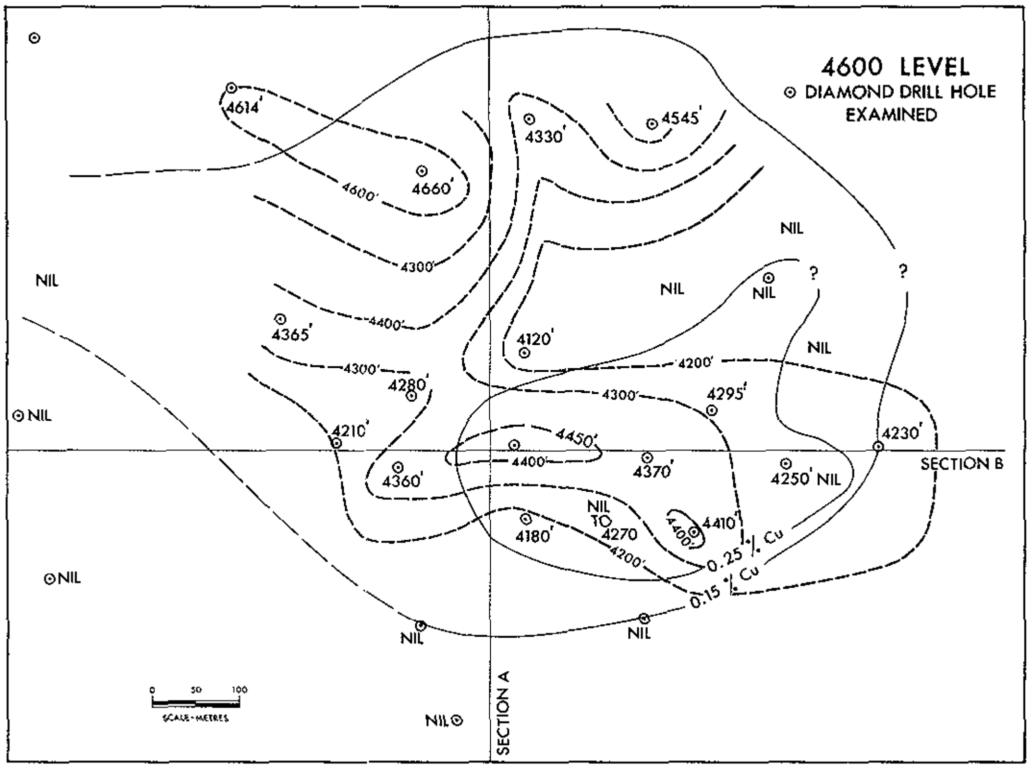

Figure 43. Plan showing upper surface of zone with gypsum veins.

Sulphide deposition decreased gradually. During the waning period barren quartz veins and quartz + sulphide ± carbonate ± hematite veins and fractures predominated. Minor amounts of gypsum + chlorite and gypsum + pyrite were also deposited. Formation of gypsum and anhydrite (Wolfhard, 1976) ± carbonate and lesser carbonate-hematite veins was followed by deposition of carbonate and finally graphitic carbonate in veins and fractures. These mark the collapse of the hydrothermal system. The sequence outlined is in general agreement with that described by Wolfhard (1976, Table 1) although in detail there are differences in interpretation.

FRACTURE AND VEIN ORIENTATIONS: Orientations of mineralized fractures and veins were measured from vertical drill holes in the deposit. Most dip between 70 and 90 degrees and a less well-developed set of structures dips about 45 degrees (Fig. 46). When the relative ages and mineralogy of the veins and fractures were considered, it became evident that fracture orientations changed slightly with time. Most of the oldest, magnetite-rich veins are subvertical, although there are lesser concentrations with dips near 65 and 15 degrees. Similarly, pyrite and chalcopyrite-bearing veins are also dominantly steeply inclined. Late-stage gypsum veinlets have dip maxima of 45 and 25 degrees. Carbonate, which is calcite in part, occurs in veins with minor amounts of chlorite. These have dip maxima of 75 and 45 degrees but a significant number also dip between 10 and 40 degrees. Younger carbonate + graphite (?) veins have steep orientations again.

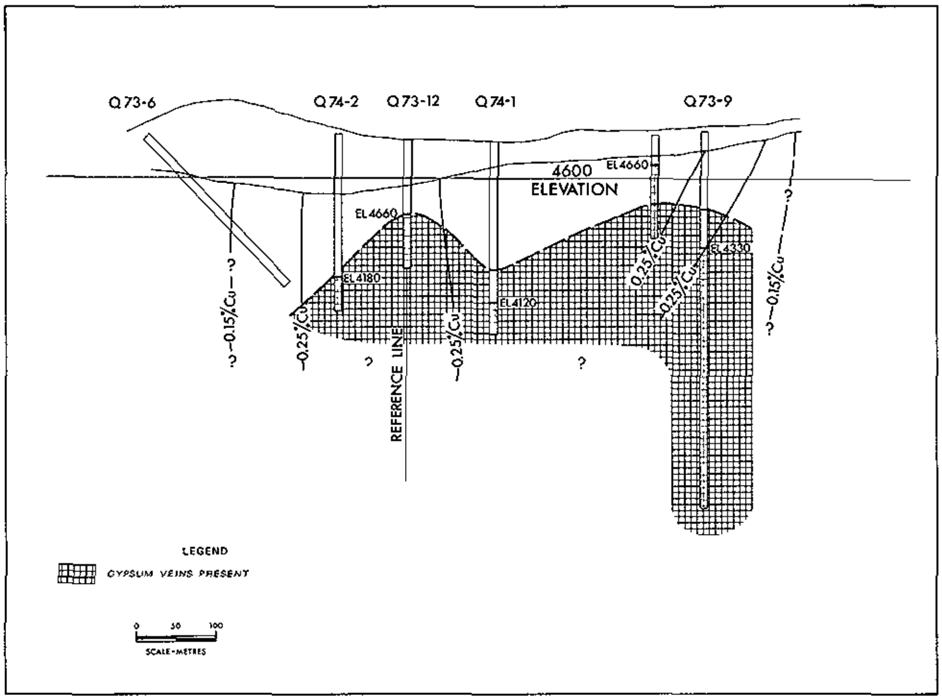

Figure 44a. Gypsum distribution in section A.

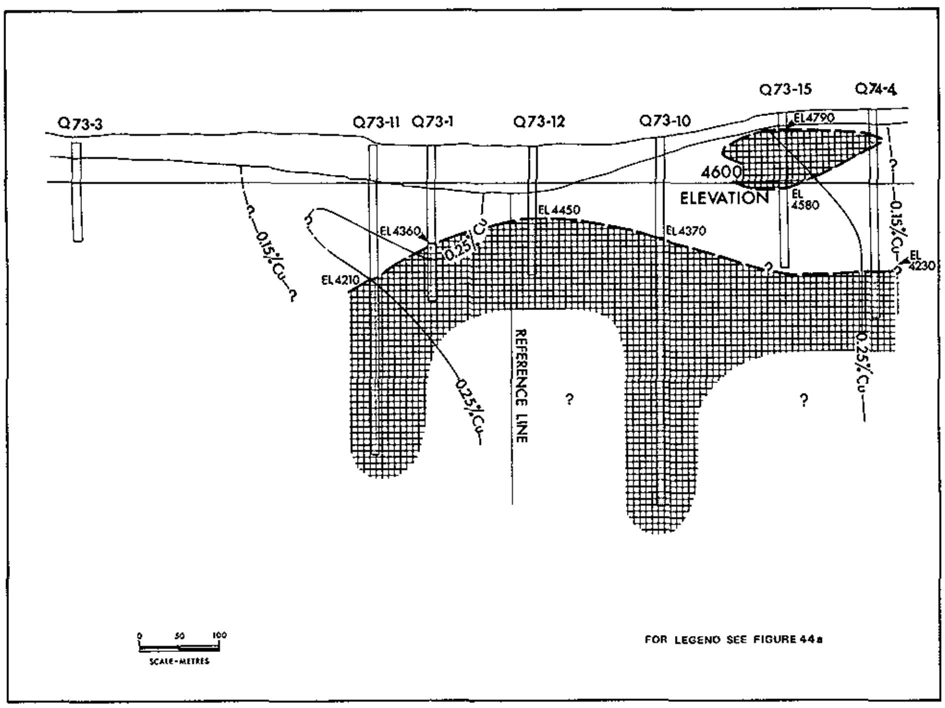

Figure 44b. Gypsum distribution in section B.

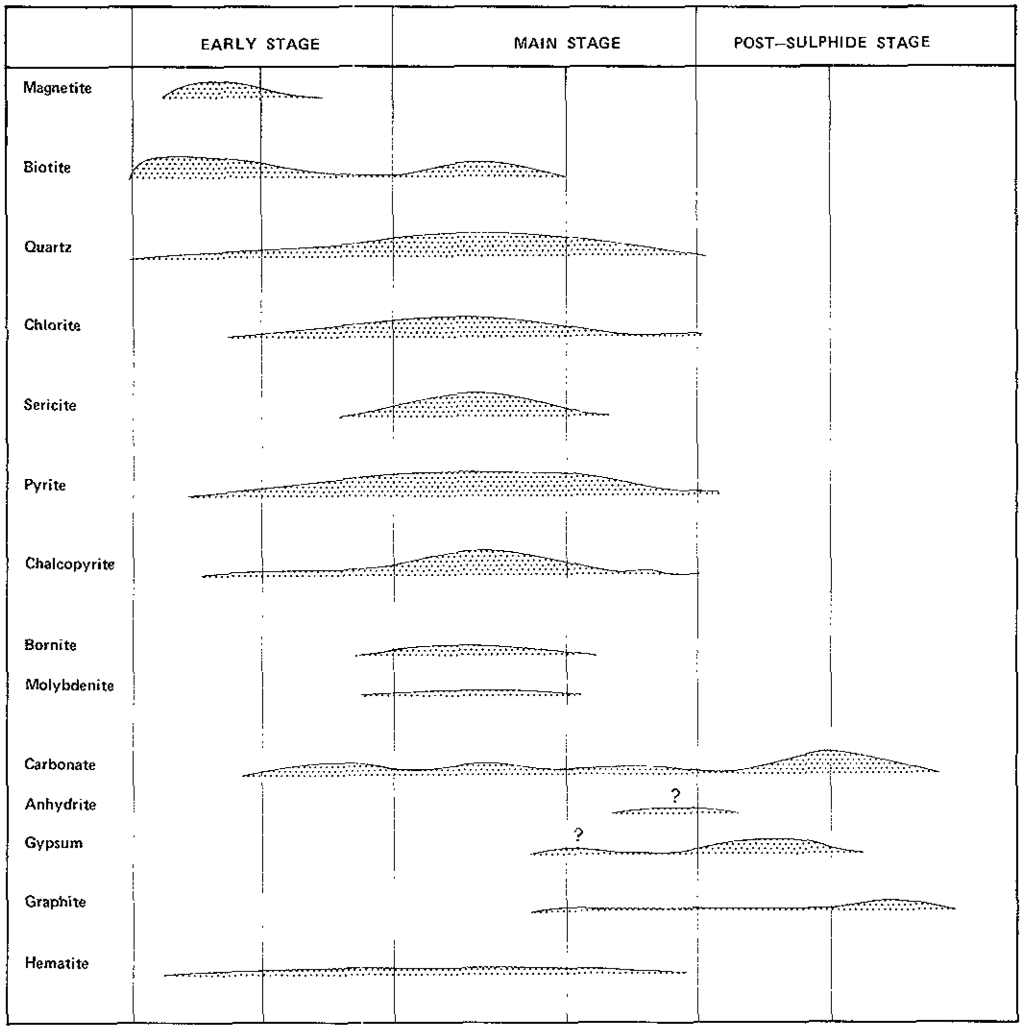

Figure 45. Timing of vein and fracture minerals, Fish Lake deposit.

SYNPOSIS OF ALTERATION AND VEINING HISTORY: Rocks of the Fish Lake prospect have a complex history of alteration. The volcanic to sedimentary country rock appears to have been subjected to at least two periods of pervasive biotite alteration; one resulted from intrusion of a large porphyritic quartz diorite stock, the other from intrusion of 'younger' plagioclase porphyry and quartz plagioclase porphyry bodies. Matrices of 'older' plagioclase porphyries were flooded with biotite during the latter event or events. Vein associations, formation in earlier intrusions, grade distribution, and the alteration zoning patterns indicate that some of the biotite alteration was of hydrothermal origin and was associated with metallization. The zone of best mineralization in the deposit has a core area of pervasive biotite alteration which is the zone of potassic alteration after the usage of Jambor and Carson (1974) or phyllic after the usage of Guilbert. Guilbert restricts the term potassic to assemblages with K-feldspar. Here, the simple term biotite alteration zone will be applied.

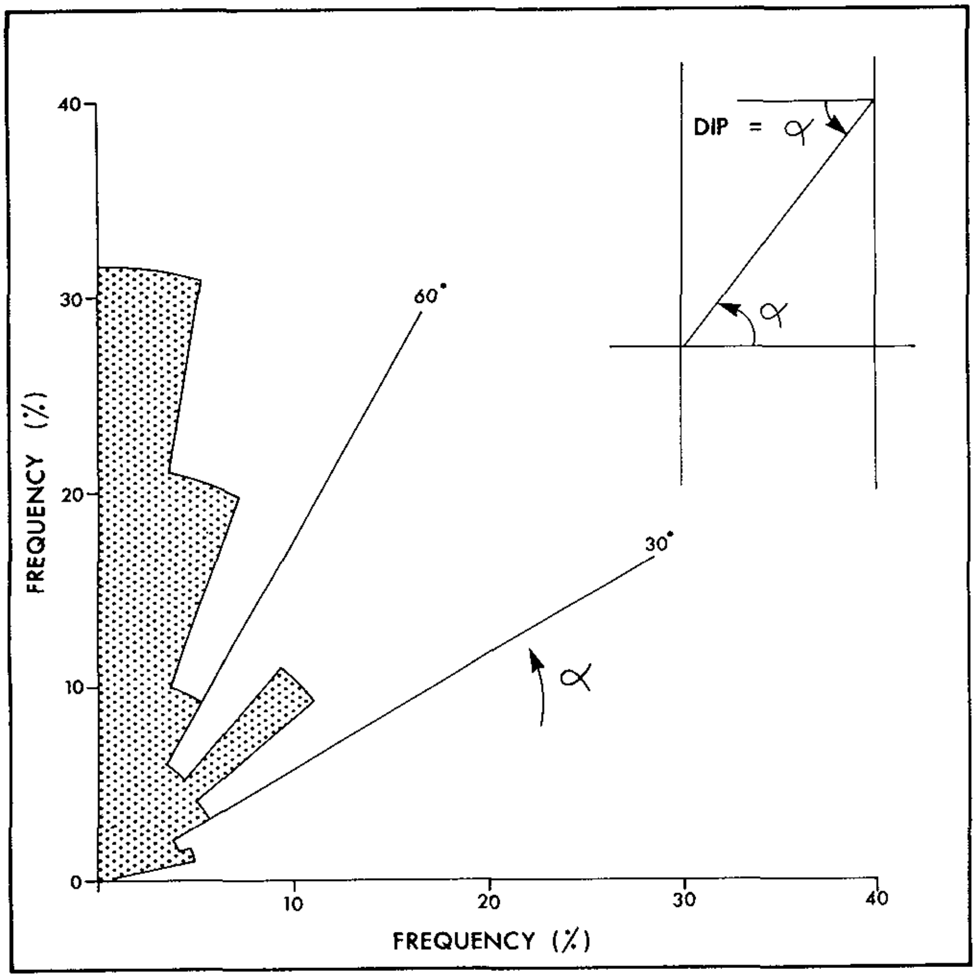

Figure 46. Composite fracture diagram, Fish Lake deposit.

From thin section work, it is evident that early biotite alteration was later partially or, in places, totally destroyed by younger alteration characterized by formation of sericite, quartz, carbonate, with lesser clay, hydromica, and some gypsum and actinolite. The distribution and relative intensity of the younger alteration have produced a zone of propy-argillic alteration which is apparently fringed by a propylitic zone. The younger alteration laps onto the biotite core and has pervasively altered large areas of hornfelsed rocks outside the 0.25 per cent copper contour. Despite the differing ages of alteration, there are coherent grade, alteration, and metal zoning patterns which appear to be controlled by the younger porphyries, particularly the quartz plagioclase porphyries. It is in, and more commonly adjacent to, these porphyries that the best copper grades occur.

The earliest veining at Fish Lake post-dates pervasive biotite alteration and consists of quartz, magnetite, hematite, sulphides, and chlorite. With time, carbonate was added to the assemblage. During main stage mineralization, sulphides were deposited along with quartz, biotite, chlorite, and sericite. The biotite and propy-argillic alteration associated with the porphyry system apparently also formed at this time. Late main stage veining comprised barren quartz, quartz with sulphides, carbonate and hematite, and gypsum with chlorite or pyrite. Gypsum with minor amounts of anhydrite followed by carbonate veining marked the collapse of the hydrothermal system.

Mineralization occurred in an area of ongoing igneous activity and this is reflected in the orientation of veins and mineralized fractures. Through time, dips of dominant fracture orientations varied from steep to moderate or low and back to steep. In part they probably reflect regional stresses but in part they are related to intrusive activity, evolution of magmatic fluids, and pressures generated by the hydrothermal system.

SUMMARY AND CONCLUSIONS: In summary, alteration at Fish Lake is related to younger porphyritic intrusions which cut a country rock comprised of older porphyritic intrusions and hornfelsed volcanic and sedimentary rocks. The best mineralization is in zones of biotite alteration adjacent to, and in, bodies of this "young" quartz plagioclase porphyry. The hydrothermal system was maintained for some time after the younger porphyries and somewhat beyond the time when post-ore hornblende plagioclase porphyry dykes were emplaced. All have been subjected to carbonate-sericite dominated propy-argillic alteration.

While main phase veins and fractures were grouped and treated as a unit here, in fact several ages of, for example, quartz + pyrite + chalcopyrite veins occur in a single piece of drill core. Mineralization obviously took place over a significant time span which saw many episodes of fracturing, healing, and refracturing. The porphyry intrusions may have acted as a heat 'engine' to drive a convective cell of metal-bearing hydrothermal fluids. Whether the metals in the system were scavenged from the country rock or supplied by the porphyries is open to speculation.

REFERENCES:

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Jambor, J. L. and McMillan, W. J. (1976): Distribution and Origin of the 'Gypsum Line' in the Valley Copper Porphyry Deposit, Highland Valley, British Columbia, *Geol. Surv., Canada,* Paper 76-1B, pp. 335–341.

Jeletsky, J. A. and Tipper, H. W. (1968): Upper Jurassic and Cretaceous Rocks of Taseko Lakes Map-Area and their Bearing on the Geological History of Southwestern British Columbia, *Geol. Surv., Canada,* Paper 67-54.

Panteleyev, A., Drummond, A. D., and Beaudoin, P. G. (1976): Berg, *CIM,* Special Vol. 15, Porphyry Deposits of the Canadian Cordillera, pp. 317–322.

Tipper, H. W. (1963): Geology, Taseko Lakes, British Columbia, *Geol. Surv., Canada,* Map 29-1963.

