Geological Fieldwork 1982

a summary of field activities

of the geological branch,

mineral resources division

Paper 1983-1

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

ISSN 0381-243S

Victoria
British Columbia
Canada

May 1983

FOREWORD

This is the ninth year of publication of *Geological Fieldwork*, a publication designed to acquaint the interested public with the preliminary results of fieldwork of the Geological Branch as soon as possible after the field season. The reports are written without the benefit of extensive laboratory or office studies. To improve the quality of presentation, figures in this year's publication were done by our draughting section.

This edition of *Geological Fieldwork* continues with the two-section format adopted in the last volume (Geological Branch Paper 1982-1). The Project and Applied Geology section includes reports of metallic and coalfield investigations, reports of District Geologists, and property examinations related to some mineral properties funded in part by Ministry programs. The Other Investigations section consists mainly of reports of work done by different universities in cooperation with the Ministry.

The cover photograph depicts geologists examining the discovery outcrops at Granduc.

Output of this publication was coordinated by A. Panteleyev and W. J. McMillan. Manuscript input was by D. Bulinckx of Geoscience Projects. Draughting of the figures in the Project and Applied Geology section of the report was by R. Hoensen, P. Chicorelli, and J. Armitage of the draughting office and Ian Webster of Geoscience Projects.

A. Sutherland Brown,
Chief Geologist,
Geological Branch,
Mineral Resources Division.

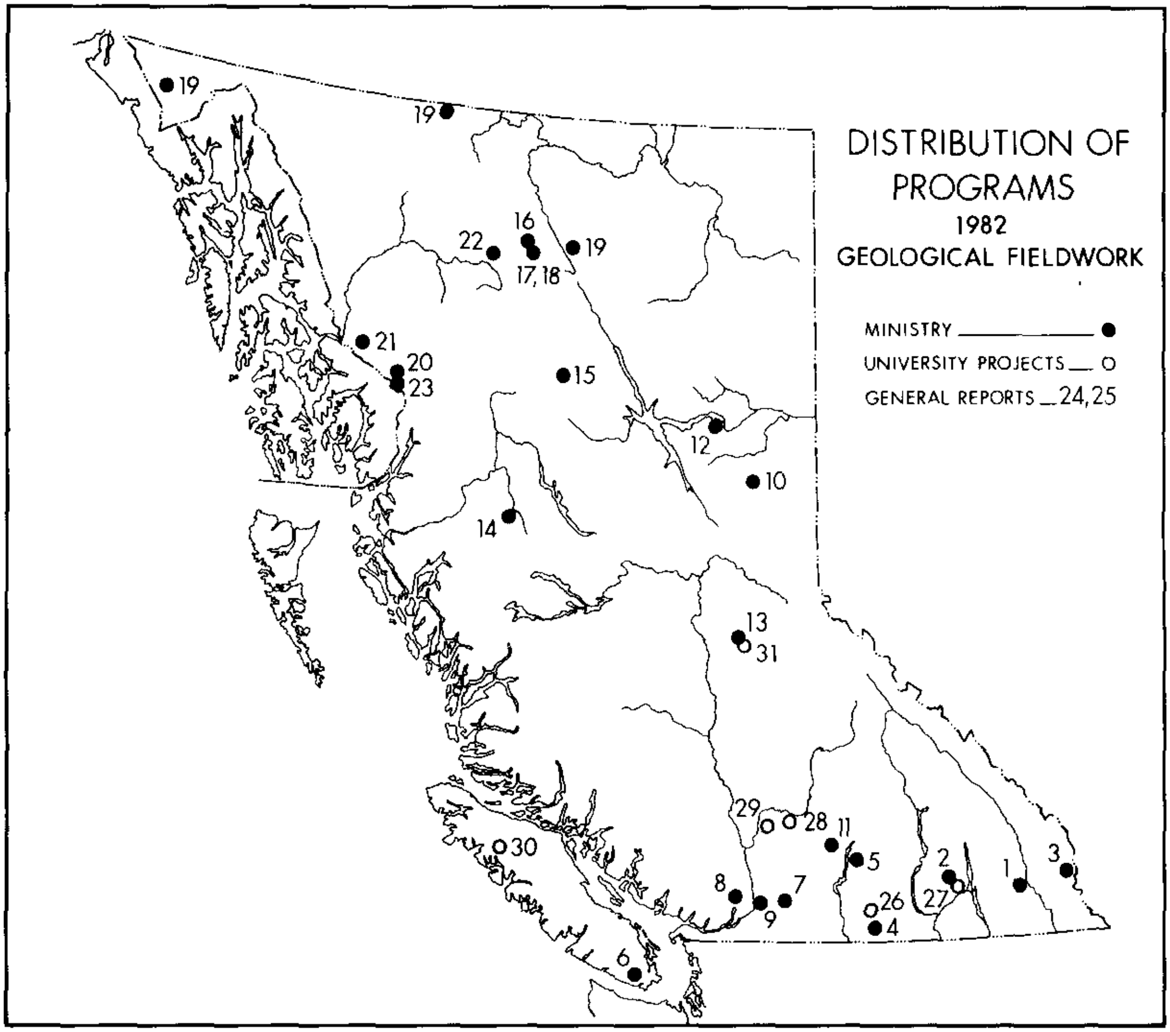


Figure 1. Distribution of program, Geological Fieldwork, 1982.

TABLE OF CONTENTS

PROJECT AND APPLIED GEOLOGY

TABLE OF CONTENTS *(Continued)*
PROJECT AND APPLIED GEOLOGY *(Continued)*

OTHER INVESTIGATIONS

TABLE OF CONTENTS *(Continuned)*

OTHER INVESTIGATIONS *(Continued)*

PROJECT AND APPLIED GEOLOGY

GEOLOGY IN THE VICINITY OF THE SULLIVAN DEPOSIT KIMBERLEY, BRITISH COLUMBIA (82F, G)

By T. Höy

INTRODUCTION

The study of the Purcell Supergroup, initiated in 1977, was intended to develop a better understanding of the stratigraphic, structural and tectonic setting, and ore controls of the Sullivan and other smaller but similar clastic-hosted lead-zinc deposits in southeastern British Columbia. Kanasewich (1968) recognized a basement structure from anomalous magnetic and gravity trends and by deep seismic reflections that cut northeasterly across the more northerly regional stratigraphic and structural trends. He concluded that the structure was a Precambrian rift and that the Sullivan deposit originated within it. The proposed rift coincides with the pronounced St. Mary-Boulder Creek and the Moyie-Dibble Creek fault systems that cut across the Purcell Mountains and the western ranges of the Rocky Mountains (Fig. 2). Lower Paleozoic (for example, Leech, 1958) and earlier Hadrynian movements, generally block-faulting and tilting (Lis and Price, 1976), had been recognized along these transverse fault systems, but earlier Purcell age movements had not been documented. A primary objective of this study was to determine if these transverse structures were active in Purcell time and could therefore have controlled the regional distribution of lead-zinc deposits.

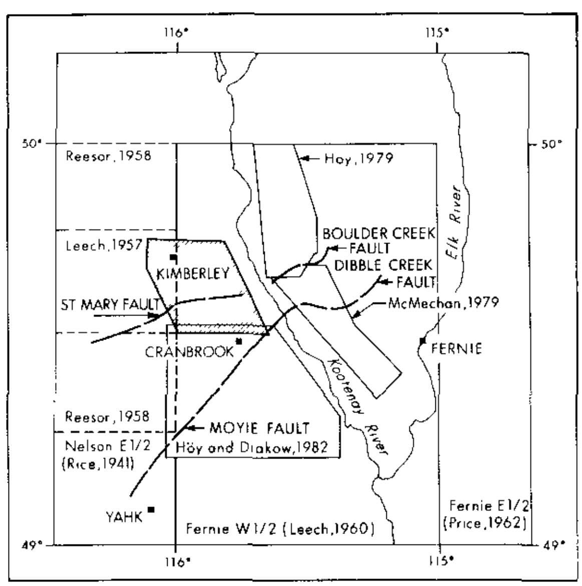


Figure 2. Location map, showing St. Mary, Boulder Creek, Moyie, and Dibble Creek faults, and published geological maps in the vicinity of the Kimberley map-area.

The study initially focused on the Kootenay Ranges east of the Rocky Mountain Trench and results were released as two preliminary maps (Höy, 1979; McMechan, 1979). Locations are given on Figure 2. Dramatic thickness increases and rapid facies changes in the Aldridge Formation (near the base of the exposed Purcell succession) occur in the vicinity of the Boulder Creek fault. The fault is interpreted to have been a growth fault which down-dropped the area to the south (Höy, 1979, 1982a). Further south, McMechan (1979, 1981) recognized that overlying Purcell platformal rocks have similar, though less dramatic, changes. These data tend to confirm the presence of a transverse Precambrian rift structure.

It was suggested (Höy, 1982b) that this transverse zone is marked in Purcell rocks to the west by the preferential distribution of intraformational conglomerate and Purcell sills. It is also characterized by anomalous concentrations of boron that are supposedly related to deep crustal fractures (Ethier and Campbell, 1977). Mapping and detailed section measurements were subsequently begun in the vicinity of the Moyie fault in the Purcell Mountains (Höy and Diakow, 1981, 1982). The work continued this past summer and was extended northward to encompass the St. Mary fault and the Sullivan mine at Kimberley. Mapping of the Kimberley map-area is being compiled and will be released as a preliminary map (1:50 000 scale) when completed. Further fieldwork on the Purcell project will be minimal and will only include fill-in traverses and section measurements; these will be completed next field season.

The Kimberley map-area is within the Fernie west-half (82G/W) sheet (Leech, 1960), and the eastern part of the St. Mary sheet (Leech, 1957). Many of the salient features of the geology were initially outlined by Rice (1937). Other maps published in the vicinity of the Kimberley sheet are shown on Figure 2.

GENERAL GEOLOGY

The Kimberley area (Fig. 3) is transected by the right lateral, reverse St. Mary fault. The fault brings Lower and Middle Aldridge rocks in its hangingwall (the St. Mary block of Benvenuto and Price, 1979) against Creston and younger Purcell rocks or, locally, Cambrian siltstone and shale of the Eager Formation. The Sullivan deposit occurs at the boundary between the Lower and Middle Aldridge within the St. Mary block. It is just south of the north-dipping, normal Kimberley fault (Hamilton, *et al.*, 1982). Sullivan is one of the largest base metal deposits in the world, having produced in excess of 100 million tonnes of ore and with remaining reserves of approximately 50 million tonnes grading 4.9 per cent lead, 6.1 per cent zinc, and 37 grams silver per tonne (Ransom, 1977; Hamilton, *et al.*, 1981, 1982). The North Star and Stemwinder deposits lie just to the south. They are small lead-zinc deposits with less than 100 000 tonnes production that are situated in the upper part of the Lower Aldridge Formation (*see* Fig. 3).

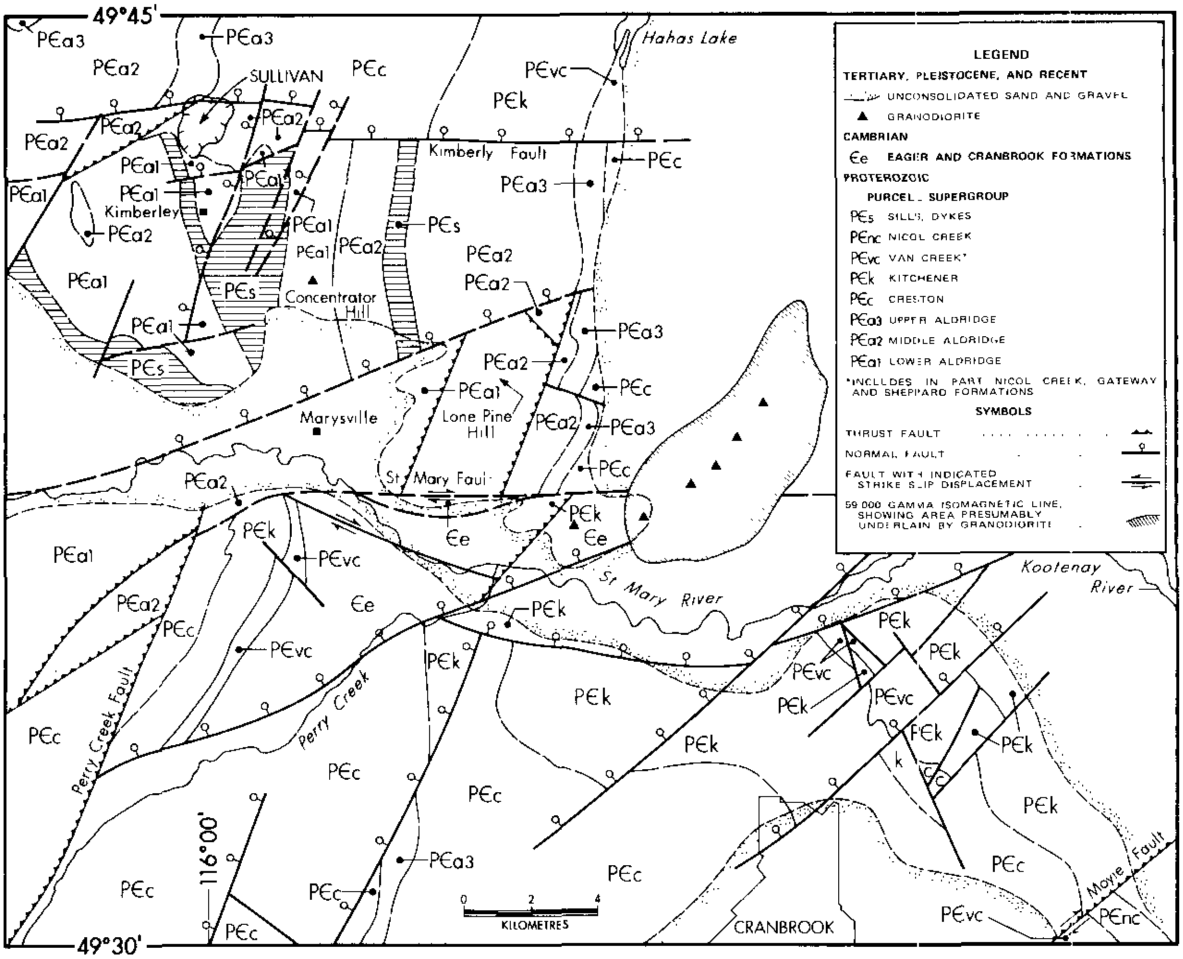


Figure 3. Geological map of the Kimberley area.

PURCELL SUPERGROUP STRATIGRAPHY

The stratigraphic succession in the Kimberley area is illustrated on Figure 4. The oldest rocks, rusty-weathering siltstone, quartz wacke and argillite of the Lower Aldridge Formation, are only exposed in the hangingwall of the St. Mary fault south of the Sullivan mine. Crossbeds and graded beds, and occasional flute casts suggest it consists largely of turbidites. A 250-metre-thick succession of grey-weathering quartzite and quartz wacke turbidite beds, which is lithologically similar to much of the Middle Aldridge succession, occurs approximately 300 metres below the Lower-Middle Aldridge boundary. It is well exposed on the western and southern slopes of North Star Hill and also a few kilometres northeast of Kimberley.

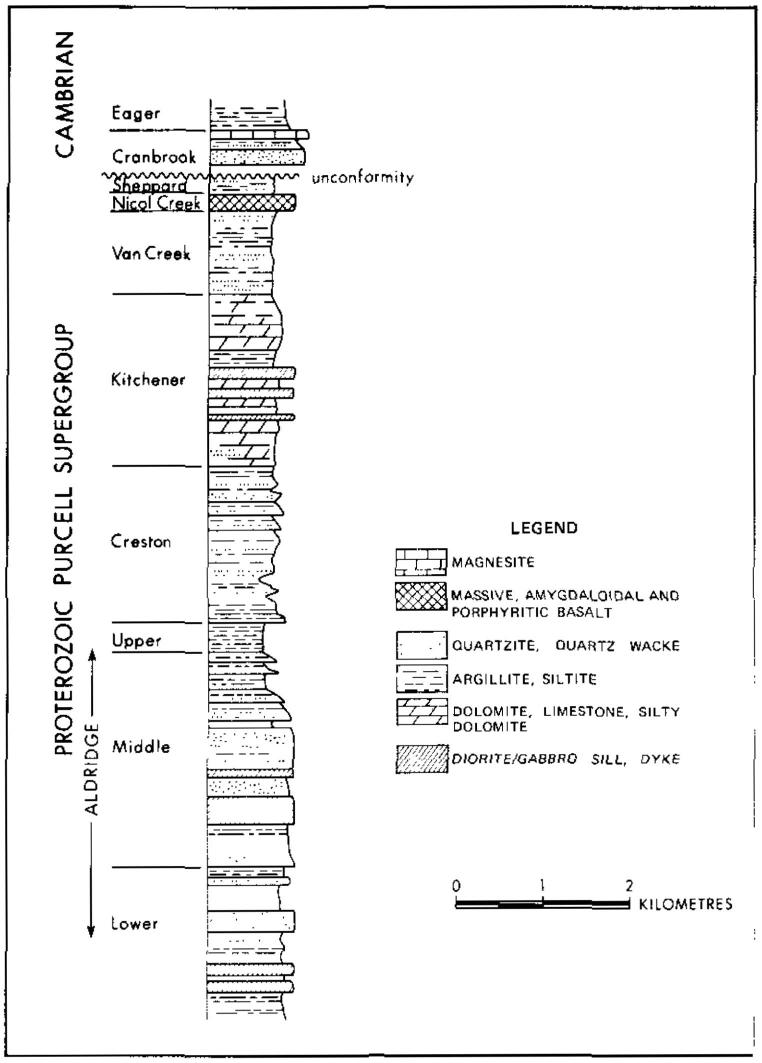


Figure 4. Stratigraphic succession in the Kimberley area.

The Lower-Middle Aldridge contact is poorly exposed. It crops out near the Sullivan deposit and subcrops on Concentrator Hill east of Kimberley. Stratigraphically, it has been placed below exposures that contain prominent, blocky, grey-weathering quartz wacke beds. Finely laminated pyrrhotite-pyrite beds in laminated argillaceous siltstone, that may be distal equivalents of the Sullivan deposit, have been described at approximately this horizon in two Cominco Ltd. diamond-drill holes that were drilled east and southeast of the Sullivan deposit (Hagen, 1978). Just west of Lone Pine Hill, the Lower Aldridge is in fault contact with the Middle Aldridge (Hagen, 1981).

The Middle Aldridge consists of grey-weathering quartz wacke and quartzite beds with local interlayered siltstone and silty argillite. It is estimated to be approximately 2 000 metres thick in the section southeast of the Sullivan mine, where individual quartzite beds are up to several metres thick. The thick quartzites may be amalgamated turbidite beds; that is, they may comprise a number of individual massive turbidite beds without either intervening silt component or recognizable graded tops. Coarse (1 to 2-millimetre) quartz grains may occur within these thicker beds. Measurements of flute casts at the base of some turbidite beds indicate a north to northwesterly current transport direction. Up section within the Middle Aldridge, the proportion of dark silty argillite increases. Locally it becomes predominant, making it difficult to distinguish isolated outcrops from Upper Aldridge exposures. The Upper Aldridge consists of approximately 300 metres of rusty to dark grey-weathering laminated argillite and silty argillite.

Rocks overlying the Aldridge Formation, the Creston, Kitchener, and Van Creek Formations (Fig. 4), are similar to those described to the south in the Cranbrook area (Höy and Diakow, 1981, 1982). Quartzites and siltstones of the Creston Formation are typically green or grey with lesser amounts of mauve-coloured siltstone. Numerous sedimentary structures indicate shallow marine subtidal to supratidal depositional environments. However, exposures of well-bedded, grey-weathering AE turbidites just northwest and northeast of Cranbrook indicate local deeper water environments. The Kitchener Formation is dominantly buff to grey-weathering dolomite, dolomitic siltstone and limestone. The Van Creek Formation is olive green, to locally mauve and tan shale and siltstone.

The Nicol Creek Formation includes tuffs; massive, porphyritic, and amygdaloidal basic lava flows; and intercalated green siltstone and quartzite. It thins northwestward from approximately 180 metres, north of Cranbrook to 36 metres south of Marysville. Only the basal few hundred metres of the overlying Sheppard Formation are exposed in the Kimberley map-area. They consist of light green, tan, and lesser purple, finely laminated siltstone and argillite.

Purcell basic igneous sills and dykes are prominent in the Lower Aldridge and lower part of the Middle Aldridge, but uncommon or absent in much of the Creston Formation. Similar rocks appear again, probably as a separate intrusive event in the Kitchener and Van Creek Formations. In contrast with Middle Aldridge sills in the Moyie Lake area that can commonly be traced tens of kilometres and are therefore valuable markers, Purcell intrusive rocks in the Kimberley area are commonly crosscutting dykes that change appreciably in attitude and thickness as they are traced in outcrops. They are locally very coarse grained and plagioclase phenocrysts can be several centimetres across.

CAMBRIAN STRATIGRAPHY

The Sheppard Formation is unconformably overlain by quartzite and carbonate of the Cranbrook Formation and shale and siltstone of the Eager Formation of Cambrian age. The contact, where exposed north of Cranbrook and near Antwerp Creek south of Marysville, is discordant. The Cranbrook Formation at Antwerp Creek consists of an interlayered sequence of pure to feldspathic quartzite and green siltstone. It is overlain by approximately 80 metres of white to light grey orthoquartzite which has a few impure siltstone layers near the top. Intercalated carbonate layers occur at the top of the unit. The carbonate is dominantly magnesite (McCammon, 1964) and one relatively pure section is approximately 7 metres thick. The Cranbrook grades up into green siltstone and shale of the Eager Formation. Dark to light grey silty argillite comprises the bulk of the Eager Formation. It is generally well cleaved and locally contains prominent cubes of pyrite.

GRANITIC ROCKS

A number of outcrops of granitic rocks, initially located by Rice (1937), crop out in the vicinity of Cranbrook airport north of the St. Mary River. Their textures range from aphanitic to coarse grained and porphyritic, with altered biotite and hornblende phenocrysts. As Rice suggested, these occurrences are probably part of a larger, unexposed granitic body. A pronounced, oval-shaped magnetic anomaly trends north-northeast over these occurrences (*see* B.C. Ministry of Energy, Mines and Petroleum Resources/Geological Survey of Canada Map 8469G and Fig. 3). The intrusive rocks straddle the St. Mary fault and therefore will provide a minimum age for movement on the fault. A megascopically similar stock in the Moyie Lake sheet (Leech, 1960; Höy and Diakow, 1982) has been dated at 122 Ma (unpublished date).

STRUCTURE

The Kimberley area is dominated by a complex array of faults. The largest of these trend easterly to northeasterly and are essentially parallel to the prominent St. Mary and Moyie faults. However, net movement on these is generally normal with north side down, in contrast to the reverse, right lateral movement on the St. Mary and Moyie faults. Apparent net normal movement on the Kimberley fault has resulted in approximately 12 kilometres strike separation of the Upper Aldridge across it, whereas right lateral reverse movement on the St. Mary fault has produced 12 kilometres of right lateral strike separation (Fig. 3).

Late north and northeasterly trending normal faults cut open to moderately tight folds with pronounced axial plane cleavage in Creston and Upper Aldridge rocks west of Cranbrook (Fig. 3). Similar late faults cut structures and displace the Kimberley fault east of the Sullivan deposit. Northwest-trending faults are conspicuous in the Moyie Lake map sheet to the south (Höy and Diakow, 1982), but in the Kimberley area, they are only prominent in the complexly faulted terrane just north of Cranbrook.

Broad open folds with pronounced axial plane cleavage occur in both Purcell and Cambrian age rocks. In the vicinity of some faults, they become tight, overturned structures.

SUMMARY

The geology of the Kimberley area will be released as a 1:50 000 preliminary map sheet, which will be the last of a series of sheets that outline the geology of the Purcell Supergroup in the vicinity of the Sullivan deposit in southeastern British Columbia. Future fieldwork, planned for 1983, will consist only of fill-in traverses in the Moyie Lake and Kimberley areas, section measuring, and sampling. Newly acquired data and previously released maps (Höy, 1979; McMechan, 1979; Höy and Diakow, 1982) will be combined and eventually published in bulletin form.

The objectives of the Purcell study have been largely realized:

(1) To provide detailed (1:50 000) geological maps of the Purcell Supergroup in the vicinity of the Sullivan and other important lead-zinc deposits.
(2) To present models, based on section and paleocurrent measurements, of the depositional environment of Purcell Supergroup rocks.
(3) To place constraints on and postulate models for regional stratigraphic, structural, and tectonic controls of mineralization in the Sullivan camp.

It is concluded that synsedimentary faulting, perhaps near the northern edge of a transverse rift structure, locally controlled and modified the distribution of Purcell rocks in Lower and Middle Aldridge time. Clastic-hosted lead-zinc deposits such as Sullivan, North Star, Stemwinder, and Kootenay King are also located near the northern edge of this transverse structure, suggesting a genetic link between mineralization and synsedimentary faulting (Höy, 1982a, 1982b).

ACKNOWLEDGMENTS

Discussions with Cominco Ltd. geologists (J. Hamilton, P. Ransom, G. Delaney, and A. Hagen) at the Sullivan mine helped clarify a number of problems, and the geology in the vicinity of the Sullivan mine (Fig. 3) is from their published work (Hamilton, *et al.*, in press). Discussions with K. McClay (Goldsmiths College, London, England), B. Lovell (University of Edinburgh, Scotland), and L. Diakow (University of Western Ontario, London, Ontario) are gratefully acknowledged. Access to unpublished maps (the Dean and All Over claims) of the North Star Hill area by Asarco Exploration Company of Canada, Limited is appreciated. Mike Fournier and Ian Webster provided cheerful and able field assistance.

REFERENCES

Benvenuto, G. and Price, R. A. (1979): Structural Evolution of the Hosmer Thrust Sheet, Southeastern British Columbia, *Cdn. Pet. Geol.*, Bull., Vol. 27, No. 3, pp. 360-394.

B.C. Ministry of Energy, Mines & Pet. Res. and *Geological Survey of Canada,* Geophysical Series (Aeromagnetic), Cranbrook, British Columbia, 1970, Map 8469G.

Ethier, V. G. and Campbell, F. A. (1977): Tourmaline Concentrations in Proterozoic Sediments of the Southern Cordillera of Canada and Their Economic Significance, *Cdn. Jour. Earth Sci.,* Vol. 14, pp. 2348-2363.

Hagen, A. S. (1978): Drilling Report, DDCH 6423, Chance No. 5 Group, *B.C. Ministry of Energy, Mines & Pet. Res.,* Assessment Rept. 6786.

.... (1981): Drilling Report, Golf 2, Fal 10, Fal 12, DDCH 6444-6446, *B.C. Ministry of Energy, Mines & Pet. Res.,* Assessment Rept. 9711.

Hamilton, J. M., Bishop, D. T., Morris, H. C., and Owens, O. E. (1982): Geology of the Sullivan Orebody, Kimberley, British Columbia, *in* Precambrian Sulphide Deposits, H. S. Robinson Memorial Vol., R. W. Hutchinson, C. D. Spence, and J. M. Franklin, editors, *Geol. Assoc. Can.,* Special Paper 25.

Hamilton, J. M., Delaney, G. D., Hauser, R. L., and Ransom, P. W. (in press): Geology of the Sullivan Deposit, Kimberley, British Columbia, Canada, *in* Sediment-Hosted Lead-Zinc Deposits, D.F. Sangster, editor, *Min. Assoc. Can.,* Short Course Notes, Chapter 2.

Hamilton, J. M., Hauser, R. L., and Ransom, P. W. (1981): The Sullivan Orebody, *in* Field Guide to Geology and Mineral Deposits, *Geol. Geol. Assoc. Can.,* pp. 44-79.

Höy, T. (1979): Geology of the Estella-Kootenay King Area, Hughes Range, Southeastern British Columbia, *B.C. Ministry of Energy, Mines & Pet. Res.,* Prelim. Map 36.

.... (1982a): Stratigraphic and Structural Setting of Stratabound Lead-Zinc Deposits in Southeastern British Columbia, *C.I.M.,* Bull., Vol. 75, No. 840, pp. 114-134.

.... (1982b): The Purcell Supergroup in Southeastern British Columbia; Sedimentation, Tectonics, and Stratiform Lead-Zinc Deposits, *in* Precambrian Sulphide Deposits, H. S. Robinson Memorial Vol., R. A. Hutchinson, C. D. Spence, and J. M. Franklin, editors, *Geol. Assoc. Can.,* Special Paper 25.

Höy, T. and Diakow, L. (1981): Geology of the Moyie Lake Area, Purcell Mountains, Southeastern British Columbia, *B.C. Ministry of Energy, Mines & Pet. Res.,* Geological Fieldwork, 1980, Paper 1981-1, pp. 9-14.

Höy, T. and Diakow, L. (1982): Geology of the Moyie Lake Area, *B.C. Ministry of Energy, Mines & Pet. Res.,* Prelim. Map 49.

Kanasewich, E. R. (1968): Precambrian Rift: Genesis of Stratabound Ore Deposits, *Science,* Vol. 161, pp. 1002-1005.

Kanasewich, E. R., Clowes, R. M., and McCloughan, C. H. (1969): A Buried Precambrian Rift in Western Canada, *Tectonophysics,* Vol. 8, pp. 513-527.

Leech, G. B. (1957): St. Mary Lake, Kootenay District, British Columbia (82F/9), *Geol. Surv., Canada,* Map 15-1957.

Leech, G. B. (1958): Fernie Map-Area, West Half, British Columbia, *Geol. Surv., Canada*, Paper 58-10.

.... (1960): Geology, Fernie (West Half), Kootenay District, British Columbia, *Geol. Surv., Canada*, Map 11-1960.

Lis, M. G. and Price, R. A. (1976): Large-Scale Block Faulting During Deposition of the Windermere Supergroup (Hadrynian) in Southeastern British Columbia, *Geol. Surv., Canada*, Paper 76-1A, pp. 135-136.

McCammon, J. W. (1964): The Marysville Magnesite Belt, *B.C. Ministry of Energy, Mines & Pet. Res.*, Ann. Rept., 1964, pp. 187-193.

McMechan, M. E. (1979): Geology of the Mount Fisher-Sand Creek Area, *B.C. Ministry of Energy, Mines & Pet. Res.*, Prelim. Map 34.

.... (1981): The Middle Proterozoic Purcell Supergroup in the Southwestern Purcell Mountains, British Columbia and the Initiation of the Cordilleran Miogeocline, Southern Canada and Adjacent United States, *Cdn. Pet. Geol.*, Bull., Vol. 29, No. 4, pp. 583-621.

Price, R. A. (1962): Fernie Map-Area, East Half, Alberta and British Columbia, *Geol. Surv., Canada*, Paper 61-24.

Ransom, P. W. (1977): Geology of the Sullivan Orebody, *in* Lead-Zinc Deposits of Southestern British Columbia, T. Höy, editor, *Geol. Assoc. Can.*, Fieldtrip Guidebook 1, pp. 7-21.

Reesor, J. E. (1958): Dewar Creek Map-Area, with Special Emphasis on the White Creek Batholith, British Columbia, *Geol. Surv., Canada*, Mem. 292, 78 pp.

.... (1981): *Grassy Mountain, Kootenay Land District, British Columbia, Geol. Surv., Canada*, Open File 820.

Rice, H.M.A. (1937): Cranbrook Map-Area, British Columbia, *Geol. Surv., Canada*, Mem. 207, 67 pp.

.... (1941): Nelson Map-Area, East Half, *Geol. Surv., Canada*, Mem. 228, 86 pp.

'A-1' BLUEBIRD ADIT
AN EXAMPLE OF GALENA-COATED JOINTS RATHER THAN VEINS
(82F/14)

By G. G. Addie

The 'A-1' Bluebird adit (Fig. 5) is a new working driven by Bob Burton, Silver Hills Consulting & Contracting Ltd., below the Blue-bird A adit which is described by C. E. Cairnes (1935).

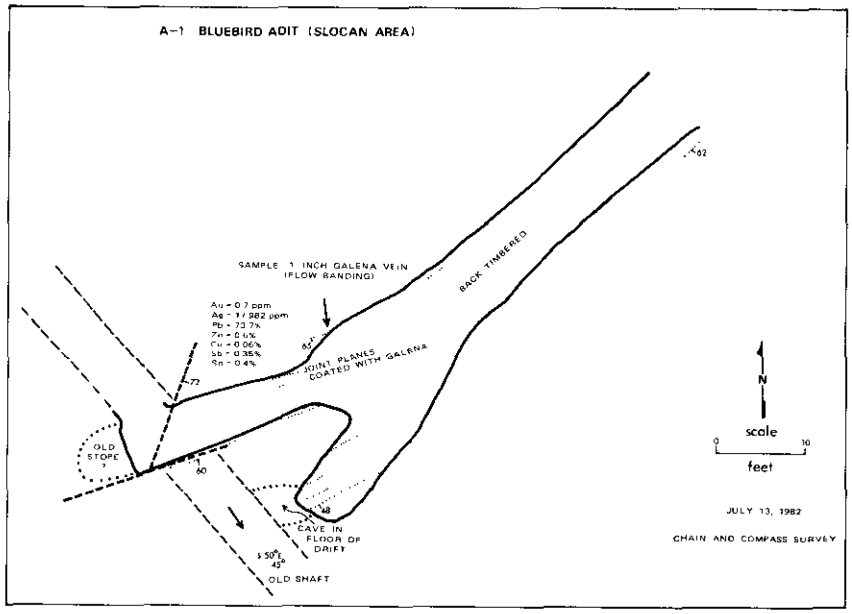


Figure 5. Location map for the 'A-1' Bluebird adit (after Fig. 1, Cairnes, 1935).

The mineralization occurs in argillites of the Slocan series (Fig. 6). The new showing consists of galena coating joint planes. One small vein was seen which has an extraordinary 17 982 ppm silver in the galena.

The mineral system was detected by a self-potential test that was run on the surface, and the propery warrants further exploration. The joint plane mineralization is too narrow for handpicking the ore. If production were initiated, a small portable mill would probably be needed to make a concentrate before shipping.

Assistance in the mapping was given by Lloyd Addie.

REFERENCE

Cairnes, C. E. (1935): Descriptions of Properties, Slocan Mining Camp, British Columbia, *Geol. Surv., Canada,* Mem. 184, 274 pp.

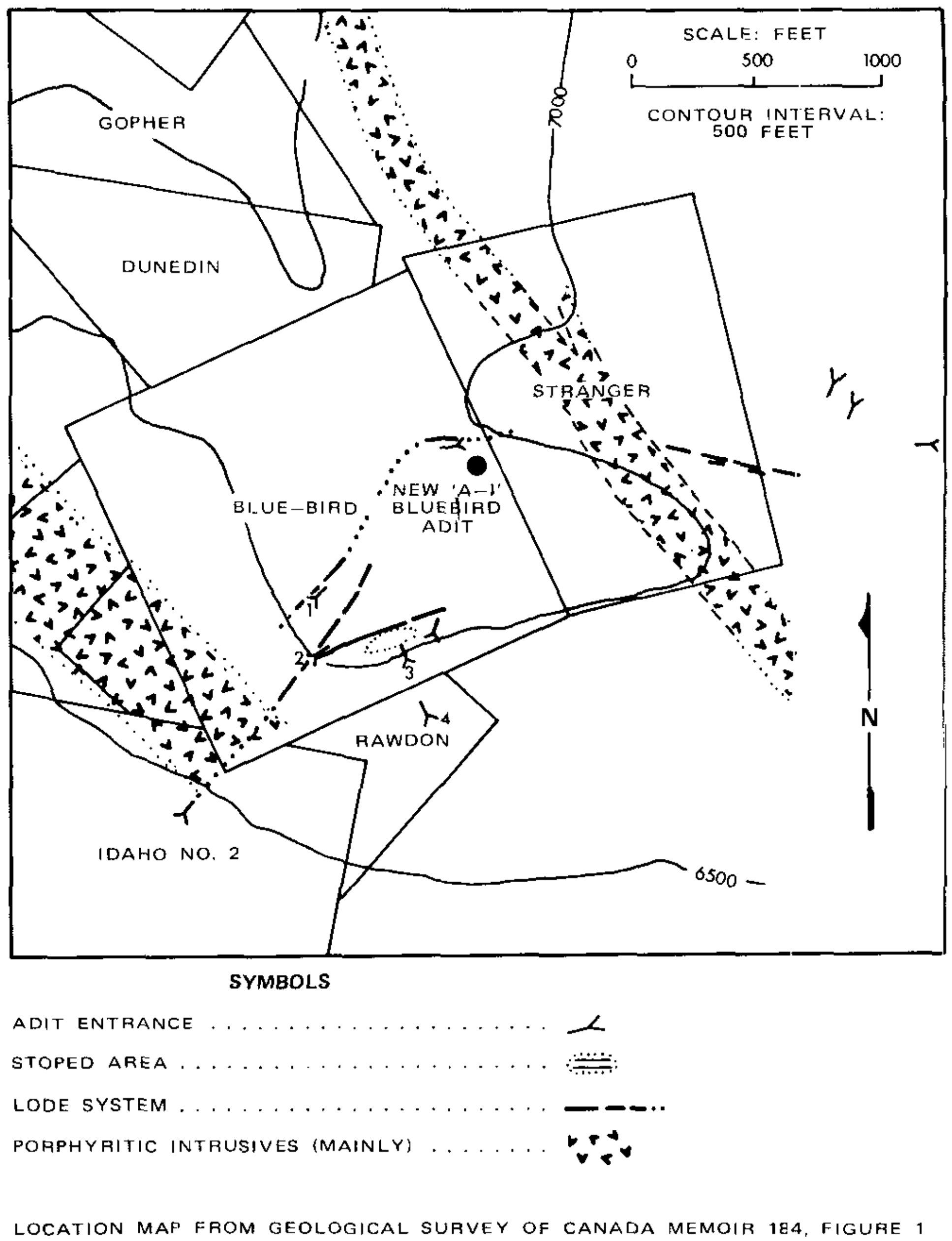


Figure 6. Geology and assay data for the 'A-1' Bluebird adit.

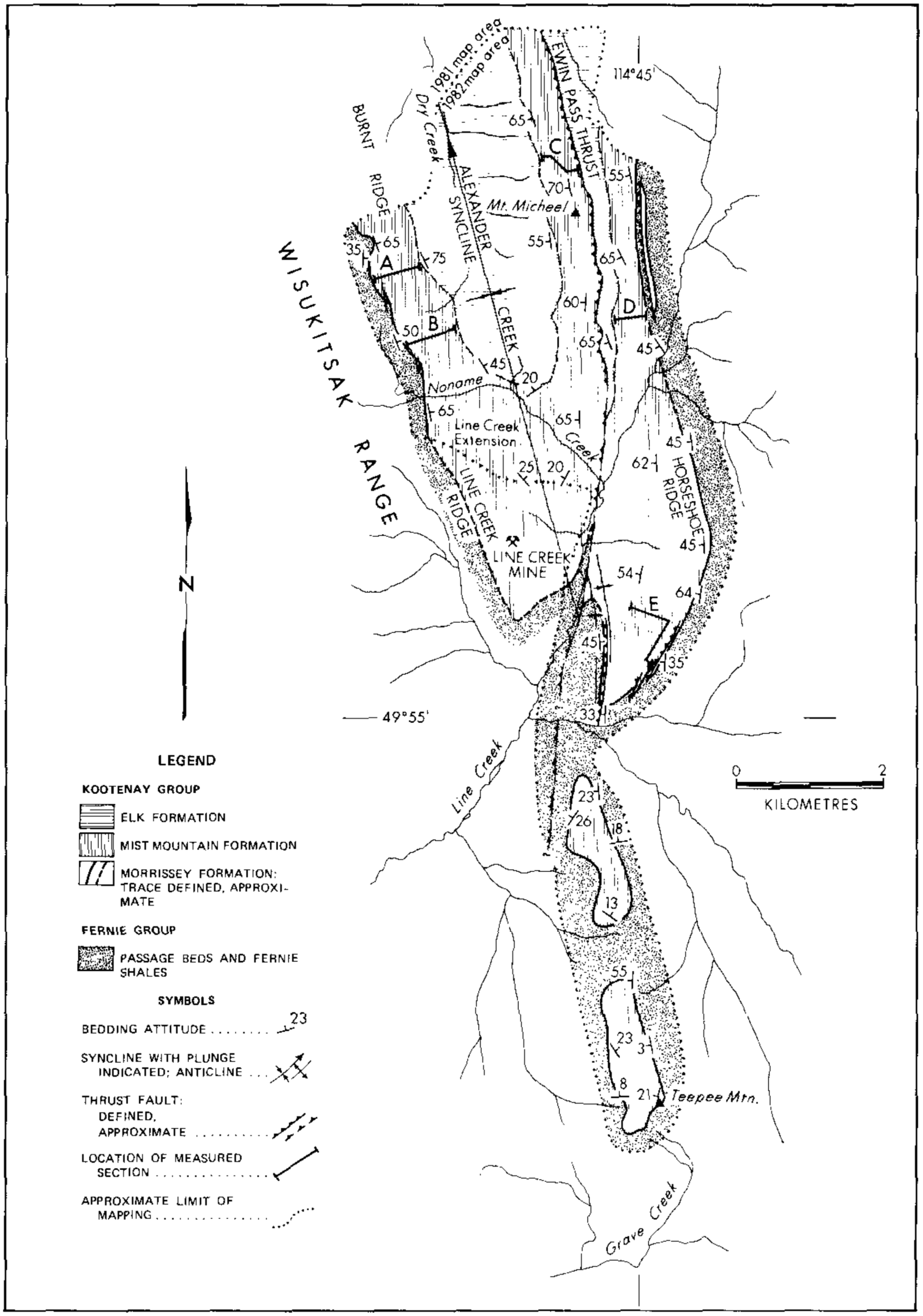


Figure 7. Geology of the Line Creek area, Elk Valley Coalfield.

LINE CREEK AND CROWN MOUNTAIN AREAS
ELK VALLEY COALFIELD
(82G/10, 15)

By D. A. Grieve and Janine M. Fraser

INTRODUCTION

The study area is in the south half of the Elk Valley Coalfield and adjoins the Mount Banner area, which was mapped in 1981 (Grieve, 1982). It includes the Crows Nest Resources Limited Line Creek minesite (not mapped) and several other properties, including Burnt Ridge, Mount Michael, Line Creek extension, Horseshoe Ridge, Teepee Mountain, and Crown Mountain (Figs. 7 and 8). With the exception of Burnt Ridge, which is freehold land with coal rights held by B.C. Coal Ltd., coal rights in the study area are held under licence and lease by Crows Nest Resources Limited.

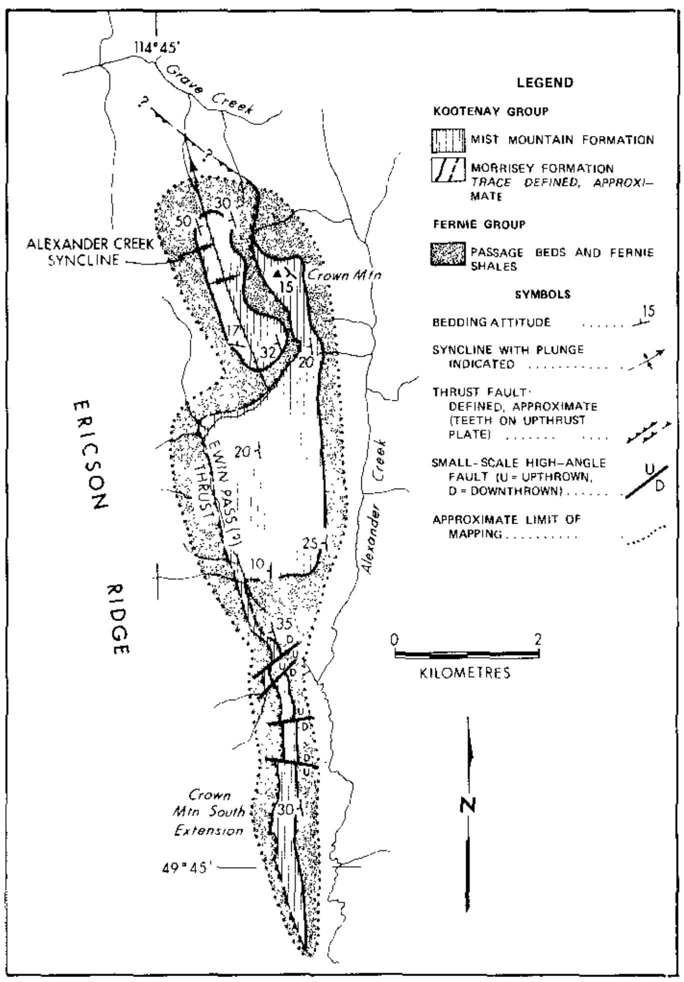


Figure 8. Geology of the Crown Mountain area, Elk Valley Coalfield.

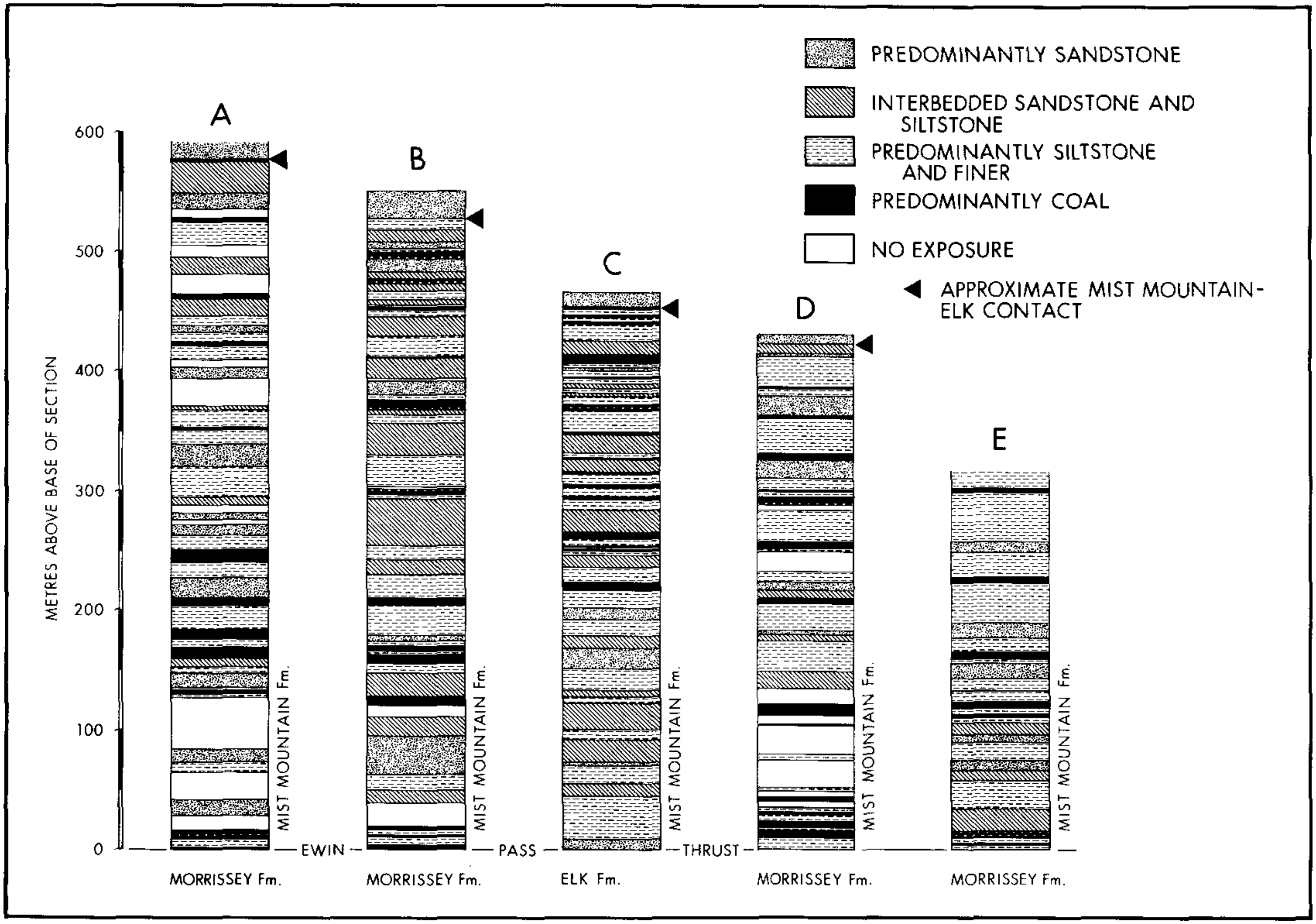


Figure 9. Generalized stratigraphic columns of the Mist Mountain Formation in the Line Creek area. Coal seams thinner than 1 metre are not indicated. See Figure 7 for locations.

Crows Nest Resources Limited began processing and shipping coal from Line Creek mine in February, 1982. The company has been actively seeking additional coal reserves adjacent to the minesite, and has undertaken detailed exploration on the north part of Line Creek Ridge (Line Creek extension), Horseshoe Ridge, and Mount Michael. Moreover, most of the study area has received some level of exploration during the past three years.

Line Creek minesite, which is 24 kilometres north-northeast of Sparwood, is accessible from the Sparwood-Elkford Highway. Good access is available into all parts of the study area using exploration, mine, and forestry roads. Elevations in the area range from 1 500 to 2 500 metres.

FIELDWORK

Field data collected was plotted directly onto British Columbia government air photographs; it will be transferred later to 10 000-scale orthophotos for publication to augment results from the last two field seasons (Grieve, 1981, 1982). Stratigraphic sections of the coal-bearing rocks were measured using pogo stick or chain and clinometer. Grab and channel coal samples were collected for petrographic analysis. Results will be included with the 1:10 000 geologic maps when they are published.

STRATIGRAPHY

Sedimentary rocks of the Jurassic-Cretaceous Kootenay Group comprise the southeast British Columbia coalfields. The Kootenay Group, as defined by Gibson (1979), consists of the Morrissey, Mist Mountain, and Elk Formations.

The basal Morrissey Formation is a prominent, cliff-forming sandstone unit that consists of the Weary Ridge and Moose Mountain members. Previously unrecorded occurrences of a pebble conglomerate facies of Moose Mountain member were noted at the south end of Burnt Ridge and on Teepee Mountain. A recessive interval of 3 metres thickness, which includes a carbonaceous zone, occurs 8 metres below the top of the Moose Mountain member at the south end of Burnt Ridge. It probably corresponds to a thin carbonaceous shale and coal parting that occurs within the Moose Mountain member at Line Creek mine. Although it is of no economic significance, it may affect stability of a mine slope or a wall formed of the basal sandstone.

The overlying Mist Mountain Formation, which consists of interbedded sandstone, siltstone, mudstone, shale and coal, is on the order of 500 metres thick in the study area (Fig. 9). Two complete sections measured west of the trace of the Ewin Pass thrust (A and B on Fig. 9) are 587 and 550 metres respectively in thickness. The one complete section measured east of the Ewin Pass thrust (D on Fig. 9) is only 430 metres in thickness. This contrast is similar to that reported from north of the study area (Grieve, 1982).

A 217-metre zone with no coal seams forms the immediate hangingwall of the Ewin Pass thrust at section C on Mount Michael (Fig. 9). Correlation between the barren zone in section C and sections A and B is uncertain because no comparable zone occurs in these sections. North and south of section C, where the fault is locally lower in the stratigraphy, a thickened coal seam of up to 20 metres apparent thickness occurs. Approximately 12 coal zones, including multiple seams, occur in the upper 250 metres of Mist Mountain Formation in section C, sections A and B have fewer comparable seams.

There are also striking contrasts between section C, in the hangingwall, and section D, in the footwall of the Ewin Pass thrust, respectively. The upper plate on Mount Michael is readily distinguished from the lower plate because there are numerous coal seams in the top 150 to 250 metres of the upper plate.

No complete Mist Mountain sections are exposed on Horseshoe Ridge, Teepee Mountain, or Crown Mountain. Horseshoe Ridge contains an estimated 350 to 400 metres of section, of which the lowest 311 metres were measured (E on Fig. 9). A resemblance to the lowest 250 metres of section on Mount Michael (D on Fig. 9) is apparent, although significant facies changes have occurred between the two sites.

Similarly, there are no complete Elk Formation sections in the study area. In the Mount Banner area to the north, the Elk Formation is estimated to be on the order of 300 metres in thickness. Strata of the Elk Formation are similar in most respects to those of the Mist Mountain Formation. The presence of Elk coal, an alginite-rich cannel coal, is used to distinguish the Elk Formation from the Mist Mountain Formation. Other criteria include a lack of coal seams greater than about 1.5 metres in thickness in the Elk, a greater number of sandstone units, and the presence of a pebble conglomerate, which crops out in the core of the Alexander Creek syncline to the east of section B.

The contact between the Mist Mountain and Elk Formations is generally placed either at the first occurrence of needle coal or at a locally mappable, resistant sandstone unit which appears to separate strata of the two formations. For example, a very prominent series of resistant channel sandstones defines the contact immediately north of Noname Creek.

STRUCTURE

The study area is part of the Lewis thrust plate; the Alexander Creek syncline is the dominant structure. In the north part of the area the fold axis plunges to the north down Dry Creek (Fig. 7) as it passes between Burnt Ridge (west limb) and Mount Michael (east limb). South of Noname Creek it passes through the east slope of Line Creek Ridge, where it separates Line Creek minesite (west limb) from Horseshoe Ridge (east limb). Near Line Creek the axis is truncated by the Ewin Pass thrust. Its trace beneath (east of) the thrust is not clear, although two very thin remnants of Kootenay Group on Teepee Mountain are in a general but irregular synclinal configuration (Fig. 7).

Alexander Creek syncline is well defined in the upper plate of the major thrust at Crown Mountain (Fig. 8). The lower plate at this point is a west-dipping monocline.

The second major structure in the study area is the west-dipping Ewin Pass thrust (Fig. 7). Its most significant effect was to emplace Mist Mountain Formation over Elk Formation on Mount Michael with approximately 600 metres of vertical displacement. As a result, numerous coal seams occur in a setting that is suitable for open-pit mining. Contrasts in thickness and lithologies of Mist Mountain Formation sections above and below the Ewin Pass thrust fault (C and D on Fig. 9) suggest that there was a significant horizontal displacement.

To the south of Mount Michael the Ewin Pass thrust cuts down-section with loss in elevation. South of Line Creek it must be within the Fernie Group. It is not entirely clear at this time if the thrust at Crown Mountain is also the Ewin Pass thrust; it emplaced the top part of the Fernie Group and basal part of the Kootenay Group over the basal part of the Kootenay Group with approximately 200 metres vertical displacement (Figs. 7 and 8).

Aside from stratigraphic evidence, the Ewin Pass thrust is also recognizable in the field because of associated complex, small-scale deformation features including drag folds, overturned zones, and thickened and sheared coal seams. Similar features also characterize numerous smaller thrust zones in various parts of the study area, particularly in the east limb of the Alexander Creek syncline. Other smaller scale structural complications in the area include a faulted, tight syncline affecting the Morrissey and basal Mist Mountain Formations at the south end of Horseshoe Ridge; it may also be related to movement on the Ewin Pass thrust. Of note are numerous thrust-related displacements and repetitions of the Morrissey Formation (Fig. 7), and a series of post-thrusting, crosscutting block faults in the Crown Mountain area (Fig. 8). The significant overturned panel found on Burnt Ridge (west limb) to the north (Grieve, 1982) does not extend into the study area.

ACKNOWLEDGMENTS

We greatly appreciate the field assistance of Suzanne Cannon and Greg Campbell. Crows Nest Resources Limited staff are thanked for permitting access to the Line Creek mine area.

REFERENCES

Gibson, D. W. (1979): The Morrissey and Mist Mountain Formations - Newly Defined Lithostratigraphic Units of the Jura-Cretaceous Kootenay Group, Alberta and British Columbia, *Cdn. Pet. Geol.*, Bull., Vol. 27, No. 2, pp. 183-208.

Grieve, D. A. (1981): Elk Valley Coalfield, *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1980, Paper 1981-1, pp. 70-72.

.... (1982): Mount Banner Area, Elk Valley Coalfield, *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1981, Paper 1982-1, pp. 47-50.

GEOLOGY AND MAGNETOMETER SURVEY OF THE SAPPHO GOLD-SILVER-PLATINUM-COPPER PROSPECT (82E/2)

By B. N. Church and S. Robertson

INTRODUCTION

This report describes results of a geological and magnetometer survey of the Sappho Crown-granted claim located near the International Boundary, approximately 4 kilometres south of Boundary Falls and 5 kilometres east of the town of Midway. The claim is currently undergoing re-examination for copper and precious metal potential by Kettle River Resources Ltd.

HISTORY

According to Minister of Mines reports, 100 tonnes of ore grading approximately 53 ppm silver and 6 per cent copper were shipped to the smelter from the Sappho claim (MI 82E/SE-147) during the period 1916 to 1918. Workings on the property consist of several pits, a shaft, and an adit dating from 1927 and earlier. A grab sample of ore taken from one of the pits assayed 3.2 per cent copper and 0.9 ppm platinum.

Recent work includes trenching, drilling, rock sampling, and geological and geophysical surveys. In the period 1963 to 1964, Triform Mining Ltd. and Coast Exploration Ltd. reported results on their trenching and rock sampling program. Apparently one 15-metre section assayed 0.2 per cent copper, a second section of 6 metres averaged 0.44 per cent copper, and a third section of 6 metres averaged 0.8 per cent copper. The operators also reported a short high-grade sulphide drill hole intersection assaying 28 ppm gold.

Rock sampling performed by Silver Standard Mines, Limited in 1967 apparently yielded 0.7 per cent copper across 9.5 metres in a trench near a north showing and 0.15 per cent copper across 17 metres in a trench on the south part of the claim (*see* Fig. 10).

Additional work was performed in the period 1975 and 1978 by G.O.M. Stewart and McIntyre Mines Limited. They confirmed the presence of platinum, quoting values for this element in the range 0.6 to 1.8 ppm from spot sampling.

Kettle River Resources Ltd. acquired the Sappho claim and the surrounding area in 1981 and renewed exploration activities.

GEOLOGICAL SETTING

Bedrock exposure in the Sappho area is minimal, revealing only fragments of the geological picture from scattered outcrops in trenches, in pits, and on a few hilltops (Fig. 10).

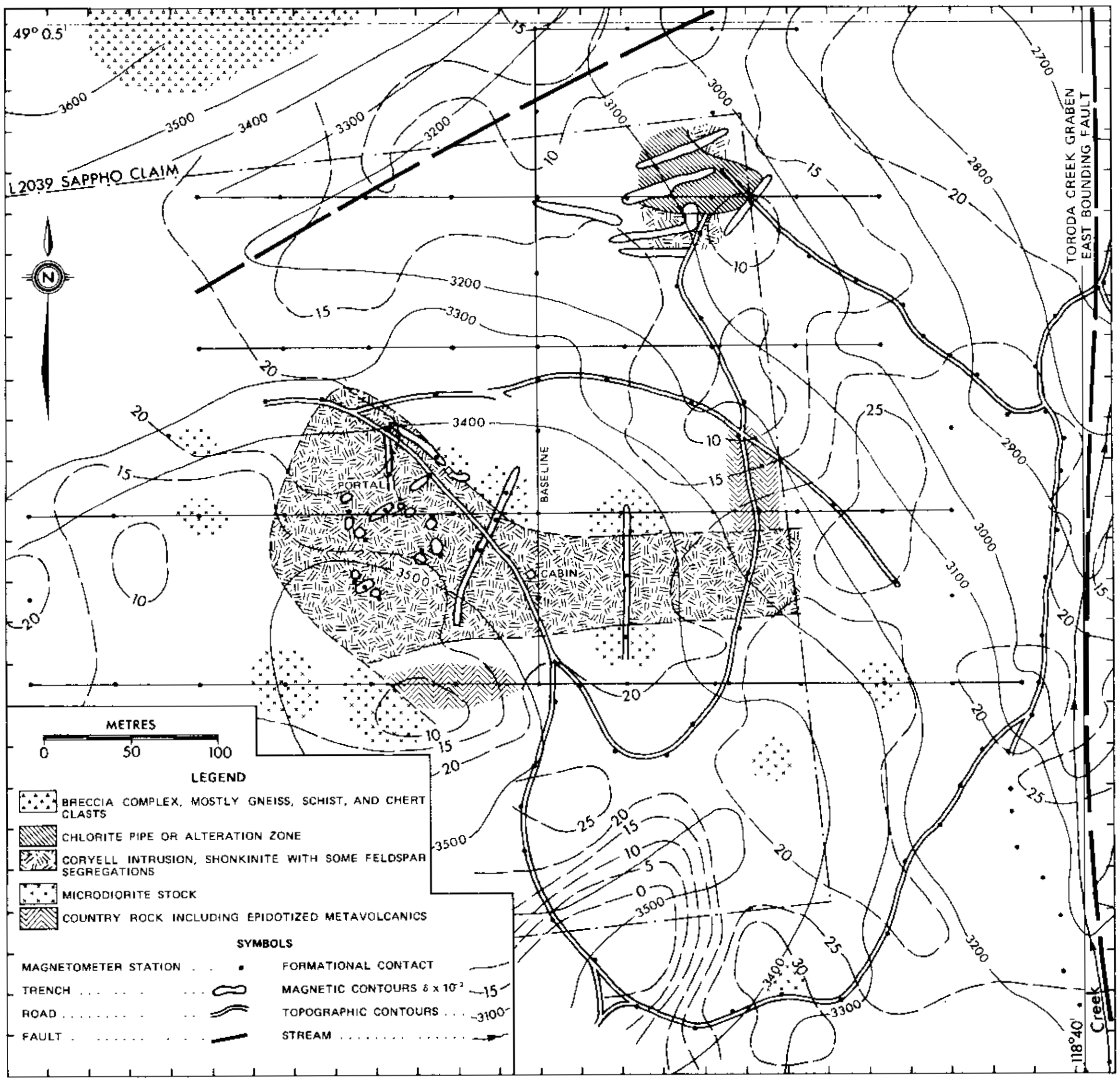


Figure 10. Geology and magnetometer survey of the Sappho prospect.