Wolfhard, M. R. (1976): Fish Lake, *CIM,* Special Vol. 15, Porphyry Deposits of the Canadian Cordillera, pp. 317–322.

EAST CENTRAL BRITISH COLUMBIA

SAM GOOSLY (93L/1E)

By T. G. Schroeter

The Sam Goosly property, comprising 312 claims including the Gaul and W, is owned by Equity Mining Corporation and is situated 40 kilometres southeast of Houston, at approximately 1 260 metres elevation.

The deposits occur within a window of rocks thought to be Hazelton Group which are surrounded by younger volcanic rocks and intruded by two stocks along the flanks of the host unit.

The deposits as presently outlined occur as tabular zones striking in a general north-south direction. Dips range from 45 to 60 degrees to the west.

The property is at an advanced stage of development, following drilling of more than 28 336 metres on both the Main and Southern zones and 177 metres of underground bulk sampling in the Main zone. In addition, pilot plant concentrate production from both the Main and Southern Tail zones and pilot plant operation of an antimony leaching and recovery circuit were carried out.

The reserves as defined by 2.0 ounces silver equivalent cutoff are estimated at:

	Tonnes	Copper *per cent*	Silver *ppm*	Gold *ppm*	Antimony *per cent*	Stripping Ratio
MAIN ZONE	29 934 878	.30	87.5	0.719	0.084	2.1:1
SOUTHERN TAIL	9 538 301	.42	84.38	1.094	0.087	2.3:1
TOTAL RESERVE	39 473 179	.33	86.88	0.813	0.085	2.1:1

These are open-pit reserves and the potential for expanding reserves at depth as well as in other parts of the property remain excellent.

Exploration on the property in 1976 was confined to the Southern Tail zone where four test pits averaging 75 square metres in length and depths of 4 metres were excavated for the purpose of supplying an 18-tonne-per-day flotation pilot mill. The pits were dug on a north-south line with the more spectacular ore coming from the most southerly pits. The host rock is a highly fractured and veined cream-coloured tuff with varying amounts of coarse-grained pyrite, tetrahedrite, and chalcopyrite. Stripping has shown that overburden depths are very shallow (for example, 1 metre) and that oxidation has been intense to a depth of about 3 metres. A grab sample of high-grade ore from the southernmost pit assayed:

	Gold *ppm*	Silver *ppm*	Copper *per cent*	Zinc *per cent*	Lead *per cent*	Antimony *per cent*
SG—10	6.25	5646.88	11.12	1.37	.25	7.65

Approximately 900 tonnes of ore was put through a crusher and pilot mill yielding a silver-copper concentrate of about 27 tonnes, of which approximately 18 tonnes was shipped to several smelters for test processing.

Clearing of land for plantsite location was completed and a new road from Houston to the property along Dungate Creek was initiated.

The peak manpower employment at the property was during pilot plant operation when 14 men were employed. A 20-man camp was purchased and installed on the property.

Assessment of environmental, social, and economic impacts were carried out.

REFERENCES:

B.C. Ministry of Mines & Pet. Res., GEM, 1969, pp. 142–148; 1970, pp. 126–129; 1973, pp. 333–338; *B.C. Ministry of Mines & Pet. Res.,* Geological Fieldwork, 1974, p. 79; 1975, pp. 55–56.

FRENCH PEAK (RIO) (93M/7W)

By T. G. Schroeter

The French Peak silver property (formerly Rio), owned by Aalenian Resources Ltd., comprises the Ute, Eldorado, Silverado, Silver Iron, and Mag Hi claims and is situated 65 kilometres north-northeast of Smithers on the southeast flank of French Peak, at approximately 1 350 metres elevation.

The Ute vein system, containing coarse-grained galena and tetrahedrite, is located in shear zones in bedded volcanic rocks of the Hazelton Group. The mineralized vein, apparently related to a major fault, has been traced for 36 metres along strike, and is of variable width.

Massive tetrahedrite and/or galena and/or chalcopyrite with disseminated pyrite was confirmed at depth along the vein structure which appears to lie in a subaerial to subaqueous volcanic sequence of rhyolitic and andesitic flows and tuffs. Mineralized vein sections vary in width from less than 2 centimetres up to 1 metre.

Rhyolitic rocks, in general, display considerable carbonate and sericite alteration and the matrix is highly clouded with hematitic (?) particles. The Rio vein system, located 122 metres to the south of the Ute vein system, consists of massive, banded chalcopyrite, tetrahedrite, and pyrite within a bedded rhyolite unit.

Work consisted of diamond drilling 29 holes totalling approximately 806 metres, upgrading the road to the property, constructing an all-weather camp, geological mapping, and magnetometer surveying.

REFERENCES:

Minister of Mines, B.C., Ann. Rept., 1956, p. 29; 1964, p. 50; *B.C. Ministry of Mines & Pet. Res.,* GEM, 1974, p. 272; *B.C. Ministry of Mines & Pet. Res.,* Geological Fieldwork, 1974, p. 82; 1975, pp. 57, 58; Assessment Report 6014.

KEMESS (94E/2W)

By T. G. Schroeter

The New Kemess 1 and 2 claims, owned by Kennco Explorations, (Western) Limited and operated by Getty Mining Pacific Limited, are situated 9 kilometres east of the north end of Thutade Lake, approximately 280 kilometres north of Smithers, between 1 350 and 1 650 metres elevation.

A northwest-trending belt of Takla Group volcanic rocks have been intruded by stocks of diorite, quartz monzonite porphyry, syenite porphyry, and a quartz feldspar porphyry, all presumably related to the same Omineca intrusion. The volcanic rocks, consisting of massive chloritic andesite and a porphyritic chloritic andesite, have been subjected to intense structural disturbances including numerous faults, shears, and fractures. The intrusive rocks show less structural disturbance. Major faulting strikes east-west and transverse faults are numerous.

Mineralization is almost entirely within the volcanic rocks and in particular the porphyritic variety with its altered equivalents. Disseminated and fracture-filling pyrite is ubiquitous in amounts averaging 5 per cent. Chalcopyrite also occurs as disseminations and in fracture fillings within the andesite. Abundant anhydrite ± quartz veins also carry varying amounts of disseminated and fracture-filling pyrite and chalcopyrite. Minor amounts of molybdenite were also noted. Magnetite is locally abundant as veinlets or blebs associated with pyrite. Pyrite is the only sulphide observed in the syenite porphyry. Coatings of chalcocite and covellite were observed in oxidized specimens.

Alteration and veining are common particularly in the volcanic rocks. Silicification is widespread and locally the andesite takes on a white colour. Epidote is also widespread and occurs in fractures as well as being pervasive. Pink laumontite is common along fractures. Hematite is present on some fractures. Most of the feldspars have been sericitized. The most significant veining is that of purple anhydrite with or without quartz. Chalcopyrite and pyrite and minor molybdenum always appear to be associated with this veining.

During 1976, seven holes were diamond drilled totalling 1 475.8 metres.

REFERENCES:

Minister of Mines, B.C., Ann. Rept., 1968, p. 149; *B.C. Ministry of Mines & Pet. Res.,* GEM, 1969, p. 104; 1971, p. 64; *B.C. Ministry of Mines & Pet. Res.,* Geological Fieldwork, 1976, pp. 66, 67.

CHAPPELLE (94E/6E)

By T. G. Schroeter

The Chappelle claims, owned by Kennco Explorations, (Western) Limited and operated by DuPont of Canada Exploration Limited, are situated 16 kilometres south-southwest of Toodoggone Lake, at approximately 1 680 metres elevation.

DuPont continued to test a pyrite, electrum, argentite, polybasite, and chalcopyrite-bearing vuggy quartz vein which has a drill outlined length of 330 metres and an average width of 3 metres. Continuation of drifting begun by Conwest in 1974, was successful in locating the faulted mineralized quartz vein. An 86.25-metre raise with three fingers at the end, termed the 5454 raise, was completed. A crosscut was extended 7.9 metres to the southwest from a point of approximately 39.62 metres in on the main drift and a second 54.55-metre raise (5450) was constructed which broke through to surface on the vein. Minor faulting of the vein (up to 8 metres) was noted.

The geology of the new workings is consistent with previous descriptions. An observed dacitic rock apparently associated with the quartz vein 'zone' is medium to light grey in colour, very fine grained, dense, and brittle, and contains numerous subrounded phenocrysts and/or fragments.

During 1976 the following work was conducted: Drifting, 5 400 level, 56.02 metres; raising, 140.8 metres; underground diamond drilling, seven holes totalling 59.43 metres; surface diamond drilling, 13 holes totalling 760.7 metres; underground workings surveyed; bulk sample, approximately 9 tonnes, taken from underground rounds for metallurgical testing.

REFERENCES:

B.C. Ministry of Mines & Pet. Res., GEM, 1970, p. 188; 1971, pp. 65–70; 1972, p. 484; 1973, pp. 458–460; 1974, p. 312; *B.C. Ministry of Mines & Pet. Res.,* Geology in B.C., 1975, p. G 79; *B.C. Ministry of Mines & Pet. Res.,* Geological Fieldwork, 1974, p. 84; 1975, pp. 68, 69; 1976, p. 67, Assessment Reports, 2581, 2891, 3171, 3198, 3343, 3367, 3417, 3418, 3419, 4066, 5268, 5667, 6096.

NORTHWEST BRITISH COLUMBIA

IN, CON (94D/3, 6)

By T. G. Schroeter

The In and Con claims, owned by Canadian Superior Exploration Limited, are situated 30 kilometres west-northwest from the north end of Bear Lake, between 1 500 and 1 650 metres elevation.

A prominent rust-stained mountain is due to an elongated, fractured, northerly trending pyritized zone developed within a Jura-Cretaceous sedimentary and volcanic sequence intruded by essentially two types of Tertiary feldspar porphyry. The intrusive rocks appear to be dyke-like with irregular contacts suggesting a subvolcanic environment of implacement. The earlier altered feldspar porphyry, belonging to the Kastberg intrusions, is cut by varieties of biotite feldspar porphyry which closely resemble the porphyries at the Babine Lake copper mines and as such represent the most northerly known porphyries of this type. A hornfels zone with secondary biotite and abundant disseminated and fracture-filled pyrite and minor chalcopyrite envelopes the intrusive masses.

Pyrite is abundant and ubiquitous and occurs as disseminations and as fracture and vein fillings. Chalcopyrite also occurs as disseminations and in fracture and vein fillings within both types of porphyries. Trace amounts of molybdenite is associated with quartz veining. Several phases of veins exist including quart + pyrite ± chalcopyrite ± calcite ± fluorite. Magnetite and hematite are also locally abundant and occur as blebs and as veinlets.

Minor veinlets carrying sphalerite and galena were also noted.

Oxidation has occurred to depths of at least 45 metres.

During 1976, two holes were diamond drilled totalling 305 metres.

REFERENCES:

Minister of Mines, B.C., Ann. Rept., 1966, p. 81; *B.C. Ministry of Mines & Pet. Res.,* GEM, 1972, p. 479; 1973, p. 405; *B.C. Ministry of Mines & Pet. Res.,* Geological Fieldwork, 1976, pp. 65, 66; Assessment Reports 3868, 4563.

RED (94D/3E)

By T. G. Schroeter

The Red claims, owned by Canadian Superior Exploration Limited, are situated adjacent to the Squingula River, 20 kilometres west-northwest from the north end of Bear Lake, at approximately 1 100 metres elevation.

The property is underlain mainly by volcaniclastic rocks of the Hazelton Group, including light green intermediate tuffs, maroon (hematitic) tuffs, and flow rocks. A lens of intercalated, impure, bioclastic, reefoid limestone mineralized with disseminations, and minor fracture fillings of chalcopyrite is contained within the volcaniclastic sequence. A gabbro sill and small microdiorite stock intrude the layered rocks east of this lens. Minor amounts of bornite and chalcocite were noted in the limestone along with traces of barite.

During 1976, three holes were diamond drilled totalling 325.6 metres.

REFERENCES:

B.C. Ministry of Mines & Pet. Res., GEM, 1973, p. 404; *B.C. Ministry of Mines & Pet. Res.*, Geological Fieldwork, 1976, p. 65; Assessment Reports 4562, 5552.

GEOLOGY OF THE DAY PORPHYRY COPPER PROSPECT (94D/7W, 10W)

By B. N. Church

INTRODUCTION: The Day claims are centred on a porphyry copper prospect located in the Swannell Range of the Omineca Mountains. The precise location is 192 kilometres north of Smithers, access being by helicopter from the Omineca Mining access road at Moosevale Creek. The property is 32 kilometres northeast of the Bear Lake extension of the British Columbia Railway right-of-way.

This is a region of sharp craggy ridges and broad U-shaped, glacial-carved valleys. The Sustut River, striking southwesterly directly across the ranges, is the principal stem of a large trellice-work of tributary streams of which Two Lake Creek, Red Creek, Pat Creek, and Harper Creek are locally the most important (Fig. 47).

Slopes rise from the junction of Harper Creek and the Sustut River at a approximate elevation of 900 metres, to an elevation of 1 440 metres in an area 3.2 kilometres to the west near the main prospect. Gyr Peak is the highest point in the area at an elevation of 1 935 metres (Plate XXXIX).

Mineralization was first discovered in the area by Wesfrob Mines Limited in the summer of 1972. This was followed by a period of intense staking which continued through to February 1973. Work performed on the property included linecutting, magnetometer and geochemical surveys, and diamond drilling. Eight holes totalling 1 360 metres were completed by the end of 1974.

The material for this report was gathered by the writer during fieldwork on the property in the latter part of July 1973 and early August 1974.

GENERAL GEOLOGY: Regional mapping by Lord (1948) of the Geological Survey of Canada and detailed studies by the British Columbia Ministry of Mines and Petroleum Resources (1973-74) shows that the area in the vicinity of the Day property is underlain by Jurassic volcanic rocks and a number of small related intrusions. The name Hazelton Group has recently been extended to bedded units of the area (GEM, 1973, p. 413), these rocks being assigned specifically to the Telkwa Formation (Tipper and Richards, *Geol. Surv., Canada,* Bull. 270) which is considered to be the lowest unit of the group.

BEDDED ROCKS: The Telkwa Formation is about 1 200 metres thick in this region and comprises a sequence of locally well-layered and more or less conformable maroon and grey tephra accumulations, some welded tuff breccias, and a few lava flows. These rocks are considered to be mostly continental in origin and have a broad basalt to rhyolite composition range (Fig. 49).

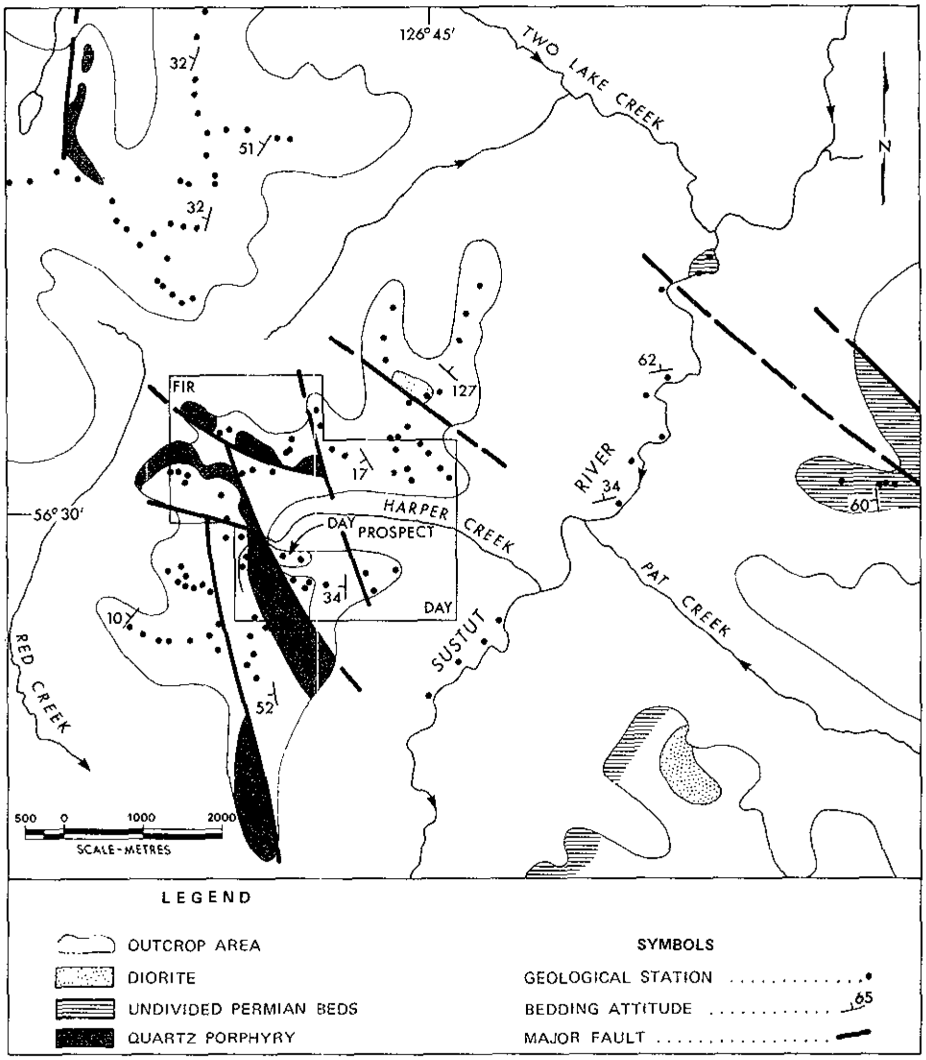

Figure 47. Location and district geology, Day prospect.

On the Day property only the uppermost thousand metres or so of the Telkwa Formation is exposed. Here the section is divided into four members: the Two Lake Creek member, West Boundary ignimbrite, Red Creek member, and the Tarn Pond member—from the base upward respectively (Fig. 48).

The Two Lake Creek member, estimated to be about 300 metres thick, is the most widely distributed unit of the Telkwa Formation, covering much of the central part of the map-area. It is a melange of brown, grey, and maroon tuffs and tuffaceous deposits, volcanic conglomerate, and poorly sorted rubble, mottled purple, red, and green breccias, and some lava, all mainly of andesite composition. Significantly, the intercalation of sedimentary rocks in the volcanic pile resembles a type section of the Telkwa Formation, the so-called 'Bear Facies,' described by Tipper and Richards 8 kilometres to the north.