The principal rock types are a microdiorite, which forms a stock that is exposed in the central area and near the southeast corner of the claim, and younger (Eocene) Coryell-type bodies. Greenstones hosting both intrusions are exposed near the east boundary of the claim and in the south-central area. Scattered occurrences of serpentinite have been reported in the northern area where chloritized rocks with mineralization are also found.

The mineralized area is delineated on the east by the east-bounding fault of the Toroda Creek graben and on the north by a major northeast-trending fracture. Tertiary rocks are found to the north and include a hill of brecciated basement rocks of apparent landslide origin caused by major faulting (Monger, 1968, p. 27).

MINERALIZATION

The Sappho prospect is one of the few known occurrences in the province of lode-type copper-platinum mineralization associated with alkaline intrusions. Other examples are the Maple Leaf showing in the Franklin camp north of Grand Forks and the Copper Mountain deposit near Princeton.

Coryell alkaline intrusions at Sappho host the mineralization both at the central showings and near the northeast corner of the claim. The principal phases of the Coryell rock are pyroxenite (shonkinite) and pyroxene monzonite. Subsidiary phases include small pegmatoid amphibole-rich segregations and alkali feldspar-rich differentiates that commonly occur as dykes or apophyses.

Mineralization consists of pyrite-chalcopyrite disseminated in shear zones and forming irregularly shaped blebs and pods of sulphide in biotite shonkinite and sericitized feldspathic phases. Sulphides are also found locally in skarn-like assemblages of chlorite, epidote, garnet, and magnetite near what appear to be intrusive margins. Veinlets of calcite are common in the mineralized areas, however, quartz veins are few.

Relations between serpentinite and mineralization are uncertain. Serpentinite fragments, which are common in the dumps of some old collapsed excavations in the northeast area, are evidence of shearing and probably a major fault zone.

MAGNETOMETER SURVEY

A magnetometer survey was conducted on the Sappho property to complement the geology, which is poorly understood because of extensive glacial cover. Existing roads and the surveyed line system were utilized for access and geographical control. Standard field methods were employed using a McPhar 700 fluxgate magnetometer with vertical sensor configuration.

The results of a scattering of 146 stations across the area show a range of approximately 4 000 gammas (that is, 36 to -4 scale divisions). The magnetic contours shown on Figure 1 were generated according to the moving average procedure using a computer program described in Geological Fieldwork, 1980 (B.C. Ministry of Energy, Mines and Petroleum Resources, Paper 1981-1, pp. 25-32) using a 50-metre radial integration distance and a radial weighting factor calculated as follows:

the moving average = T/S
S = S + (1/R) the sum of weighted factors and
T = T + [A*(1/R)] the sum of weighted distances,
R being the radius of integration and
A the field readings within the area of integration

Two typographical errors in the original printing of the computer program (Table 1, p. 27) are as follows:

Line 160 statement IF SQR $(A(1) - \emptyset)^2 + (2(2) - Q*1)^2$ should read
IF SQR $(A(1) - \emptyset)^2 + (A(2) - Q)^2$
Line 220 statement P = P + 0 should read P = P + 1.

The survey shows a magnetic low immediately east and south of the northern mineral showings and trenched area, a magnetic trough to the northwest coincident with a topographic lineament, and what appears to be a magnetic dipole in the area of microdiorite exposures near the south boundary of the map-area. The results appear to confirm the previously inferred position of a major fault on the north. They also suggest that the chloritized contact zone extends to the east and south of the northern trenches and may extend to zones of faulting or alteration related to the contacts of the microdiorite. The features offer some new interpretations of the geology and re-evaluation of exploration targets.

REFERENCES

Minister of Mines, B.C., Ann. Repts., 1916, p. 518; 1917, p. 449; 1918, p. 211; 1927, pp. 234, 235; 1928, p. 250; 1964, p. 110; 1967, p. 226.

B.C. Ministry of Energy, Mines & Pet. Res., Exploration in B.C., 1975, pp. E12, E13; Geological Fieldwork, 1980, Paper 1981-1, pp. 25-32.

Church, B. N., Fahrni, K. C., and Preto, V. A. (1982): Guidebook of Copper Mountain and Phoenix, *Geol. Assoc. Can.,* Mineral Deposits Section, 72 pp.

Dobrin, M. B. (1960): Introduction to Geophysical Prospecting, *McGraw-Hill,* 446 pp.

Gilmour, W. R. (1981): The Sappho Property, Norwegian Creek, Greenwood Mining Division, *B.C. Ministry of Energy, Mines & Pet. Res.,* Assessment Rept. 9364, 18 pp.

Jakosky, J. J. (1980): Exploration Geophysics, *Trija Pub. Co.,* California 1195 pp.

Lahee, F. H. (1941): Field Geology, *McGraw-Hill*, 853 pp.

McPhar Geophysics Co. Ltd., Manual to the M700 Magnetometer, 12 pp.

Monger, J.W.H. (1968): Early Tertiary Stratified Rocks, Greenwood Map-Area, (82E/2), British Columbia, *Geol. Surv., Canada,* Paper 67-42, 39 pp.

O'Neill, J. J. (1918): The Platinum Situation in Canada, *Geol. Surv., Canada,* Summ. Rept., 1918, Pt. G, 19 pp.

Paxton, J. (1971): A Geochemical Report on a Geochemical Soil Survey on the KIS Claim Group for the Granby Mining Co. Ltd., *B.C. Ministry of Energy, Mines & Pet. Res.*, Assessment Rept. 3335, 6 pp.

Seraphim, R. H. (1967): Map of the Cabin Claims, *Silver Standard Mines, Limited,* private company rept. (unpublished map).

TABLE 1. CHEMICAL ANALYSES OF BASALTS FROM THE OKANAGAN HIGHLANDS

	1	2	3	4	5	6	7	8
Oxides recalculated to 100								
SiO_2	47.84	48.30	48.69	49.77	48.63	49.67	50.09	50.85
TiO_2	2.21	3.21	2.07	2.06	2.00	3.06	2.35	2.48
Al_2O_3	17.08	17.22	15.93	16.44	18.16	17.84	16.21	17.58
Fe_2O_3	4.56	4.62	2.95	5.40	3.34	4.57	4.28	4.14
FeO	8.31	9.01	9.28	9.17	8.90	7.67	8.08	7.79
MnO	0.18	0.20	0.18	0.22	0.19	0.18	0.18	0.23
MgO	6.65	4.40	6.96	3.88	5.22	4.18	6.31	3.95
CaO	8.56	7.51	8.74	6.95	8.14	7.46	6.60	5.86
Na_2O	3.61	4.08	3.88	4.35	4.06	4.18	4.21	5.04
K_2O	1.00	1.45	1.32	1.76	1.36	1.19	1.69	2.08
Oxides as determined								
H_2O+	1.13	1.18	0.60	1.21	0.82	1.11	1.70	1.07
H_2O-	0.68	1.00	0.50	0.79	0.73	0.78	1.03	0.81
CO_2	<0.1	0.06	2.63	0.21	2.08	0.17	<0.07	<0.1
S	<0.01	0.01	0.02	0.04	0.02	0.01	0.02	0.01
P_2O_5	0.42	1.26	0.55	1.05	0.71	0.22	0.32	0.70
BaO	0.02	0.06	0.04	0.10	0.03	0.07	0.06	0.07
SrO	0.06	0.10	0.09	0.07	0.07	0.09	0.07	0.11
Molecular Norm								
Or	5.94	8.69	7.80	10.55	8.06	7.11	10.00	12.32
Ab	32.56	37.14	33.11	39.62	34.31	37.94	37.84	42.42
Ne	-	-	1.02	-	1.34	-	-	1.75
An	27.60	24.75	22.16	20.44	27.40	26.71	20.39	19.26
Wo	6.02	5.21	8.47	5.82	5.24	4.28	4.96	3.95
En	3.42	2.01	-	2.38	-	7.78	3.70	-
Fs	1.23	1.04	-	1.69	-	3.00	1.33	-
Fo	11.27	7.73	14.41	6.36	10.84	2.92	10.31	8.20
Fa	4.06	3.99	7.08	4.50	6.52	1.12	3.71	4.31
Il	3.09	4.53	2.88	2.91	2.79	4.31	3.28	3.46
Mt	4.79	4.90	3.08	5.73	3.50	4.83	4.48	4.34
Cor	-	-	-	-	-	-	-	-

Key to Analyses

1. Pyroxene-olivine basalt on Long Mountain, east of Oyama Lake.
2. Pyroxene-olivine basalt east of Harris Creek.
3. Reversed olivine basalt above King Edward Creek, south of Coldstream (K/Ar whole rock date of 20.4±1.4 Ma).
4. Basalt with bladed plagioclase phenocrysts west of Oyama Lake.
5. Olivine basalt 5 kilometres southeast of Coldstream.
6. Pyroxene-olivine basalt 7 kilometres southeast of Coldstream.
7. Basalt with lherzolite inclusions in the Grizzly Hills area.
8. Olivine basalt west of Daves Creek (K/Ar whole rock date of 14.9±0.9 Ma).

GEOLOGY AND MAGNETOSTRATIGRAPHY OF MIOCENE BASALTS OF THE OKANAGAN HIGHLANDS, BRITISH COLUMBIA

(82L/2, 3)

By B. N. Church and U. Suesser

Several outliers of Miocene basalt have been delineated by recent mapping in the Okanagan Highlands south and southeast of Vernon. The total area, underlain by lavas and breccia, is about 200 square kilometres (Fig. 11). Locally these volcanic rocks, which range in age from 14.9 to 20.4 Ma, were deposited on placer-bearing gravels. Generally they cover a rolling terrane of crystalline basement rocks. The basalt formation, divided locally into three members by interbedded volcaniclastic rocks, has a maximum thickness of about 340 metres comprising more than 15 individual flows (Fig. 12).

The basalts range from vitrophyric to sugary-textured varieties, the latter having greatest magnetic susceptibility. A few lava flows are characterized by large bladed phenocrysts of plagioclase or, less commonly, lherzolite xenoliths. Chemical analysis show that most of the rocks are normal olivine basalts (Table 1), although a few samples are slightly enriched in alumina and alkalis.

Preliminary magnetostratigraphic studies using a fluxgate magnetometer indicate that the placer gravels are associated with 'reversed' basalts of the lowest member. Younger basalts in the succession have 'normal' polarity, however, magnetic vectors show a marked range in azimuth and angle of plunge (Fig. 13). Success in the magnetic determinations was dependent in large measure on the near horizontal bedding of the basalts which did not require arbitrary rotation of magnetic vectors or other manipulation of the data to restore bedding attitudes. Corrections for azimuth measurements from sun bearings at sample stations were applied according to the computer program in Table 2.

TABLE 2. COMPUTER PROGRAM FOR SIGHT REDUCTION CALCULATION OF SUN AZIMUTHS

```
  5 SELECT D
 10 SELECT PRINT 211(156)
 20 PRINT 'SIGHT REDUCTION CALCULATION FOR SUN AZIMUTH
 30 INPUT 'DAY OF YEAR,' C
 40 INPUT 'TIME IN HOURS DECIMALS,' A
 50 INPUT 'LONGITUDE IN DECIMAL DEGREES,' B
 60 INPUT 'LATITUDE IN DECIMAL DEGREES,' L
 70 H = 15*(A-12) + (120-B)
 80 D = -23.5*COS(0.025*C+C)
 90 T = ARCSIN((SIN(D)*SIN(L)+COS(D)*COS(L)*COS(H)))
100 X = ARCCOS((SIN(D)-SIN(L)*SIN(T))/(COS(L)*COS(T)))
110 IF H<0 THEN 130
120 IF H>=0 THEN 140
130 Z = X: PRINT Z
135 END
140 Z = 360-X: PRINT Z: GOTO 135
```

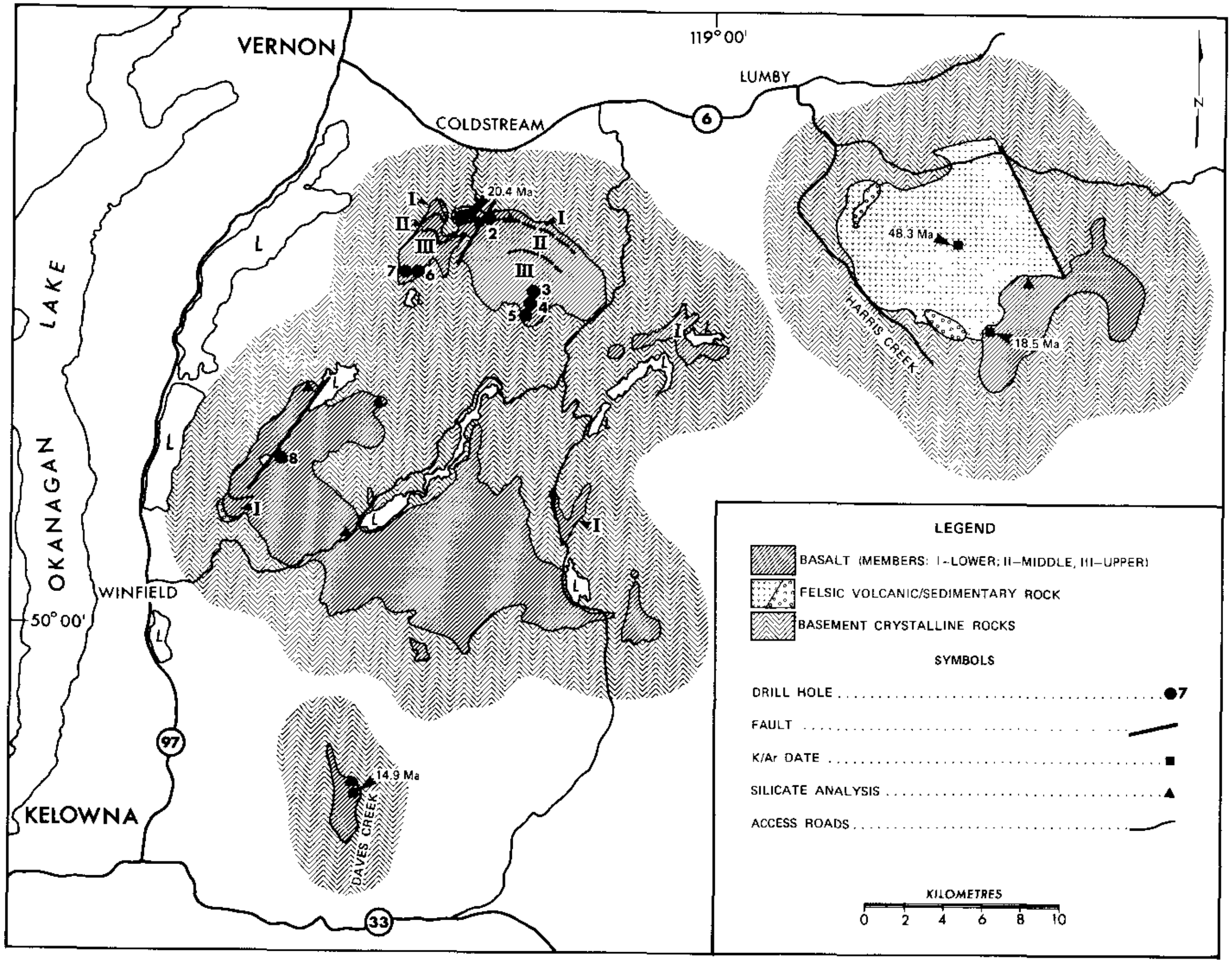


Figure 11. Basalts of the Okanagan Highlands.

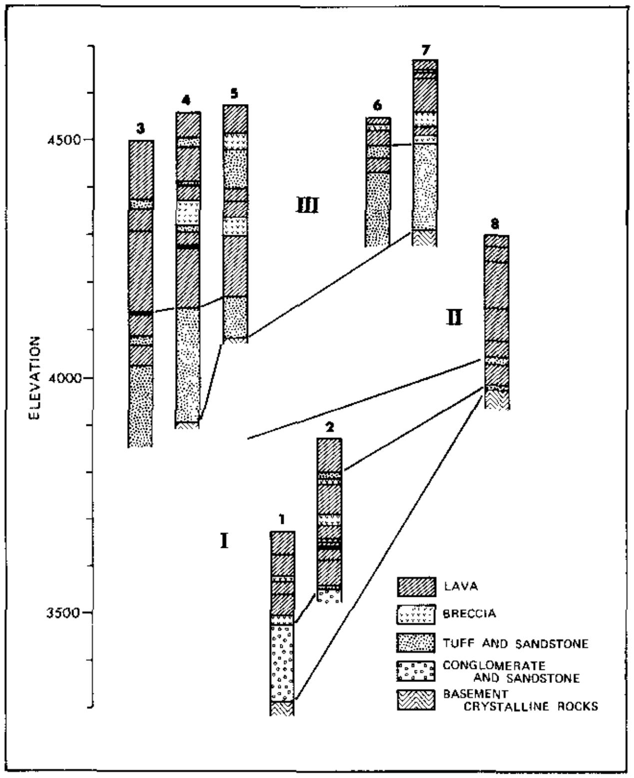


Figure 12. Drill hole sections of basalt and channel deposits.

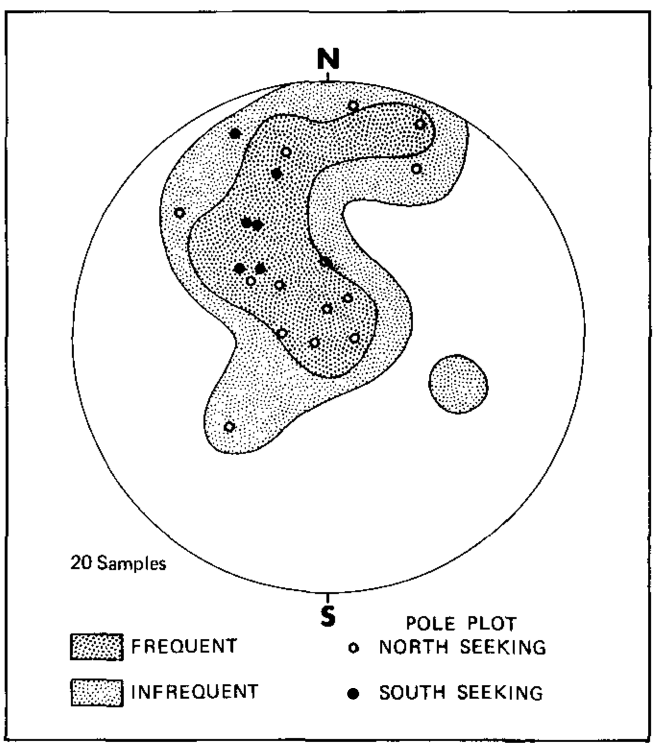


Figure 13. Magnetic vectors in basalt lavas.

Mining exploration is focused on gold and uranium-bearing stream channel deposits below the basalt. The King Edward placer (latitude 50 degrees, 11.3 minutes; longitude 119 degrees, 11.2 minutes) south of Coldwater is a typical example. The placer gold occurs in loose sand, pebbles, and cobbles weathered from a Miocene conglomerate channel underlying the basalt bluff overlooking King Edward Creek. The channel deposit, which has a maximum thickness of about 160 metres, has been prospected along strike for about 2 kilometres, and is currently worked on a small scale by Harry Arnold of Vernon. In the late 1970's the same channel was the target of a uranium diamond-drill program.

Winfield placers are near the base of the basalt bluff northeast of Winfield (latitude 50 degrees, 3.5 minutes; longitude 119 degrees, 19.7 minutes). A buried fluvial deposit is the source of the placers. It consists of light-coloured sandstones with conglomerate beds with abundant quartz clasts. According to Jones (1959), more than 2 300 grams of gold were obtained between 1933 and 1945 from a series of small adits.

The exact age of some of the channel deposits is controversial. Two deposits of polymictic conglomerate, shale, and sandstone in the Harris Creek area are associated with an Eocene rhyolite complex dated at 48.3 Ma. Adjacent and overlying Miocene basalt lavas have 'normal' polarization, unlike the lower basalts in the Winfield and Coldstream area. Placer potential in such Eocene channel deposits is thought to be low. They probably form part of the Eocene highland terrane upon which the Miocene basalts were deposited.

ACKNOWLEDGMENTS

Thanks are owing to Ken Daughtry and William Gilmour of K. L. Daughtry and Associates Ltd. in Vernon for guidance and much helpful information on the geology and mineral deposits of the Okanagan Highlands.

REFERENCES

Collinson, D. W., Creer, H. M., and Runcorn, S. K. (1967): Methods in Paleomagnetism, *Elsevier Pub. Co.*

Jones, A. G. (1959): Vernon Map-Area, British Columbia, *Geol. Surv., Canada,* Mem. 296, 186 pp.

Okulitch, A. V. (1979): Thompson-Shuswap-Okanagan Mineral Occurrence Map, *Geol. Surv., Canada,* Open File Map 637c.

Suesser, U. (1980): Techniques in Collection and Preparation of Basalt Samples for Determination of Remnant Magnetic Pole Orientation, *University of Victoria,* Rept. on Co-Op Project, 12 pp.

LEECH RIVER AREA, VANCOUVER ISLAND
(92B/5, 12)

By G.E.P. Eastwood

INTRODUCTION

Placer gold was mined from the Leech River in quantity in 1864 and has been the object of intermittent prospecting and small-scale mining since then. The river name has been used for the metasedimentary bedrock formation on which the placer deposits rest and for a major fault which juxtaposes the Leech River Formation against the Eocene Metchosin basalt to the south. The Leech River Formation has not been dated, and suggestions as to its age have ranged from Carboniferous to Cretaceous. The formation contains numerous quartz veins carrying trace amounts of gold, and Clapp (1917) concluded that the placer gold was derived from them.

In 1981 and 1982, four placer miners continued to work sections of Martins Gulch, when the volume of water permitted. After years of prospecting, Robert Beaupre had by the end of 1981 found gold in small quartz veins in rocks of the Leech River Formation west of the upper Leech River. In 1982 Grizzly Rock Services Ltd. started to drive a water-supply tunnel for the Greater Victoria Water District. It will run from Deception Gulch toward the end of the new road along the north side of the Leech River. In 1981 the writer made a reconnaissance survey of a strip between the mouth of the West Leech River and the Sooke River. In 1982 the reconnaissance across the Leech River Formation was completed to Sooke Lake. Sections of the tunnel were mapped, and a detailed survey was made of the lower part of Martins Gulch (*see* Fig. 14).

The area may be reached from Shawnigan Lake Road via Sooke Lake Main and Leechtown Main. The former bridge over the upper Sooke River is gone, but at low water the river can be forded by truck immediately above its confluence with the Leech River. Alternatively, access was from Sooke via Pacific Forest Products' Boneyard road. As hauling was in progress on week days, a radio was borrowed from the company. The Greater Victoria Water District has locked gates at the Sooke Lake spillway, north of Macdonald Lake, and on the road along the north side of the Leech River due south of Macdonald Lake. In addition to borrowing keys, it was necessary to obtain permits for specific days to enter the watershed behind the spillway gate and the Macdonald Road gate.

The principal topographic features in the area are a ridge in the northwest, the valleys of the Leech and Sooke Rivers, and a large basin between the tunnel portal and Sooke Lake. Macdonald Lake lies on the level floor of a valley that separates the ridge from a low, irregular hill to the east. Martins Gulch is actually a V-shaped creek valley with a moderate gradient. Outcrop is semicontinuous in the lower half of the gulch and along the section of the Leech River between the end of the

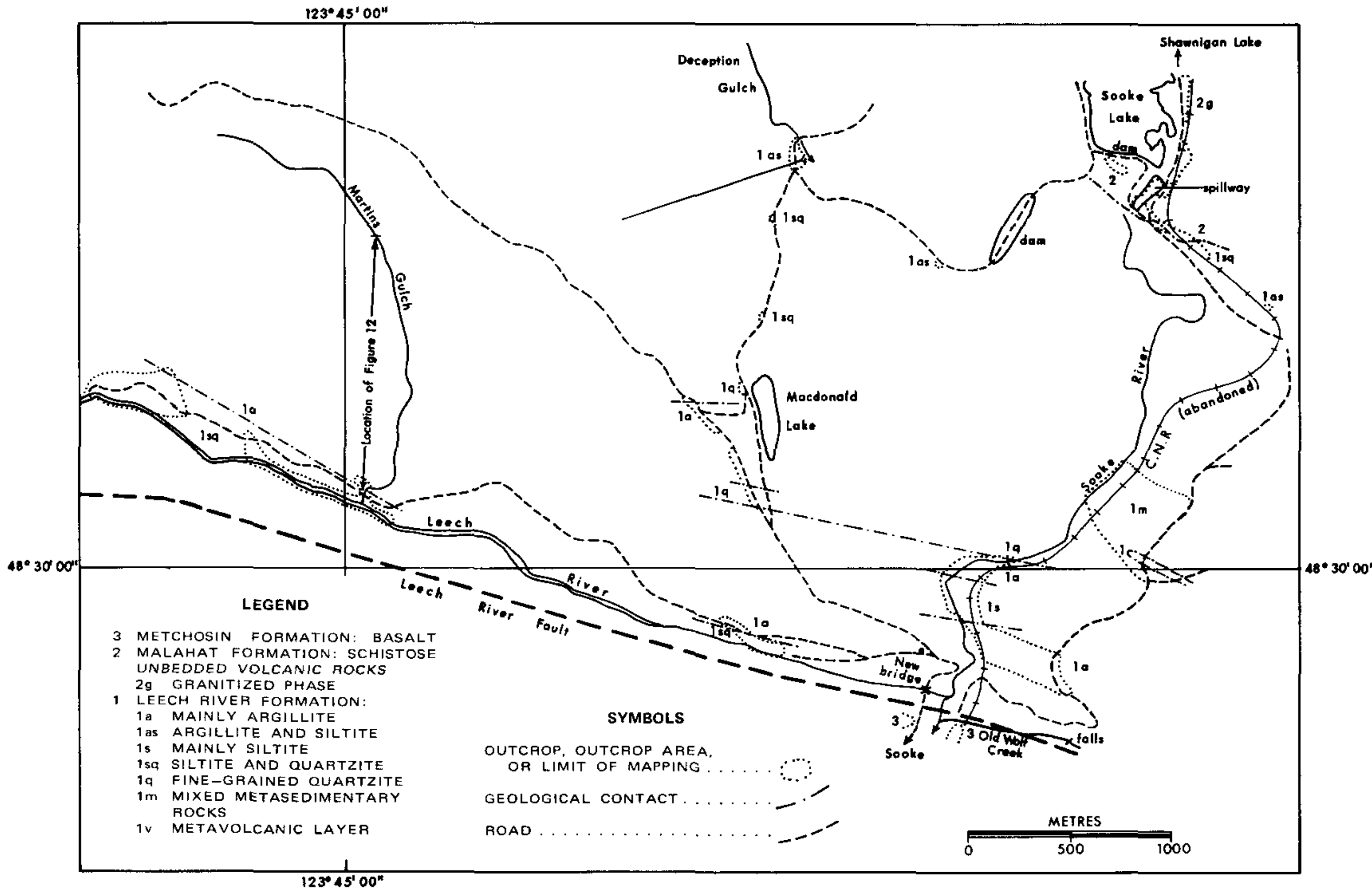


Figure 14. Geology of the Leech River area, southern Vancouver Island.

north-side road and lowest outcrop area shown on Figure 14. Exposure is fairly good to the south and east of Sooke Lake and in road cuts between the cabin and a point west of Macdonald Lake. Elsewhere outcrop is patchy or nonexistent.

GENERAL GEOLOGY

The Leech River Formation in this area consists mainly of deformed and metamorphosed mixed clastic sedimentary rocks. Distinct layers of metamorphosed tuff and volcanic breccia are exposed in Martins Gulch and on Leechtown Main. Unbedded light grey bands in the first few metres of the water tunnel and in exposures around the portal may also have been tuffs. Unbedded greenish grey schists in the spillway and north along Leechtown Main are evidently Clapp's 'Malahat volcanics.' Northward these schists are increasingly granitized and pass gradationally into granitic rocks that Clapp assigned to the Colquitz. Thin sheets of slightly gneissic granitic rock are exposed in a road cut on the north side of the Leech River about 800 metres west of the new bridge.

Mixing of the sediments was accomplished mainly by interbedding but also by incomplete or poor sorting. Definite graded bedding was not found. The rocks are described in terms of the metamorphosed end members, quartzite, siltite, and argillite. The quartzites are fine grained and medium grey to white in colour. The thicker quartzite units commonly have a massive core, with beds above and below delineated by partings of siltite or argillite. The siltites are generally dark grey to black, but are medium to light grey along the Leech River, and, in one distinctive unit in Martins Gulch, they are yellow. They are uniformly thin bedded. The argillites are black, do not show internal bedding, and are phyllitic to schistose.

The well-exposed section in Martins Gulch was mapped in detail to serve as a reference section. Numerous dragfolds indicate that the section faces uniformly to the north. Definite stratigraphic tops were not found but, assuming the whole section is not overturned, the fold pattern is that of younger beds riding southward over older toward the crest of an anticline. The rocks were grouped into stratigraphic packages referred to as units. Since the base of the Leech River Formation is not exposed and the upper part is poorly exposed, any system of designation has to be arbitrary. The distinctive volcanic unit was assigned No. 100, and the other units numbered accordingly. An inferred fault between units 75 and 76 may signify a gap, but otherwise the section appears to be mostly complete. The units are shown in plan on Figure 15 and their lithology is summarized in Table 1. The difference in elevation between the base of unit 104 and the road embankment is about 150 metres.

The contact between units 66 and 67 can be identified near the end of the north-side road and less confidently in the exposures 800 metres west of the new bridge over the Leech River. Using the traces of this contact derived on Figure 14, the quartzite unit south of Macdonald Lake should correlate with any or all of units 84, 86, and 88. Correlation of the volcanic unit on Leechtown Main with unit 100 is therefore possible, although it is not exposed on the road near Macdonald Lake. The tunnel as shown represents its position in mid-June. The inner part is mainly silty argillite and argillite, with interbands of siltite. Three quartzite units between 690 and 500 metres from the portal are comparable with quartzite units in Martins Gulch. The outer part of the tunnel is driven through argillite and siltite, and exposures around the portal are mostly argillite. A covered section northeast of this is probably underlain by recessive argillite. The volcanic rocks overlie silty argillite at the junction of the Sooke Lake and Leechtown roads, but quartzite and siltite on the Canadian National Railway line to the east, indicating a disconformity.

TABLE 1. STRATIGRAPHIC SECTION IN LOWER MARTINS GULCH

Unit	Lithology
104	Mainly black argillite, with minor quartzite interbedded in the lower part and greenish beds, probably altered tuffs, interbedded in the upper part of the exposed section.
103	Mostly thinly interbedded quartzite and argillite, with dark grey siltite at the base and interbedded quartzite and dark grey siltite at the top.
102	Interbedded light grey siltite and black argillite in the lower part, overlain by mostly argillite.
101	Mainly dark siltite and less quartzite; layers of argillite near base and in the upper third.
100	Hard light green tuff and volcanic breccia.
99	Mainly dark grey siltite.
98	Argillite, silty in lower part.
97	Mainly siltite and quartzite, both interbedded and as separate layers. Minor layers of argillite and argillite interbedded with quartzite.
96	Mainly argillite; minor interbedded siltite and quartzite.
95	Quartzite.
94	Lower part: argillite, in part interbedded with siltite. Middle part: interbedded argillite and quartzite. Upper part concealed.
93	Mainly quartzite, with siltite at base and top.
92	Sandy siltite in lower half and mainly interbedded siltite and argillite in upper half.
91	Mainly argillite, silty in part; some interbedded quartzite in middle and at top.
90	Quartzite interlayered with less silty argillite.
89	Sandy siltite interlayered with less silty argillite, argillite, and quarztite.

TABLE 1. STRATIGRAPHIC SECTION IN LOWER MARTINS GULCH (Continued)

Unit	Lithology
88	Mainly quartzite; interbedded with dark siltite in upper part.
87	Dark grey and black siltite. About 50 per cent exposed.
86	Mostly grey quartzite, with some interbedded dark grey siltite.
85	Lower half: silty argillite; upper half: thinly interbedded siltite and quartzite with an interlayer of silty argillite.
84	Quartzite.
83	Silty argillite containing interlayers of yellow quartz-siltite.
82	Mainly quartzite; some interlayered dark grey to black siltite.
81	Argillite and silty argillite.
80	Dark grey siltite containing quartzite beds and layer.
79	Argillite and silty argillite.
78	Mainly compact quartzite.
77	Mainly black argillite; some quartzite interbedded in upper part.
76	Mainly compact, cliff-forming quartzite; in part dirty and interbedded with siltite.
75	Argillite containing beds and lenses of quartzite.
74	Compact interbedded siltite and quartzite with thinly foliated siltite at base and top.
73	Interbedded quartzite and argillite in lower part, overlain by silty argillite.
72	Mixed unit, ranging from quartzite at base and top to argillite in upper half.
71	Mainly argillaceous; mainly interbedded quartzite and silty argillite in lower part; mainly argillite in middle; mainly interbedded quartzite and argillite in upper part with some interlayered quartzite and siltite.
70	Mainly quartzite, massive to slabby; siltite layer at base; minor interbedded argillite.
69	Argillite.
68	Sandy siltite and interbedded quartzite and siltite.
67	Silty argillite, with some interbedded quartzite in upper part.
66	Mainly siltite with some interlayered argillite.

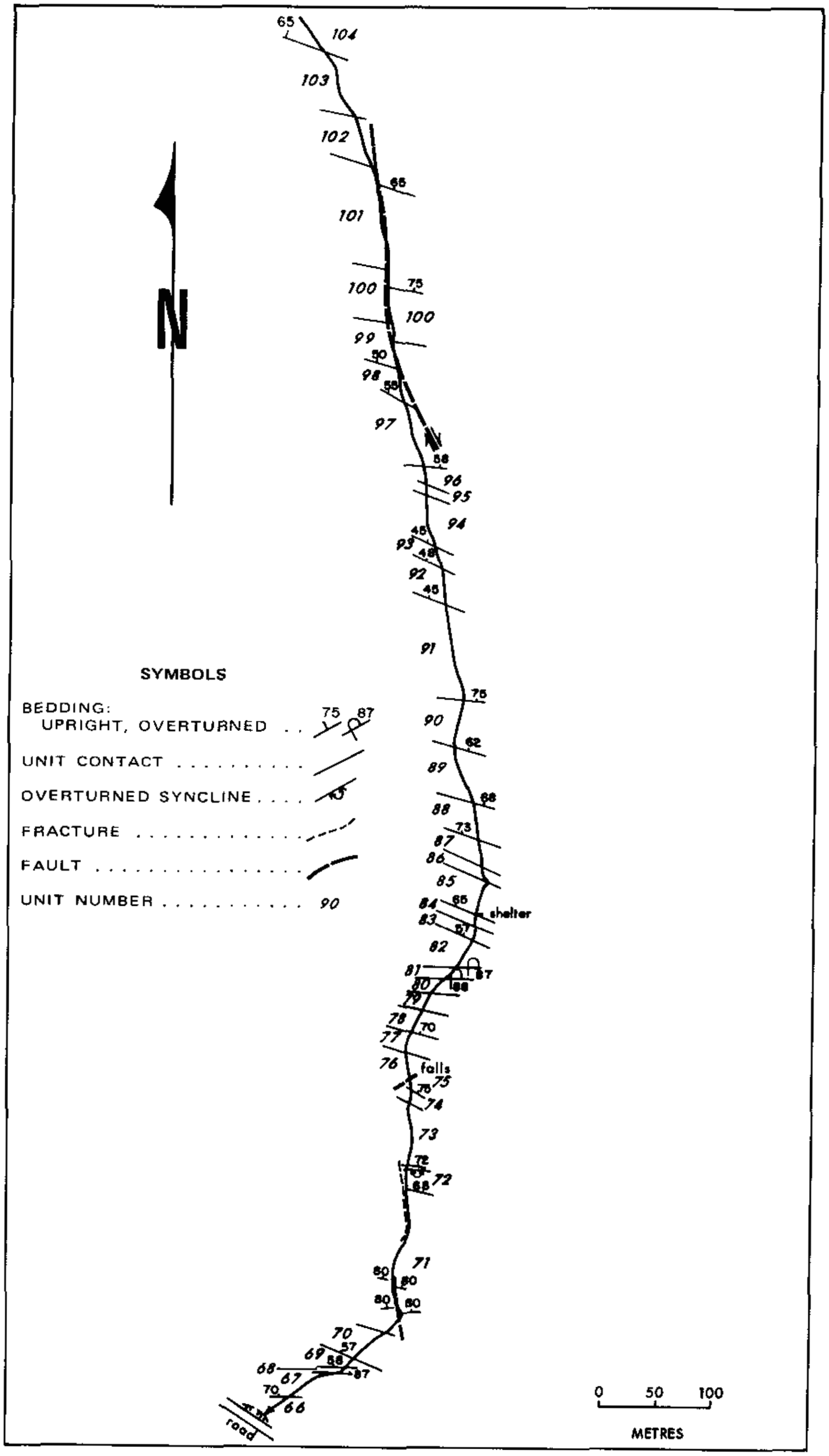


Figure 15. Geology of Martins Gulch (for location see Fig. 14).

STRUCTURAL GEOLOGY

Overall, the Leech River beds dip and face north-northeast at moderate to steep angles. Locally they have overturned, steep south dips. The structural behaviour of the rocks is well displayed in Martins Gulch. Massive quartzite does not show folding within outcrop limits. Bedded quartzite is commonly closely dragfolded, with limb dips decreasing to as little as 20 degrees in the centres of some units. The combination of low internal dips and piled-up dragfolds has greatly increased the outcrop width of many of the quartzite units. Siltites and isolated quartzite beds have been thrown into dragfolds that are approximately isoclinal, with limbs nearly parallel to an axial plane cleavage. The contact dips shown on Figure 15 are those of nearby unfolded beds. Bedding has not survived in the argillites; they show only a cleavage or schistosity parallel to the axial plane cleavage. The largest fold seen in Martins Gulch is an overturned syncline in quartzite in the upper part of unit 72. Since the lithology does not repeat north of this quartzite and quartzite beds in unit 73 show dragfolds indicating overriding to the south, it is assumed that the corresponding anticline has been sheared out along the axial plane cleavage. Some larger folds are indicated in the sections west and south of Macdonald Lake and along the Sooke River by reversals in the direction of overriding, but they do not appear to repeat whole units.

At the mouth of Martins Gulch, in the Leech River, the structural style changes. In the gulch section most dragfolds are complete, whereas in the river most have been pulled apart, leaving only rod-like thickened axial portions. Also, dragfolds are more numerous, smaller, and tighter in the river. Finally, there is a progressive change in dip of foliation and remnant bedding across the river section. Dips are steep north on the north side but steep south on the south side, near the Leech River fault. This changed style is interpreted to represent a superimposed second deformation in response to initial compression and subsequent tension caused by movement on the fault (Eastwood, 1982).

Quartz veins are common in all the rocks, but they are more abundant in argillite units. In the Martins Gulch section there appears to have been little or no movement in the argillites after deposition of quartz veins along the foliation. In contrast, quartz in the outer part of the water tunnel is in lenses and the schistose argillite has been wrapped around them, creating a wavy to curly schist. Post-quartz movement is indicated by a high polish on the schist surface against the quartz. This slick rock presents a ground-support problem. The post-quartz movement may be related to faulting. Muller (1980) has postulated a Shawnigan fault extending along Macdonald Lake Valley and under Sooke Lake, offsetting a postulated Survey Mountain fault which juxtaposes Leech River (and Malahat) rocks against Colquitz gneiss. However, as already noted, the Malahat schists pass gradationally into the Colquitz. Any fault in this part of the area would have to pass southwest of the schists and the sedimentary beds immediately underlying them, and would therefore lie within the Leech River Formation. Any movement under Macdonald Valley would have to be slight as the units appear to match up across it.

Three small faults are inferred to underlie Martins Gulch (Fig. 15). The north one is indicated by right hand offset of the contacts of unit 100, and northerly deviations in the strikes of beds can be attributed to drag on this fault. Attitudes in the vicinity have argillite of unit 75 striking into quartzite of unit 76; a fault is postulated to separate them. Movement would have to be left hand, as unit 74 is too thin to be the continuation of 76. A small fault in unit 71 is indicated by right hand offset of two fairly distinctive beds, represented by bedding symbols with 80-degree dips. An open crack in units 71 and 72 locally contains mylonite, but no offset could be detected. There are doubtless other small cross-faults in the area, which could be detected with good exposure and detailed mapping.

AGE AND CORRELATION

No radiometric ages have been obtained from the present area. The nearest dated samples (Wanless, *et al.*, 1978) are from 800 metres southwest of West Leech Falls; actinolite schist yielded a K/Ar age of 41.1 ± 2.8 Ma and sills intruding it an age of 36.7 ± 2.6 Ma. The actinolite represents a much higher grade of metmorphism than is found in the present area, and evidently was produced by a Tertiary metamorphic event penecontemporaneous with intrusion. A minimum age for the Leech River Formation is imposed by the fact that the overlying Malahat schists must pre-date the Colquitz. Muller (1980) quotes K/Ar dates for the Colquitz ranging from 131 to 182 Ma. The Malahat and Leech River must therefore be of Bonanza age or older. Of the various formations on Vancouver Island, they most nearly resemble the Sicker Group. Unit 100 closely resembles a common type of Sicker volcanic rock. The Sicker sedimentary beds exposed in Chemainus River are somewhat thicker than the thin Leech River beds, but their lithology is similar and they have been folded in a similar way. The volcanic-sedimentary sequence appears to be reversed, and it is suggested that the Malahat and Leech River together are correlative with Sicker volcanic rocks, the sediments accumulating distally to continued volcanism in the Sicker type area. Recent usage by Muller and others has been to include the Malahat in the Leech River, but it is much thicker than the volcanic units within the Leech River and appears to overlie it disconformably, therefore it is useful to retain it as a separate formation.

ECONOMIC GEOLOGY

The writer was shown nugget and fine gold recovered from the gravels in Martins Gulch, but no visible gold was found in the bedrock. A small proportion of the numerous quartz veins in Martins Gulch and in the tunnel contained appreciable pyrite. Of nine pyritic veins sampled, only one contained gold or silver above the detection limit, and it had only 0.3 ppm gold. Shear and gouge zones appeared barren.

In the spillway of Sooke Lake dam, under the bridge and for some distance above, the Malahat schists contain disseminated chalcopyrite and bornite. This is evidently a localized zone, as mineralization was not found in road and railway cuts. However, the schists pass out of the watershed a short distance east of the Canadian National Railway line, and prospecting there for similar zones is warranted.

REFERENCES

Clapp, C. H. (1917): Sooke and Duncan Map-Areas, Vancouver *Island, Geol. Surv., Canada,* Mem. 96, pp. 366-368.

Eastwood, G.E.P. (1982): Leech River Area, Vancouver Island, *B.C. Ministry of Energy, Mines & Pet. Res.,* Geological Fieldwork, 1981, Paper 1982-1, pp. 70-74.

Fairchild, L. H. and Cowan, D. S. (1982): Structure, Petrology, and Tectonic History of the Leech River Complex Northwest of Victoria, Vancouver Island, *Can. Jour. Earth Sci.,* Vol. 19, pp. 1817-1835.

Muller, J. E. (1980): Geology Victoria Map Area, *Geol. Surv., Canada,* Open File 701.

Wanless, R. K., Stevens, R. D., Lachance, G. R., and Delabio, R. N. (1978): Age Determinations and Geological Studies, K/Ar Isotopic Ages, *Geol. Surv., Canada,* Paper 77-2, 60 pp.

SICKER PROJECT
(92B/13)

By G.E.P. Eastwood

A radiometric age was obtained in 1982 that requires revision of the concept of the Sicker Group. The geology of the Mount Richards area is shown on British Columbia Ministry of Energy, Mines and Petroleum Resources Preliminary Map 40 and described in *Geological Fieldwork,* 1979. Briefly, Sicker volcanic and less sedimentary rocks are intruded by large dykes and irregular stocks of gabbro-like shonkinite. This is the gabbro-diorite of Clapp (1917) and evidently the diabase of Muller's (1980a, 1980b) sediment-sill unit. A CanPac Minerals Limited diamond-drill hole, drilled in or about 1972, passed through part of the dyke north of Breen Lake, and the writer logged and sampled the core. A hornblende separate was made and submitted to the University of British Columbia for K/Ar determination. J. Harakal reported an age of 363±13 Ma and commented that the material was of superb quality.

The Sicker rocks have been traced into the type area on Big Sicker Mountain, where they are similarly intruded by shonkinite. Schist belts were developed in the Sicker rocks prior to intrusion. Thus the type Sicker is Middle Devonian and/or older. The Buttle Lake limestone has been dated paleontologically as Middle Pennsylvanian or possibly Early Permian. Thus it and other Paleozoic deposits that postdate the deformation and intrusion are not Sicker. It is therefore possible that the host rocks of Westmin Resources Limited's Buttle Lake massive sulphide deposits are not Sicker.

REFERENCES

Clapp, C. H. (1917): Sooke and Duncan Map-Areas, Vancouver Island, British Columbia, with Sections on the Sicker Series and the Gabbros of East Sooke and Rocky Point by H. C. Cooke, *Geol. Surv., Canada,* Mem. 96, pp. 125-172, Map 42A.

Eastwood, G.E.P. (1980a): Sicker Project - Mount Richards Area, *B.C. Ministry of Energy, Mines & Pet. Res.,* Geological Fieldwork, 1979, Paper 1980-1, pp. 49-51.

.... (1980b): Geology of the Mount Richards Area, *B.C. Ministry of Energy, Mines & Pet. Res.,* Prelim. Map 40.

.... (1982): Geology of the Whitehouse Creek Area, *B.C. Ministry of Energy, Mines & Pet. Res.,* Geological Fieldwork, 1981, Paper 1982-1, pp. 78-83.

Muller, J. E. (1980a): The Paleozoic Sicker Group of Vancouver Island, British Columbia, *Geol. Surv., Canada,* Paper 79-30.

.... (1980b): Geology Victoria Map Area, *Geol. Surv., Canada,* Open Open File 701.

GEOLOGY AND GRAVITY SURVEY OF THE TULAMEEN COAL BASIN (92H)

By B. N. Church and D. Brasnett

INTRODUCTION

This report reviews the coal deposit and host rocks of the Tulameen basin in the light of new geological and geophysical data. The new information includes petrological and age determinations, and a gravity survey that gives insight into the structure of the basin.

HISTORY

Coal was discovered near Blakeburn Creek in the Tulameen basin prior to 1900. In 1904 control of the deposit was secured by B.C. Coal and Coke Co. and this was soon followed by large-scale exploration. Work commenced simultaneously on the northeast side of the basin on Collins Gulch and near Blakeburn Creek to the south. Activity continued over the next 30 years with the development of five underground mines in the Blakeburn area.

In 1913 Coalmont Collieries Ltd. gained control and initiated work at mine Nos. 1 and 2. An aerial tramway was constructed in 1920 to carry the coal from the minesite to the railway at Coalmont where it could be processed and readily transported to markets. Mines No. 3 and 4 began operations in the mid-1920's, however, floods and fires caused their eventual closures in the mid-1930's. The last operating mine, No. 5, opened in 1931 and produced for nine years. In 24 years of operation 2 144 657 tonnes of coal were shipped from Tulameen Coalfield. In the years 1954 to 1957, Mullin's Strip Mine Ltd. operated at Blakeburn, at the site of some of the old underground workings, producing 148 239 tonnes of coal. Imperial Metals & Power Ltd. continued active exploration in the 1960's with much trenching in the northwest part of the basin. Cyprus Anvil Mining Corporation continued this work plus additional diamond drilling in 1977 and 1978 under option agreement.

GEOLOGICAL SETTING

The Tulameen basin, centred 2 kilometres west of Coalmont, is a Tertiary outlier with an elliptical northwest-southeast elongated sedimentary core measuring 5.4 kilometres by 3.6 kilometres (Fig. 16). The geology of the basin has been previously described by Camsell (1913), Rice (1947), Shaw (1952), and Evans (1978) and examined in specific aspects by Hills, *et al*. (1967), Donaldson (1973), and Peavers, *et al*. (1980).

Eocene volcanic and sedimentary rocks rest unconformably on Triassic greenstones and metasedimentary rocks. They are overlain by Miocene basalt lavas and breccias.

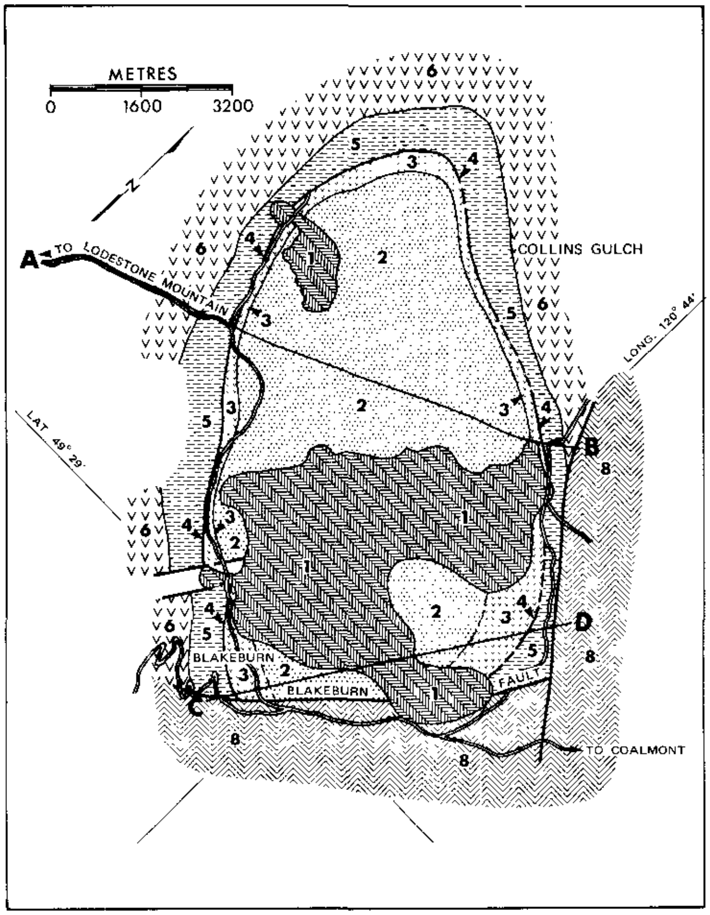


Figure 16. Geology of the Tulameen basin.
(See Fig. 18 for legend.)

TABLE 1. CHEMICAL ANALYSIS OF VOLCANIC ROCKS OF THE TULAMEEN BASIN

Oxides recalculated to 100%	1	2	Oxides as determined	1	2
SiO_2	68.61	80.21	H_2O+	0.85	3.80
TiO_2	0.45	0.11	H_2O-	1.23	3.18
Al_2O_3	16.63	15.98	CO_2	0.70	1.39
Fe_2O_3	2.59	0.01	P_2O_5	0.28	<0.08
FeO	0.38	0.47	S	<0.01	0.03
MnO	0.04	0.01	SrO	0.08	0.003
MgO	1.38	0.48	BaO	0.19	0.07
CaO	2.81	0.51			
Na_2O	4.29	0.10			
K_2O	2.87	2.12			
	100.00	100.00			

Key to Analyses: 1 = Hornblende dacite of Cedar volcanic rocks from road cut on south slope of Hamilton Hill. 2 = Rhyolite tuff band near top of coal measures in Blackburn pit.

The Eocene beds are estimated to be 800 metres thick where best developed. The coal measures, about 30 metres thick (Blakeburn), are sandwiched between 200 metres of sandstone and shale below, and 60 metres of fissile shales above (Collins Gulch section). An estimated thickness of 500 metres of quartzose sandstone and conglomerate forms the uppermost part of the sedimentary succession in the central part of the basin.

The Eocene volcanic rocks, named 'Cedar volcanic series' by Camsell (1913), are partly intercalated with the basal sedimentary units. The volcanic series attains a thickness of about 500 metres on Hamilton Hill and Mount Jackson, where the typical rock is light grey dacite with small hornblende needles (*see* analysis No. 1, Table 1). However, arc fusion analyses of 51 lava samples show a full range in compositions from basalt to rhyolite (Fig. 17). The frequency of felsic volcanic rocks increases stratigraphically upward to where rhyolite ash forms 12 separate bands in the upper part of the coal measures (*see* analysis No. 2, Table 1).

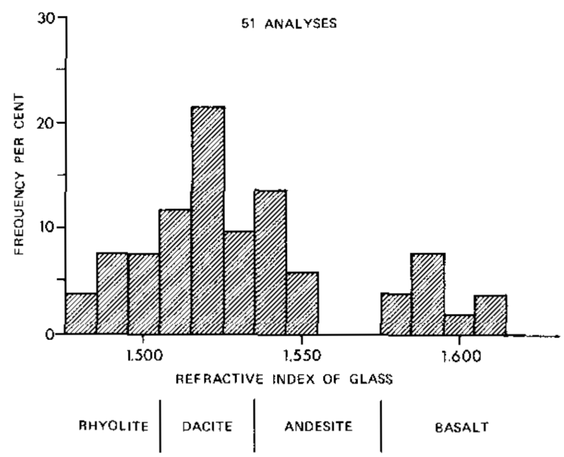


Figure 17. Refractive index frequency plot for the Eocene volcanic rocks of the Tulameen basin.

The age of these rocks is placed near the boundary between Lower and Middle Eocene, based on the recent determination of a sample of amphibole submitted to J. Harakal at the University of British Columbia. This is comparable to previous K/Ar results on beds associated with the Princeton and Hat Creek coal deposits (*see* Table 2).

TABLE 2. RADIOMETRIC AGE DETERMINATIONS OF EOCENE COAL MEASURES, SOUTH-CENTRAL BRITISH COLUMBIA

No.	Rock Source	Mineral	North Lat.	West Long.	K %	Ar^{*40} cc/gm	Ar^{*40} %	Age (Ma)
1	Cedar dacite	amphibole	49°30.2'	120°46'	0.761	1.469	75.6	49.0±1.7
2	Princeton ash	biotite	49°27.4'	120°32'	6.76	1.31	84	49.2±2
3	Hat Creek rhyolite	biotite	50°40.5'	121°34.5'	6.87	1.39	90	51.2±1.4

No. 1 = this study, No. 2 = Mathews (1964, p. 465), and No. 3 = Church (1975, p. G10) corrected according to the method of Steiger and Jager (1977).

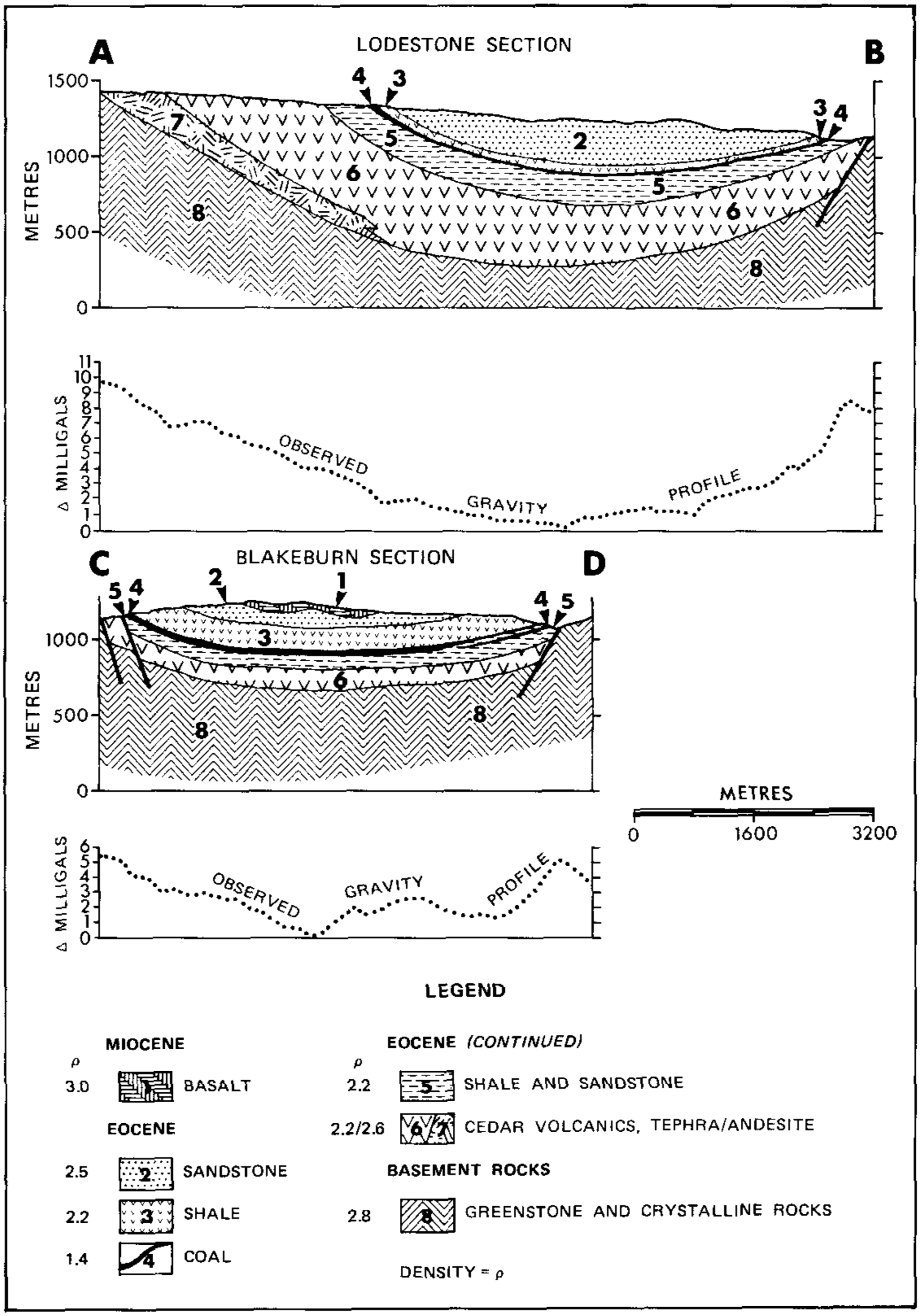


Figure 18. Geological cross-sections and gravity profiles of the Tulameen Basin. (Refer to Fig. 16 for position of sections.)

Miocene basalt (dated 9.0±0.9 Ma by Evans, 1978) are up to about 100 metres thick. These lava flows unconformably overlie the Eocene sedimentary rocks in the southern and west-central part of the basin. Feeder dykes to the basalt flows cut older rocks in the area, including coal beds north of Blakeburn pit. Here a large dyke about 50 metres wide intrudes the fault zone and divides the old mine workings.

GRAVITY SURVEY

A gravity survey conducted by Brasnett (1981), on behalf of the *Ministry, facilitates preparation of structural cross-sections of the* basin. A synthesis of two cross-sections shown on Figure 18 is based on total gravity response in terms of thickness and densities (ρ) of major stratigraphic units.

A LaCoste-Romberg gravity meter was employed in the survey and operated according to manual specifications. Readings were performed at 50-metre intervals at topographic stations established by Ager, Beretta and Associates Ltd.

The north line of the survey proceeds 5.1 kilometres on a course of approximately 060 degrees from 'A,' at the western margin of the basin on the Lodestone Mountain road, and ends at 'B' near the Bear's Den coal prospect on the east side (Fig. 18). The main features seen in this section are gentle-dipping beds (maximum dip of about 35 degrees), a down-faulted eastern margin, and westerly thickening stratigraphic units. The axial plane of this elongated basin is inclined with a keel displaced more than 1 kilometre westerly from the axial trace as seen in surface plan (*see* Evans, 1978, p. 84).

The south line follows an old tramway 3.2 kilometres on a course of 045 degrees from Blakeburn pit. Notably, this section shows a Miocene basalt cap on a relatively thin and gently dipping Eocene sequence. The keel of *the basin on this line is roughly 450 metres higher in elevation than* on the north line, which is closer to the centre of the basin. This indicates that the overall structure is not simply a southeasterly plunging syncline as suggested by Evans.

In summary, the evidence suggests that the basin developed as a drainage trap accumulating first sandstone, then shales and coal which thickened westerly against the still active Cedar volcanic pile. A final influx of quartzose sand and conglomerate completed an infill cycle following a late episode of rhyolite volcanism and subsidence. Preservation of these strata from erosion was effected by normal faulting on the east and southeast margins of the present Eocene outlier and extrusion of capping Miocene basalt lavas.

THE COAL DEPOSIT

Drilling by Cyprus Anvil Mining Corporation in the northwest part of the sedimentary basin shows that coal may occur anywhere in the shale facies. According to Shaw (1952), the lowest coal seam is about 120 metres above the Cedar lavas and breccias and 40 metres below the principal coal measures. Shaw also reported coal in the upper quartzose sandstone-conglomerate unit.