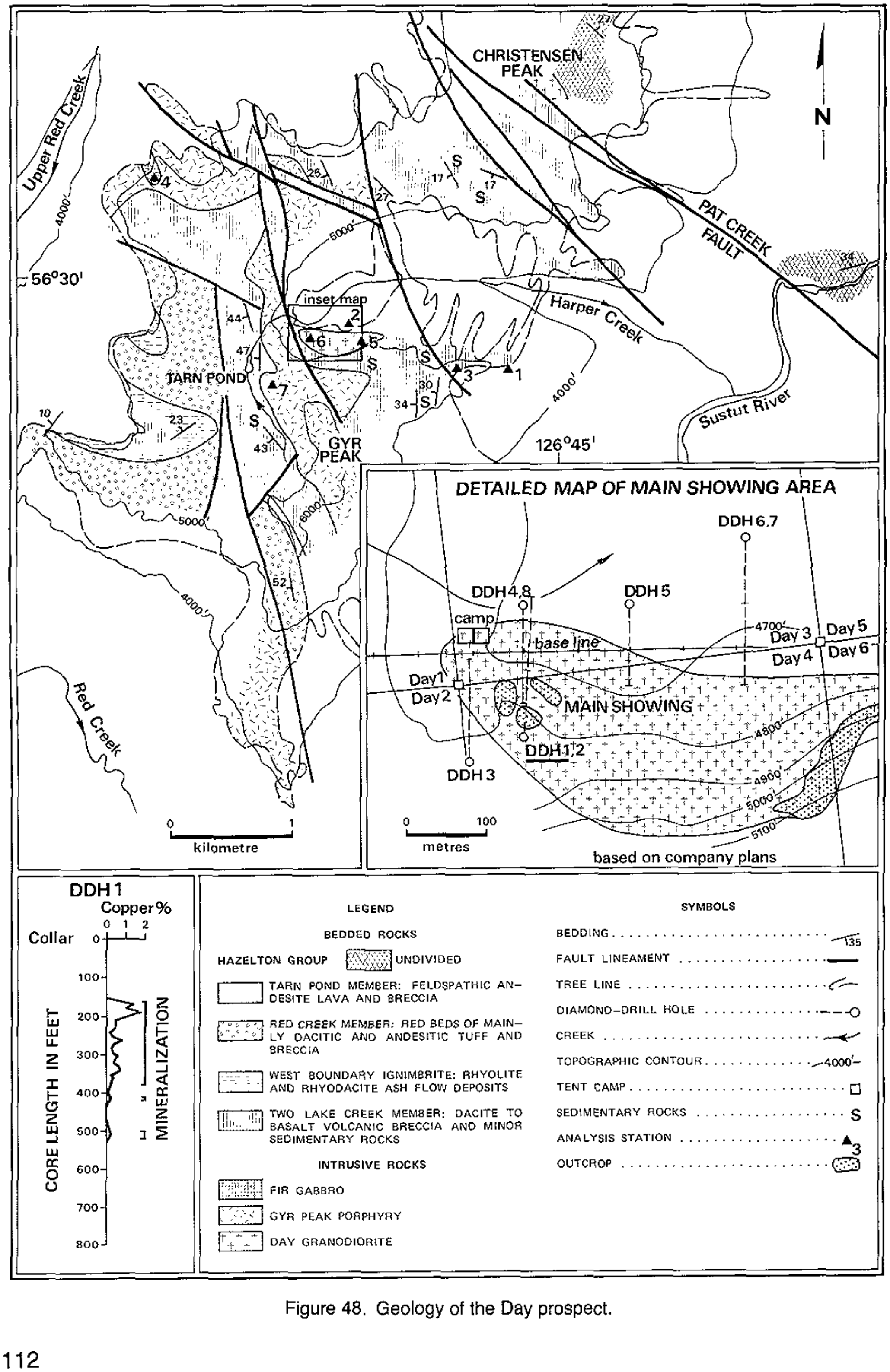

Figure 48. Geology of the Day prospect.

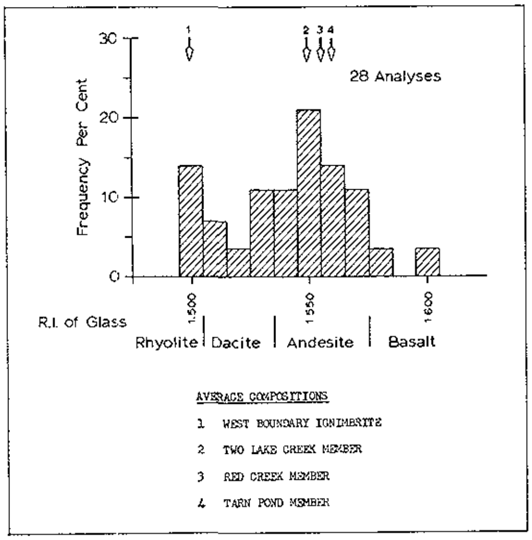

Figure 49. Composition distribution of Hazelton volcanic rocks in the vicinity of the Day prospect.

In thin section the rocks commonly show an abundance of feldspar, some pyroxene (both orthorhombic and monoclinic varieties) and, less commonly, quartz. Chemically, the compositions follow the calc-alkaline trend (analyses Nos. 1, 2, and 3 in Table 10). Above average alkali content observed in some rocks (analysis No. 2) is attributed to metasomatism caused by nearby igneous intrusions.

The West Boundary ignimbrite is a rhyodacite ash flow member exposed at several localities west and southwest of Gyr Peak near the western margin of the Day claims. In general form the deposit is sheet-like having a total thickness of about 75 metres. The morphological bluff-bench expression of the unit in some localities suggests a composite structure comprising two or several very similar ash flows which were possibly extruded in rapid succession from the same source.

The rock is typically light coloured and massive. Flattened pumice blocks are observed locally aligned subparallel to the base of the flow. In thin section the rock consists of broken plagioclase crystals and a minor amount of biotite within fragments of lava which are contained in a matrix of lithic and vitric tuff and dust.

Source of the ignimbrite appears to be the Gyr Peak porphyry, a sinuous intrusive assemblage of small felsic stocks, dykes, and sill-like bodies occurring a few thousand metres to the east.

The Red Creek member is a 150-metre-thick aggregation of grey-brown andesite and dacite tephra displayed on the cliffs above Red Creek in the western part of the map-area. The unit consists of a repetition of well-layered and sorted air-fall tephra intercalated with occasional thin bands of tuffaceous maroon mudstone, some massive grey tuffs, and a few basalt lava flows.

The Tarn Pond member is a capstone of resistant feldspathic andesite lava and breccia, about 45 metres thick in the uppermost part of the Telkwa formation in this area. Exposures are restricted to a small fault-bounded wedge of the unit centred about 750 metres west of Gyr Peak. Similar rock occurs in the ranges to the north and dykes cutting older facies of the Telkwa Formation several kilometres to the northeast of the Day property are considered to be related to this member.

TABLE 10. CHEMICAL ANALYSES

	1	2	3	4	5	6	7
Oxides Recalculated to 100—							
SiO_2	50.43	62.84	65.56	50.76	60.96	61.43	78.30
TiO_2	0.95	0.40	0.34	0.84	0.39	0.39	0.14
Al_2O_3	16.92	17.72	17.48	16.01	18.64	18.66	12.19
Fe_2O_3	1.64	2.18	0.92	3.51	3.52	4.26	1.05
FeO	6.70	2.43	2.54	6.76	1.75	1.11	0.19
MnO	0.22	0.16	0.12	0.93	0.24	0.23	0.02
MgO	3.84	2.08	2.00	8.30	2.05	2.24	0.03
CaO	8.38	3.40	1.32	7.96	3.35	4.71	0.06
Na_2O	4.62	6.47	5.52	2.99	6.72	3.78	4.67
K_2O	1.19	2.32	2.20	1.94	2.18	3.19	3.35
	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Oxides as Determined—							
$+H_2O$	2.75	0.76	2.12	2.62	1.46	1.88	0.34
$-H_2O$	0.28	0.21	0.30	0.48	0.36	0.30	0.05
CO_2	1.14	0.82	0.17	0.48	1.30	2.18	0.16
P_2O_5	0.27	0.21	0.23	0.15	0.28	0.28	<0.18
S	0.33	0.01	0.01	0.025	0.02	<0.01	0.01
SrO	0.06	0.04	0.10	0.04	0.08	0.06	0.008
BaO	0.03	0.07	0.06	0.07	0.08	0.06	0.02
R.I.	1.572	1.537	1.517				
Molecular Norms—							
Qz	—	5.22	16.36	—	3.37	12.87	35.00
Or	7.40	13.50	13.10	11.50	12.70	19.00	19.95
Lc	—	—	—	—	—	—	—
Ab	42.45	57.15	50.05	27.06	59.46	34.10	42.25
Ne	0.75	—	—	—	—	—	—
An	22.62	12.30	6.60	24.78	14.08	23.50	0.30
Wo	9.30	1.72	—	6.01	0.92	—	—
En	—	5.66	5.58	10.51	5.58	6.22	0.08
Fs	—	2.20	3.34	3.69	0.26	—	1.34
Fo	8.38	—	—	9.44	—	—	—
Fa	7.30	—	—	3.31	—	—	—
Mt	1.80	2.25	0.97	3.70	3.63	3.84	0.22
Cor	—	—	4.00	—	—	0.47	0.86

Key to Analyses

1.—Hazelton Group, tuff from ridge south of Harper Creek.
2.—Hazelton Group, volcanic breccia from diamond drill core DDH 6-447′.
3.—Hazelton Group, tuff breccia east of DAY showing and south of Harper Creek.
4.—Fir Gabbro, northwest of the DAY showing on the FIR claims.
5.—Day Granodiorite, fresh sample near east contact.
6.—Day Granodiorite, altered phase from main showing.
7.—Gyr Peak Porphyry, southwest of the Day showing.
(Sample locations are shown on Figure 42.)

IGNEOUS INTRUSIONS: The suite of igneous intrusive rocks includes the main mineralizing stock, known as the Day granodiorite, and two younger bodies, the Gyr Peak porphyry and Fir gabbro.

The Day granodiorite, centrally located in the map-area, outcrops south of the upper course of Harper Creek near the base of a precipitous cirque. Only the roof of the stock, about 360 metres in diameter, has been exposed by glacial erosion.

The rock is, medium to fine grained, with a homogeneous texture, ranging in colour from green-grey to creamy grey. In thin section it consists of about 40 per cent plagioclase plates, 0.5 to 3 millimetres long, and about 8 per cent, somewhat smaller individual crystals and clusters of amphibole, suspended in a fine-grained felsic matrix. Alteration has greatly affected some phases of the intrusion transforming the feldspar to clay and fine mica and amphibole to chlorite, calcite, and iron oxide. Comparing the chemistry of fresh rock (analysis No. 5) with altered samples (analysis No. 6) it is evident that an Alteration is accompanied by a significant loss of soda and a gain in potassium and carbon dioxide.

The Day granodiorite has intruded its own mantling pile of volcanic debris sending dykes vertically and laterally into the surrounding pyroclastic beds. A hornblende separate obtained by the writer from the Day stock yields a K/Ar age of 184±11 Ma. This is equivalent to Middle Sinemurian (Lower Jurassic) age according to the Elsevier 1975 geological time scale. The Pat intrusion, a similar dioritic body located just south of the Sustut River (Fig. 47) yields a very similar K/Ar age of 186±6 Ma, also on hornblende.

The Gyr Peak porphyry as noted previously is the probable source rock for the West Boundary ignimbrite and is therefore younger than the Day granodiorite, the assumed source and the age equivalent of the Two Lake Creek member. The Gyr Peak porphyry which lies mostly just to the east of the West Boundary ignimbrite can be traced as dykes, *sills, and small stocks in a series of outcrops for about 11 kilometres* north-northwest from near the junction of Red Creek and the Sustut River.

The porphyry is a light grey to pink, massive, resistant rock underlying a rough terrain of crags and bluffs. Petrographically the rock contains about 5 per cent phenocrysts, 0.5 to 2 millimetres in diameter, scattered throughout a fine-grained, occasionally flow-banded felsic matrix. The phenocrysts are divided more or less equally comprising quartz, sanidine, and albite. Chemical analysis of the rock (analysis No. 7) gives a rhyolite composition with an abundance of silica and a very small amount of iron oxide, lime, and magnesia.

The Fir gabbro is a small intrusion, a few hundred feet in diameter, cutting the Gyr Peak porphyry in the western part of the Fir claims. This is one of the youngest intrusions in the area and is thought to be a feeder to basalt lavas of the Red Creek member. The rock is dark coloured, rusted in places, medium grained, and massive. In thin section subhedral augite crystals, measuring to 3 millimetres in diameter, and smaller wedges of pyroxene associated with chlorite and magnetite are scattered in a matrix of randomly oriented plagioclase laths 0.5 to 1 millimetre in length. Modal analysis of the rock shows 70 per cent plagioclase, 14 per cent pyroxene, 10 per cent chlorite, 5 per cent magnetite, and 1 per cent apatite—a ratio of ferromagnesian minerals to feldspar similar to the normative mineralogy calculated from a chemically analysed sample (analysis No. 4).

STRUCTURE: The area is intersected by several major faults, the most important of which strikes northeast at 025 degrees, following the course of the Sustut River, and two strong southeast-striking faults that coincide with pronounced lineaments which parallel Two Lake Creek and Pat Creek. In the area west of the Sustut River bounded by Two Lake Creek and Pat Creek lineaments, the Telkwa strata are inclined at moderate to moderately steep angles northerly and easterly. In the main area to the southwest most beds dip in a westerly direction. Here the strata are disrupted by a number of large gravity faults resulting in repetition of the formations and an apparent thickening of section.

A statistical study of minor fractures is shown on Figure 50. Of three prominent fracture sets identified only one corresponds to a major fault direction. This is a steeply dipping joint set striking about 140 degrees, coinciding in average direction to the Two Lake Creek and Pat Creek fault systems. The strongest joints are bedding crossfractures which are

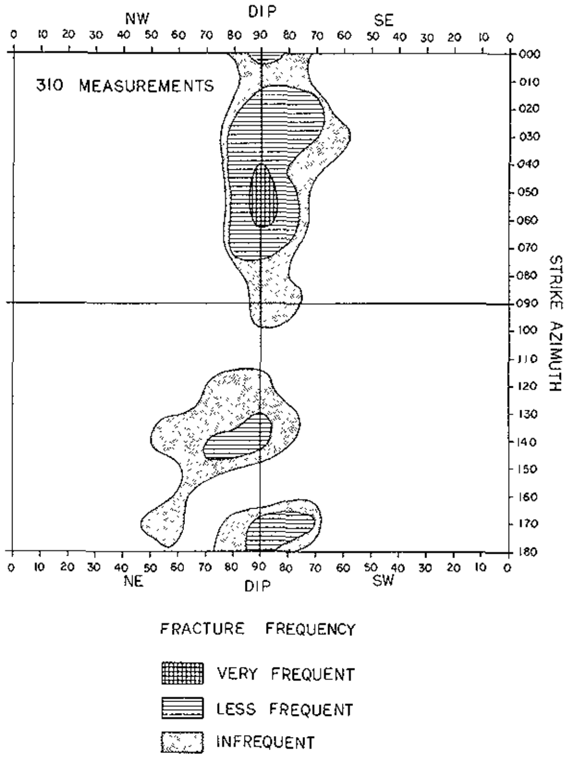

Figure 50. Day prospect, fracture frequency plot.

usually very steep and strike about 050 degrees. An array of northerly oriented fractures pervading the central zone of the map-area trends subparallel to the overall alignment of the Gyr Peak porphyry intrusions.

MINERALIZATION: The main showing comprises several outcrops of altered Day granodiorite in a small area a few hundred feet in diameter immediately south of Harper Creek and the Wesfrob camp (Fig. 48). Here mineralization consists mostly of pyrite and chalcopyrite in vuggy quartz veinlets and fillings on cracks and disseminations of pyrite, chalcopyrite, and magnetite (Plate XL). Some molybdenite has also been reported in core samples.

Drill holes Nos. 1, 2, 4, and 8, below the main showing cut 60-metres of mineralization grading more than 1.5 per cent copper. Other holes to the east collared in overburden failed to intercept any significant sulphides, and cut mostly altered volcanic rocks peripheral to the granodiorite.

The largest outcrop of granodiorite exposed along the base of the cliff about 360 metres east of the main showing locally displays abundant disseminated pyrite, minor chalcopyrite, and a few 15 to 30-centimetre-wide barren carbonate veins.

REFERENCES:

B.C. Ministry of Mines & Pet. Res., GEM, 1973, pp. 408, 411 (*see* Fig. 34); GEM, 1974, p. 298; *B.C. Ministry of Mines & Pet. Res.*, Geological Fieldwork, 1974, pp. 53, 54; *Geol. Surv., Canada*, Mem. 251; *Geol. Surv., Canada*, Bull. 270; Assessment Report 5107.

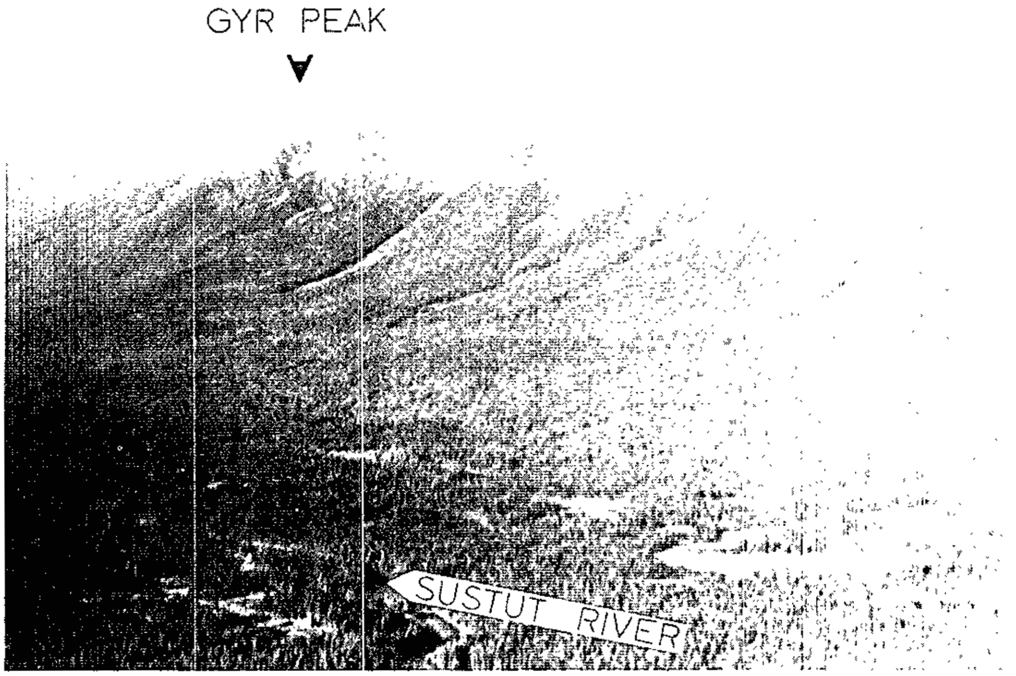

Plate XXXIX. Day prospect, panorama of the Discovery Peak area, looking southwest.

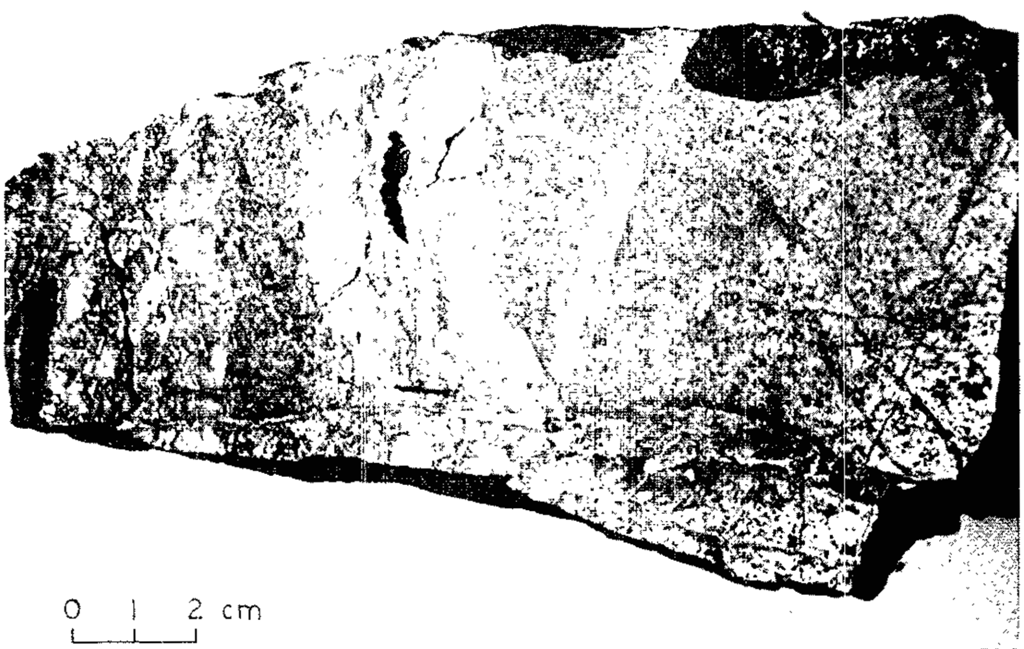

Plate XL. Day prospect, well-mineralized sample of Day granodiorite.

WEST CENTRAL BRITISH COLUMBIA

BELL MOLY (103P/6W)

By T. G. Schroeter

The Bell Moly property, consisting of the R, G, and Fubar claims, is owned by Bell Molybdenum Mines Limited and under option to Climax Molybdenum Corporation of British Columbia Limited. The claims are situated 10 kilometres east-southeast of Alice Arm at approximately 690 metres elevation.

One drill hole (DDH 76-8) was drilled on the northeast part of the Main zone and the other seven were drilled on a newly discovered zone located approximately 1 370 metres to the southwest of the Main zone in an area of hornfelsed sedimentary rocks overlain by a capping of flat-lying Quaternary basalt. The lava appears to be underlain by a thin (approximately 15 metres) layer of angular breccia and unconsolidated silty material (up to 30 metres thick). Drill holes collared in basalt went through this sequence and into mineralized hornfels and intrusive rock at depth. The intrusive is a leucocratic quartz monzonite but its geometry is not known. Post-mineral basic dykes, possibly related to the basalt flows, cut both the sedimentary and plutonic rocks. Molybdenite mineralization in the form of selvages in quartz veinlets occurs in both the quartz monzonite and biotote hornfels similar to that in the Main zone. Significant amounts of pyrrhotite and pyrite occur as disseminations and as fracture fillings.

During 1976, seven BQ holes totalling 2 550 metres were drilled on R 4 claim and one BQ hole totalling 280 metres was drilled on the R 2 claim.

REFERENCES:

Minister of Mines, B.C., Ann. Rept., 1967, pp. 44–47; *B.C. Ministry of Mines & Pet. Res.,* Geological Fieldwork, 1976, p. 58; Assessment Report 6082.

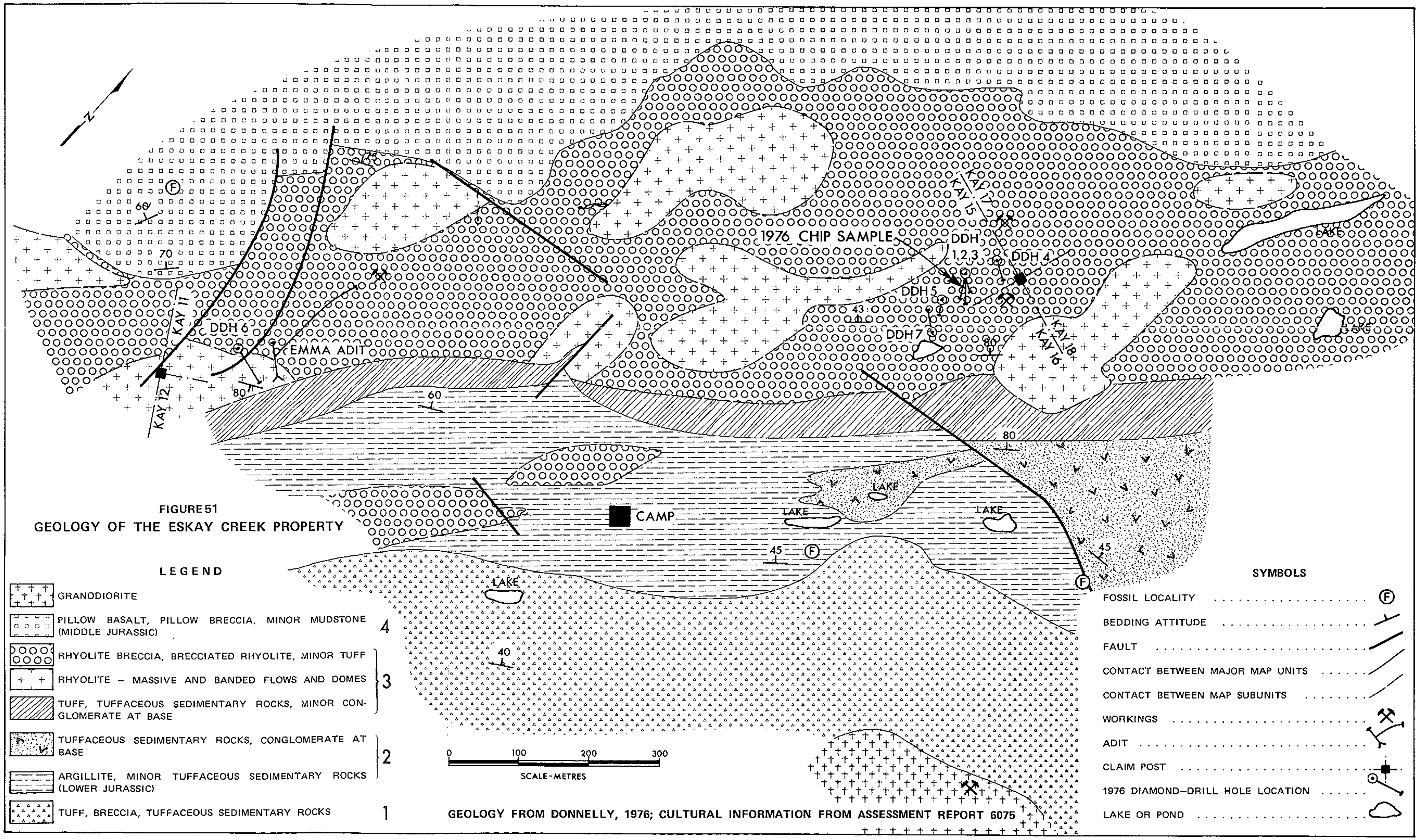

Figure 51. Geology of the Eskay property.

NORTHWEST BRITISH COLUMBIA

KAY (ESKAY CREEK PROPERTY) (104B/9W)

By A. Panteleyev

HISTORY: The Eskay Creek property near Tom MacKay Lake was discovered in 1932 by an air-supported prospecting group headed by T. S. MacKay. Since its discovery the deposit has been explored by numerous companies, initially as a gold prospect and later as a polymetallic deposit. Extensive exploration efforts include two adits, several thousand metres of diamond drilling, and at least 40 pits, trenches, and open cuts. In 1971 a 1.5-tonne shipment of ore yielded 8.5 grams gold, 6800 grams silver, 29 kilograms lead, and 42.6 kilograms zinc.

An abundance of reports outlines the history of the deposit and gives various geological interpretations which led to different concepts of ore genesis and guided exploration efforts. Published reports include:

Minister of Mines, B.C., Ann. Repts., 1933, p. A61; 1934, pp. B30–B33; 1935, pp. B9, B27; 1938, p. B3; 1939, p. 65; 1946, p. 85; 1953, pp. 87–89 and Fig. 4; 1963, p. 10; 1964, p. 20; 1965, p. 44; 1967, p. 30; *B.C. Ministry of Mines & Pet. Res.,* GEM, 1970, pp. 64, 65; 1971, p. 36.

The first published report by J. T. Mandy (1933) describes the deposit as 'a large siliceous replacement-zone generally heavily pyritized and carrying zinc-blende, galena, and some chalcopyrite mineralization.' In 1934 Mandy pointed out that siliceous domes were present and presumed that they were metasomatic and cored or underlain by diorite. He described the mineral showings as 'quartz stringers and partial silicification occurring in irregular areas of slightly porphyritic lavas along the contacts of the latter rocks with tuffs.'

In more recent descriptions, opinions have varied about origin of the bedded rocks, silicified zones, and the relative importance of stratigraphic as opposed to structural ore controls. Bacon in a short 1953 report emphasized the close association between the zone of 'widespread silicification' and a 1,500-foot-wide fault zone, whereas a brief description in the 1964 Annual Report of the Minister of Mines and Petroleum Resources, page 20, states that 'gold, silver, lead, and zinc minerals occur in a bed of volcanic breccia.' In 1970 Grove reported on the basis of regional mapping and fossil collections that the age of the host rocks was Early to Middle Jurassic. The emphasis was again placed on structural ore controls, mainly the 'Eskay Creek shear zone.' Mineralized host rocks were described as 'green, well-bedded volcanic sandstones, conglomerates, breccias, and lenticular pillow volcanic units.' In this report the siliceous ridges (domes) were regarded to be 'metasomatized volcanic conglomerates.' Following this report a 1971 description stated that quartz stockworks are present in 'deformed silicified sedimentary rock.'

In 1975 Texasgulf Inc. examined the property and developed exploration guidelines based on Kuroko-type environments. A volcanogenic model was proposed and emphasis was placed on stratigraphic ore controls, notably flanks of siliceous domes. Drilling in 1976 lent some support to volcanogenic concepts when some thinly banded, presumably stratabound, pyrite-sphalerite-galena was located by diamond drilling. However the low copper content of the siliceous mineralized rocks and the absence of barite and gypsum are difficult to reconcile with a Kuroko-type model. In any case, interpretation of the deposit as a volcanogenic type did not appreciably enhance the economic or exploration potential in the opinion of Texasgulf and the option was terminated.

GEOLOGY: The following geologic description and sketch map are a summary taken from a study by D. A. Donnelly (1976): 'A Study of the Volcanic Stratigraphy and Volcanogenic Mineralization on the Kay Claim Group, Northwestern British Columbia.'

Donnelly mapped and studied a 1 100-metre-thick succession of volcanic and sedimentary rocks in which he recognized four major map units. All are part of the Hazelton Group and from base to top consist of:

(1) An undivided unit of volcanic fragmental rocks, the upper part of which consists of crystal tuff, lapilli tuff, and agglomerate.

(2) A sedimentary unit 130 metres in thickness of predominantly well-bedded black argillite and some tuffaceous sandstone and pebble conglomerate interbeds. These strata contain the Lower Jurassic pelecypod *Welya* and ammonite *Paltarpites.* Contained in argillite is one rhyolite body at least 60 metres thick.

(3) The mineralized unit of acidic tuff, breccia, and flows or domes. This map unit has a basal sequence of lithic tuff or tuffaceous wacke and grades upward into lapilli tuff, rhyolite breccia and tuff, and massive banded rhyolite.

(4) Basaltic pillow lavas and pillow breccias with minor thin mudstone units containing the Middle Jurassic ammonites, *Stephanoceras.*

A simplified sketch map based on Donnelly's outcrop map is shown on Figure 51. Also shown are 1976 drill locations and the location of a trench that was sampled by this writer. Two contiguous chip samples from the well-mineralized trench which was tested at depth by 1976 diamond-drill holes 1, 2, and 3 gave the following results:

Length	Au gm/tonne	Ag gm/tonne	Cu Per Cent	Pb Per Cent	Zn Per Cent
1.2m	<1	148	.065	6.0	12.2
1.2m	<1	26	.001	0.13	0.21

REFERENCE:

Donnelly, D. A. (1976), A Study of the Stratigraphy and Volcanogenic Mineralization on the Kay Claim Group, Northwestern British Columbia, unpublished B.Sc. Thesis, *U.B.C.,* 61 pp., 1 map.

GC, HAB, BUY (STIKINE COPPER) (104G/3W)

By A. Panteleyev

INTRODUCTION: Exploration resumed at the Galore Creek copper deposits after a two-year interruption. A systematic fill-in diamond-drill program in the Central zone that was started in 1972 by Hudson Bay Mining and Smelting Co., Limited was continued during the 1976 field season when 5 233.2 metres of NQ core drilling was completed in 24 diamond-drill holes (numbers 346 to 369). The main area tested was the northern part of the Central zone along the north and northeastern side of a bench-like area on which the Galore Creek airstrip is located. (Fig. 52.)

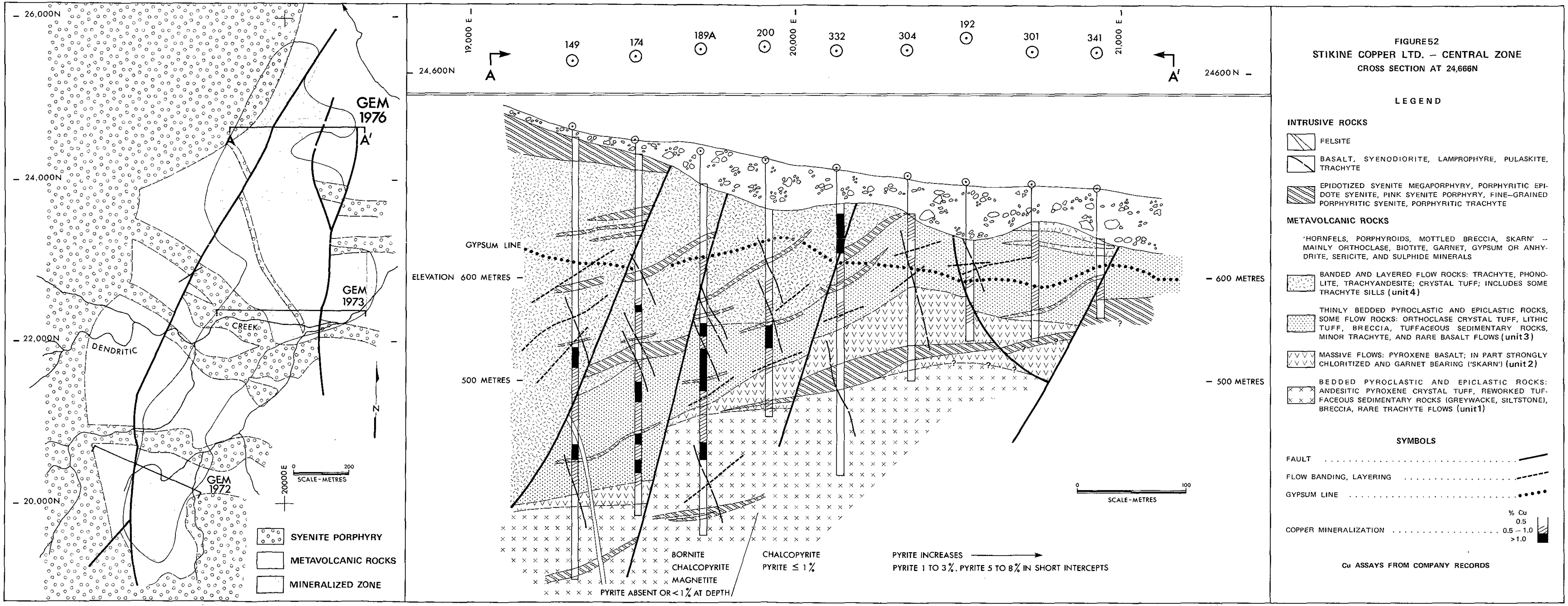

Figure 52. Stikine Copper, geology of the Central zone.

Resumption of exploration at Galore Creek also facilitated completion of a study of the Central zone that was started by the writer in 1972. A fence of nine diamond-drill holes from the north Central zone at approximately 24 666 North was examined in detail. The geological section studied is the last and most northerly of three cross sections from the Central zone, the other two having been described earlier in *Geology, Exploration and Mining in British Columbia,* 1972, pages 519 to 526, and 1973, pages 501 to 504.

GEOLOGY OF THE NORTH CENTRAL ZONE: The northern part of the Central zone is well mineralized with copper. Drill intercepts containing in excess of 1 per cent copper are common throughout the 60 to 180-metre-thick westward-dipping mineralized zone that contains at least 0.5 per cent copper. Mineralized host rocks are similar to those in the southern part of the Central zone but there is a marked decrease in the amount of syenite porphyry intrusions.

Syenite porphyry dykes are abundant in the north Central zone but they are rarely more than 10 metres wide and consequently the total volume of syenite intrusions in the mineralized zone is significantly less than to the south. The large area of epidotized syenite megaporphyry mapped along the northwest margin of the Central zone is shown in drill holes 149 and 174 to be a flat-lying sheet which is underlain at depth by the mineralized zone. Epidotized syenite megaporphyry and its finer grained textural variant, porphyritic epidote syenite, are the main types of syenite. Dark syenite porphyry and garnet syenite megaporphyry have not been recognized. Minor syenite dykes (those less than 1 metre to a few metres wide) are described collectively as pink syenite porphyry, porphyritic trachyte, and fine-grained porphyritic syenite. Several ages of these minor syenite dykes are indicated. For example, pyritic porphyritic syenite is probably equivalent to fine-grained syenite porphyry, a rock that is known elsewhere (GEM, 1973, p. 503) to be older than epidotized syenite megaporphyry. The pyrite-deficient pink syenite porphyry, porphyritic trachyte, and fine-grained syenite dykes are possibly temporal equivalents or might even be younger than epidotized syenite megaporphyry.

All syenite dykes are known from core measurements to be relatively flat lying and are parallel or subparallel to layering in the metavolcanic host rocks. The numerous, thin basic dykes and rare felsite dykes are steeply dipping. They are shown for diagramatic simplicity on Figure 52 to have uniform eastward dips.

Bedded rocks can be readily subdivided on the basis of distinctive lithologic compositions and origins into four persistent map units. Especially useful is a unit composed of pyroxene basalt which serves as an unmistakable marker near the base of the drilled section and can be used to determine the sense and magnitude of fault movements. Dip directions can be determined from an abundance of flow bands and layers in orthoclase-rich volcanic rocks and from well-layered epiclastic and sedimentary units. These primary layers show beds to dip gently westward throughout the cross section with steepest dips in the west.

The major map units shown on Figure 52 from oldest to youngest are described as follows:

(1) **Bedded pyroclastic and epiclastic rocks:** The rocks are mainly tuff and tuffaceous reworked sediments (epiclastic volcanics, greywacke, siltstone) with minor breccia and rare trachyte flows (possibly sills). Tuffs are lithic and pyroxene crystal tuffs in which orthoclase crystals are absent. Chlorite is abundant and the rocks are dark, chloritic, biotite-rich metavolcanics ('hornfels') or dark, mottled metavolcanics with some garnet and orthoclase.

(2) **Massive pyroxene basalt flows:** A distinctive unit of flow rocks which is characterized by euhedral pyroxene phenocrysts up to 55 millimetres in size. The margins of this map unit are altered to granular biotite-chlorite-feldspar or garnet-biotite-

diopside-feldspar ('skarn') assemblages. Elsewhere the rock is extensively chloritized and contains minor pyrite and chalcopyrite but magnetite is generally absent.