The thickest and most continuous coal deposit is in the Blakeburn area where Donaldson (1973) described in detail a 27-metre section of coal at the site of the old mining operation. The original mining excavation followed a 2 to 4-metre-thick seam with a strike length of 2.3 kilometres. The coal is a high volatile bituminous B and C variety, having 2 to 5 per cent moisture content, 4 to 16 per cent ash, 0.3 per cent sulphur, and yielding about 3 000 kilogram calories. The usual bright character of the coal is due to high vitrinite composition. Reflectance measurements on the vitrinite ($\bar{R}_o$) range from 0.79 to 0.94, showing a general increase downward (*see* Table 3 and Donaldson, 1973, p. 8). Individual seams above and below the mine seam are separated by clay layers, rhyolite ash bands, or shaly partings.

TABLE 3. VARIATION OF VITRINITE REFLECTANCE ($\bar{R}_o$) THROUGH THE BLAKEBURN COAL MEASURES

Metres below top of coal measures	Reflectance $\bar{R}_o$
0.3	0.804
1.0	0.831
2.0	0.846
2.7	0.822
4.2	0.790
8.0	0.847
11.0	0.843
13.0	0.928
17.0	0.884
20.0	0.944

Laterally the coal beds 'shale out' as is typical of limnic deposits. The main coal zone has been traced 3 to 4 kilometres along strike northwest from the Blakeburn pit to where the measures are 15 to 20 metres thick. However, to the east and south the coal horizon diminishes to a few thin seams at Collins Gulch and impure carbonaceous beds at the Bear's Den and Hayes-Vittoni prospects.

According to Peavers, *et al.* (1980), the high vitrinite content of the coal suggests a woody source and probable forest-moor origin. Stagnant acid conditions converted much of the interbedded rhyolite ash to kaolinite. The regularity of alteration textures and the continuity of these ash bands suggests a quiet, low detrital transport domain. The local clastic character of the coal is tectonic, resulting from bedding plane faulting related to concentric folding. Such movements are most prominent in deeper sections of the basin and in steeply dipping segments near the east margin.

The unexpected high rank of the coal is apparently due to a high geothermal gradient, ascribed to Eocene volcanism in the region. Donaldson (1973, p. 9) discounts any contact metamorphic effect from the overlying Miocene basalt. The general downward increase in the reflectance of vitrinite seems to be a function of depth of burial. Peavers, *et al.* (1980) determined the relation between reflectance $\bar{R}_o$, paleotemperatures, and time. Accordingly, observed reflectance values would result from a minimum paleotemperature of 75 degrees Celsius for a period of 50 million years or a more reasonable estimate of 130 degrees Celsius for 10 million years.

CONCLUSIONS

The Tulameen basin is a faulted elliptical structure of possible volcano-tectonic origin. New radiometric determinations give an Eocene age comparable to previous K/Ar results from other major limnic coal deposits of the southern interior region such as in the Hat Creek and Princeton areas.

A gravity survey gives a profile of the Tertiary formations, delineating the basal volcanic and sedimentary rocks and coal measures. The 800 metres of strata comprising the basin record a history of early volcanic eruption causing disruption of drainage patterns, stagnation leading to sedimentation and coal formation, and finally infilling by coarse sandstones and conglomerates. Preservation of these rocks resulted from normal faulting, folding, and extrusion of young basalt lavas.

Rhyolite ash bands concentrated in the upper part of the coal measures may reflect a resurgent volcanic event associated with high geothermal gradients. Evidence suggests that anomalous Eocene geothermal gradients are responsible for the comparatively high rank of the coal.

REFERENCES

Adamson, T. J. (1978): Tulameen Coal Project, *Cyprus Anvil Mining Corporation,* Assessment Rept. 77-(1)A.

Brasnett, D. (1981): The Tulameen and Colwood Gravity Surveys, *University of Victoria,* Co-Op Work Term Rept., 26 pp.

Camsell, C. (1913): Geology and Mineral Deposits of the Tulameen District, British Columbia, *Geol. Surv., Canada,* Mem. 26, 98 pp.

Church, B. N. (1975): Geology of the Hat Creek Coal Basin, *B.C. Ministry of Energy, Mines & Pet. Res.,* Geology, pp. G99-G118.

Donaldson, J. R. (1973): The Petrography of the Coal from the Blakeburn Strip Mine in the Tulameen Coal Area, British Columbia, *Geol. Surv., Canada,* Paper 72-39, 13 pp.

Evans, S. H. (1978): Tulameen Coal Basin, *B.C. Ministry of Energy, Mines & Pet. Res.,* Geological Fieldwork, 1977, Paper 1978-1, pp. 83, 84.

Hills, L. V. and Baadsgaard, H. (1967): Potassium-Argon Dating of Some Lower Tertiary Strata in British Columbia, *Cdn. Pet. Geol.,* Bull., Vol. 15, No. 2, pp. 138-149.

Mathews, W. H. (1964): Potassium-Argon Age Determinations of Cenozoic Volcanic Rocks from British Columbia, *Geol. Soc. Am.,* Bull., Vol. 75, pp. 465-468.

Peavers, D. R., Williams, V. E., and Mustoe, G. E. (1980): Kaolinite, Smectite, and K-Rectorite in Bentonites: Relation to Coal Rank at Tulameen, British Columbia, unpub. manu., 28 pp.

Rice, H.M.A. (1947): Geology and Mineral Deposits of the Princeton Map-Area, British Columbia, *Geol. Surv., Canada,* Mem. 243, 136 pp.

Shaw, W. S. (1952): The Tulameen Coalfield, British Columbia, *Geol. Surv., Canada,* Paper 52-19, 13 pp.

Steiger, R. H. and Jager, E. (1977): Subcommision on Geochronology: Convention of the Use of Decay Constants in Geo and Cosmochronology, *Earth and Planet. Sci. Lett.,* Vol. 36, pp. 359-367.

THE NAGY GOLD OCCURRENCES, DOCTORS POINT, HARRISON LAKE (92H/12W)

By G. E. Ray

INTRODUCTION

During the summers of 1981 and 1982, the author briefly examined gold occurrences situated near Doctors Point, which is on the west side of Harrison Lake approximately 45 kilometres north-northeast of Harrison Hot Springs. The property is reached via an unpaved road passing north from Weaver Creek Provincial Park. The occurrences were discovered by a prospector, George Nagy, and have been tested by trenching and some recent drilling. The No. I occurrence lies close to the lakeshore at the north end of Doctors Bay approximately 150 metres north of George Nagy's cabin (Fig. 20). The No. II occurrence is seen in a quarried exposure alongside the road, about 300 metres southwest of the cabin. This write-up briefly describes the geologic setting and mineralization observed in the trenches and reports some gold-silver assays and trace element analyses of mineralized grab samples collected by the author.

GENERAL GEOLOGY

The regional geology, adapted after compilations by Roddick (1965) and Monger (1970), is shown on Figure 19. Major, southeasterly trending fractures passing along Harrison Lake are associated with regional hot spring activity and separate the highly contrasting geological regimes exposed on the northeastern and southwestern shores of the lake. The Nagy gold occurrences lie close to this fracture system and also close to the intrusive contact between a younger quartz diorite body and hornfelsed country rocks that are of uncertain age and origin. Further west, Roddick (1965) assigns rocks correlative with the country rocks to the Jurassic or Cretaceous Fire Lake Group (Fig. 19); Monger's (1970) compilation assigns the country rocks of the occurrences to the Middle Jurassic Mysterious Creek Formation.

GEOLOGY OF NO. I OCCURRENCE

A 7-metre by 7-metre excavated trench exposes a very fine-grained, massive textured, dark to medium grey hornfels. This rock is cut by prominent jointing or fracture cleavage. Fractures are 2.5 to 7.5 centimetres apart; they strike 170 degrees and dip 45 degrees west. In thin section the hornfels has a marked decussate texture. Untwinned plagioclase and quartz crystals generally range between 0.05 to 0.1 millimetre in diameter but some remnant plagioclase crystals are up to 0.25 millimetres. These larger feldspars have recrystallized into a fine, polygonal mosaic of small crystals. Biotite forms minute (less than 0.1-millimetre), randomly orientated, subhedral laths and comprise

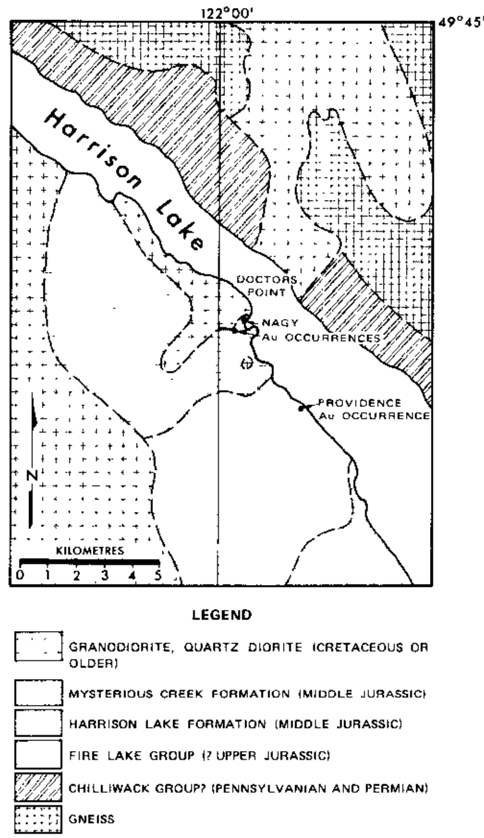


Figure 19. Regional geology of the Doctors Point area, Harrison Lake. (Geology adapted after Monger, 1970).

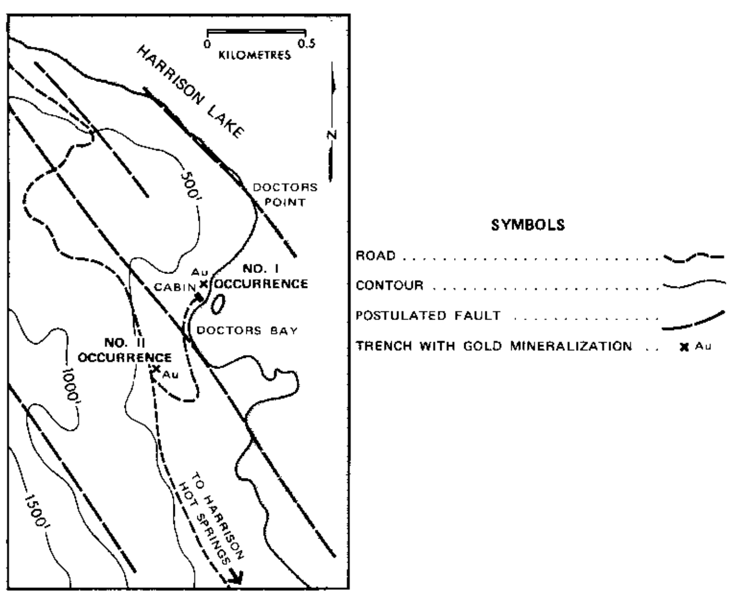


Figure 20. Location of the Nagy gold occurrences, Doctors Point, Harrison Lake.

up to 10 per cent of the total rock. Accessory minerals include epidote, zoisite, clinozoisite, sericite, chlorite, muscovite, and opaques. The muscovite occurs as late, ragged, poikiloblastic crystals with many inclusions; it may be intergrown with biotite. The opaques form less than 1 per cent of the total rock. They are largely minute magnetite granules but there are minor amounts of pyrite. In outcrop numerous randomly orientated sulphide-rich veins cross the hornfels. Most are less than 2 centimetres wide but some are up to 12.5 centimetres in width. These veins contain massive pyrite and arsenopyrite with lesser amounts of limonite, jarosite, scorodite ($FeAsO_4 \cdot 2H_2O$), sericite, quartz, and chlorite. Less commonly, thinner (generally less than 1 centimetre wide) quartz veins cut the hornfels. Some quartz veins contain central vugs lined with small euhedral quartz crystals.

Gold and silver assays and trace element analyses from grab samples of sulphide vein material from the No. I occurrence are shown in Table 1. The gold-silver mineralization is associated with anomalous amounts of bismuth, cobalt, copper, mercury, molybdenum, tungsten, lead, and arsenic.

TABLE 1. TRACE ELEMENT ANALYTICAL RESULTS FROM MINERALIZED GRAB SAMPLES FROM THE NO. I NAGY OCCURRENCE

	GR 40	GR 210	GR 211
Au*	0.7 ppm	5.4 ppm	5.8 ppm
Ag*	8 ppm	6.2 ppm	40.9 ppm
As*	0.35%		
Bi*	56 ppm		
Co*	11 ppm		
Cu*	0.15%		
F**	178 ppm		
Hg***	280 ppb		
Mo*	10 ppm		
Sb*	<5 ppm		
W****	26 ppm		
Pb*	56 ppm		
Ni*	6 ppm		
Zn*	165 ppm		

*Atomic absorption
**Ion specific electrode
***Cold vapour AA
****Colourimetric

GR 40 - Hornfels with sulphide veins up to 5 centimetres wide, collected from south end of trench.

GR 210 - Hornfels with thin sulphide veins and vuggy quartz veins, collected from north end of trench.

GR 211 - Massive pyrite-arsenopyrite from 12-centimetre-wide sulphide vein, collected from south end of trench.

GEOLOGY OF NO. II OCCURRENCE

The No. II occurrence is seen in a quarried exposure on the east side of the main access road, approximately 50 metres north of the turnoff to Doctors Bay (Fig. 20). Mineralization is localized along the faulted contact between a quartz diorite to the north and structurally underlying fine-grained, massive grey hornfelsic rocks to the south.

The mineralized zone, which is up to 0.7 metres wide and exposed for 20 metres along strike, trends 130 degrees and dips gently (20 to 30 degrees) northward parallel to the faulted margin of the overlying quartz diorite. Mineralization consists mainly of coarse pyrite and arseno-pyrite with abundant light green scorodite ($FeAsO_4 \cdot 2H_2O$). In addition, the zone carries limonite, quartz, sericite, and feldspar. Locally the mineralization is rhythmically zoned and vuggy while elsewhere the sulphides have been extensively leached, producing a pronounced boxwork texture. Remnant coarse crystals of quartz and altered feldspar in these leached areas resemble those in the hangingwall quartz diorite.

Minor normal faults and numerous small fractures striking 160 degrees and dipping 75 degrees east cut and displace the main mineralized zone. Thin mineralized veins in these younger fractures, suggest some late stage remobilization of the sulphides. Gold and silver assays and trace element analyses of sulphide-rich grab samples from the mineralized zone are shown in Table 2.

TABLE 2. TRACE ELEMENT ANALYTICAL RESULTS FROM MINERALIZED GRAB SAMPLES FROM THE NO. II NAGY OCCURRENCE

	GR 213	GR 215
Au*	19.9 ppm	34.6 ppm
Ag*	10.69 ppm	112.6 ppm
As**	>3%	>3%
Bi**	Tr	Tr
Mo**	Tr	Tr
W**	Tr	Tr
Sb**	0.02%	0.02%

*Atomic absorption
**Semiquantitative emission spectroscopy

GR 213 - Sulphide-rich grab sample from northern exposed portion of mineralized zone.

GR 215 - Sulphide-rich grab sample from southern exposed portion of mineralized zone.

Both in hand specimen and thin section the footwall hornfels closely resembles the hornfels that hosts the No. I occurrence. However, at the No. II occurrence they are coarser grained (up to 0.3 millimetres) and contain appreciably more sericite, magnetite, and other opaque minerals; the coarser texture presumably reflects its closer proximity to the quartz diorite pluton. Recognition of vague, remnant clasts under thin section suggests that the hornfels is either thermally metamorphosed tuff or clastic sedimentary rock.

The hangingwall quartz diorite is a massive, coarse-grained rock with crystals varying from 2 to 10 millimetres in diameter. It consists of 15 to 20 per cent hornblende which forms subeuhedral prisms and commonly encloses remnant, corroded augitic cores. Biotite forms 1 to 3 per cent of the rock; some is intergrown with the hornblende. It is partially altered to chlorite. The plagioclase (An_{30-47}) forms well-twinned, zoned crystals with clouded cores and clear margins; many are partially saussuritized. Quartz makes up 1 to 3 per cent of the rock, and sub-euhedral pyrite crystals are recognizable in hand specimen.

The quartz diorite generally has a fresh, homogeneous appearance but immediately adjacent to its faulted contact with the hornfels it is leached and highly fractured. In a highway exposure on the hairpin bend approximately 1.2 kilometres north-northwest of the No. II occurrence, numerous subhorizontal, 7 to 10-centimetre-wide veins of leucocratic biotite quartz diorite cut the pluton. At this locality a steep westerly dipping, north-south-trending fault zone cuts the body. Intense fracturing and alteration over a 5-metre width marks this fault. Gently plunging slickensides (23 degrees toward 200 degrees) suggest some subhorizontal movement.

DISCUSSION

The two most likely explanations concerning the controls and origin of the Nagy gold occurrences are:

(1) The mineralization was genetically related to the quartz diorite intrusion, which explains its spatial association with the hornfelsed margin. If correct, this suggests that the remaining margin of the quartz diorite body and possibly those of other granitoid plutons in the area, particularly where they intrude the Fire Lake or Harrison Lake Groups (Fig. 21), may represent good exploration targets for similar gold-silver mineralization.

(2) Mineralization was preferentially emplaced along the faulted pluton margin during hydrothermal activity which was not necessarily related to the quartz diorite intrusion. The Nagy occurrences lie close to a regional fracture system that is associated with one former gold producer (Providence, MI 92H/NW-30), numerous other gold occurrences, and regional hot spring activity (Fig. 21). Thus, the

Harrison Lake fault system, particularly its northern section where it intersects both granitic plutons and the Fire Lake Group, could represent an interesting exploration target for both higher temperature vein and epithermal, Cinola-type gold mineralization.

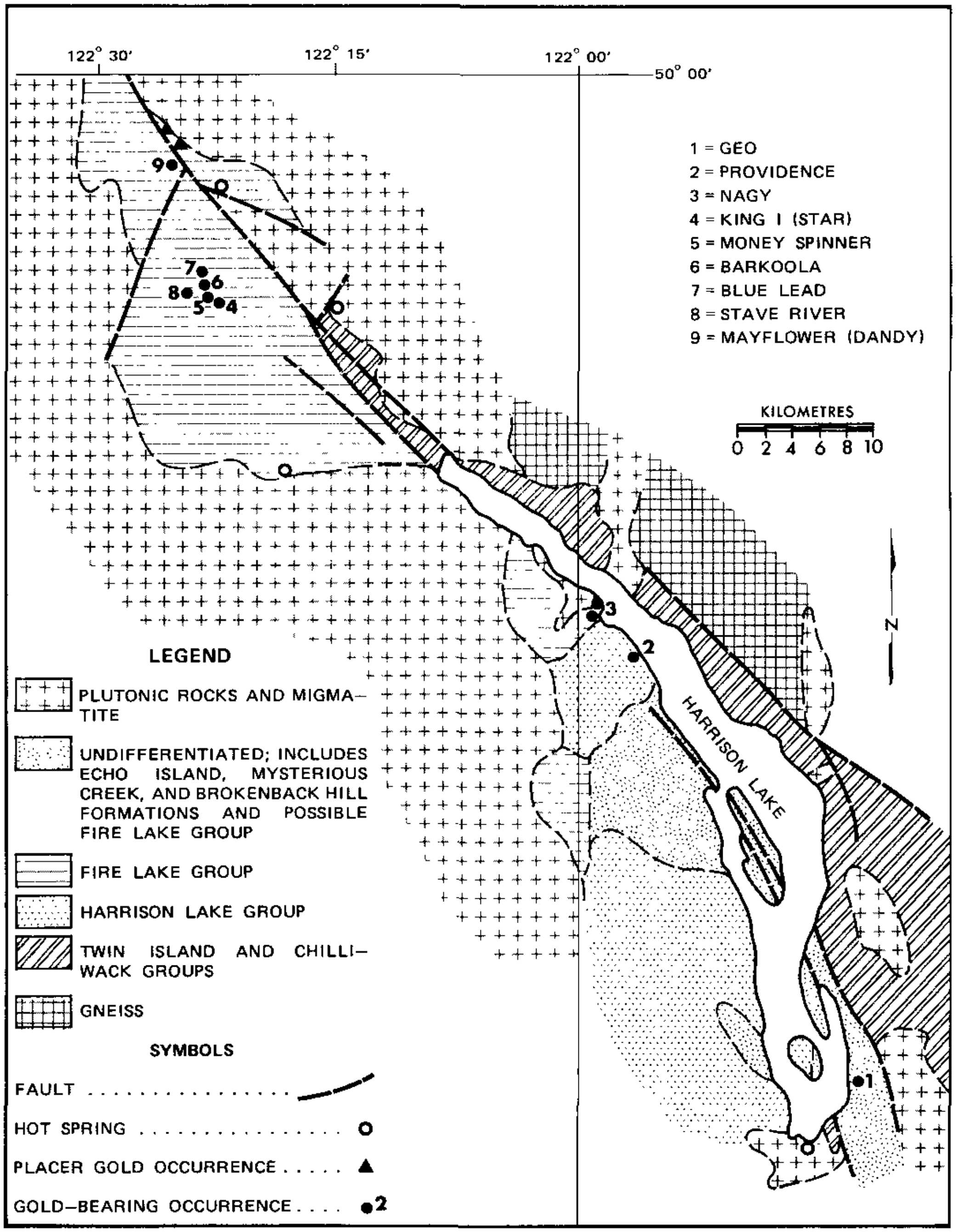


Figure 21. Regional geology of the Harrison Lake fault system showing hot spring and gold occurrences. [Geology adapted after Roddick (1965) and Monger (1970)].

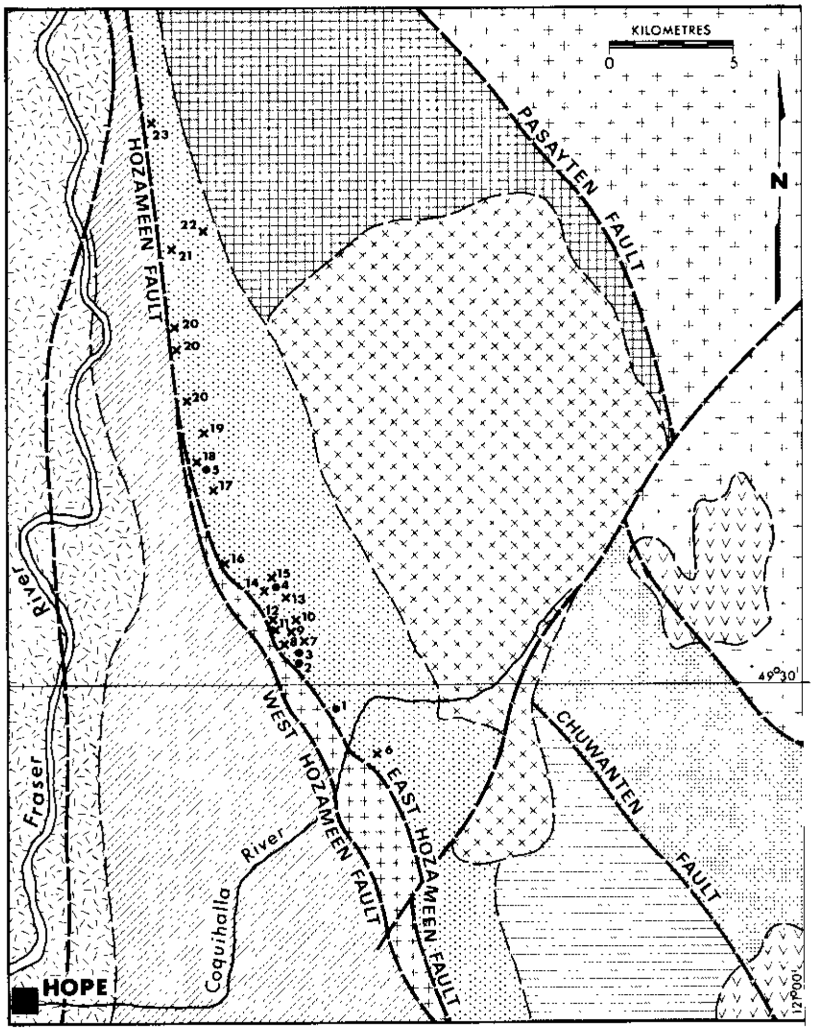
ACKNOWLEDGMENTS

Thanks are extended to George Nagy of Nagyville Mining Ltd. for his assistance and cooperation. Dr. J. Kwong assisted with some X-ray identifications.

REFERENCES

Monger, J.W.H. (1970): Hope Map-Area, West Half (92H W 1/2), British Columbia, *Geol. Surv., Canada,* Paper 69-47, 75 pp.

Roddick, J. A. (1965): Vancouver North, Coquitlam and Pitt Lake Map-Areas, British Columbia, *Geol. Surv., Canada,* Mem. 335, 276 pp.



LEGEND

COQUIHALLA GROUP
NEEDLE PEAK PLUTON
PASAYTEN GROUP
JACKASS MOUNTAIN GROUP
DEWDNEY CREEK GROUP
LADNER GROUP
COQUIHALLA SERPENTINE BELT
FOLIATED GRANODIORITE
HOZAMEEN GROUP
GNEISSES AND GRANITES

● PAST AND PRESENT GOLD PRODUCERS (*SEE* TABLE 2)

1 = EMANCIPATION
2 = AURUM
3 = IDAHO ZONE (CAROLIN MINE)
4 = PIPESTEM
5 = WARD

✖ REPORTED GOLD OCCURRENCES (*SEE* TABLE 3)

6 = BROKEN HILL
7 = SNOWSTORM
8 = MONTANA
9 = RUSH OF THE BULL
10 = GOLDEN CACHE
11 = McMASTER ZONE
12 = MURPHY
13 = GEM
14 = STAR
15 = HOME X
16 = NORM AND GEORGIA 2
17 = EMIGRANT
18 = RODDICK
19 = MARVEL
20 = SPUZ A, B, G AND MONUMENT
21 = MAJESTIC
22 = GOLD COIN
23 = GOLD CORD

Figure 22. Regional setting of the Coquihalla gold belt showing location of gold deposits and occurrences. (Geology adapted after Monger, 1970).

CAROLIN MINE - COQUIHALLA GOLD BELT PROJECT (92H/6, 11)

By G. E. Ray

INTRODUCTION

The second season of fieldwork studying the geology and mineralization of the Coquihalla gold belt was carried out by a two-man field crew. The area studied in 1982 is situated approximately 20 to 25 kilometres northeast of Hope. This work included the following:

(1) Regional geological mapping (scale 1:50 000) of the belt from Mount Snider in the south northward toward Siwash Creek. A third field season's work should complete the regional geological mapping of the gold belt northward to the vicinity of Chapmans Bar.

(2) Geological mapping, at a scale of 1:6000, of an area between Spider Peak and the Coquihalla River. This area contains most of the gold occurrences in the belt, many of the past gold producers, such as the Emancipation, Aurum, and Pipestem, as well as the presently operating Carolin mine.

(3) Detailed surface geological mapping (scale 1:500) over the former Pipestem gold mine (MI 92H/NW-11), together with underground mapping and sampling (scale 1:250) of the lower, most extensive (No. 4) level of the old Pipestem mine workings.

(4) Surface geological mapping and sampling of the 'McMaster zone' gold mineralization, situated approximately 0.5 kilometres southeast of McMaster pond.

(5) Sampling the Home X gold occurrence (MI 92H/NW-13) and the newly discovered 'Murphy occurrence.'

(6) Collection of approximately 80 silt samples from streams draining the belt. These are being assayed for gold, arsenic, chromium, copper, mercury, nickel, lead, antimony, zinc, and cobalt, and this data will be used in conjunction with the results of the 1981 Regional Geochemical Survey (RGS 7) to determine whether any regional geochemical patterns are associated with mineralization in the belt.

REGIONAL GEOLOGY

Gold occurrences in the Coquihalla gold belt are regionally clustered close to the eastern margin of the Coquihalla serpentine belt (Fig. 22). This serpentine belt forms an elongate, north-northwesterly trending, steeply dipping unit separating supracrustal rocks of the Ladner Group in the east from the Hozameen Group in the west (Fig. 22). The serpentine belt reaches its maximum development in the Carolin mine-Coquihalla River area where it exceeds 2 kilometres in width. It gradually narrows to the south and north until in the Boston Bar and Manning Park areas (Monger, 1970; Coates, 1974; Cardinal, 1982) the Hozameen and Ladner Groups are in direct fault contact. Dark, highly sheared to massive serpentinite of probable peridotite parentage (Cairnes, 1929; Table 5) characterizes the belt but it also contains substantial amounts of highly altered gabbro-diabase rocks (Table 7).

The eastern margin of the serpentine belt is sharply delineated by the Hozameen fault which, due to its close spatial association with many gold occurrences, has been mapped and studied in some detail (Cairnes, 1924, 1929; Cochrane, *et al.*, 1974; Anderson, 1976; Cardinal, 1981, 1982; Ray, 1982; Wright, *et al.*, 1982). In contrast, the western margin of the serpentine belt has previously been largely ignored. However, current mapping suggests it too represents a major fracture, which like its eastern counterpart, has had a long and complex history of both vertical and horizontal movements. The eastern boundary fracture is herein termed 'East Hozameen fault;' the hitherto unnamed western tectonic boundary is called the 'West Hozameen fault.' With the gradual disappearance of the serpentine belt both north and south, these boundary fractures merge into a single tectonic feature, the Hozameen fault (Fig. 22).

The Hozameen Group consists largely of cherts, pelites, and altered spilitic basalts (Daly, 1912; Cairnes, 1924; McTaggart and Thompson, 1967; Monger, 1970). Monger (1975) interprets this as an oceanic supracrustal sequence of Triassic or pre-Triassic age. In the map-area the Hozameen Group rocks have been subjected to lower greenschist metamorphism and strong deformation; some parts are overprinted by either a schistosity or an intense, subhorizontal mullion structure. Close to the serpentine belt, Hozameen Group rocks commonly show signs of increased deformation and crushing, minor silicification, late brittle faulting, and pronounced slickensiding. The West Hozameen fault appears to dip steeply east, and serpentinites in the immediate vicinity contain highly sheared talcose rocks and, in rare instances, poor quality nephrite.

The Ladner Group (Cairnes, 1924) comprises a sequence of fine-grained, poorly to well-bedded slaty argillites and siltstones with minor amounts of coarser grained material. These metasedimentary rocks have a weak to intense slaty cleavage and were subjected to at least three periods of regional folding (Table 1). Despite this, Ladner Group rocks give an overall impression of being less deformed than the Hozameen Group, and a wide variety of sedimentary structures are commonly preserved (Ray, 1982). Regional folding has resulted in widespread structural repetition and many sections of the Ladner Group adjacent to the Coquihalla serpentine belt, including those hosting the gold mineralization at Carolin mine (Idaho zone), are structurally inverted (Table 1). Cairnes (1924) considered the thickness of the Ladner Group in the Coquihalla

River-Ladner Creek area to be approximately 2 000 metres, but recognition of widespread structural repetition suggests its true thickness may be considerably less.