(3) **Thinly bedded tuffs, flows, and reworked tuffaceous sediments:** This heterogeneous unit consists mainly of tuff and breccia with some trachyte, trachyandesite, and rare pyroxene basalt flows in what is now a highly variable, mottled metavolcanic sequence. Orthoclase rather than pyroxene is abundant in tuff and in reworked tuffaceous sandstone beds. Grading and possibly crossbedding are evident in drill core. The rocks are now strongly mottled medium to coarse-grained porphyroblastic rocks (porphyroids) composed mainly of biotite and orthoclase with less common garnet and chalcopyrite. Similar well-mineralized rocks are present in the south Central zone and were previously referred to as mottled biotite orthoclase 'hornfels' or orthoclase-biotite-garnet 'hornfels.'

(4) **Massive flows, some tuff (may include sills and dykes):** These rocks are present in the western half of the cross section and are mainly layered and flow banded pink and grey orthoclase-rich flows (trachyte, phonolite, and trachyandesite). Some of the more massive members in the sequence are suspected to be sills and dykes. The base of this map unit is composed of flows, orthoclase crystal tuff, and crystal-lithic tuffs. Overlying rocks are banded but not extensively brecciated flows whose origin might be, in part, subaerial welded ash flows. The rocks are now orthoclase-rich metavolcanics (previously called orthoclase 'hornfels' or orthoclase-biotite 'hornfels') in which sericite and sericite-biotite patches or atolls around sulfide grains impart a subdued mottled texture. Some sericite-orthoclase alteration patches are subhedral and might represent relict replacements of coarse pseudoleucite phenocrysts.

Ore minerals, mainly chalcopyrite and lesser bornite, are most abundant throughout the strongly mottled metavolcanic rocks (map unit 3). Near the base of the layered orthoclase-rich flow rocks (map unit 4) bornite is common. Pyroxene basalt (map unit 2) is a poor host for ore minerals and contains only minor pyrite and chalcopyrite except along the highly altered upper contact with tuffaceous rocks where some better grade zones containing chalcopyrite are known to occur. The chloritic basic tuffs and epiclastic rocks (map unit 1) are sparsely mineralized except in one diamond-drill hole (189A).

Lateral mineralogical zoning is evident with bornite abundant in the western part of the north Central zone, mainly chalcopyrite present in the central part, and pyrite increasingly abundant toward the east. Similar vertical zoning is exhibited in which bornite is abundant together with some magnetite, chlorite, and minor chalcocite in orthoclase-rich flow rocks near the top of the mineralized zone; chalcopyrite is the main ore mineral in the biotite-rich zone beneath the bornite-bearing rocks; and pyrite with some chalcopyrite is present in pyroxene basalt and chloritic biotite-bearing rocks at depth.

From the distribution and zoning of ore minerals strong lithological controls of mineralization are evident. Ore fluids evidently flowed most extensively through the permeable pyroclastic rocks of map unit 3 but affected only slightly the more massive and less permeable footwall pyroxene basalt and hangingwall orthoclase-rich banded flow rocks. Reactions of ore fluids with host rocks to produce the observed ore mineral assemblages are implied. Redox reactions and mineralogical buffers controlled by the composition of the host rocks (for example the chlorite buffer controlled by biotite-chlorite-magnetite-pyrite stability relations) might have been the dominant influence in determining ore mineralogy. Such seems to be the case here where discrete mineral associations of pyrite and chalcopyrite, chalcopyrite alone, chalcopyrite and bornite with erratic magnetite, and bornite-magnetite-chlorite are observed and can be interpreted in terms of decreasing sulphur availability.

In summary, the northern part of the Central zone is as well mineralized as the rest of the Central zone. The abundance of bornite will yield a high-grade concentrate in which gold and silver content can be expected to be greater than in any simple chalcopyrite concentrate from other parts of the Central zone. However, the best mineralization is at depth and dips westward under a thick cover of waste rock. The resulting higher overall stripping ratio in the north Central zone will be slightly alleviated by less dilution in the ore zone due to the decreased abundance of barren syenite dykes.

REFERENCES:

B.C. Ministry of Mines & Pet. Res., GEM, 1972, pp. 520–526; 1973, pp. 502–504; Allen, D. G., Panteleyev, A., and Armstrong, A. T. (1976), *CIM,* Special Vol. 15, pp. 402–414.

RED-CHRIS DEPOSIT (104H/12W)

By A. Panteleyev

INTRODUCTION: During 1976 Texasgulf Inc. continued to explore the Red-Chris porphyry copper deposit. Eighteen new diamond-drill holes were completed and two holes drilled in 1975 were extended, together totalling 3 045 metres of diamond drilling. In total, 49 diamond and 24 percussion-drill holes had been completed to the end of 1976. On the basis of this drilling, a drill indicated and inferred reserve mineable by open pit of 45.2 million tons grading 0.56 per cent copper and .01 ounce per ton gold has been announced by Silver Standard Mines Limited in its 1977 Annual Report. The reserve is a total of the Main zone and the smaller, higher grade East zone.

The free access to diamond-drill core and information, and the hospitality of Texasgulf Inc., particularly Mr. J. R. Forsythe, is gratefully acknowledged by the writer.

GEOLOGY: The mineralized zone consists of chalcopyrite and pyrite-bearing quartz stockwork systems within an east-northeasterly trending pyritic feldspar porphyry stock (Fig. 53). The stock has intruded Upper Triassic sedimentary and volcanic rocks and is in fault contact on the south with Middle to Upper Jurassic sedimentary rocks of the Bowser Lake Group. (Plate XLI).

The stock has been described by various investigators as felsite, feldspar porphyry, quartz diorite, diorite, monzodiorite, quartz monzodiorite, and monzonite. On the basis of four silicate analyses of rocks representing the two main intrusive phases, and three rock analyses reported by Templeton (1976), the stock can now be described as an altered, medium-grained hornblende feldspar porphyry of monzonite composition. Altered rocks exhibit some base and alkali leaching as well as metasomatism. This results in increased silica, alumina, and water content and the development of abundant carbonate, iron oxides, clay, and sulphide minerals. An increased normative quartz and corundum content demonstrates increasing alteration intensity. In the least altered feldspar porphyry, modal quartz content varies from nil to 7 per cent.

The age of the stock has been determined by radiometric dating to be Late Triassic to Early Jurassic from two samples submitted to the writer in 1975 by E. A. Schink. Analytical results for the K-Ar age determinations are given in the accompanying Table. (Table 11).

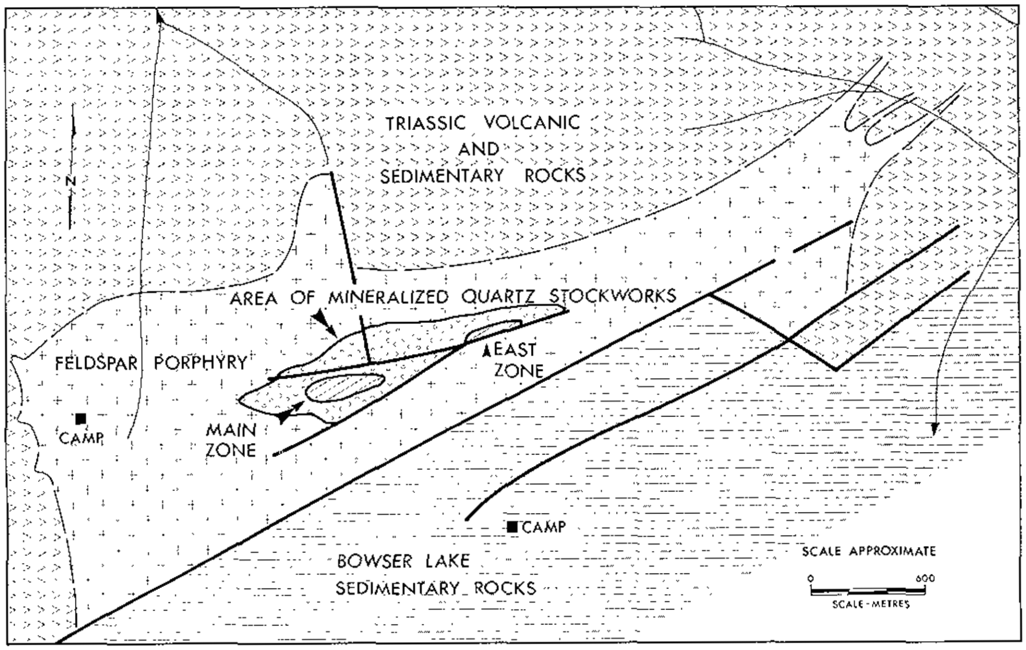

Figure 53. Geologic sketch map of the Red-Chris deposit.

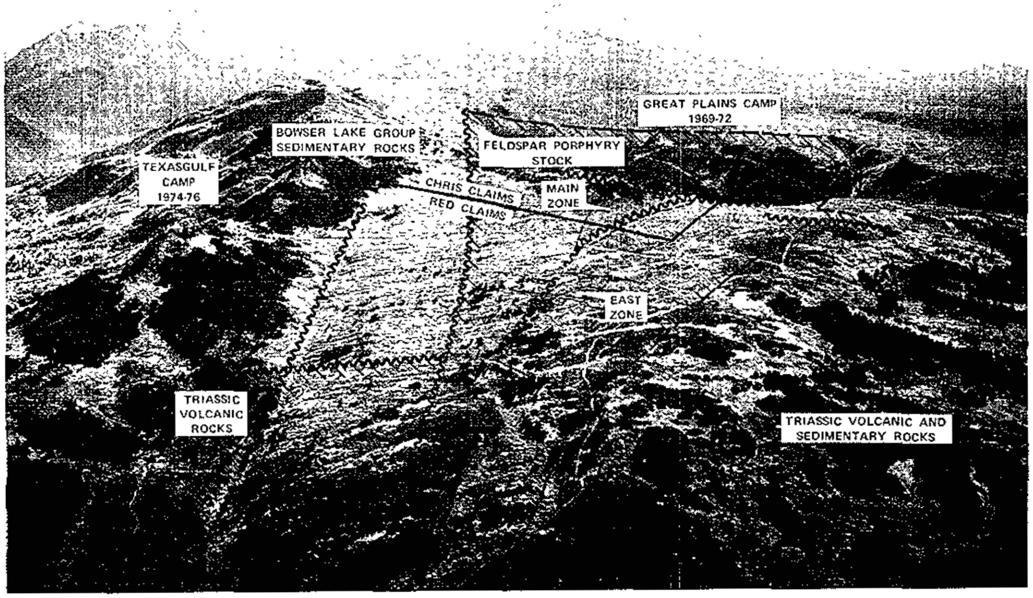

Plate XLI. View east-southeast toward the Red-Chris deposit.

TABLE 11. K-AR ANALYTICAL DATA AND AGE DETERMINATION

Sample No.	DDH-33C75-687′ Red/Chris
Material Analyzed.	Biotite
Potassium (%K)[1]	$\bar{X} = 7.12 \pm 0.08$.
Ar^{x40}/Total Ar^{40}	0.952
$Ar^{x40}(10^{-5}$cc STP/g)	5.851
Ar^{x40}/K^{40}	1.205×10^{-2}
Apparent Age.	195 ± 8 M.Y.
Sample No.	E.A.Schink 24/6-6 Red/Chris
Material Analyzed.	Whole Rock
Potassium (%K)[1]	$\bar{X} = 3.79 \pm 0.04$
Ar^{*40}/Total Ar^{40}	0.950
$Ar^{*40}(10^{-5}$cc STP/g)	3.367
Ar^{*40}/K^{40}	1.302×10^{-2}
Apparent Age.	210 ± 7 M.Y.

Footnotes: 1. Number in parenthesis refers to number of K analyses.

Constants Used: $\lambda e = 0.585 \times 10^{-10} yr^{-1}$
$\lambda_{\beta} = 4.72 \times 10^{-10} yr^{-1}$
$K^{40}/K = 1.19 \times 10^{-4}$
Ar^{*40} refers to radiogenic Ar^{40}.
6 = standard deviation.
J. Harakal, Analyst, The University of British Columbia.

The 210 Ma specimen is a typical sericite-altered feldspar porphyry of the main intrusive phase. The 195 Ma biotite specimen is from a basic dyke (biotite trachyandesite) that intrudes the altered main porphyry phase. The dyke is hydrothermally altered and pyritized along its margins and therefore was involved in mineralization.

Mineralization resulted in sulphide-bearing quartz veins and stockworks in which early quartz-pyrite-chalcopyrite veins are cut by pyrite-chalcopyrite-bearing fractures followed, in turn, by carbonate-pyrite veins, vuggy calcite veins, and locally, gypsum veins. The feldspar porphyry host rocks are extensively altered in the mineralized zone to quartz-sericite-pyrite, quartz-carbonate-hematite, and quartz-carbonate-clay assemblages. Rarely zones of quartz-sericite with minor amounts of molybdenite are present. Elsewhere some green to maroon or red-coloured zones of albite-magnetite-chlorite alteration were noted. These appear to be either isolated remnants of an early, pervasive deuteric alteration of the stock or are a younger alteration type formed by late magmatic fluids that were more reduced than the oxygenated and CO_2-rich hydrothermal fluids. Brecciation and faulting took place both prior and following the main mineralizing stages.

REFERENCES:

B.C. Ministry of Mines & Pet. Res., GEM, 1974, pp. 340–343; Templeton, T. J. (1976), Petrography and Geological Events of Triassic-Jurassic Rocks, Northwest British Columbia, unpublished thesis, *Univ. of Western Ontario*, 46 pp.

KUTCHO CREEK MAP-AREA (104I/1W)

By A. Panteleyev and D. E. Pearson

INTRODUCTION: Geologic investigations in the Kutcho Creek area were initiated by the Ministry in 1974 (GEM, 1974, pp. 343–348) in the vicinity of stratabound cupriferous pyrite showings on the SMRB and JEFF claim groups. Studies proceeded in 1975 (Geological Fieldwork, 1975, pp. 86–92; GEM, 1975, pp. G-87–G-93) and continued in 1976 (Geological Fieldwork, 1976, pp. 74–76).

The approximate extent of the volcanic map unit in which the sulphide deposits occur was determined from east of Tucho River to west of Kutcho Creek, a distance of 19 kilometres. The north and northwest boundary is a fault contact with rocks of the Cache Creek Group; to the east, quartz monzonite intrusions occur; on the south are greenstones and phyllites of possible Triassic age. The favourable volcanic unit continues to the west and west-southwest of Kutcho Creek for at least 15 kilometres and probably for a considerably greater distance.

Volcanic rocks that host the mineralized zones are locally overlain on the north by conglomerate, a more or less continuous limestone unit commonly a few tens of metres in thickness, and a thick sequence of shale and sandstone.

The structural style of overturned tight isoclinal folds described in 1975 (Geological Fieldwork, 1975 and GEM, 1975) held up to closer scrutiny although some revision and refinement of structures was possible as a result of detailed mapping in the mineralized area and access to diamond-drill core. The major structure mapped is an east-west-trending anticlinorium, the northern limb of which contains a number of smaller folds. The northern synclinal-anticlinal pair shown previously in cross section A-B, Fig. G-38, *Geology in British Columbia, 1975* is now known to be much smaller in size and is just one of a number of minor folds that are present on the northern limb of the major anticline. Therefore the mineralized bed can be regarded to be a single horizon on the northern limb of the major fold and no repetition by folding is expected in the area between Kutcho Creek on the north and the known trace of the mineralized zone on the south.

AGE OF ROCKS: The age of the host rocks for the Kutcho Creek deposits is still unresolved. A Sr-Rb isochron radiometric age determination from volcanic host rocks gives a Paleozoic date (R. L. Armstrong, personal communication, 1976). This is compatible with geologic interpretations in the vicinity of the mineralized zone but conflicts with conclusions based on more widespread field observations, mainly west of Kutcho Creek. There, geologic mapping and fauna suggest a Mesozoic age is probable for the volcanic rocks in the Kutcho Creek assemblage. A similar conclusion has been reached by the Geological Survey of Canada on the basis of recent regional mapping (L. Thorstad, personal communication, 1977).

It was suggested earlier that volcanic rocks at Kutcho Creek are Paleozoic, the overlying sedimentary rocks are Mesozoic, and that a folded unconformity is present (Geological Fieldwork, 1976, p. 75). This conclusion was founded on geological mapping in the vicinity of the main mineral showings east of Kutcho Creek. Mapping suggests some stratigraphic units (notably pyritic sericite schists) are cut out to the west by an apparently transgressive, westward thickening conglomerate lens. We, therefore, assumed that an erosional break was probable in the stratigraphic succession at the base of the conglomerate member which overlies the mineralized rocks. The conglomerate is, in turn, overlain by limestone and a thick shale unit. This interpretation was supported by an apparent Sr-Rb isonchron date of 280 ± 30 Ma obtained from a suite of six volcanic and related intrusive rocks and by the presence of sparse scleractinian (that is, Mesozoic) corals* in the overlying limestone unit.

However, after closer scrutiny of the radiometric data, R. L. Armstrong noted (written communication, 1977) that the Sr-Rb isochron date was based on only four samples, the other two being rejected as anomalous. Dr. Armstrong concluded 'the rocks are **all** unusually low in both Sr and Rb. The isochron is quite short, based on only four samples, and perhaps fortuitous.'

The main geological evidence for a Mesozoic age of at least the mineralized volcanic rocks is found a few kilometres west of Kutcho Creek. There, sericite schists and quartzose volcanic rocks identical to rocks from the main mineralized zone east of Kutcho Creek are intermingled with the Mesozoic limestone and 'conglomeratic' units. West of Kutcho Creek sericite schist is found both above and below the fossiliferous Mesozoic limestone unit and in one locality pyritic sericite schist is immediately overlain by the limestone.

A potassium-argon date from coarse grained white mica obtained by D. E. Pearson from pyritic sericite schist in the mineralized horizon two kilometres west of Sumac Mines Limited camp returned a date of 189 ± 3 Ma. This suggests a late Triassic/early Jurassic age of mineralization. Analytical data are given below:

LITHOLOGIES: The coarse-grained, quartz-bearing feldspathic chlorite schists referred to in 1975 as 'grits' (Geological Fieldwork, 1975, p. 88; Geology in British Columbia, 1975, p. G-88) were re-examined. The extent and origin of this rock type are of great interest as it is closely associated with mineralized zones and favourable stratigraphic units.

Sample: Kutcho Creek, 16257M.

Description: White mica (phengite) from pyritic sericite schist, 60 to 80 mesh.

Per cent K; 4.20 ± 0.01 % (2).

$\frac{Ar^{40*}}{\text{Total } Ar^{40}}$: 0.938.

Ar^{40*}: 32.840×10^{-6} cc/gm.

$\frac{Ar^{40*}}{K^{40}}$: 1.136×10^{-2}.

Apparent age: 189 ± 3 Ma.

NOTES:

Per cent K determined by the Analytical Laboratory, Ministry of Energy, Mines and Petroleum Resources; number in parenthesis refers to number of analyses.

Ar determination and age calculation by J. E. Harakal, University of British Columbia.

Constants used: $\lambda_e = 0.581 \times 10^{-10}yr^{-1}$,

$\lambda\beta = 4.96 \times 10^{-10}yr^{-1}$,

$K^{40}/K = 1.167 \times 10^{-4}$.

* Identification of the corals was provided by E. W. Bamber, Institute of Sedimentary and Petroleum Geology, J. W. H. Monger, personal communication, 1976.

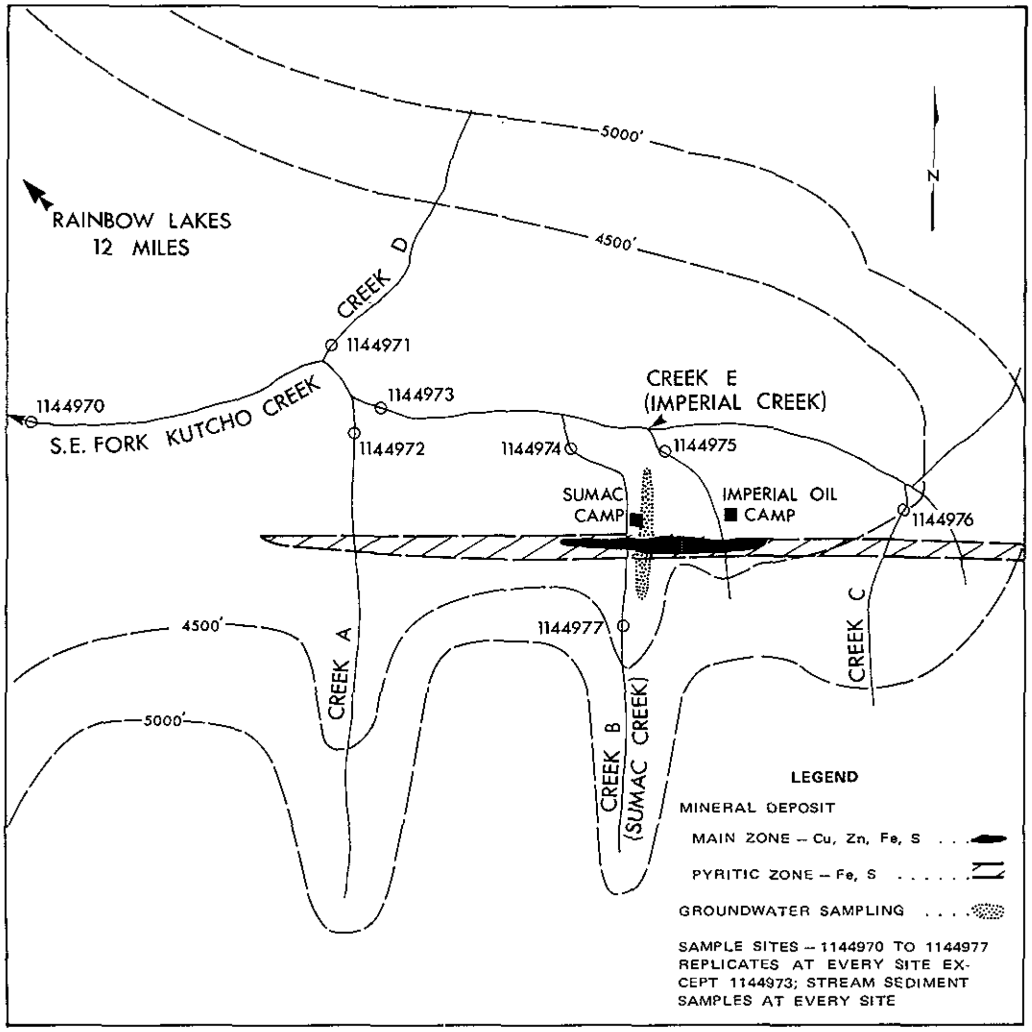

Figure 54. Stream sample sites, Kutcho deposit.

The quartz-eye-bearing feldspathic chlorite schist (called by some as 'quartz porphyry' or 'quartz feldspar porphyry') exhibits some compositional variation which is indicated by different proportions of quartz eyes and feldspar phenocrysts. The main variation in this map unit is textural. Where quartz feldspar chlorite schists are homogeneous, coarse-granular rocks with euhedral or subhedral phenocrysts they take on the appearance of porphyries. These were probably emplaced as dykes, sills, and lenticular intrusions that might have formed small domes. In some places such as in the hangingwall of the main sulphide zone, fragments of quartz feldspar porphyry up to 1 metre in size are present in a finely comminuted matrix of similar composition and the rocks are thought to be autobrecciated flows. Locally tuff breccia or agglomerate with a mixture of polylithologic and quartz feldspar porphyry fragments is present. Elsewhere, particularly where quartz is abundant, feldspar is subordinate or absent, and rock fragments are rare and small in size, the rocks are suspected to be subaqueous ash flows (*see* Schermerhorn, 1970; Niem, 1977). On the basis of chemical composition, mineralogy, and grain size we believe the quartz feldspar chlorite schists are genetically related to the trondjhemites that are found along the southern part of the map-area.

A sericite schist unit at least 400 metres thick is host to the mineralized beds. The lower part of the sericitic map unit contains abundant chlorite and is made up of quartz-sericite-chlorite-carbonate schists, quartz-chlorite schists, and feldspathic chlorite schists. The massive sulphide member is near the top of the sericitic unit and is contained in pyritic siliceous dolomitic sericite schist. Discrete lenses of dolomite are commonly present in the hangingwall of the massive sulphide member.

The hangingwall rocks are commonly quartz bearing and are present either as laminated dolomitic sericite schist with minute quartz eyes and rare rhyolite fragments or as coarse quartz-eye-bearing rocks that were formerly described as part of the 'grit' map unit. In the eastern part of the mineralized zone the coarse quartz-eye rock directly rests on or closely overlies the massive sulphide body. Elsewhere they are separated by up to 30 metres of laminated dolomitic sericite schist with fine quartz grains. In the western part of the mineralized zone, the hangingwall coarse quartz-eye rock is fragmented and is present as blocks up to 1 metre in size in what appears to be a volcanic breccia or agglomerate.

Overlying the hangingwall coarse quartz-eye sericitic schists are graded, fine-grained feldspathic tuff, tuffaceous sandstone, siltstone, and black shale. The latter rocks contain minor pyrrhotite and traces of chalcopyrite.

WATER AND SILT GEOCHEMISTRY: A limited stream sediment and baseline water quality sampling program was done during July and partly repeated in August. The sampling was done largely in response to an invitation by Sumac Mines Limited to document some natural stream water, sediment, and groundwater characteristics, especially metal content, in the vicinity of the newly discovered mineral deposits.

Sampling and silt analyses were done by British Columbia Ministry of Mines and Petroleum Resources personnel and water samples were analysed at the Environmental Laboratory, Water Resources Service, Vancouver. Analysis and evaluation of stream water samples were done in co-operation with J. M. Goddard, Environmental Studies Division, Water Investigations Branch; groundwater samples were analysed in co-operation with E. G. Le Breton, Hydrology Division, Water Investigations Branch.

Stream water and sediment samples were collected from eight sites using sampling procedures identical to those used in geochemical exploration surveys. At each sample site (*see* Fig. 54) two water samples were taken, a one-half-gallon sample for general analyses and a 500-millilitre sample for metals. Water samples were not filtered nor chemically treated in any manner prior to being shipped with ice packs in coolers for analysis. The following 22 parameters were determined within 48 hours from time of sampling.

TABLE 12. LIST OF WATER CHEMISTRY PARAMETERS

Alkalinity	—phenolphthalein	Nitrogen	—nitrite + nitrate
Alkalinity	—total	Nitrogen	—total Kjeldahl
Arsenic	—total	pH	
Calcium	—dissolved	Phosphorus	—dissolved
Chloride	—dissolved	Phosphorus	—total
Copper	—total	Potassium	—dissolved
Hardness	—total	Residue	—filterable
Iron	—total	Sodium	—dissolved
Lead	—total	Specific conductance	
Magnesium	—dissolved	Sulphate	—dissolved
Manganese	—dissolved	Zinc	—total

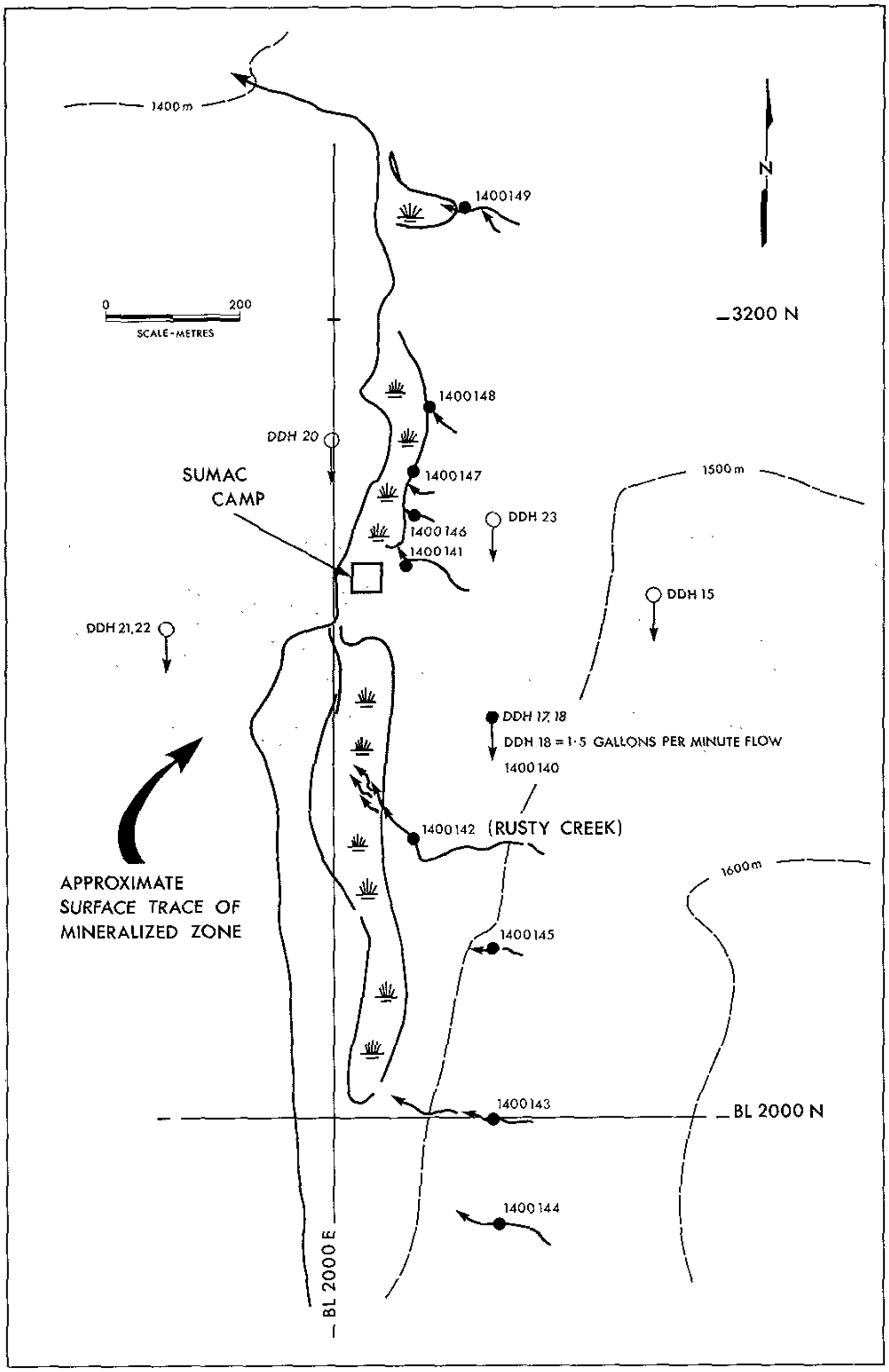

Figure 55. Groundwater sample sites, Kutcho deposit.

All eight sites were sampled initially on July 27 and seven of the sites were resampled on August 24. Sampling was done during a period of somewhat greater than normal summer precipitation. During the July sampling from one to four separate stream sediment samples were collected at each of the eight water sampling sites. Sediment samples were dried, screened, and the minus 80 mesh fraction was analysed for copper, nickel, colbalt, lead, zinc, gold, silver, and arsenic.

Groundwater samples were taken in July at 10 sites, nine of which were natural springs or ponded seepage areas and one of which was a 1.5-gallon-per-minute discharge from drill casing at the collar of diamond-drill hole KT18 (Fig. 55).

Results of the most significant parameters from stream water analyses are given in Table 13 and show that creeks tested all have water of excellent quality although concentrations of certain metals are evident in waters that pass over or come from the mineralized zone. The following is a summary of data provided by J. M. Goddard:

The data indicate that creeks A, B, C, and E which emanate in areas of volcanic rock and flow across the mineralized zone have very soft water which is low in suspended solids and very low in total dissolved solids (indicated by specific conductance). Total nitrogen and phosphorus values were low, and dissolved nitrogen and phosphorus were undetectable. Arsenic and lead (total) were also undetectable, as were total zinc and copper in Creeks A and C (those which cross the outer margins of the massive sulphide zone). Creeks B and E (flowing across the main part of the mineralized zone) showed detectable quantities of total zinc and copper, but the values are low and well within the recommended limits for drinking water (British Columbia Health Branch, 1969).

Creek D which emanates in siltstone and black shales on the north side of the valley showed quite different water characteristics. The data indicated a medium hard water, of slightly alkaline nature, and with markedly higher values for suspended solids and total dissolved solids than occurred in the other creeks discussed above. Total nitrogen and total phosphorus values were low, and dissolved nitrogen and phosphorus were undetectable. The heavy metals tested (arsenic, copper, lead, and zinc) were all undetectable.

The lower reaches of the southeast fork of Kutcho Creek (samples at site 1144970) showed the expected effect of mixing of creek D water with that from creeks A, B, C, and E. Thus values recorded for the major parameters (Table 13) are intermediate between those of creek D and those of the other creeks.

Analyses of the minus 80 mesh fraction of stream sediments are shown in Table 14. In all cases gold is less than the 1 ppm detection limit and silver is below the 10 ppm detection limit. Only one creek (creek E, sample site 1144975) is anomalous for copper and zinc, although creek B (sample site 1144974) might be considered slightly anomalous for copper.

Spring water samples (Table 15) exhibit greater variation and higher metal concentrations than stream waters. Sample 1400140 is unique in the sample group as it was collected as discharge from diamond-drill hole KT18 which intersected mineralized rocks in a carbonate-rich zone. The water is alkaline and rich in sulphate but does not have any detectable copper, zinc, or iron, presumably because the water tested emanated from below the water table in a zone where oxidation of sulphide minerals is minimal. Other groundwaters passed closer to surface where oxidation and leaching of sulphide minerals is taking place and therefore waters are more acidic and enriched in metal ions. Sample 1400142 is the most clearly anomalous; it comes from a creek in which creek walls and boulders are covered with a rusty coloured limonitic stain. Sample 1400149 is from a ponded seepage area and is also slightly anomalous. It is more noteworthy than is first apparent because the anomalous copper content is present despite a mildly alkaline water pH (8.2).

TABLE 13. SUMMARY OF STREAM WATER PARAMETERS

Sample Site	1144970	1144971	1144972	1144973	1144974	1144975	1144976	1144977
Creek	Kutcho	D	A	Kutcho	B	E	C	B
Estimate of Flow Volume (ft³/sec.)	110	1	20	70	15	6	8	10
pH	8.0, 7.8	8.4, 8.2	7.8, 7.8	7.9,	7.7, 7.5	7.6, 7.6	7.8, 7.7	7.6, 7.4
Conductance (μ mho)	93, 1.1	185, 190	68, 76	73,	51, 59	67, 77	55, 68	43, 50
Suspended solids—								
Residue filterable (105°C) mg/L	60, 64	108, 116	50, 48	48,	38, 46	48, 58	40, 48	34, 34
Alkalinity (total) ppm	43, 46	94, 96	30, 32	33,	21, 23	21, 25	23, 27	18, 20
Hardness (total) ppm	43, 46	92, 94	30, 35	32,	21, 26	28, 33	23, 31	18, 21
Sulphate (dissolved) ppm	<5, 5.4	<5, 5.4	6.1, 6.3	<5,	<5, 6.3	11.4, 12.4	6.1, 5.9	<5, <5
Copper (total) ppm	<.001, <.001	<.001, <.001	<.001, <.001	.001,	.004, .007	.003, .003	.002, <.001	<.001, <.001
Zinc (total) ppm	<.005, <.005	<.005, <.005	<.005, <.005	<.005,	<.005, <.005	.04, .025	.007, <.005	<.005, <.005
Iron (total)ppm	.1, .1	.1, .1	.1, .1	.1,	.1, .2	.1, .2	.6, .3	.3, .1

NOTE: The first value is for the July sample, the second for the August sample.

TABLE 15. SUMMARY OF GROUNDWATER PARAMETERS

Sample Site	1400140	1400141	1400142	1400143	1400144	1400145	1400146	1400147	1400148	1400149
pH	8.3	7.6	4.3	7.7	7.6	7.2	7.4	7.8	7.9	8.2
Conductance (μ mho)	330	72	203	78	40	83	45	71	75	125
Suspended solids—										
Residue filterable (105°C) mg/L	210	60	> Detect limit	48	28	72	56	70	58	80
Alkalinity (total) ppm	126	24	<0.5	27	20	20	20	36	337	633
Hardness (total) ppm	155	31	59.6	33	17	35	21	36	34	59
Sulphate (dissolved) ppm	47.8	11.9	90.8	12.7	<5	19.2	<5	<5	<5	<5
Copper (total) ppm	<.001	.002	0.83	.003	.002	.006	.005	.004	.005	.02
Zinc (total) ppm	<.005	<.005	0.29	.006	<.005	.016	.006	.008	.006	.016
Iron (total)ppm	<0.1	0.3	0.8	0.2	0.2	2.3	0.4	0.2	0.1	1.0

TABLE 14. STREAM SEDIMENT ANALYSES—ppm METAL IN −80 MESH FRACTION

	Cu	Zn	Pb	As	Ni	Co
1144970 Kutcho CK	88	85	4	8.7	522	18
	82	99	10	10.0	58	16
	71	101	<2	12.9	49	14
	81	79	<2	8.9	109	21
1144971 CK D	65	82	6	7.4	51	16
	71	89	11	8.9	57	22
1144972 CK A	79	98	9	8.2	48	14
	66	116	10	10.9	43	19
1144973 Kutcho CK	69	92	3	8.7	43	14
	73	99	3	8.6	45	15
1144974 CK B	98	97	8	5.0	22	15
	80	92	7	6.0	24	12
	79	94	8	8.0	21	15
1144975 CK E	295	1 734	12	6.0	50	22
	351	2 067	11	8.0	56	23
1144976 CK C	69	82	4	7.2	20	18
	61	71	11	5.4	25	15
	52	66	9	6.8	22	17
1144977 CK B	33	76	6	6.0	25	18

In summary, creeks and groundwaters emanating from or flowing over mineralized rocks have anomalous concentrations of metals especially where sulphide zones are present near surface and are being oxidized and leached. However, all creeks tested carry water of excellent quality.