The broad stratigraphic sequence recognized within the Ladner Group in the Carolin mine-Ladner Creek area (Ray, 1982) continues further north into the vicinity of the Pipestem mine (Fig. 23). The Ladner Group rests either unconformably or disconformably upon an older volcanic greenstone; its lowermost stratigraphic portion consists of a thin, heterogeneous assortment of coarse clastic, partly volcanogenic sedimentary rocks that pass upward into a thicker sequence of well-bedded siltstones. These are overlain in turn by a thick unit of carbon and iron-rich argillites. The lower clastic unit which hosts the Carolin gold mineralization (Idaho zone) comprises discontinuous wedges of interbedded greywacke, lithic wacke, conglomerate, and possible reworked tuff with intercalated units of argillite and volcanogenic siltstone. The basal portion also includes rare, thin horizons of clastic, impure limestone. The conglomerates contain angular to well-rounded clasts; most are of volcanic origin but there are minor amounts of quartz, jasper, chert, limestone, granite, and gabbroic material. While most of the volcanic pebbles are identical to the underlying greenstone unit, clasts of recrystallized, altered porphyritic and nonporphyritic flow-layered dacites are locally common.

The economically important lower clastic unit shows great variation in thickness along the belt. In most parts it is either thin or absent; for example, near the Emancipation mine it is less than 5 metres thick, while in the vicinity of Carolin mine (Ray, 1982) it is approximately 200 metres thick.

The Ladner Group stratigraphically overlies older greenstones which are traceable discontinuously for more than 15 kilometres along the eastern side of the East Hozameen fault (Fig. 23); in many places it structurally overlies the Ladner Group. The greenstone-Ladner Group contact is commonly marked by faulting and shearing, but in places the sedimentary rocks rest directly on the volcanic rocks with either an unconformable or a disconformable relationship. A local basal conglomerate of variable thickness contains abundant clasts of material clearly derived from the underlying greenstones. Refractive index determinations on fused glass beads and chemical analyses (Table 6) indicate that the greenstones are highly altered andesitic to basaltic volcanic rocks. The greenstones are fine to medium grained and are generally characterized by their massive, homogeneous appearance; some specimens contain randomly orientated, late crystals of stilpnomelane. Many outcrops close to the Ladner Group contact display remnant vesicles, pillow structures, aquagene breccias, and weak layering, while their high sodium content (Table 6) indicates the presence of some spilitic lavas. Rare lenses of immature volcanic sandstone and conglomerate are also seen, while bodies of gabbro-diorite are present within the volcanic unit near Emancipation mine. The age of the volcanic rocks is uncertain and some rare examples of interpillow cherts in the greenstones have been examined for microfossils without

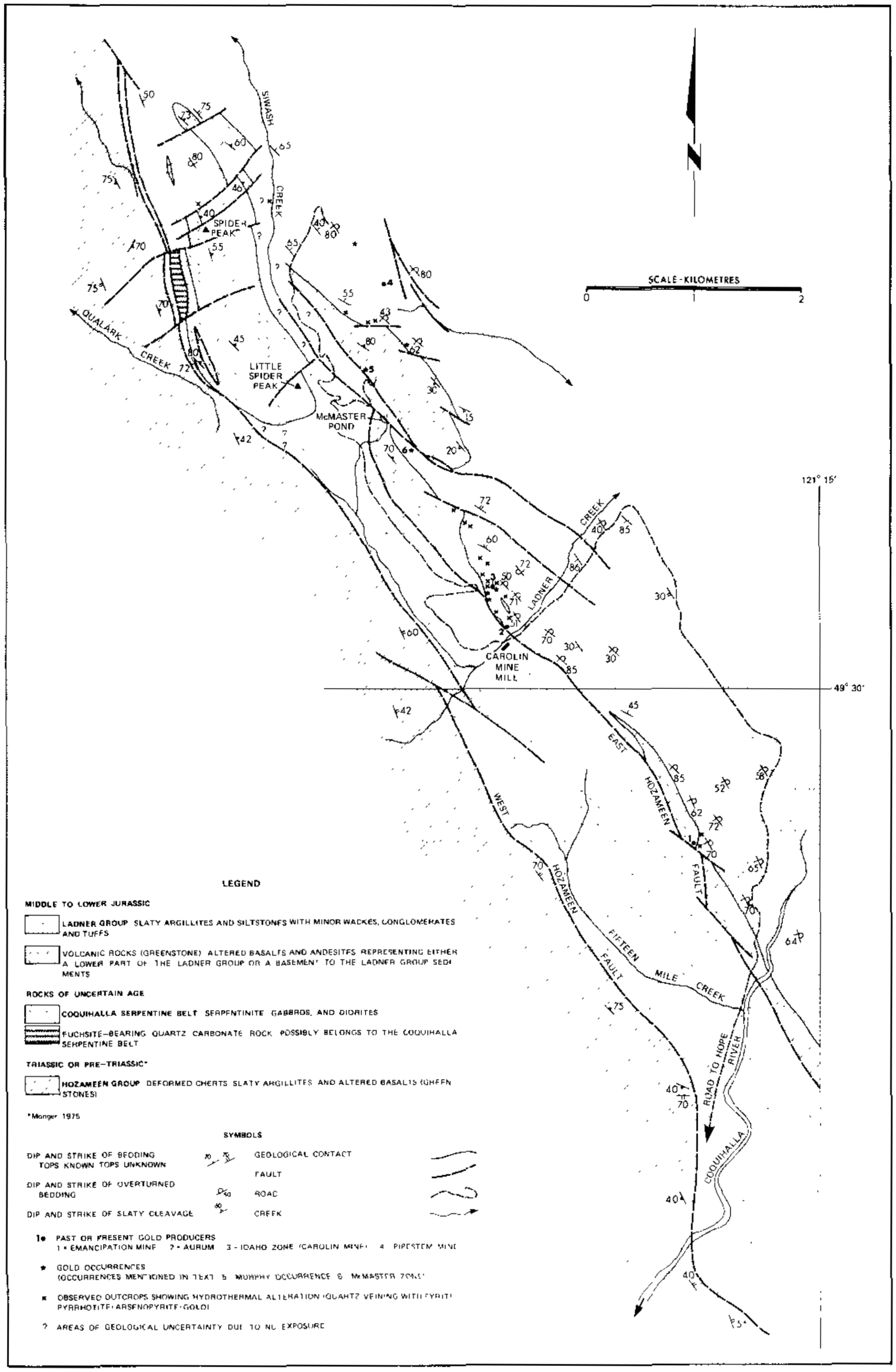


Figure 23. Regional geology of the Carolin-Pipestem-Emancipation gold mines area.

success. However, at one locality east of Serpentine Lake, a 1-metre-wide chert breccia horizon that separates pillowed greenstones from the Ladner Group contains conodonts of Early Triassic age (M. Orchard, personal communication). This horizon probably originated from pre-Ladner weathering and concentration of interpillowed chert breccia material present in the greenstones. This would strongly suggest that the volcanic rocks are Early Triassic in age.

Both the Ladner and Hozameen Groups are cut by a wide variety of intrusive rocks. A distinctive suite of leucocratic quartz porphyry sills is restricted to the Hozameen Group. These sills contain large, rounded phenocrysts of quartz and some rare flakes of biotite, set in a fine to medium-grained quartz-feldspar matrix. The quartz porphyries look fresh but their restriction to the Hozameen Group suggests that they predate the tectonic emplacement of this unit adjacent to the serpentine belt.

The Ladner Group is cut by two main intrusive suites. One forms dykes, sills, and irregular masses up to 300 metres in width that display wide variations in texture and composition. Individual bodies are zoned with gabbroic and ultrabasic cores grading out to granitic contact zones. The other suite forms narrow dykes and sills of feldspar porphyry that are locally syenitic (Bateman, 1911; Cairnes, 1924). Quartz veining with minor pyrite, arsenopyrite, and traces of gold occur in some sills and dykes. Consequently Bateman (1911) and Cairnes (1924, 1929) considered these intrusive rocks to be genetically related to some gold mineralization in the district.

GOLD MINERALIZATION IN THE BELT

GENERAL

The locations of deposits and occurrences comprising the Coquihalla gold belt are shown on Figure 22 and further details are listed in Tables 2 and 3. Most gold production has come from five deposits (Table 2); only the newly opened Carolin Mines Ltd. operation on the Idaho zone is currently being worked. Information on early gold production from the belt, particularly from the Aurum and Ward deposits, is poorly documented and unreliable. Nevertheless, until closure of the Emancipation mine in 1941, approximately 119 000 grams of gold had been won from the belt. Of this, the majority (90 104 grams) came from Emancipation mine, the most southerly deposit in the belt (Fig. 22).

Carolin Mines Ltd. is planning to mill 1 350 tonnes of ore per day, grading 4.2 grams gold per tonne (P. W. Richardson, personal communication). Shortly, one month's production from the Idaho zone is expected to exceed that from the previous 70-year history of the belt.

IDAHO ZONE (CAROLIN MINE)

No futher surface or underground mapping of the Idaho zone was undertaken by the author during the 1982 field season, although laboratory investigation of the ore geochemistry and petrology continued. Hopefully underground mapping by J. T. Shearer and R.J.E. Niels of Carolin Mines Ltd., together with a study of the sulphide distribution in the Idaho zone (Shearer, 1982), will delineate the ore controls and morphology of the deposit. Underground work on the property (R.J.E. Niels, J. T. Shearer, personal communication) indicates that the Idaho zone consists of at least two major orebodies; a lower (No. 1 orebody), and an upper (No. 2 orebody), separated by highly sheared and faulted carbonaceous argillites. The upper orebody crops out just north of the old Idaho adit (Ray, 1982) and was discovered during the initial surface exploration. A rusty-weathering, 13-metre-wide zone assaying up to 4 800 ppb gold outcropping approximately 160 metres south-southeast of the old Idaho adit, may be the surface expression of the lower orebody. Comparative analyses on mineralized and unmineralized wackes in the Idaho zone (Table 4) suggest that mineralization was accompanied by the introduction of silica, sodium and sulphur, the removal of magnesium, potassium, calcium and carbon dioxide, and the conversion of ferrous to ferric iron. Introduction of sodium resulted in the formation of abundant white albite (An_{3-5}) in the ore zone. Trace element analyses (Table 4) show that the the Idaho zone is weakly to strongly anomalous in copper, arsenic, molybdenum, antimony, and tungsten.

Shearer (1982), in a study on the sulphide distribution within the Idaho zone, made the following observations:

(1) Mineralized samples from the zone are separable into pyrite dominant and pyrrhotite dominant types. Consequently, the deposit may be zoned.

(2) Small grains of gold, up to 0.02 millimetre in size, occur either as inclusions within pyrite and arsenopyrite or as rims on pyrite and chalcopyrite.

(3) Small grains of free gold, apparently spatially independent of sulphides, are present inside some quartz, calcite, and feldspar crystals.

These observations explain how samples 25163M and 25164M (Table 4), which are arsenopyrite rich and arsenopyrite poor respectively, could both contain high gold values. They also suggest that economical gold mineralization is possible in sulphide-poor parts of the Idaho zone. Thus, while arsenic is a pathfinder for gold exploration in parts of the belt, gold could also occur without arsenic geochemical anomalies.

Examination of thin and polished sections from the Idaho zone reveals a complex history of mineralization, alteration, and structural deformation. The mineralized wackes consist largely of quartz, albite-oligoclase, and calcite with lesser amounts of chlorite, sericite, and opaque minerals. These opaques, which make up between 1 and 15 per cent of the rock by volume, are mainly pyrrhotite, arsenopyrite, pyrite, and magnetite. Less common opaques, in decreasing abundance, include chalcopyrite, bornite, and gold (Kayira, 1975). Ore specimens are characterized by coarse, subhedral crystals of pyrite and arsenopyrite with finer grained disseminations and clusters of pyrrhotite, magnetite, and pyrite. The magnetite shows no spatial association with sulphides and is the oldest opaque mineral present in the ore. Arsenopyrite also appears to have been introduced early because some crystals are partly rimmed with small blebs of pyrite and pyrrhotite.

The Idaho zone is characterized by a closely spaced, irregular network of white vein material, representing the injection of many generations of quartz, calcite, and albite. The development of sigmoidal gash fractures and the wide variation in vein deformation, from highly folded to apparently undeformed, suggests that the multistage injection occurred during a long period of recurrent structural deformation. White quartz veins, generally less than 15 centimetres wide, comprise the commonest vein material on megascopic scale. At least three generations are recognized and all appear to postdate the main period of gold-sulphide mineralization. Many veins are monomineralic but in others the quartz crystals are intergrown with variable amounts of calcite, albite, and clinozoisite; in rare instances there are small flakes of pyrobitumen. Some quartz veins that cut and postdate the main F_2 slaty cleavage (*see* Table 1) are seen under thin section to be folded and contain strained quartz crystals that are elongated parallel to both the F_2 fold axial planes and the slaty cleavage. These veins are interpreted to be of syn-F_2 age, being injected after the main cleavage development, but before that period of deformation had ceased. Larger quartz crystals in these veins display finely sutured margins suggesting crystallization during strain (Spry, 1969).

While quartz veining is ubiquitous in the Idaho zone, calcite veining is far less abundant and tends to be localized. The calcite veins appear to postdate all other veining episodes and show no evidence of folding. However, minor faulting has occurred along some and in thin section many calcite crystals exhibit deformed twin planes.

On the megascopic scale, albite veining is less evident than either quartz or calcite. However, in thin section the effects of sodium metasomation are reflected by at least three generations of albitization. Disseminated and partially altered albite-oligoclase (An_{3-15}) crystals make up a significant proportion of the fine-grained ore groundmass and represent the oldest generation of albitic material. This disseminated albitic groundmass is cut by numerous thin, folded veins of poorly twinned second generation albite. The youngest material generally forms veinlets and disseminated masses throughout the ore zone. It consists of coarse, well-twinned albite crystals (An_{3-5})* up to 8 millimetres in length with locally deformed twin planes. Locally, small angular fragments of sulphide-rich ore are entirely engulfed in this third generation albitic material.

Pyritic argillites with abundant quartz veining occur within and adjacent to the Idaho zone but these rocks generally contain no gold (R.J.E. Niels, personal communication). Abundant minute carbonaceous lenticules

*Identified by X-ray diffraction using a method described by Bambauer, *et al.*, 1967.

are seen under thin section. They are elongated parallel to the F_2 chlorite-sericite cleavage (Table 1). These argillites have preferentially taken up strain and are cut by many fault planes that are smeared with carbonaceous material and marked by slickensiding. X-ray examination shows that the carbonaceous material in both the fault planes and argillites is amorphous; thus the regional metamorphic grade was too low to produce crystalline graphite.

In rare instances, white quartz veins contain small flakes of pyrobitumen whose optical and physical characteristics suggest it has acquired a maturation equivalent to meta-anthracite (J. Kwong, personal communication). These pyrobitumen flakes are believed to represent original amorphous carbonaceous material derived from the wallrocks and metamorphosed during the quartz vein injection. Since meta-anthracite forms between 238 and 266 degrees Celsius at an equivalent pressure of about 0.2 GPa (Brownlow, 1979), its presence may indicate the approximate temperature pressure range attained in the Idaho zone.

MURPHY GOLD OCCURRENCE

The Murphy gold occurrence is located approximately 400 metres north-northwest of McMaster pond (Fig. 23). It was discovered in 1982 by prospector D. Murphy, while investigating a soil geochemical gold anomaly outlined by Carolin Mines Ltd. The mineralization consists of fine gold with pyrite and arsenopyrite in a quartz vein between 5 and 20 centimetres in width. The vein can be traced discontinuously for 20 metres within altered greenstones immediately adjacent to their faulted contact with highly sheared talcose serpentinites. This fracture zone represents the steeply dipping East Hozameen fault; the quartz vein, however, dips very gently northeastward into the hillside. The dark brick red soil over the occurrence contains pannable gold.

The mineralized white quartz vein contains small vugs lined with clear quartz crystals, and the sulphides are visually estimated to form less than 2 per cent by volume. Gold is most commonly seen as a fine coating on chocolate brown alteration products; the latter contains a mixture of goethite, hematite, and lepidocrocite with some remnant pyrite. Elsewhere, fine gold is associated with both pyrite and arsenopyrite and, in rare instances, it is free in the quartz. Both gold and sulphides occur at the vein margins and vein centres.

SILT GEOCHEMISTRY

Approximately 80 silt samples were collected from streams within the mapped area; these have been assayed for gold, arsenic, chromium, copper, mercury, nickel, lead, antimony, zinc, and cobalt. No statistical analysis of the data has been made yet, but the following points are noted:

(1) Tangent Creek, which drains the old Emancipation mine, is the only stream with marked arsenic and mercury anomalies (152 ppm and 180 ppb respectively).

(2) Some streams draining the serpentine belt are highly anomalous in chromium and nickel (up to 0.11 per cent and 0.14 per cent respectively).

(3) Many streams draining the eastern side of Ladner Creek Valley are weakly to moderately anomalous in zinc (up to 287 ppm). These streams drain the Needle Peak pluton and its wide thermal metamorphic aureole in the Ladner Group.

(4) No anomalous cobalt or antimony values were recorded.

(5) One large stream flowing southwestward from Mount Snider into Sowaqua Creek contains anomalous lead (58 ppm) and zinc (606 ppm). This raises the possibility that the stream drainage basin is underlain by lead-zinc-silver veins, similar to those found around Treasure Mountain 10 kilometres further west.

DISCUSSION

DEPOSITIONAL ENVIRONMENT AND STRATIGRAPHY OF THE LADNER GROUP

Overall, the Ladner Group is an upward fining succession. It passes from a thin, heterogeneous, coarsely clastic unit at the base into a much thicker sequence of finely bedded siltstones and argillites. The lowermost unit includes discontinuous wedges of coarse, poorly sorted material interbedded with lesser amounts of finer sediment. This implies rapidly alternating periods of low and high energy deposition, the latter involving high density turbidites and chaotic slumping. The extreme variation in thickness and character of the lower clastic unit suggests that either rapid lateral facies changes existed or that the marine transgression took place across an irregular basement topography. Overturned flame structures in some basal beds indicate an easterly derivation, while the assorted pebble lithologies show a source underlain by greenstones, granitic and gabbroic rocks, flow-banded acid to intermediate volcanic rocks, and some limestones.

The finely bedded siltstones and argillites comprising the higher portion of the Ladner Group succession (Ray, 1982) are believed to represent DE turbidites (Bouma, 1962) deposited in a low energy, deeper water environment. In parts, this sequence contains thin, impersistent horizons of coarse wacke which reflect the periodic influx of higher energy turbidite sediments. One such wacke horizon is traceable for 900 metres and hosts the gold mineralization at Pipestem mine. It also contains belemnites and bivalves, the only Ladner Group fossils seen in the district.

GREENSTONES

The greenstones are generally massive but adjacent to the Ladner Group contact there are aquagene breccias and vesicular pillowed basalts, while further west, adjacent to the East Hozameen fault, the unit includes bodies of gabbro-diorite (Fig. 24A). These bodies may have formed feeders to the overlying lavas and thus the present westerly progression from submarine extrusive basalts to plutonic gabbros could reflect a gradation from near surface to deeper levels.

The Ladner Group-greenstone contact is believed to represent an unconformity. This is tentatively supported by microfossil evidence and by the presence of both greenstone and gabbroic clasts in the basal Ladner Group conglomerates. These suggest that the Lower Triassic volcanic pile was deeply eroded prior to the onset of Lower Jurassic (Coates, 1974) Ladner Group sedimentation.

EVOLUTION OF THE COQUIHALLA SERPENTINE BELT

Extensive serpentine belts throughout the world are believed to represent either oceanic crust or upper mantle material that was emplaced either as low temperature, plastic intrusions along vertical fractures or as slices in allochthonous thrusts formed during major orogenic plate movements. Serpentine belts are generally associated with fundamental fractures that are believed to mark major crustal boundaries (Shackleton, 1976). The Coquihalla serpentine belt separates two important geological units, the Hozameen and Ladner Groups, that are of different age and contrasting character. It is bounded by major fractures that are interpreted to be refolded thrust faults. Field and laboratory data explaining the origin and development of the Coquihalla serpentine belt is preliminary and inconclusive; consequently two alternative models are presented (Figs. 24B and 24C). The serpentine belt may represent obducted oceanic crust (Ray, 1982; Fig. 24B) which originally underlay, and formed a basement to, the Hozameen Group. In this model both allochthonous units were emplaced by easterly directed overthrusting that caused tectonic inversion in some parts of the Ladner Group (Fig. 24B). This model suggests that the main overthrusting occurred along the East Hozameen fault, and that the serpentinites and greenstones are unrelated. However, this obduction model is difficult to reconcile with the plate tectonic models proposed by Monger, *et al.* (1972) and Monger (1977) to explain the formation of the Canadian Cordillera. Furthermore, X-ray and thin section examination of rocks immediately adjacent to the East Hozameen fault reveals no high temperature minerals like those found in the thin, basal aureoles underlying many obducted, Alpine-type ophiolite complexes (Williams and Smyth, 1973).

An alternative proposal (Fig. 24C) is that the serpentinites and greenstones are related, and represent lower and upper oceanic crustal material which originally underlay and acted as basement to the Ladner Group. Structural inversion of these units took place during easterly

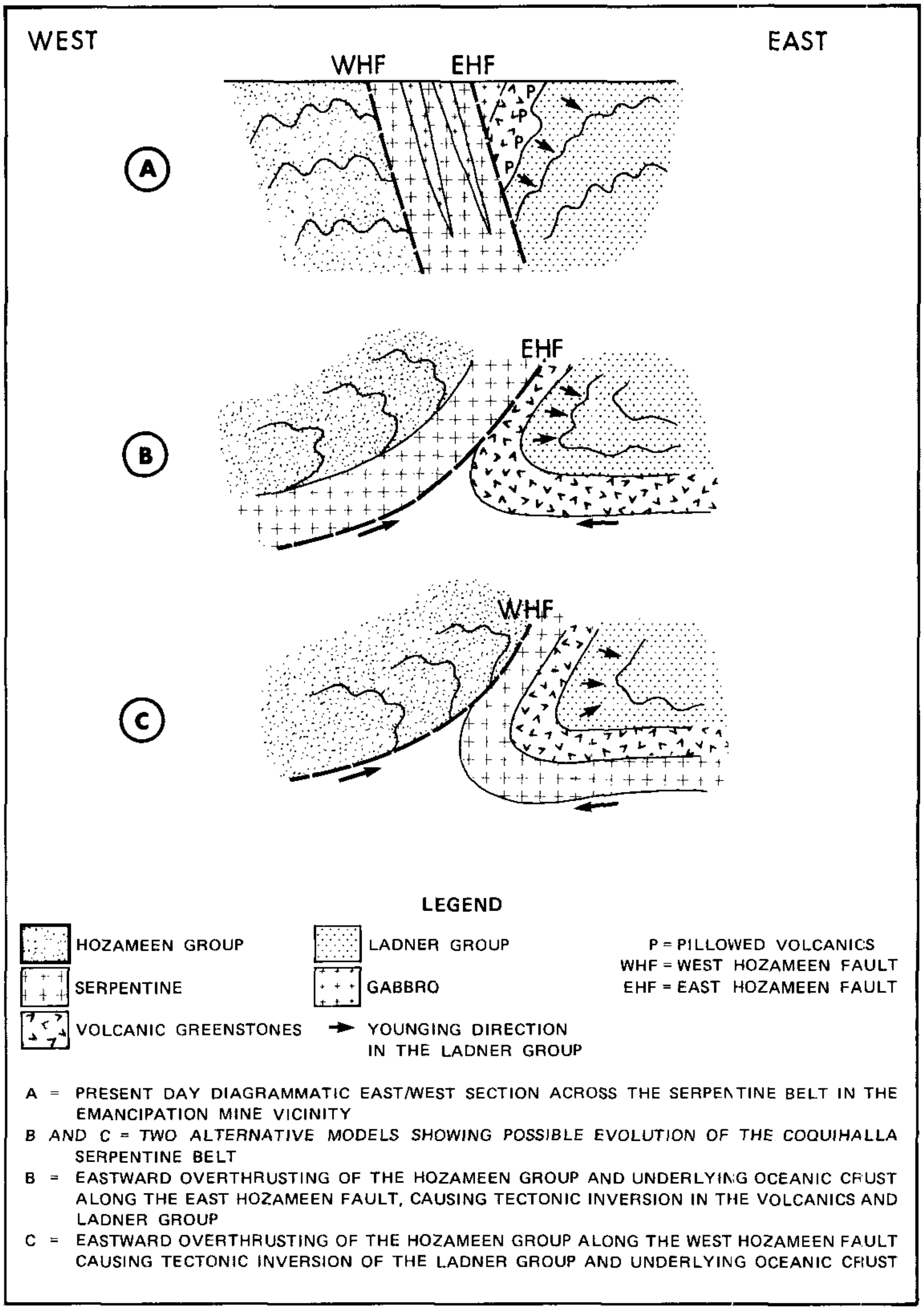


Figure 24. Evolution of the Coquihalla serpentine belt.

overriding of the Hozameen Group but the main movement in this model took place along the West Hozameen fault. The Ladner Group, the greenstones, and the serpentinite-gabbro belt could represent respectively the classical oceanic layers 1, 2, and 3 (Cann, 1974) although no sheeted dykes are recognized in the Coquihalla belt.

Different tectonic relationships are implied in these two models, but in both, the Ladner Group is interpreted to be deposited on oceanic crust, and the Hozameen Group is viewed as allochthonous. However, interpretation is complicated by accompanying right lateral transcurrent movements along the Hozameen fault system, similar to that described in other major strike-slip faults in the Canadian Cordillera (for example, Templeman-Kluit, 1977; Monger, 1977) and by subsequent deformation and refolding.

GOLD MINERALIZATION

An overall examination of deposits and occurrences in the Coquihalla gold belt (Fig. 22; Tables 2 and 3) reveals the following features:

(1) Coquihalla gold belt mineralization is proximal to greenstones, fault-bounded serpentinites, and small outcrops of fuchsite-bearing quartz carbonate rock. These associations are similar to that seen at the Bralorne-Pioneer mines (Cairnes, 1937; Joubin, 1948), the Cassiar gold camp (Panteleyev and Diakow, 1982), and the Mother Lode belt of California (as noted by Cairnes, 1929).

(2) The occurrences and deposits, with the possible exception of the Norm and Georgia 2 occurrences whose precise locations are uncertain, are situated east of the East Hozameen fault (Fig. 22).

(3) The gold is generally fine grained; coarse visible gold is relatively uncommon throughout the belt (a noted exception is the Aurum mineralization).

(4) All gold mineralization in the belt is in highly fractured host rocks. It was accompanied by the introduction of silica which forms either discreet, generally narrow quartz veins (Emancipation mine, Murphy occurrence, Monument vein) or wider zones of intense network veining and diffuse silicification (Idaho and McMaster zones).

(5) Gold throughout the belt is associated with varying degrees of sulphide mineralization (*see* Ray, 1981). These sulphides include pyrite, arsenopyrite, pyrrhotite, and chalcopyrite.

(6) Gold mineralization occurs in a wide variety of fractured host rock types that includes greenstone (Emancipation mine and Murphy occurrence), felsite porphyry sills (Ward and Emigrant), and metasedimentary rocks of the Ladner Group (Idaho and McMaster zones, Pipestem, Rush of the Bull, Gem, Golden Cache, Home X, and the Spuz

occurrences). However, these host rocks share a common characteristic -- *they are more competent than the surrounding country rock.* Consequently they were brittle and subject to open space fracturing. Gold mineralization in the belt is therefore preferentially hosted either within the wackes and felsite sills or in fault zones between competent and incompetent units, like those separating greenstones from metasedimentary rocks.

(7) Studies are incomplete, but few occurrences in the belt, including the Idaho zone, show enrichment in mercury. However, Tangent Creek, which drains the Emancipation mine, has anomalous mercury silt values (up to 180 ppb mercury) which suggests a gold-mercury association in this deposit.

(8) Gold mineralization in the Spuz occurrence and at the Idaho zone is associated with weak tungsten geochemical anomalies.

(9) The source of the Idaho zone gold mineralization is uncertain. However, the introduction of sodium, which is probably derived from the nearby spilitic volcanic rocks, suggests that the greenstones could represent the source of the gold.

Weathered, gold-bearing outcrops of the Idaho and McMaster zones are characterized by black manganese oxide and rusty staining, together with sulphide mineralization and a dense network of quartz veins. However, many other similarly mineralized quartz veined outcrops exist throughout the belt, particularly north of the Aurum deposit (Fig. 23) where the lower clastic unit of the Ladner Group is best developed. A few carry gold but most appear barren and there is no reliable field method for distinguishing these two, although outcrops with chalcopyrite tend to carry gold also. Future studies may reveal zoning patterns, raising a possibility that some of these barren sulphide-bearing, quartz veined outcrops could pass into gold-bearing ore at depth.

The temperature of mineralization in the Idaho zone is uncertain. However, the stability data for meta-anthracite from the Idaho zone quartz veins suggest temperatures of 250 degrees Celsius were attained. This lies within the temperature range established by fluid inclusion studies for many vein-type deposits (Spooner, 1981).

ACKNOWLEDGMENTS

The author wishes to thank the management and staff of Carolin Mines Ltd. and Aquarius Resources Ltd. for their active cooperation and encouragement during this project, particularly D. G. Cardinal, K. Collins, C. Hrkac, R.J.E. Niels, P. W. Richardson, and J. T. Shearer. Thanks are also expressed to M. Orchard of the Geological Survey of Canada for the preparation and identification of microfossil material and to the staff of the B.C. Ministry of Energy, Mines and Petroleum Resources Laboratory for analytical and X-ray work. W. J. McMillan and T. Höy edited the manuscript. The fieldwork was helped by the continued excellent performance of Patrick Desjardins as field assistant.

TABLE 1. STRUCTURAL HISTORY OF THE CAROLIN MINE AREA

	Late faulting.
F_4	Sporadically developed, minor conjugate folds associated with kink banding and crenulation cleavage.
F_3	Major asymmetric folding of the Ladner Group. Folds have subhorizontal axes with southeast-striking axial planes that dip steeply northeast. No associated metamorphic axial planar fabric recognized.
F_2	Major disharmonic folds having subvertical, southeast-striking axial planes and gently plunging axes. It is associated with the regional axial planar slaty cleavage and mineral lineation in the Ladner Group. Major disruption and quartz veining along some fold limbs and axial planes.
F_1	Widespread structural inversion of the Ladner Group and greenstones, related to the easterly overthrusting of the allochthonous Hozameen Group. No associated axial planar fabric recognized.
Early to Middle Jurassic ? (Coates, 1974)	Deposition of the Ladner Group sedimentary rocks.
	- Unconformity -
Early Triassic ?	Submarine volcanism with extrusion of pillowed basalts (greenstones).