REFERENCES:

B.C. Ministry of Mines & Pet. Res., GEM, 1974, pp. 343–348; Geology in B.C., 1975, pp. G.87–G.93;Geological Fieldwork, 1975, pp. 86–92; 1976, pp. 74–76.

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TOM, KEN (SNOWDRIFT) (104I/5E)

By T. G. Schroeter

The Tom and Ken claims, owned by Utah Mines Ltd., are situated 30 kilometres southeast of Dease Lake, at the headwaters of Snowdrift Creek, between 1 380 and 1 650 metres elevation.

The property consists of a steeply dipping northwest-trending zone of shearing and alteration in a diorite-granodiorite which has intruded andesitic flows and pyroclastic rocks. The quartz-sericite 'greisen' zone varies from a width of 300 metres in the southeast to a width of 1 000 metres in the northwest. Outcrops are leached, but locally pyrite is present in amounts up to 5 per cent. No copper mineralization was observed in the altered area, although minor malachite, chalcopyrite, and chalcocite are present in shears and quartz-carbonate stringers in unaltered volcanic rocks. Lazulite appears disseminated in parts of the altered zone. Significant concentrations of ferricrete fill the valley bottoms and presumably have been concentrated from the gossaniferous volcanic rocks.

During 1976, three holes totalling 275 metres were diamond drilled.

REFERENCES:

B.C. Ministry of Mines & Pet. Res., GEM, 1973, p. 511; *B.C. Ministry of Mines & Pet. Res.,* Geological Fieldwork, 1976, p. 69; Assessment Reports 4644, 5769.

EAGLE (104I/6E, 11E)

By T. G. Schroeter

The Eagle claims, owned by Imperial Oil Limited, are situated 50 kilometres east of Dease Lake and 6.5 kilometres southeast of Eaglehead Lake, at approximately 1 500 metres elevation.

Work was done in three zones (Camp, Pass, and Bornite) along a linear direction over 3 000 metres long and 800 metres wide. The main host rock is an altered biotite-hornblende granodiorite and biotite-quartz diorite in sheared contact with Lower Jurassic sedimentary rocks. Alteration includes strong saussuritization of feldspar, ± feldspathization, ± chloritization. Mineralization appears to be concentrated in steeply dipping shear zones, especially those containing chlorite, and consists of chalcopyrite, bornite, molybdenite, and pyrite. Minor amounts of sulphides occur in quartz veins. Mineralization also appears to be related to K-feldspar flooding.

During 1976, five holes totalling 1 045 metres were diamond drilled and 11.2 kilometres of induced polarization surveying was done over the southeast extension and 4 kilometres of IP was re-run over the Bornite zone.

REFERENCES:

B.C. Ministry of Mines & Pet. Res., Ann. Rept., 1963, p. 6; 1965, p. 16; *B.C. Ministry of Mines & Pet. Res.,* GEM, 1971, pp. 45, 46; 1972, pp. 540–543; 1973, p. 511; 1974, p. 349; *B.C. Ministry of Mines & Pet. Res.,* Geological Fieldwork, 1976, p. 68; Assessment Reports 585, 3476, 4256, 6068.

COAL INVESTIGATIONS

WAPITI RIVER AREA, PEACE RIVER COALFIELD (93I/8, 9, 10, 15)

By B. P. Flynn, R. D. McMechan, and M. McMechan

INTRODUCTION: A relative lack of information on the stratigraphy, structure, and coal resources of the southeastern one-third of the Peace River Coalfield resulted in a field investigation of this area by the Geological Division of the Ministry of Mines and Petroleum Resources during 1976. This was one part of the Northeast Coal Study, a study undertaken by the Provincial Government, to ascertain various aspects of the possible exploitations of the Peace River Coalfield.

The objectives of the 1976 study were twofold. Firstly, the reconnaissance mapping of the area (designated the Wapiti River map-area) at a scale of 1:50 000 and secondly, an evaluation of the potential coal resources.

LOCATION: The Peace River Coalfield lies in the foothills of the Rocky Mountains, northeastern British Columbia and trends northwesterly from the British Columbia-Alberta border to the Williston Reservoir (Fig. 56).

The area mapped in 1976, the Wapiti River map-area, lies 110 to 150 kilometres south of Dawson Creek. It extends from Kinuseo Creek in the northwest to the Narraway River in the southeast, encompassing an area of approximately 550 square kilometres, over a strike length of 56 kilometres.

Within the map-area coal licences, which are held by McIntyre Mines Limited and Canadian Superior Explorations Limited and by Belcourt Coal Limited, occupy two narrow linear belts (excluding the Saxon property in the southeast, which was not part of the map-area).

PREVIOUS WORK: Geological knowledge of the map-area prior to this report was based on D. F. Stott's regional mapping of northeastern British Columbia (Peace River area) from 1958 to 1972. In 1968 a 1 inch equals 4 mile geological map of the area, Peace River to the Smoky River, was published as part of Geological Survey of Canada Bulletin 152 (Stott, 1968). In 1975 this map was superseded by a set of preliminary geological maps of northeastern British Columbia, effectively covering the Peace River Coalfield (Stott, 1975).

GENERAL GEOLOGY: The Peace River Coalfield is underlain by Upper Jurassic to Upper Cretaceous formations with a northwest-southeast regional strike. Within the map-area, the Upper Jurassic to Lower Cretaceous Minnes Group forms the base of the section and is overlain by the Lower Cretaceous Bullhead and Fort St. John Groups.

The Foothills thrust, which has brought the Paleozoic and Mesozoic strata of the Rocky Mountains in contact with Lower Cretaceous strata, forms the southwestern boundary of the map-area. The northeast boundary is delineated by non-coal-bearing Upper Cretaceous formations.

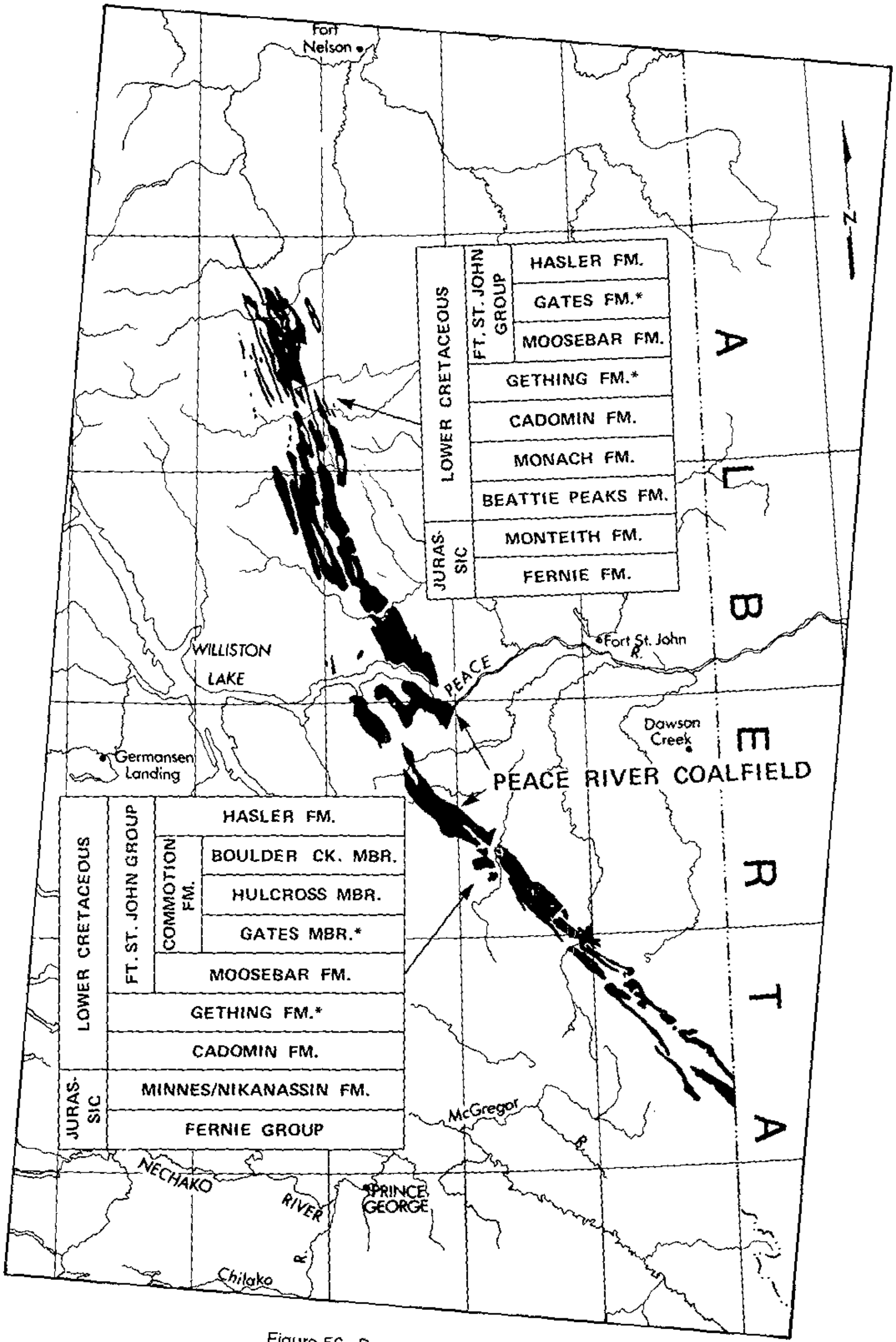

Figure 56. Peace River Coalfield.

The general structure of the area is that of a large northwesterly trending anticlinorium, cored by Minnes Group sedimentary rocks, with Bullhead and Fort St. John Group strata forming the southwestern and northeastern flanks. In the extreme southeast, the Bullhead and Fort St. John Groups are exposed in the Saxon syncline.

Excluding the Saxon syncline, which was not mapped, the map-area can be divided into three broad belts. A central, intensely folded belt of Minnes Group strata; a southwestern belt of relatively undeformed Bullhead and Fort St. John sedimentary rocks; and a northeastern belt of complexly folded and faulted Bullhead and Fort St. John Groups.

The Upper Jurassic and Cretaceous sedimentary rocks of the Peace River Coalfield were folded during the Laramide orogeny. This folding is the dominant structural control of the aforementioned belts, as it is in the remainder of the coalfield. Within the map-area, the folds are often cut by northwesterly trending thrust faults dipping predominantly southwest.

The Majority of the economic coal of the Peace River Coalfield occurs in the Gething Formation of the Bullhead Group,over the northwestern half of the coalfield, and in the Gates member (Commotion Formation) of the Fort St. John Group, over the southeastern half. Economically mineable coal seams occur in both units, in the central area, around Bullmoose Mountain.

DETAILED GEOLOGY: A breakdown of the stratigraphy of the map-area appears in the accompanying table. Other than a brief description, (Fig. 56). For a more detailed account the reader is referred to Geological Survey of Canada Bulletin 152 (Stott, 1968).

MINNES GROUP: The Minnes Group forms the base of the section, occupying the core of the broad northwesterly trending anticlinorium. Thinly bedded alternating medium-grained brown sandstone, dark grey shales, mudstones, siltstones, conglomerate, and coal characterize the lithology.

Intense structural deformation, compounded by a paucity of marker horizons, and insufficient time did not facilitate the measurement of a complete section through the group in 1976. As a result the area underlain by Minnes sedimentary rocks was principally prospected for coal.

A conglomerate exposed in a creek northeast of Mount Belcourt was first assigned to the Cadomin Formation (Stott, 1960) but later to the Minnes Group (Stott, 1968, p. 15). Further exposures were mapped during 1976 on either side of the Red Deer Creek valley. The conglomerate is ascribed to the Minnes Group in this paper.

In all three exposures, the conglomerate is massive and cliff forming, with no or very thin interbedded sandstones. Clasts are well rounded and composed of quartzite, quartz, green chert, and black fossiliferous chert. Pebble size is uniform, ranging from 1 centimetre to 2 centimetres with no large cobbles. This is in marked contrast to the Cadomin conglomerate which contains sandstone beds up to a metre or more thick, and highly variable pebble size with cobbles up to 13 centimetres. Its massive nature and thickness of 30 metres plus serve to differentiate it from the thinner Gates and Gething conglomerates. It is overlain by interbedded sandstone and shale. Due to a lack of stratigraphic control, its position within the Minnes section was not determined.

Coal seams are present within the group, but with the exception of three coal seams (1.9, 2.8, and 3.5 metres thick) exposed on the first southwesterly trending ridge southeast of Belcourt Mountain, seams ranged from decimetres to less than 1.5 metres.

CADOMIN FORMATION: The Cadomin Formation unconformably overlies the Minnes Group, and is composed of massive, siliceous, chert-rich conglomerates with some interbedded sandstones. The Cadomin conglomerate can be traced along strike throughout the map-area, and, with a few exceptions, forms resistant ridges. As a result it proved to be an excellent and, in many cases, the only marker horizon.

A maximum thickness of 188 metres was measured near Mount Belcourt. From this locus of maximum deposition, the Cadomin thins northwestward and southeastward to an average of 60 metres. In the northeastern belt the average thickness is 60 metres.

GETHING FORMATION: The Gething Formation consists of fine to coarse-grained carbonaceous and calcareous sandstones, siltstones, mudstones, conglomerates, and coal. The conglomerates differ from that of the Cadomin Formation in that they are much thinner, 1 to 10 metres thick, have a smaller and more uniform pebble size, and are characterized by calcareous cement, whereas the Cadomin conglomerates are siliceous.

Although the Gething Formation is 600 metres to a possible maximum of 900 metres thick in the northwestern portion of the coalfield, it thins progressively southeast. In the southwestern belt of the map-area thickness ranges from 90 metres in the northwest to 22 metres (Mount Belcourt) in the southeast and from 135 metres in the northwest to 66 metres in the southwest of the northwestern belt. The formation conformably overlies the Cadomin Formation and is in turn overlain by the Moosebar Formation.

Unlike the northwest part of the coalfield, where the economically exploitable coal seams are in the Gething Formation, it is of relatively minor importance within the map-area.

MOOSEBAR FORMATION: The recessive dark grey marine shales, mudstones, and siltstones of the Moosebar Formation were, in many areas, seldom seen in outcrop, and its position was thus inferred from negative topographical features. Where exposed, the base is marked by a glauconitic pebble zone a few centimetres thick. The upper section of the Moosebar is defined by a 'transition' zone, varying from a few to over 10 metres thick of interlaminated fine sands and silts characterized by bioturbation and worm burrows. In the Bullmoose Mountain area the transition zone is up to 132 metres thick and is known as the Sukunka member of the Commotion Formation. The formation averages 55 metres in thickness.

GATES MEMBER: The Gates Member conformably overlies the Moosebar Formation and is composed of fine to coarse-grained carbonaceous and calcareous, brown sandstones, mudstones, siltstones, conglomerates, and coal. The lower contact is usually marked by a thick, fine-grained, flaggy sandstone, often with limonitic concretions, lying above the transition zone.

Plant fossils are abundant in the lower to middle Gates and the flora noted include some of the following species:

Sagenopteris
Onychiopsis
Brachphyllum
Elatides
Elatocladus
Gleichenites
Dentalium

In the southwestern belt, the member averages 335 metres, but in the northeastern belt it has thickened to 518 metres, with a maximum of possibly 640 metres.

Prominent with the Gates member (in some locations) are conglomerates, ranging from less than 1 metre to a maximum of 20 metres thick. They are often associated with coal seams, which are occasionally both overlain and underlain by conglomerates. On Mount Belcourt, a 3.7-metre seam is closely overlain by a thick conglomerate.

The Gates member is the main coal-bearing unit of the southeastern half of the coalfield, and this was confirmed within the map-area.

HULCROSS MEMBER: The recessive blocky rusty weathering marine shales and mudstones of the Hulcross Member were occasionally observed in outcrop but in most cases were inferred from negative topographical features. Average thicknesses are in the order of 46 metres.

BOULDER CREEK MEMBER: the base of the member is often delineated by a 5 to possibly 15-metre-thick conglomerate which was traceable over most of the southwestern belt. Dense tree growth obscured most of the exposures above the conglomerate, but, where observed, the conglomerate is overlain by fine to medium-grained crossbedded sandstones and siltstones with minor coals. Thickness varies from 60 to 90 metres. Although a 0.5-metre-thick coal seam occurs within the member near Duke Mountain, the member is not thought to contain coal seams of mineable thickness.

SHAFTESBURY FORMATION: The Shaftesbury Formation lies at the top of the succession in the map-area, and is composed of marine shales, siltstones, and some sandstones. It is not coal bearing.

STRUCTURE: *The general structure of the map-area is that of a broad, northwesterly* trending moderately deformed anticlinorium. Three very broad structurally distinct belts are recognized, based firstly on differing type and degree of deformation (mostly folding) controlled by stratigraphy, and secondly, spatial changes in deformational intensity. A northwesterly trending central belt, underlain by exposed Minnes Group sedimentary rocks, forms the core of the anticlinorium, and two structurally distinct flanking belts of Bullhead and Fort St. John Group strata form the flanks.

CENTRAL BELT: The Minnes Group which underlies this belt has undergone intense deformation relative to the other two belts. Folding at all scales predominates, the axes of which are aligned to the regional northwest trend. In the thicker more competent beds, broad folds are characteristic while the less competent thinly interbedded sands and silts are highly contorted. Chevron folds are common and well exposed south of Red Deer Creek.

The highly contorted nature of the Minnes Group is attributed to the general incompetency of the Minnes sedimentary rocks and the capping effect of the competent Cadomin Formation. Dips vary greatly from 85 degrees to horizontal.

SOUTHWESTERN BELT: The southwestern belt is the last structurally deformed of the three and is in fault contact with Mesozoic and Paleozoic strata of the Rocky Mountains along its entire southwestern length. It is subdivided into two distinct structural entities.

ONION SYNCLINE-ANTICLINE: Situated in the extreme northwest of the belt the doubly plunging symmetrical Onion syncline is defined by a resistant rim of Cadomin conglomerates. Dips average 50 degrees. Along the northeastern limb, a thrust fault has repeated Cadomin and Gething sedimentary rocks. The youngest strata in the trough of the syncline is that of the Gates member. The southwestern limb of the syncline forms the northeastern limb of the Onion anticline which is cored by the Minnes Group. The southwestern limb of the anticline is truncated by the Foothills thrust.

SOUTHWESTERN DIP SLOPE: The remainder of the belt is characterized by a northwesterly trending dip slope. The succession is repeated along strike northwest of Belcourt Mountain by the Saxon thrust. Other than the Saxon thrust, the belt appears undeformed, although the possibility of small-scale folding and normal faulting does exist. In the extreme southeast the Bullhead and Fort St. John Group sedimentary rocks have been folded into a northwesterly, gently plunging syncline of which most of the southwest limb has been removed by the Foothills thrust.

Northeast of the Saxon thrust the dip slope is underlain by Cadomin through Boulder Creek sedimentary rocks. Southwest of the thrust, Minnes and Cadomin sedimentary rocks underlie the dip slope southeast of Belcourt Creek.

Dips are to the southwest and range from 53 to 15 degrees but average 35 to 40 degrees. They shallow toward the Foothills thrust and also southeastward.

NORTHEASTERN BELT: The northeastern belt is structurally very complex and is subdivided into four structurally distinct entities.