TABLE 2. MAJOR GOLD PRODUCERS IN THE COQUIHALLA GOLD BELT (see Fig. 22)

No. on Fig. 22	Name of Mine	Year(s) of Production	Total Production (g) Au	Ag	Sources
1	Emancipation	1916-1941	90 104	18 818	1
2	Aurum	1930-1932 1939-1942	16 578	3 017	1
3	Idaho zone (Carolin mine)	1981-1982	253 216	Not reported	2
4	Pipestem	1935-1937	8 460	1 151	1
5	Ward	1905	4 199	Not reported	1

Sources
1 B.C. Mineral Inventory File.
2 Gold shipped up to December 31, 1982; P. W. Richardson, personal communication.

TABLE 3. REPORTED GOLD OCCURRENCES IN THE COQUIHALLA GOLD BELT (see Fig. 22)

No. on Fig. 22	Name	Details	Sources
6	Broken Hill	Single quartz vein up to 3 metres wide and 60 metres long in Ladner Group slates close to their contact with greenstones. Uncertain gold values with pyrite, arsenopyrite and rare galena.	1
7	Snowstorm (Pittsburg)	Twelve-metre-long adit along mineralized zone between Ladner Group and volcanic greenstones. Quartz vein up to 3 metres wide with pyrite, arsenopyrite, pyrrhotite, and gold. Cairnes (1924) reports gold values of up to $8.00 per ton.	1, 2
8	Montana	Gold and pyrite-bearing, 5-centimetre-wide quartz veins in greenstones close to contact with Ladner Group.	1
9	Rush of the Bull	Two narrow (10-centimetre) quartz veins, mineralized with coarse arsenopyrite and free gold. Veins cut Ladner Group slates near their contact with a feldspar porphyry sill.	2
10	Golden Cache	At least six narrow quartz veins sparingly mineralized with pyrite-arsenopyrite and low gold values. Veins believed to lie close to the Ladner Group-volcanic greenstone contact.	2
11	McMaster zone	Network quartz veining with pyrite, arsenopyrite, and gold, hosted in highly fractured, Ladner Group wackes and siltstones close to their contact with greenstones. Mineralization and network veining closely resembles that in the Idaho zone.	15
12	Murphy	Visible gold with pyrite and arsenopyrite hosted in a thin, vuggy quartz vein cutting greenstone close to their faulted contact with serpentinite.	15
13	Gem	Two-metre-wide quartz vein within Ladner Group. Both vein and wallrock show sparse pyrite-arsenopyrite mineralization with pannable gold.	2
14	Star	Quartz stringers up to 15 centimetres wide cutting Ladner Group rocks, carry pyrite, arsenopyrite, and low gold values.	12
15	Home X	Numerous thin quartz stringers containing pyrite, arsenopyrite, and low gold values. Veins cut black slates of the Ladner Group close to their contact with a fossiliferous wacke horizon. A collapsed adit of unknown length is on property.	3, 15

TABLE 3. REPORTED GOLD OCCURRENCES IN THE COQUIHALLA GOLD BELT (Continued)

No. on Fig. 22	Name	Details	Sources
16	Georgia 2	Precise location uncertain. Pyrite, arsenopyrite, and gold within faulted diorites (probably part of greenstone package). Some confusion over gold values. Cairnes (1929) reports 2.5 tons of ore gave $9.00 per ton gold.	4, 15
16	Norm	Claims are in the vicinity of Georgia 2 occurrence near Spider Peak. Gold geochemical anomalies and pannable gold from quartz-veined, mariposite-fuchsite-bearing rocks.	5, 15
17	Emigrant	Minor gold in quartz veins associated with felsic porphyry sills intruding the Ladner Group slates.	6
18	Roddick	No geological description available. In 1901 adits and crosscuts 106 metres in length were driven through material valued at $15.00 to $25.00 per ton gold.	7
19	Marvel	No geological description available. In 1906 existing adits were extended and a six-stamp mill installed.	7
20	Spuz A, B, G, and Monument	Weak gold mineralization in quartz veins and silicified zones within the Ladner Group close to the Hozameen fault. One major vein, the Monument, is up to 2 metres wide and traceable for 80 meters. It carries pyrite, with rare arsenopyrite, chalcopyrite, and gold. Gold also found associated with rare scheelite in felsic porphyry sills.	9, 10, 15
21	Majestic	No geological description available.	11
22	Gold Coin	No geological description available.	13
23	Gold Cord	No geological description available.	14

Sources

1 Cairnes, 1920.
2 Cairnes, 1924.
3 Minister of Mines, B.C., Annual Report, 1933.
4 Cairnes, 1929.
5 B.C. Ministry of Energy, Mines & Pet. Res., Exploration in B.C., 1978.
6 Bateman, 1911.
7 B.C. Mineral Inventory File, MI 92H/NW-17.
8 Minister of Mines, B.C., Annual Report, 1906.
9 Cochrane and Littlejohn, 1978.
10 Cardinal, 1982.
11 B.C. Mineral Inventory File, MI 92H/NW-33.
12 B.C. Mineral Inventory File, MI 92H/NW-14.
13 B.C. Mineral Inventory File, MI 92H/NW-32.
14 B.C. Mineral Inventory File, MI 92H/NW-31.
15 Observed by author.

TABLE 4. WHOLE ROCK AND TRACE ELEMENT ANALYSES. A COMPARISON BETWEEN MINERALIZED AND UNMINERALIZED WACKES FROM THE IDAHO ZONE (CAROLIN MINE)

	25163M[1]	25164M[1]	25167M[1]	25168M[2]
SiO_2	55.20	60.62	53.11	48.92
Al_2O_3	12.64	15.42	14.51	14.05
Fe_2O_3	7.11	0.45	1.20	0.22
FeO	2.39	3.89	7.94	6.26
MgO	0.82	0.68	1.16	3.30
CaO	2.66	2.37	4.49	9.07
Na_2O	7.49	9.09	7.81	2.45
K_2O	0.05	0.09	0.30	2.84
TiO_2	0.33	1.00	1.22	0.83
MnO	0.06	0.07	0.11	0.13
CO_2	2.08	2.78	3.46	6.85
S	3.84	1.91	3.41	0.12
Au ppm	17.5	16.0	3.5	<1
Ag ppm	<10	<10	<10	<10
As	6.23	0.46	1.18	0.007
Cu ppm	89	81	161	49
Hg ppb	72	112	78	76
Sb ppm	185	13	<10	<10
Mo ppm	75	20	<2	<2
W ppm	8	19	13	<2
Cr ppm	16	24	29	22
Ba ppm	<100	<100	155	1 184
Ni ppm	14	12	18	8
Pb ppm	21	15	15	16
Sn ppm	<1	<1	<1	<1
Co ppm	19	13	20	15

In per cent except as noted.

[1]Sulphide-rich wackes in Idaho zone showing albite metasomatism and abundant quartz veining.
[2]Unmineralized wackes adjacent to the Idaho zone. Some quartz veining but no sulphides or albitic alteration.

TABLE 5. WHOLE ROCK AND TRACE ELEMENT ANALYSES OF VARIOUS SERPENTINITE SAMPLES FROM THE COQUIHALLA SERPENTINE BELT AND ELSEWHERE

	25478[1]	25479[2]	25482[3]	25486[4]	A	B
SiO_2	39.41	36.30	41.15	35.40	40.7	41.7
Al_2O_3	1.15	5.99	0.32	0.59	1.0	0.8
MgO	38.29	36.20	39.41	37.26	36.4	38.5
CaO	0.14	0.05	<0.01	0.18	0.1	0.4
Na_2O	<0.06	<0.06	<0.06	<0.06	N.D.	N.D.
K_2O	<0.01	<0.01	<0.01	<0.01	N.D.	N.D.
TiO_2	0.03	0.42	<0.01	0.04	N.D.	N.D.
MnO	0.09	0.20	0.069	0.16	N.D.	N.D.
$+H_2O$	12.0	12.2	12.3	10.5	12.4	11.0
$-H_2O$	0.79	0.60	0.57	0.62	N.D.	N.D.
CO_2	0.10	0.1	0.01	6.20	0.2	0.0
P_2O_5	0.08	0.08	0.08	0.08	N.D.	N.D.
FeO	1.08	3.00	1.03	3.49	1.2	2.1
Fe_2O_3	5.73	4.27	4.23	5.47	6.6	4.1
S	0.02	0.03	0.16	0.12		
SrO ppm	<3	<3	<3	8		
BaO ppm	3	7	6	11		
Zr ppm	7	30	5	20		
Y ppm	<3	7	<3	<3		
Co ppm	59	55	58	74		
Cr	0.15	0.24	0.18	0.10		
Cu ppm	8	100	8	16		
Mo ppm	<3	<3	<3	3		
Ni	0.24	0.14	0.27	0.24		
Pb ppm	12	12	10	12		
Au ppb	<20	<20	<20	<20		
Ag ppm	<0.5	<0.5	<0.5	<0.5		
Sb ppm	<10	<10	<10	22		
Zn ppm	50	59	28	66		
As ppm	51	45	45	75		

In per cent except as noted.

[1]Antigorite-bastite-rich serpentinite with some remnant enstatite. Coquihalla serpentine belt.
[2]Antigorite-rich serpentinite. Coquihalla serpentine belt.
[3]Antigorite-rich serpentinite. Coquihalla serpentine belt.
[4]Serpentine with antigorite pseudomorphs after olivine. Coquihalla serpentine belt.

A Serpentinite derived from dunite. Cornwall, England (Pirsson and Knopf, 1966).

B Serpentinite derived from pyroxenite. Mount Diablo, California (Pirsson and Knopf, 1966).

TABLE 6. WHOLE ROCK AND TRACE ELEMENT ANALYSES OF VARIOUS VOLCANIC GREENSTONE SAMPLES

	25465[1]	25466[2]	25470[3]	25472[4]
SiO_2	50.77	50.16	48.58	46.26
Al_2O_3	14.48	13.77	14.81	13.27
MgO	6.24	3.16	7.33	6.60
CaO	6.97	7.86	6.86	7.40
Na_2O	5.46	7.20	4.58	3.51
K_2	0.42	0.02	0.06	0.69
TiO_2	1.53	1.27	1.78	1.81
MnO	0.19	0.19	0.19	0.17
$+H_2O$	2.47	1.17	3.34	4.14
$-H_2O$	0.99	0.10	0.20	0.25
CO_2	0.85	6.90	0.01	4.90
P_2O_5	<0.08	<0.08	<0.08	<0.08
S	0.01	2.60	0.11	0.04
FeO	7.31	3.09	10.10	8.84
Fe_2O_3	1.69	2.60	1.78	0.64
SrO	0.03	0.03	0.01	0.02
BaO	0.007	0.005	0.006	0.007
Zr ppm	50	40	90	70
Y ppm	30	22	38	30
Co ppm	21	20	25	23
Cr ppm	95	14	21	59
Cu ppm	22	37	53	30
Mo ppm	<3	32	<3	<3
Ni ppm	54	26	31	39
Pb ppm	8	17	12	12
Au ppb	<20	33	<20	<20
Ag ppm	<0.5	<0.5	<0.5	<0.5
Sb ppm	<10	<10	13	10
Zn ppm	72	22	98	103
As ppm	<15	48	15	39

In per cent except as noted.

[1]Augite-bearing pillowed greenstone. East of Serpentine Lake.

[2]Sulphide-bearing, carbonate veined greenstone. Emancipation mine.

[3]Augite-bearing altered volcanic greenstone showing aquagene brecciation. Carolin mine.

[4]Altered greenstone volcanic. Drill core sample. South of Pipestem mine.

TABLE 7. WHOLE ROCK AND TRACE ELEMENT ANALYSIS OF GABBROIC ROCKS WITHIN THE COQUIHALLA SERPENTINE BELT

	25481[1]	25483[2]
SiO_2	50.19	48.73
Al_2O_3	13.15	14.44
MgO	7.16	6.92
CaO	9.66	11.09
Na_2O	4.09	3.60
K_2O	0.05	0.12
TiO_2	1.66	1.37
MnO	0.19	0.18
$+H_2O$	12.2	0.16
$-H_2O$	0.18	0.12
CO_2	0.10	0.14
P_2O_5	0.08	0.08
S	0.15	0.03
FeO	9.03	8.25
Fe_2O_3	1.31	1.21
SrO	0.05	0.06
BaO ppm	21	33
Zr ppm	80	66
Y ppm	24	24
Co ppm	26	26
Cr ppm	70	57
Cu ppm	30	71
Mo ppm	<3	<3
Ni ppm	53	56
Pb ppm	8	10
Au ppb	<20	<20
Ag ppm	<0.5	<0.5
Sb ppm	16	12
Zn ppm	102	86
As ppm	<15	15

In per cent except as noted.

[1]Altered augite-hornblende gabbro. 15 mile Creek Bridge.
[2]Altered gabbro. East of Serpentine Lake.

REFERENCES

Anderson, P. (1976): Oceanic Crust and Arc-Trench Gap Tectonics in Southwestern British Columbia, *Geology,* Vol. 4, pp. 443-446.

Bambauer, H. U., Corlett, M., Eberhard, E., and Viswanathan, K. (1967): Diagrams for the Determination of Plagioclases Using X-ray Powder Methods, *Schweiz. Min. Pet. Mitt.,* Vol. 47, pp. 333-349.

Bateman, A. M. (1911): Geology of Fraser Canyon and Vicinity, British Columbia -- Siwash Creek Area, *Geol. Surv., Canada,* Summ. Rept., 1911, pp. 125-129.

Bouma, A. H. (1962): Sedimentology of some Flysch Deposits, *Elsevier Pub. Co.,* Amsterdam, 168 pp.

Brownlow, A. H. (1979): Geochemistry, Englewood Cliffs, New Jersey, *Prentice-Hall Inc.,* 498 pp.

Cairnes, C. E. (1920): Coquihalla Area, British Columbia, *Geol. Surv., Canada,* Summ. Rept., 1920, Pt. A, pp. 23-42.

.... (1924): Coquihalla Area, British Columbia, *Geol. Surv., Canada,* Mem. 139, 187 pp.

.... (1929): The Serpentine Belt of Coquihalla Region, Yale District, British Columbia, *Geol. Surv., Canada,* Summ. Rept., 1929, Pt. A, pp. 144-197.

.... (1937): Geology and Mineral Deposits of Bridge River Mining Camp, British Columbia, *Geol. Surv., Canada,* Mem. 213, 140 pp.

Cann, J. R. (1974): A Model for Oceanic Crustal Structure Developed, *Geophysics Jour. Roy. Astron. Soc.,* Vol. 39, pp. 169-187.

Cardinal, D. G. (1981): Hope Group Property (Emancipation Mine), *Aquarius Resources Ltd.,* unpub. rept.

.... (1982): Report on Portions of the Spuzzum Group Properties, *Aquarius Resources Ltd.,* unpub. rept.

Coates, J. A. (1974): Geology of the Manning Park Area, *Geol. Surv., Canada,* Bull. 238, 177 pp.

Cochrane, D. R., Griffiths, D., and Montgomery, J. T. (1974): Aurum-Idaho-Pipestem Project, *B.C. Ministry of Energy, Mines & Pet. Res.,* Assessment Rept. 4852.

Cochrane, D. R. and Littlejohn, A. L. (1978): Spuz A, B, and G Claims, Longbar Minerals Ltd., *B.C. Ministry of Energy, Mines & Pet. Res.,* Assessment Rept. 6962.

Daly, R. A. (1912): Geology on the North American Cordillera at the Forty-Ninth Parallel, *Geol. Surv., Canada,* Mem. 38.

Joubin, F. R. (1948): Bralorne and Pioneer Mines, *in* Structural Geology of Canadian Ore Deposits, *C.I.M.,* Jubilee Vol., pp. 168-177.

Kayira, G. K. (1975): A Mineralographic and Petrographic Study of the Gold Deposit of the Upper Idaho Zone, Hope, British Columbia, unpub. B.Sc. thesis, *University of British Columbia.*

McTaggart, K. C. and Thompson, R. M. (1967): Geology of Part of the Northern Cascades in Southern British Columbia, *Cdn. Jour. Earth Sci.,* Vol. 4, pp. 1199-1228.

Monger, J.W.H. (1970): Hope Map-Area, West Half (92H W1/2), British Columbia, *Geol. Surv., Canada,* Paper 69-47, 75 pp.

.... (1975): Correlation of Eugeosynclinal Tectono-Stratigraphic Belts in the North American Cordillera, *Geoscience Canada,* Vol. 2, pp. 4-10.

.... (1977): Upper Paleozoic Rocks of the Western Canadian Cordillera and Their Bearing on Cordilleran Evolution, *Cdn. Jour. Earth Sci.,* Vol. 14, pp. 1832-1859.

Monger, J.W.H., Souther, J. G., and Gabrielse, H. (1972): Evolution of the Canadian Cordillera: A Plate Tectonic Model, *Am. Jour. Sci.,* Vol. 272, pp. 577-602.

Panteleyev, A. and Diakow, L. J. (1982): Cassiar Gold Deposits, McDame Map-Area, *B.C. Ministry of Energy, Mines & Pet. Res.,* Geological Fieldwork, 1981, Paper 1982-1, pp. 156-161.

Pirsson, L. V. and Knopf, A. (1966): Rocks and Rock Minerals, *John Wiley,* p. 331.

Ray, G. E. (1981): Geology and Gold Mineralization of the Coquihalla Belt, with Particular Reference to the Carolin Gold Deposit, *in* Rocks and Ores of the Middle Ages, *Geol. Assoc. Can.,* Cordilleran Section, February, 1981, Abstr., pp. 24, 25.

.... (1982): Carolin Mine -- Coquihalla Gold Belt, *B.C. Ministry of Energy, Mines & Pet. Res.,* Geological Fieldwork, 1981, Paper 1982-1, pp. 87-101.

Shackleton, R. M. (1976): Shallow and Deep Level Exposures of Archean Crust in India and Africa, *in* The Early History of the Earth, B. F. Windley (editor), *Wiley,* pp. 317-321.

Shearer, J. T. (1982): Preliminary Investigation on Sulphide Distribution, Idaho Orebody, *Carolin Mines Ltd.,* unpub. Progress Rept. No. 1.

Spooner, E.T.C. (1981): Fluid Inclusion Studies of Hydrothermal Ore Deposits *in* Fluid Inclusions: Application to Petrology, L. S. Hollister and M. L. Crawford, editors, *Min. Assoc. Canada,* Short Course, Calgary, May, 1981, pp. 209-240.

Spry, A. (1969): Metamorphic Textures, *Pergamon Press,* London.

Templeman-Kluit, D. J. (1977): Stratigraphic and Structual Relations between the Selwyn Basin, Pelly-Cassiar Platform, and Yukon Crystalline Terrane, *Geol. Surv., Canada,* Paper 77-1A.

Williams, H. and Smyth, W. R. (1973): Metamorphic Aureoles beneath Ophiolite Suites and Alpine Peridotites: Tectonic Implications with West Newfoundland Examples, *Am. Jour. Sci.,* Vol. 273, pp. 594-621.

Wright, R. L., Nagel, J., and McTaggart, K. C. (1982): Alpine Ultramafic Rocks of Southwestern British Columbia, *Cdn. Jour. Earth Sci.,* Vol. 19, pp. 1156-1173.

THE BLUESKY - A STRATIGRAPHIC MARKER IN NORTHEASTERN BRITISH COLUMBIA (93I, O, P)

By G. V. White

Over the past 25 years there has been extensive drilling by both petroleum and coal exploration companies south of the John Hart Highway in northeastern British Columbia. Correlation of formation tops from the geophysical logs taken from the drill holes allows accurate prediction of formation thicknesses over an extensive area. As part of a study of Lower Cretaceous sedimentary rocks in northeastern British Columbia, an isopach map of the Bluesky transitional unit (Fig. 25) was produced from drill hole information.

The Gething Formation as described by D. C. Pugh (1960) consists of 'grey, silty, fine- to coarse-grained siltstones, grey to brownish grey, silty, fine to coarse-grained sandstones, and dark grey and black, carbonaceous shales and coal.' Most of the better coals are found in the Upper Gething and these coals are sought after by numerous exploration companies in northeastern British Columbia. It is because much of the coal is found in the upper section that it is important to establish the top of the Gething Formation, which is marked by a transitional unit called the Bluesky.

The Bluesky is a transitional unit between continental sedimentary rocks of the Gething Formation and marine shales of the overlying Moosebar Formation. The Bluesky was first described in 1954 by the Alberta Study Group who took their description from the Bluesky well No. 1 in Alberta (4-29-81-1, W6). The Bluesky at this location was found in the interval 834 metres and 856.5 metres, with a total thickness of 22.5 metres. The unit was described as 'fine- to medium-grained sandstone with interbeds of shale.' The top was characterized by black, rounded chert granules and pebbles which decreased in abundance downward. Glauconite was common in this type section of the Bluesky.

In 1960, D. C. Pugh proposed using Fort St. John well No. 10 from interval 987.6 metres to 999 metres as the typical representative Bluesky section in northestern British Columbia. It was described as '24 feet [7.3 metres] of very fine-grained, glauconitic sandstone with carbonaceous inclusions, 5 feet [1.5 metres] of glauconitic, sandy shale and 11 feet [3.4 metres] of porous, fine-grained, glauconitic sandstone.' Pugh extended his study of the Bluesky in British Columbia to the area north of the John Hart Highway, where petroleum exploration companies had extensively drilled.

In this preliminary study emphasis is being placed on the Bluesky unit because it marks the top of the Gething Formation, which contains important economic reserves of coal. As well, in some northeastern British Columbia localities, the Bluesky contains significant oil and gas

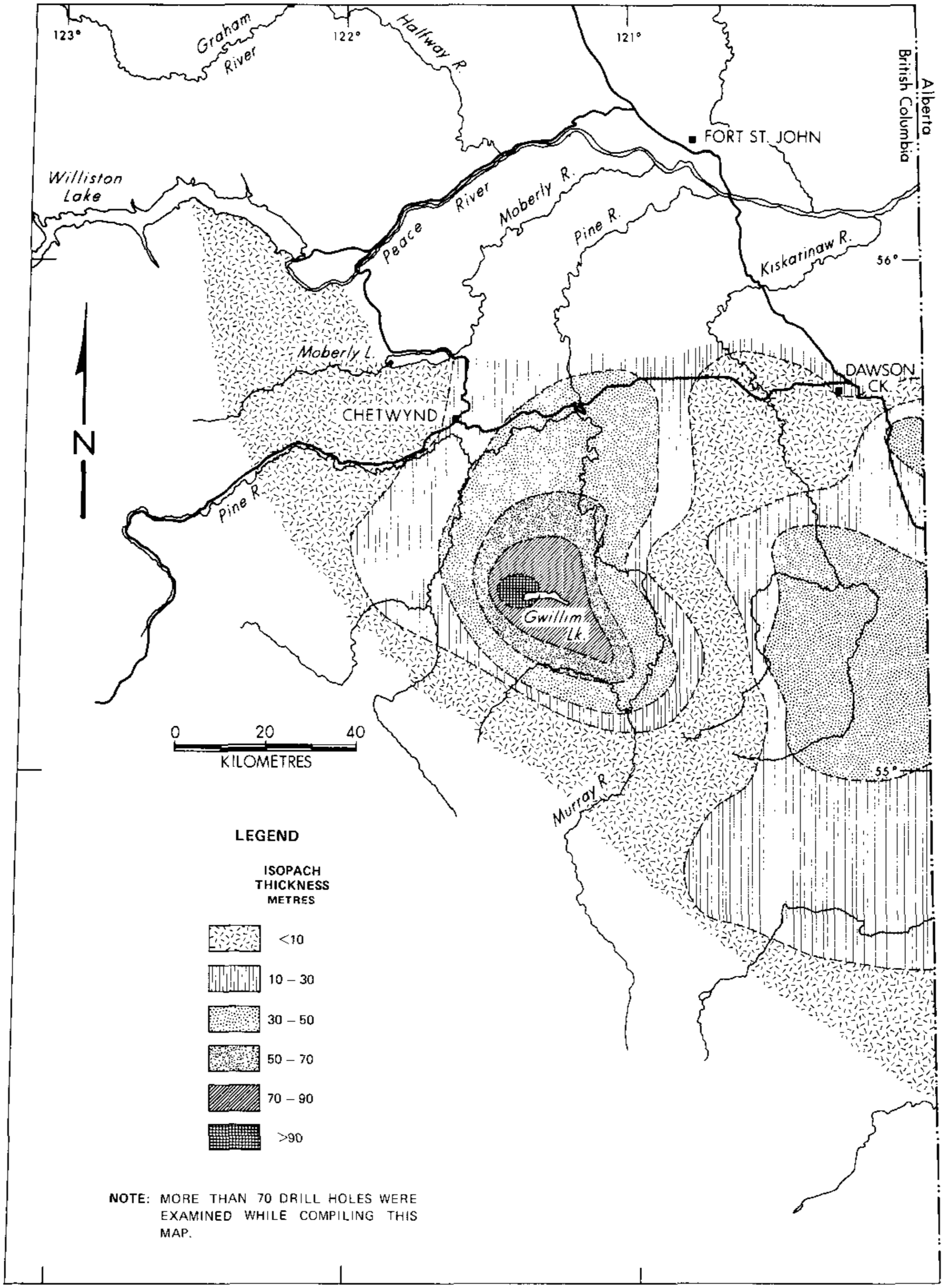


Figure 25. Isopach map of the Bluesky unit, Gething Formation south of Peace River in northeastern British Columbia.

reserves. Further examination of outcrops, drill core, and geophysical logs during this study will emphasize the distribution and character of the Bluesky unit throughout the Peace River Coalfield.

REFERENCES

Alberta Study Group (1954): Lower Cretaceous of the Peace River Region, Western Canada Sedimentary Basin, *in* Western Canada Sedimentary Basin, *Am. Assoc. Pet. Geol.*, R. L. Rutherford Memorial Vol., pp. 268-278.

Hudson, J. A. (1979): Map - Structure on Top of Bluesky - Gething, *B.C. Ministry of Energy, Mines & Pet. Res.*

Karst, R. H. (1981): Correlation of the Lower Cretaceous Stratigraphy of Northeastern British Columbia from Foothills to Plains, *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1980, Paper 1981-1, pp. 78-89.

Pugh, D. C. (1960): The Subsurface Gething and Bluesky Formations of Northeastern British Columbia, *Geol. Surv., Canada*, Paper 60-1, 20 pp.

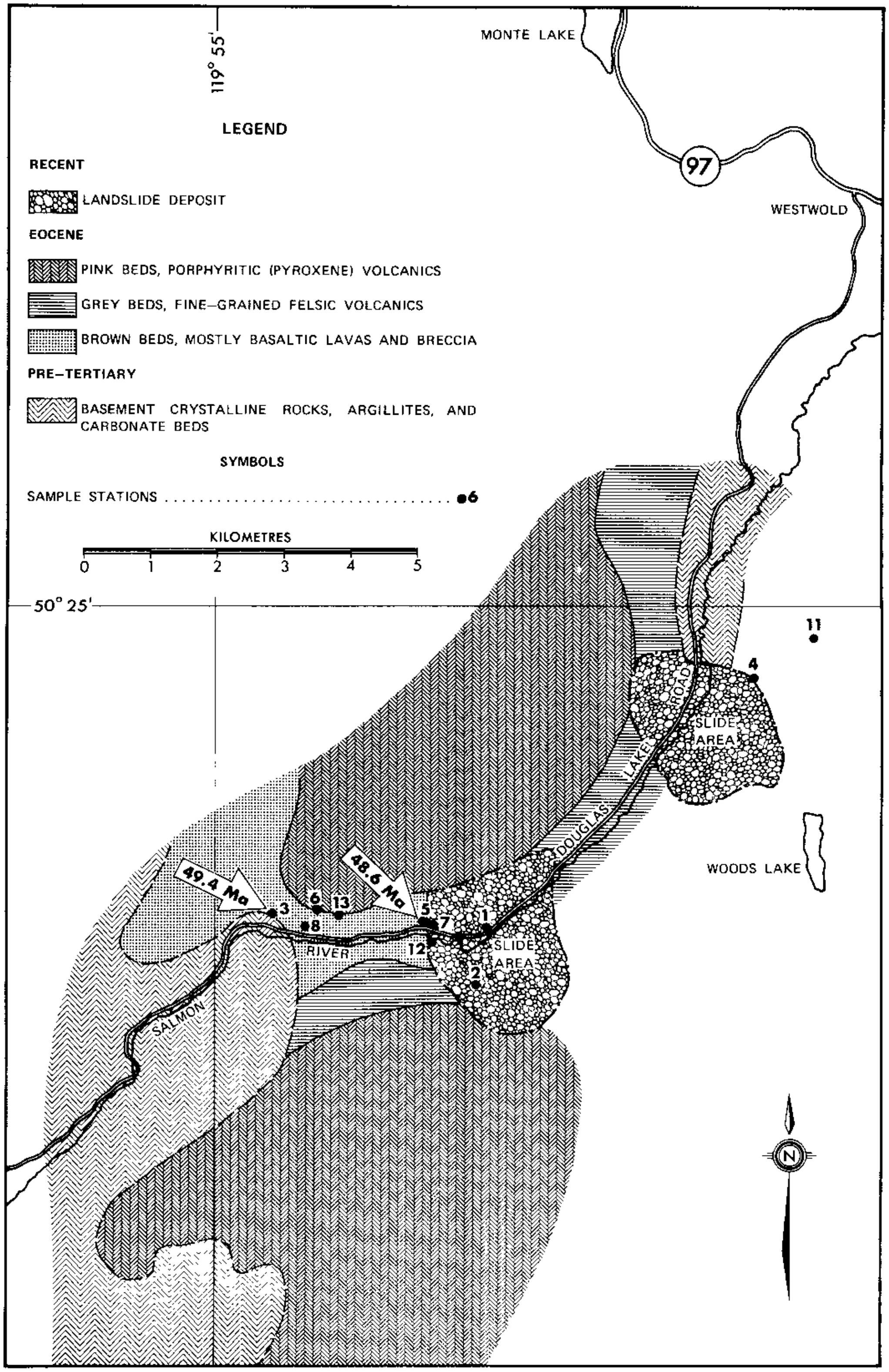


Figure 26. Sketch map of the geology of the Salmon River area.

BASALTS OF THE KAMLOOPS GROUP IN SALMON RIVER AREA (82L/5)

By B. N. Church and S. G. Evans

The Salmon River Valley is the site of several large landslides (Evans and Cruden, 1981) which are of some concern for road and power access to the Douglas Lake area to the west and regions beyond. Source of the slides appears to be mainly incompetent Tertiary basaltic units exposed on Douglas Lake Road 8.5 to 10.5 kilometres and 12.5 to 15 kilometres south from Westwold (*see* Fig. 26). This report considers the strati-stratigraphic setting and petrology of the basalts.