DUKE MOUNTAIN AREA: The area northwest of Dokken Creek is characterized by northwesterly trending, *en echelon* folding of the succession, which are cut by southwesterly dipping thrusts. Minnes Group to Shaftesbury Formation sedimentary rocks are exposed in the anticlines and synclines respectively.

LITTLE PRAIRIE CREEK AREA: Southeast of Dokken Creek to northwest of Red Deer Creek, lies an area of comparatively undeformed Bullhead and Fort St. John sedimentary rocks, separating deformed areas to the northwest and southeast. The strata dip steeply to the northeast. Northwest of the Wapiti River dips of 80 degrees were recorded in the Cadomin Formation but dips shallow northeastward. The Little Prairie thrust, which has moved older Shaftesbury strata over younger Shaftesbury and Upper Cretaceous strata, forms the northeastern boundary. The thrust dies out in the vicinity of Dokken Creek. To the southeast folds have exposed Gates sedimentary rocks over a large area, which is in contact with Minnes Group along a thrust to the southwest.

The immediate vicinity of Red Deer Creek is characterized by a complexity of thrusting which would have required more time than was available to adequately map and interpret. However the existing interpretation appears reasonable.

HOLTSLANDER CREEK SYNCLINE: The doubly plunging, westerly trending Holtslander Creek syncline occupies the area between Red Deer Creek and Belcourt Creek. Part of the northeastern limb has been removed by the Holtslander thrust.

The northwestern half of the syncline is structurally simple with subsidiary folds along the northeastern limb. Complex folding and some thrusting characterizes the southeastern half. There is also a pronounced change of strike from 105 degrees in the northwestern half to 130 degrees in the southeastern half and is possibly related to thrusting. The Shaftesbury Formation is the youngest strata exposed in the trough of the syncline. A large area of Gates sedimentary rocks is exposed by folding in the extreme southeastern portion.

OMEGA HILL AREA: Extending from southeast of Belcourt Creek to the British Columbia-Alberta border, Gates sedimentary rocks have been exposed by folding and thrusting over most of this area. It is bounded by two thrust faults, bring Gates member in contact with Shaftesbury Formation to the northeast and Minnes Group to the southwest.

An overturned anticline, which has been thrust faulted further to the northwest along the fold axis, dominates the structure southeast of Belcourt Creek. Both limbs dip to the southwest. The Gates member has been folded into a number of anticlines and synclines exposing Hulcross and Boulder Creek in two synclines.

SAXON SYNCLINE: The extreme northwestern portion of the southeasterly plunging Saxon syncline was mapped during 1976. It is bounded by the Saxon thrust on the southwest. Gates member sedimentary rocks are the youngest exposed in the syncline.

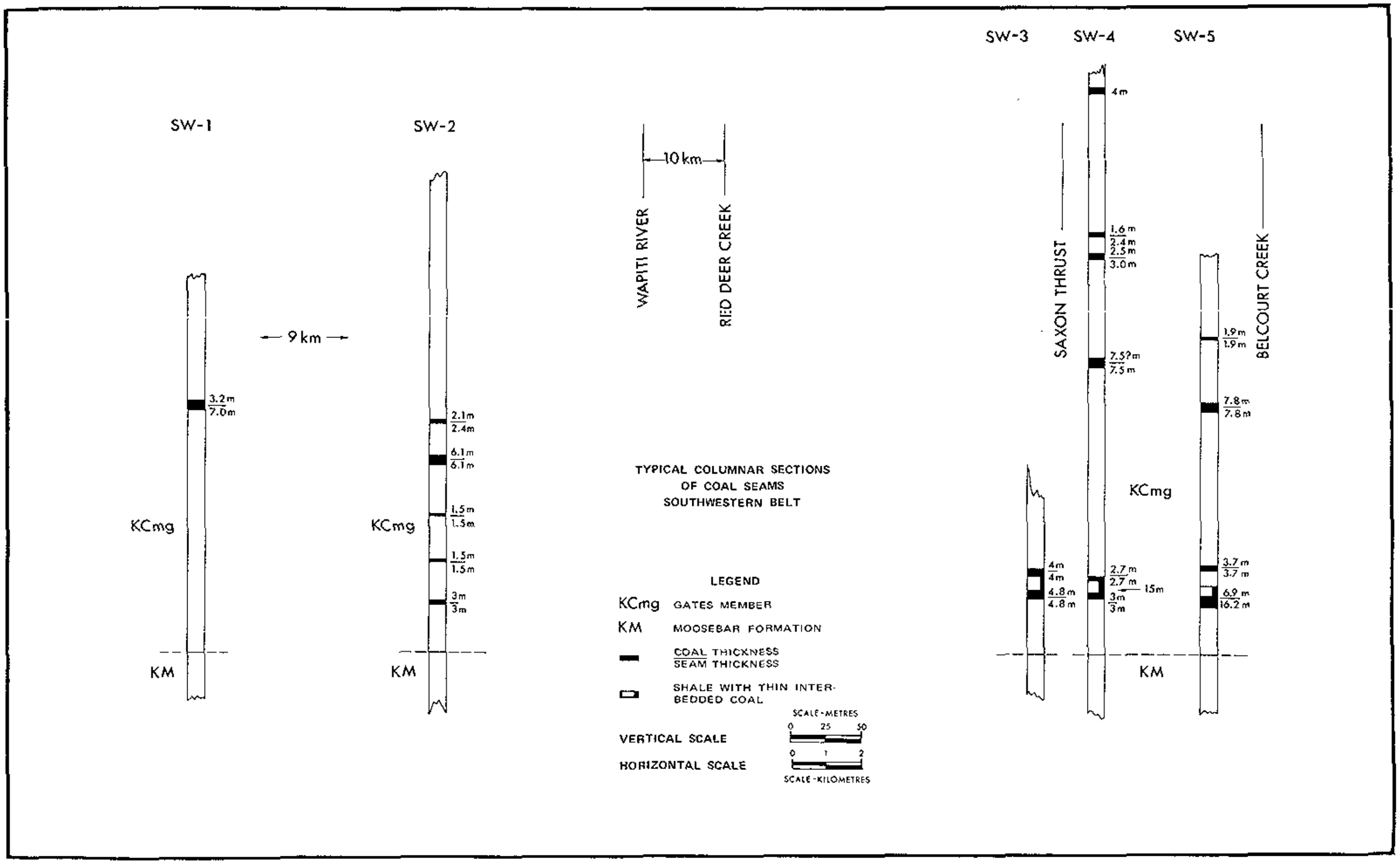

Figure 57. Typical columnar sections of coal seams, Southwestern Belt.

COAL RESOURCE POTENTIAL: Coal seams of mineable thickness occur within the Gething Formation over the northwestern half of the Peace River Coalfield and in the Gates member over the southern half of the field. Within the Sukunka River-Wolverine River area potentially mineable seams occur in both the Gething Formation and the Gates member.

Although coal seams over 1.5 metres thick were located in the Gething Formation in the map-area, and are worthy of further exploration, the potential resources are contained within the Gates member.

The Gates member was outcropped over large portions of the map-area below the tree line (1 680 metres), where dense tree cover hampered or rendered the location of seam exposures impossible. This was particularly so of parts of the southwestern belt and the area around Wapiti River in the northeastern belt.

Due to an interdependence of coal seams and structure with regard to continuity, form, and mineability, the coal resource potential is discussed in the context of the three structurally distinct belts.

CENTRAL BELT: Coal seams, ranging from decimetres to a metre plus, occur within the Minnes Group. However, except for the three seams southeast of Mount Belcourt no other seams over 1.5 metres were measured. As the cut-off figure for mineable coal seams is at present 1.5 metres and as the above three seams could not be traced for any lateral extent, the Minnes Group does not appear to have any potential. The intense structural deformation would be a further complication.

SOUTHWESTERN BELT

ONION SYNCLINE-ANTICLINE: Typical columnar sections of coal seams located within this belt are illustrated on Figure 57. A 7-metre coal seam is exposed in the Onion syncline, in Onion Creek. The seam has numerous shaly partings and the creek flows along the coal seam for a considerable distance. It lies approximately 178 metres above the Moosebar shales.

SOUTHWESTERN DIP SLOPE: Dense tree cover over Gates strata resulted in only three traverses locating coal seams. At location SW 2, five seams totalling 14.5 metres over a 138-metre interval were intersected.

The lack of coal seams intersected between SW 2, and SW 3, a distance of 27.5 kilometres, is a result of dense tree cover, from which the absence of coal seams within the Gates section, over this distance, cannot be inferred.

On Mount Belcourt, SW 5, a 12-metre plus coaly zone approximately 30 metres above the Moosebar Formation, mentioned by Stott (1960), was found to be a 16.2-metre dirty coal seam, containing numerous shaly partings and 6.9 metres of coal. This seam can be traced northwestward, SW 4, and was also found on the northeast plate of the Saxon thrust, SW 3, where 4-metre and 4.8-metre-thick seams are separated by 10 metres of thinly interbedded silts and coals.

At location SW 4, six seams with an aggregate thickness of 22.6 metres were located along traverse and on Mount Belcourt, SW 5, four seams with an aggregate thickness of 20.3 metres were intersected. Southeast of Mount Belcourt, the Gates member is covered by surficial deposits, over which Belcourt Creek flows for part of the way. No coal seams were located here.

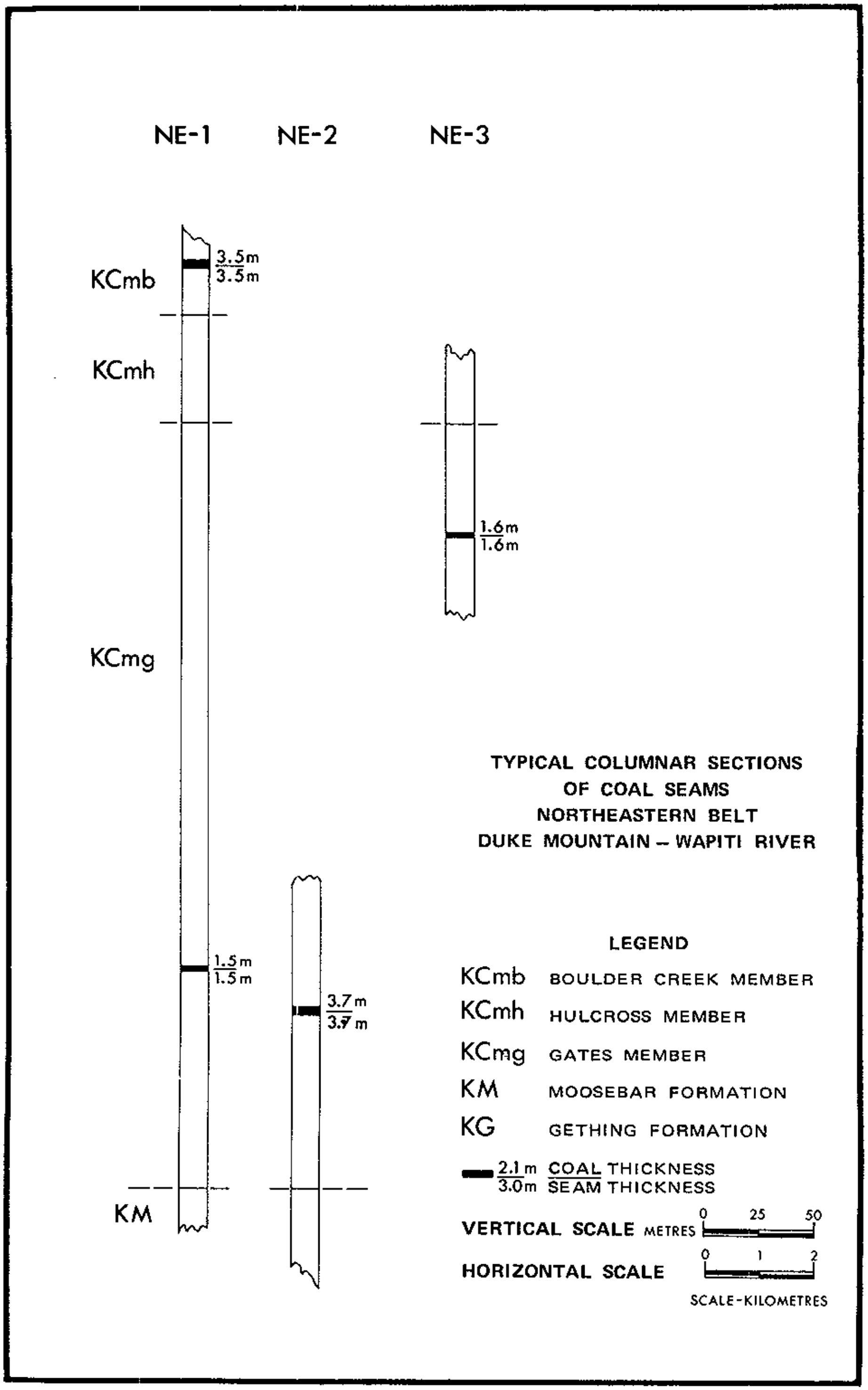

Figure 58. Typical columnar sections of coal seams, Northeastern Belt, Duke Mountain-Wapiti River.

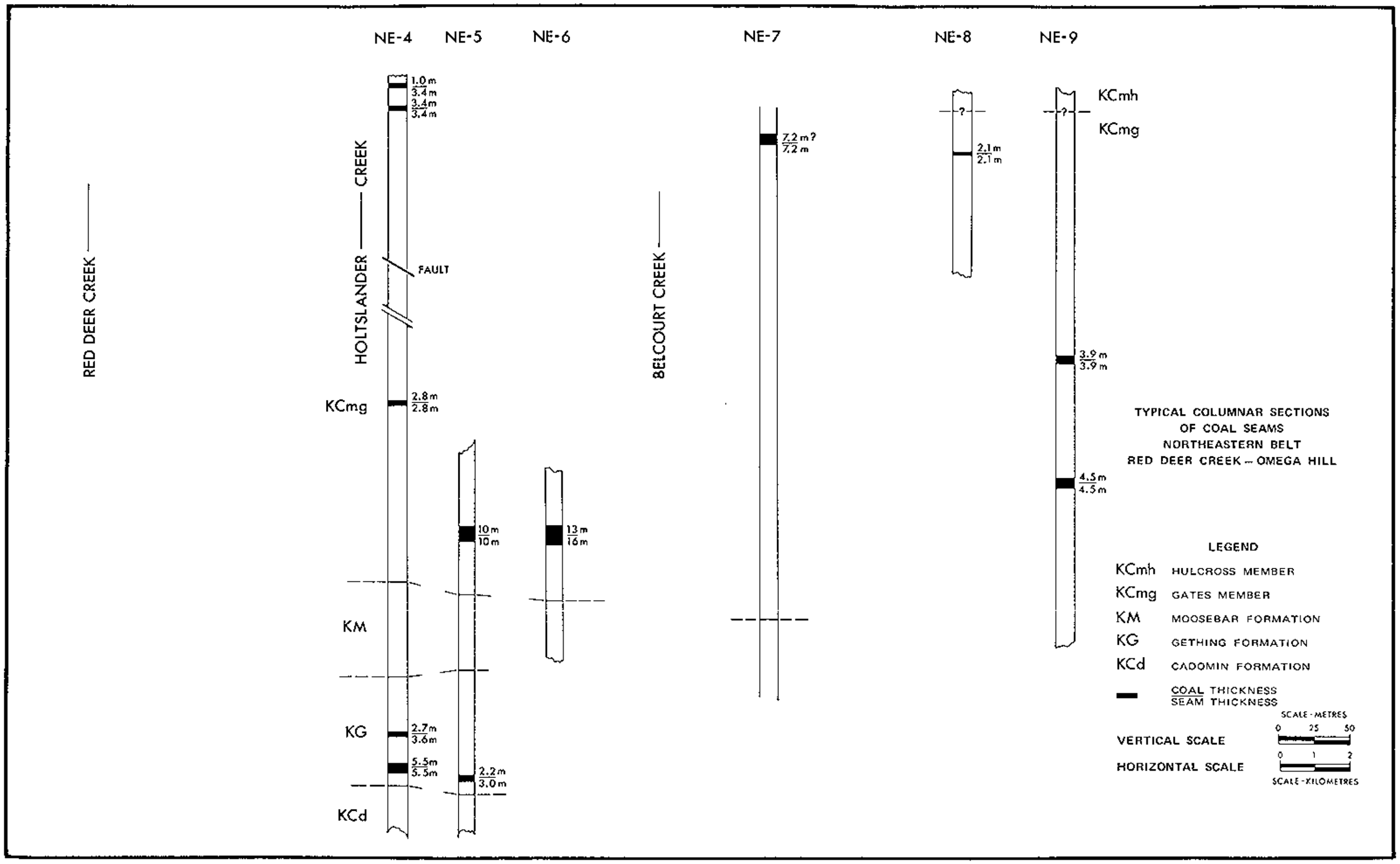

Figure 59. Typical columnar sections of coal seams, Northeastern Belt, Red Deer Creek-Omega Hill.

NORTHEASTERN BELT

DUKE MOUNTAIN AREA: Figure 58 illustrates coal seams located in this area. Alluvium and glacial debris covered large portions of the area which is also densely treed.

A 1.5-metre seam and a number of thinner seams were located in the Gates member near Duke Mountain, NE 1. At NE 2, a 3.7-metre seam is exposed approximately 74 metres above the Moosebar Formation in a syncline, and a 1.6-metre seam near the Hulcross contact at NE 3.

WAPITI RIVER AREA: No seams were located, except for the extreme southeast, as the Gates Formation is everywhere mantled by a dense tree cover.

HOLTSLANDER CREEK AREA: All coal seams were located on the southwestern limb and are shown on Figure 59. South of Holtslander Creek at NE 4 and NE 5, Gething coals are exposed. They occur in the lower Gething Formation.

Gates coals are well represented in this area, the most noteable of which is a 16-metre seam 36 metres to 50 metres above the Moosebar Formation, intersected at NE 5 and NE 6. At NE 6 the seam lies within a syncline occupying the crest of a ridge, and has been structurally thickened to 21 metres along the fold axis at the northwestern end. Northeast of this syncline, a 45-metre seam is exposed on the northeast flank of the anticline exposing Moosebar Formation in its core. This is correlated with the 16-metre seam, indicating a thinning to the northeast at NE 4; a thrust fault has resulted in repetition of the seams.

OMEGA HILL AREA: Two seams, 175 metres and 84 metres above the Moosebar Formation, totalling 8.4 metres, were located on Omega Hill, NE 9. A 2.1-metre seam occurs near the Hullcross Mountain contact on Ptarmigan Ridge, NE 8. An untrenched 7.2-metre seam occurs 300 to 600 metres stratigraphically above the Moosebar Formation in overturned Gates strata at NE 7.

COAL RESOURCES: A conservative estimate of 1 400 million tonnes of inferred inplace resources was computed for the Gates member of the map-area.

SUMMARY: In conclusion, Upper Jurassic Minnes Group and Lower Cretaceous Bullhead and Fort St. John Groups underlie the map-area. Three broad belts based on stratigraphy and structure are recognized; a central belt of Minnes Group occupying the core of a northwest-trending broad anticlinorium and two structurally distinct, narrow flanking belts of Bullhead and Fort St. John Groups. The coal resources of the map-area are contained within the Gates member of the Commotion Formation although two seams over 1.5 metres were intersected within the Gething Formation.

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