The total section of Tertiary rocks in the region exceeds 750 metres, comprising alternating lava flows and breccia. Reddish weathering augite porphyry, exposed on the upper faces of slide escarpments and in cliffs, is the uppermost unit in the local volcanic assemblage. This formation is approximately 450 metres thick north and west of the Salmon River and wedges out to the south where the unit laps onto pre-Tertiary formations. A grey aphanitic sequence of lavas and breccias below the augite porphyry thickens northerly toward Monte Hills, attaining maximum thickness of about 200 metres. The basal unit in the section is an assemblage of basaltic rocks 200 to 250 metres thick. It rests on pre-Tertiary argillites near the 17-kilometre marker on the Douglas Lake Road. The basalts are crumbly, dark brown, often highly vesicular, and occasionally rich in zeolites which fill cracks and amygdales. Tuffaceous bands with clay partings in the basaltic unit are glide surfaces for some of the landslide movement.

Correlation of the Salmon River volcanic rocks with other Tertiary sections is uncertain owing to the limited nature of detailed mapping in the area. The 'basalt assemblage' of this report is essentially the same as the 'basal beds and brown beds' of Evans and Cruden (1981). These appear to correlate with the Monte Lake Formation of Ewing (1981, p. 1472) and the Attenborough Creek Formation of Church (1980, 1982). The age of two samples of Salmon River basalt (Table 1) was determined by J. Harakal (University of British Columbia), by K/Ar analysis of whole rock specimens, as 48.6 and 49.4 Ma. These values are comparable to the results of 48±2 Ma reported by Mathews (1964) for the Attenborough Creek ash.

TABLE 1. WHOLE ROCK K/AR ANALYSIS OF TWO SALMON RIVER BASALT SAMPLES

Field No.	Latitude North	Longitude West	K %	Ar^{*40} (cc/gm)	Ar^{*40} %	Age (Ma)
EV-3	50°26.6'	119°54.3'	2.31	4.497	93.8	49.4±1.7
EV-5	50°22.4'	119°52.2'	1.88	3.597	95.2	48.6±1.7

TABLE 2. CHEMICAL ANALYSES AND NORMATIVE COMPOSITION OF TERTIARY VOLCANIC ROCKS IN THE SALMON RIVER AREA

	1	2	3	4	5	6	7	8	9	10	11	12	13
SiO_2	50.71	54.86	51.60	55.93	51.09	49.72	48.13	51.27	52.67	53.70	49.84	44.97	50.00
TiO_2	0.89	0.97	1.00	1.01	0.90	0.96	0.81	0.84	0.94	1.04	0.94	0.83	0.93
Al_2O_3	13.43	14.65	15.57	16.19	13.74	13.76	12.30	13.57	14.15	15.59	12.28	11.96	14.11
Fe_2O_3	1.55	2.30	3.37	3.14	1.48	6.26	6.23	7.44	3.39	3.01	1.81	5.46	6.66
FeO	6.65	5.31	4.28	4.41	6.59	1.60	1.79	0.86	4.05	4.05	7.23	3.04	1.16
MnO	0.15	0.12	0.17	0.13	0.15	0.12	0.14	0.11	0.14	0.12	0.16	0.14	0.11
MgO	10.09	5.78	6.32	4.37	10.14	6.73	10.07	7.07	7.33	5.11	13.29	10.31	5.80
CaO	8.26	6.50	8.53	6.91	8.26	7.78	6.48	7.22	6.82	7.76	8.29	8.05	8.03
Na_2O	2.99	2.41	3.17	2.93	2.63	1.69	2.82	2.66	2.66	3.01	2.35	1.28	1.72
K_2O	2.31	3.90	2.66	3.35	2.34	3.19	2.55	2.60	3.08	3.02	2.14	1.99	3.41
$+H_2O$	1.75	1.21	1.63	0.77	2.12	4.81	5.02	2.51	1.90	1.30	1.45	6.20	4.44
$-H_2O$	0.73	0.98	0.74	0.89	0.89	3.39	4.26	2.39	2.99	1.69	0.51	5.43	2.97
CO_2	0.20	0.35	0.19	0.20	0.25	0.10	0.47	0.33	0.79	0.77	0.26	0.84	0.30
S	0.012	0.012	<0.008	<0.008	0.008	<0.008	0.008	0.008	0.008	0.008	<0.008	<0.008	<0.008
P_2O_5	0.44	0.44	0.54	0.32	0.43	0.61	0.30	0.52	0.30	0.39	0.16	0.32	0.66
BaO	0.15	0.20	0.18	0.21	0.16	0.15	0.18	0.16	0.19	0.17	0.16	0.24	0.17
SrO	0.10	0.09	0.11	0.11	0.13	0.12	0.05	0.08	0.08	0.08	0.09	0.11	0.22
NiO	0.015	Tr.	Tr.	Tr.	0.015	Tr.	0.015	0.01	0.01	Tr.	0.015	0.015	Tr.
Cr_2O_3	0.025	0.01	0.01	Tr.	0.03	0.01	0.05	0.03	0.015	Tr.	0.05	0.05	0.01
						Molecular Norm							
Qt	-	2.93	-	4.37	-	5.06	-	3.83	1.32	2.07	-	1.51	5.38
Or	13.82	23.84	16.16	20.33	14.00	20.65	16.26	16.43	18.99	18.51	12.57	13.32	22.10
Ab	27.17	22.37	29.26	27.01	23.86	16.58	27.24	25.54	24.93	28.03	20.99	13.01	16.99
Ne	-	-	-	-	-	-	-	-	-	-	-	-	-
An	16.62	18.25	20.99	21.67	19.02	22.56	14.44	18.59	18.37	20.81	16.58	23.77	22.74
Wo	9.95	6.04	9.01	5.40	8.97	7.90	8.08	7.87	6.78	7.63	9.74	8.57	8.40
En	6.08	16.51	11.17	12.38	11.26	20.37	18.87	20.86	21.14	14.62	8.74	32.21	17.59
Fs	2.01	6.81	2.74	4.76	3.69	0.00	0.00	0.00	4.09	4.33	2.37	0.00	0.00
Fo	16.59	-	5.08	-	12.80	-	8.32	-	-	-	20.84	-	-
Fa	5.49	-	1.25	-	4.20	-	0.00	-	-	-	5.65	-	-
Il	1.25	1.40	1.43	1.44	1.26	1.47	1.22	1.25	1.37	1.50	1.30	1.30	1.42
Mt	1.64	2.55	3.62	3.37	1.56	1.88	2.65	0.27	3.70	3.26	1.88	6.04	0.82
He	0.00	0.00	0.00	0.00	0.00	3.53	2.91	5.36	0.00	0.00	0.00	0.27	4.55
Cor	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Key to Analyses

1. Olivine basalt core from drill hole on north side of the Salmon River at 5.6 metres depth.
2. Platy jointed basaltic andesite from Shell Creek slide on B.C. Hydro access road.
3. Basal basalt east of Twig Creek (K/Ar dated).
4. Andesite from Adelphi Creek at Ford's water intake.
5. Olivine basalt from Campbell's road cut (K/Ar dated).
6. Altered lava in upper part of basalt section.
7. Oxidized olivine basalt from Campbell's road cut.
8. Oxidized basalt from base of section.
9. Andesite from road cut at Monte Lake.
10. Andesite from road cut at Monte Lake.
11. Olivine basalt on Woods Lake Road.
12. Pyroxene basalt from exposure on Salmon River.
13. Amygdaloidal basaltic andesite, near top of basaltic section.

The augite porphyry and grey aphanitic sequences overlying the basaltic formation correspond to the 'red beds and salmon beds' of Evans and Cruden (1981). They may correlate in part with the Tuktakamin Formation of Ewing (1981) near Monte Lake but there is no clear tie with the Tertiary section in the Terrace Mountain area.

Petrographic study of the basalts shows a predominance of small (less than 0.25-millimetre) laths of plagioclase along with an ample admixture of olivine, pyroxene, and magnetite grains; accessory biotite and apatite; scattered olivine and, less commonly, pyroxene phenocrysts. Amygdales and cracks are commonly filled with calcite, brown chlorite, and zeolites such as heulandite, chabazite, thomsonite, stilbite, and less frequently, stevensite, levyne, and offretite.

Except for the most felsic rock in the collection (No. 4), chemical analyses of volcanic rocks from the Salmon River area show relatively low alumina content, averaging 13.5 per cent (Table 2). Sample No. 4 is similar to an andesite (No. 10), from the Monte Lake area. Sample Nos. 1, 5, 7, and 11 are typical olivine basalts; No. 12 is pyroxene rich. These basalts tend to weather and disintegrate readily, especially the breccias and highly vesicular phases.

Basal basaltic rocks of the Kamloops Group in the Salmon River section bear greatest lithostatic pressure. Consequently, landslides occur along tuffaceous bands and other incompetent zones, particularly where the volcanic rocks are altered, highly vesicular, or fragmental. Weak zones are commonly intensely fractured and consist of red oxidized rocks with clay on slip surfaces and abundant calcite or zeolite in cracks and joint sets.

REFERENCES

Church, B. N. (1980): Geology of the Terrace Mountain Tertiary Outlier, *B.C. Ministry of Energy, Mines & Pet. Res.*, Prelim. Map 37.

.... (1982): Notes on the Penticton Group: Progress Report on a New Stratigraphic Subdivision of the Tertiary, South-Central British Columbia, *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1981, Paper 1982-1, pp. 12-15.

Evans, S. G. and Cruden, D. M. (1981): Landslides in the Kamloops Group in South-Central British Columbia: A Progress Report, *in* Current Current Research, Pt. B, *Geol. Surv., Canada*, Paper 81-1B.

Ewing, T. E. (1981): Regional Stratigraphy and Structural Setting of the Kamloops Group, South-Central British Columbia, *Can. Jour. Earth Sci.*, Vol. 18, No. 9, pp. 1464-1477.

Mathews, W. H. (1964): Potassium-Argon Age Determinations of Cenozoic Volcanic Rocks from British Columbia, *Geol. Soc. of Am.*, Bull., Vol. Vol. 75, No. 5, pp. 465-468.

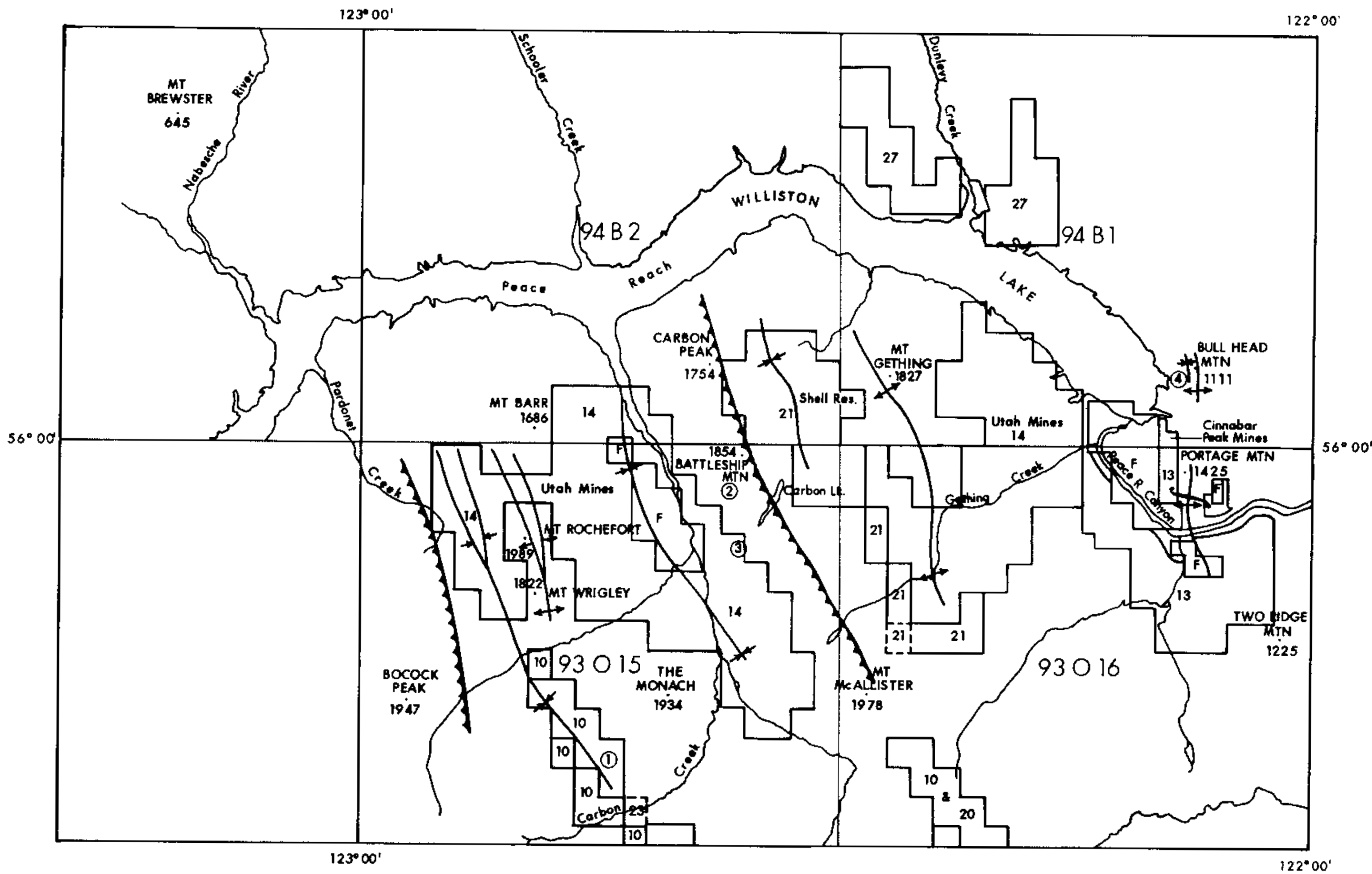


Figure 27. Coal licence boundaries, elements of structure, and locations of sections for Bullhead Mountain-Pardonet Creek area.

STRATIGRAPHY AND SEDIMENTOLOGY NOTES ON THE BULLHEAD MOUNTAIN-PEACE RIVER CANYON, CARBON CREEK AREA NORTHEASTERN BRITISH COLUMBIA (93O/15, 16; 94B/1, 2)

By A. Legun

INTRODUCTION

As the new District Geologist at Charlie Lake, 1982 fieldwork was oriented toward gaining a grasp of the regional and local stratigraphy and sedimentology of the coal-bearing sequences in the Northeast Coalfield. *In this regard I am indebted to Dave Gibson and Don Stott of the* Geological Survey of Canada, Paul Cowley and Norman Duncan of Utah Mines Ltd., and Charlie Williams of Gulf Canada Resources Inc. for informative discussions.

Fieldwork was concentrated in the area between Bullhead Mountain on the east and Pardonet Creek on the west (Fig. 27). This area includes coal licences of Utah Mines Ltd., Gulf Canada Resources Inc., Shell Canada Resources Limited, and Cinnabar Peak Mines Ltd. Recently published papers on the area include those of Gibson (1978), Stott and Gibson (1980), and Anderson (1980).

There are two coal-bearing formations in the area, the Gething Formation of the Bullhead Group and the Bickford Formation of the Minnes Group. The Gething Formation overlies the Bickford Formation and is separated from it by the Cadomin Formation, which is variably pebbly sandstone to conglomerate (*see* stratigraphic column, Table 1). Regionally the Cadomin Formation may rest on units lower in the succession than the Bickford. According to Stott (1973) this is due to an unconformity which progressively truncates underlying strata in a southwest-northeast direction.

TABLE 1. SIMPLIFIED STRATIGRAPHY OF THE MINNES AND BULLHEAD GROUPS (UPPER JURASSIC-LOWER CRETACEOUS) IN THE BULLHEAD MOUNTAIN-PARDONET CREEK AREA

Bullhead Group	Gething Formation	Coal measures
	Cadomin Formation	Pebbly sandstone, quartzitic sandstone, conglomerate
Minnes Group	Bickford Formation	Carbonaceous measures
	Monach Formation	Feldspathic sandstone, minor amounts of quartzite
	Beattie Peaks Formation	Interbedded sandstone and shale
	Monteith Formation	Upper quartzites Lower grey sandstones, feldspathic sandstones

The stratigraphy of the area is not yet satisfactorily resolved (D. F. Stott, personal communication). Problems include:

(1) Identifying the Cadomin Formation in places where it is a sandstone rather than a pebbly sandstone or a conglomerate. It is difficult to distinguish the Cadomin Formation where it overlies sandstone of formations such as the Monach.

(2) Lateral facies variations within formations of the Minnes Group.

(3) The nature of the unconformity at the base of the Cadomin Formation. Does it have relief and hence control the thickness and distribution of the Cadomin?

The Carbon Creek basin continues to be a focus of these stratigraphic difficulties. For example, coal measures initially identified as Gething Formation were temporarily re-interpreted to be Bickford Formation by Stott and Gibson (1980).

STRATIGRAPHIC SETTING OF THE CADOMIN FORMATION

A number of sections were examined in order to establish the stratigraphic setting of the Cadomin Formation in the area. These are summarized as follows (*see* Fig. 27 for location):

(1) *Ridge Southwest of Mount Monach*

Coal measures	Gething Formation
Thick units of pebbly quartzitic sandstone; local siltstone and recessive beds	Cadomin Formation
Gradational contact ?	
Salt-and-pepper sandstone, siltstone (calcareous), mudstone, carbonaceous shale, coal	Bickford Formation
Massive flaggy sandstone	Monach Formation

(2) *Battleship Mountain (tributary to Carbon Creek on west side)*

Coal measures	Gething Formation
Thick units of sandstone to pebble sandstone, local recessive interbeds	Cadomin Formation
Contact covered	
Massive quartzitic sandstone, salt-and-pepper sandstone	Monach Formation

(3) *East of Carbon Creek Road and Carbon Lake*

Coal measures	Gething Formation
Pebbly quartzitic sandstones, quartzite locally at base, coal	Cadomin Formation
Contact sharp	
Salt-and-pepper to quartzitic sandstone, minor amounts of burrowed siltstone	Monach Formation

(4) *Bullhead Mountain - west side*

Pebbly sandstone, conglomerate	Cadomin Formation
Contact sharp	
Feldspathic sandstone (flaggy), salt-and-pepper sandstone, kaolinitic quartzite bed near top	Monach Formation
Interbedded feldspathic sandstone, burrowed siltstone, black mudstone	Beattie Peaks Formation
Quartzite, minor amounts of black mudstone, feldspathic sandstone, dark grey sandstone	Monteith Formation

The Monach, Bickford, Cadomin, and Gething Formations are exposed in the 'Whiterabbit' licence area of Gulf Canada Resources Inc. and in ridges extending southwest and west of Mount Monach. They comprise the eastern limb of a major syncline. The Bickford Formation is several hundred metres thick and grades into the Cadomin over a width of about 5 metres. An interbed of salt-and-pepper sandstone, typical of the Bickford Formation, lies above the 10-metre thick basal, sparsely pebbly quartzitic sandstone of the Cadomin Formation. Nineteen kilometres to the northeast, on the east side of the Carbon Creek syncline, the Bickford Formation is missing. There the pebbly Cadomin Formation abruptly overlies a burrowed siltstone (marine ?). Off Carbon Creek Road, on the west side of Battleship Mountain, it rests on flaggy massive sandstone units (Monach Formation ?).

Either the Bickford Formation develops a marine sandy facies eastward or it is truncated by the regional unconformity described by Stott (1973). Rocks in the anticlinal structure near Mount Rochfort and Mount Wrigley may hold the key. Just west of the core of the anticline on the west sides of the two mountains, a thin zone of Bickford Formation may be exposed. On a ridge northwest of Mount Wrigley, Paul Cowley of Utah Mines Ltd. (personal communication) describes a carbonaceous mudstone, siltstone, and sandstone sequence that underlies salt-and-pepper (to quartzitic) sandstones of the Cadomin Formation. However, pebbly sandstone below and within the sequence makes it unclear whether it is all Cadomin or whether both Cadomin and Bickford Formations are present.

East of the Carbon Creek basin at Bullhead Mountain the Cadomin is separated from underlying mottled (bioturbated ?) quartzite by several centimetres of coal (the contact is exposed only on the south side of the mountain along the hydro line). Below this are feldspathic sandstones, a shaly transition zone, and quartzite. The feldspathic sandstones correspond to either the Monach Formation or a sandy upper facies of the Beattie Peaks Formation. The transitional sequence below consists of interbedded quartzite, black shale, burrowed mudstone, feldspathic sandtone, and ferruginous shale. It is probably the Beattie Peaks Formation. This sequence grades downward into thick quartzite beds of the Monteith Formation which are in rather sharp contact with underlying dark grey sandstones (also Monteith Formation). These dark sandstones crop out at the base of Bullhead Mountain on both its west and south sides.

At Bullhead Mountain the Cadomin Formation is in part conglomeratic and locally more than 200 metres thick (Stott, 1973). Stott also described 30 metres of conglomerate at the mouth of Carbon Creek. At Battleship Mountain, however, only one 10-metre bed was pebbly and the total thickness of the formation is at most 200 metres. In the Mount Rochfort-Mount Wrigley area the Cadomin is predominantly sandstone. Its appearance is not distinctive and it was mapped as part of the Monach sandstone. As a consequence, pebbly sandstones that are stratigraphically much higher (in the Gething Formation), were mislabelled as Cadomin. Southwest of Mount Monach the Cadomin is apparently thick (400 metres ?) but only sparsely pebbly (maximum clast size 2 to 3 centimetres). Clearly the Cadomin Formation is not a simple westward thickening and coarsening fan of fluvial sediment. A local isopach map, distribution of paleocurrent flow directions, and maximum clast size are required to determine what controls its thickness and lithology in the Bullhead Mountain-Pardonet Creek area.

TRACE FOSSILS

Some rather spectacular examples of trace fossils are evident in the Beattie Peaks Formation along Carbon Lake Road. Abundant vertical pipe-like burrows up to 3 centimetres in diameter are present as well as vertical 20-centimetre-deep U-shaped and steeply inclined rhizocorallium burrows (U-shaped and spreite-filled). They are particularly well developed in a number of regressive, coarsening up sequences (shale-sandstone). The structures correspond to the Skolithos facies of Seilacher (1967) and represent suspension feeders found in the shallowest parts of the sea.

PEACE RIVER CANYON

A section was examined starting at the toe of the dam and continuing along the north shore to Gething Creek. It has been previously described by Stott (1973), McLearn (1923), and others. The first 57 metres of the sequence at the toe of the dam includes three thick sandstone units and is assigned to the Cadomin Formation by Stott. These units are gritty at the base, fine upward, and are ripple cross-laminated at the top. The middle zone has extensive convoluted bedding. The units all have a sharp flat base and two of the three are marked by inclined interbedding of sandstone and shale at the top and coal at the base. These features suggest the sandstone bodies may represent distributaries of the lower or transitional delta plain rather than fluvial channels of the upper delta plain. Foraminifera indicating marine influence were collected by Chamney (*in* Stott, 1973) from finer sedimentary rocks between the sandstone units but according to Gibson (personal communication) the work requires re-examination. The overlying Gething Formation sediments are predominantly a monotonous, repeated sequence of sandstone, horizontally interbedded shale, and coal. Interesting features do include some channel structures, lateral accretion bedding (indicative of meandering), minor upward coarsening burrowed sequences (bay fills ?), and coal-bounded crevasse splay deposits.

Various floral and faunal collections have been made from the Gething Formation in the Peace River Canyon. They include dinosaur bones and trackways, pelecypods, foraminifera, spores, and remains of ferns, cycads, and conifers. The writer recently collected a well-preserved silicified tree trunk in the east side of the canyon in view of the dam. The trunk measures about a metre in diameter and a metre in height. Growth rings are well preserved and alternating thin and thick bands appear to indicate seasonal variations of climate at the time of growth. Excavation revealed that a laminae of coal enveloped the buried part of the trunk and extended under the flat base of the trunk; perhaps it represents original bark. A number of thick roots extend radially and horizontally from the base. This suggests that the roots were tapping a high water table. The trunk (weighing nearly 1 400 kilograms) has been transported to Charlie Lake and eventually will be placed in the Fort St. John museum.

REFERENCES

Anderson, R. B. (1980): Carbon Creek - Geology and Coal Resources, Paper presented at *Symposium on Northeast Coal*, February 1980, 27 pp.

Gibson, D. W. (1978): Stratigraphy and Sedimentology of the Lower Cretaceous Gething Formation, Carbon Creek Coal Basin, Northeastern British Columbia, *Inst. Sed. & Pet. Geol.*, internal rept.

McLearn, F. H. (1923): Peace River Canyon Coal Area, *Geol. Surv., Canada*, Summ. Rept., 1922, Pt. B, pp. 1-46.

Seilacher, A. (1967): Bathymetry of Trace Fossils, *Marine Geology*, Vol. 5, pp. 413-429.

Stott, D. F. (1973): Lower Cretaceous Bullhead Group between Bullmoose Mountain and Tetsa River, Rocky Mountain Foothills, Northeastern British Columbia, *Geol. Surv., Canada*, Bull. 219, 228 pp.

Stott, D. F. and Gibson, D. W. (1980): Minnes Coal, Northeastern British Columbia, *in* Current Research, Pt. C, *Geol. Surv., Canada*, Paper 80-1C, pp. 135-137.

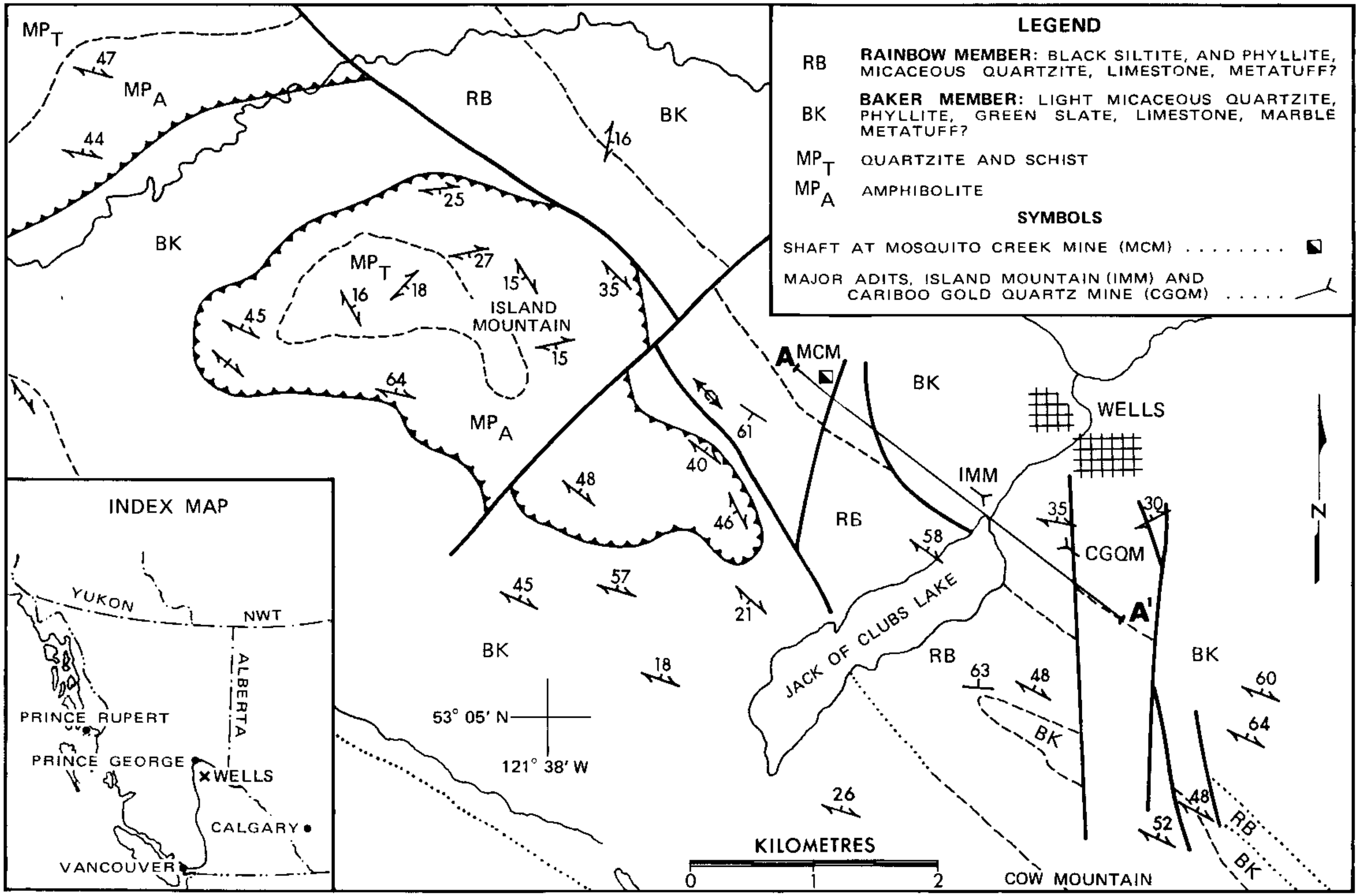


Figure 28. Geology of the Mosquito Creek mine area (modified after Struik, 1982a).

THE MOSQUITO CREEK MINE, CARIBOO GOLD BELT (93H/4)

By D. J. Alldrick

INTRODUCTION

The underground mine of Mosquito Creek Gold Mining Company Limited is located in east-central British Columbia 2 kilometres west of the historic mining town of Wells at latitude 56 degrees 6 minutes north and longitude 121 degrees 36 minutes west. The Ministry initiated this field project in May, 1982 in response to the general revival of interest in precious metals in British Columbia and the renewed mining and exploration activity in the Wells area.

The specific objectives of the project are:

(1) To document structural and stratigraphic controls of the mineralized zones and to identify potential marker horizons that could be useful in exploration programs.

(2) To sample one representative ore zone and its host rocks for study of their petrographical and geochemical characteristics.

(3) To collect samples for fossil and radiometric studies to determine the age of host rocks, metamorphism, and mineralization.

HISTORY AND PREVIOUS WORK

Prospectors discovered the first placer gold deposits in the region during the winter of 1860. Since then production has been virtually continuous. Several major placer operations were active during the 1982 season; many are reworking old placer leases with mechanized mining equipment which enables them to reach deeper Tertiary gravel beds that were inaccessible to early miners.

Hardrock mining started at the Cariboo Gold Quartz mine in 1933 and at Island Mountain mine in 1934. Apart from a four-year shutdown during the war, Cariboo Gold Quartz mine operated until 1959 and Island Mountain mine until 1967. The latest underground operation began in 1980 with the opening of the Mosquito Creek mine.

Sutherland Brown (1957, p. 10) reviewed the extensive early geological work in the region. Since that bulletin, major studies undertaken in the area include two unpublished summary reports by Campbell (1966, 1969), radiometric studies of precious metal deposits in the cordillera by Andrew (1982) and Andrew, Godwin, and Sinclair (this volume), and a continuing program of regional mapping by Struik of the Geological Survey of Canada (1980, 1981a, 1981b, 1982a, 1982b). Carlyle (in press)

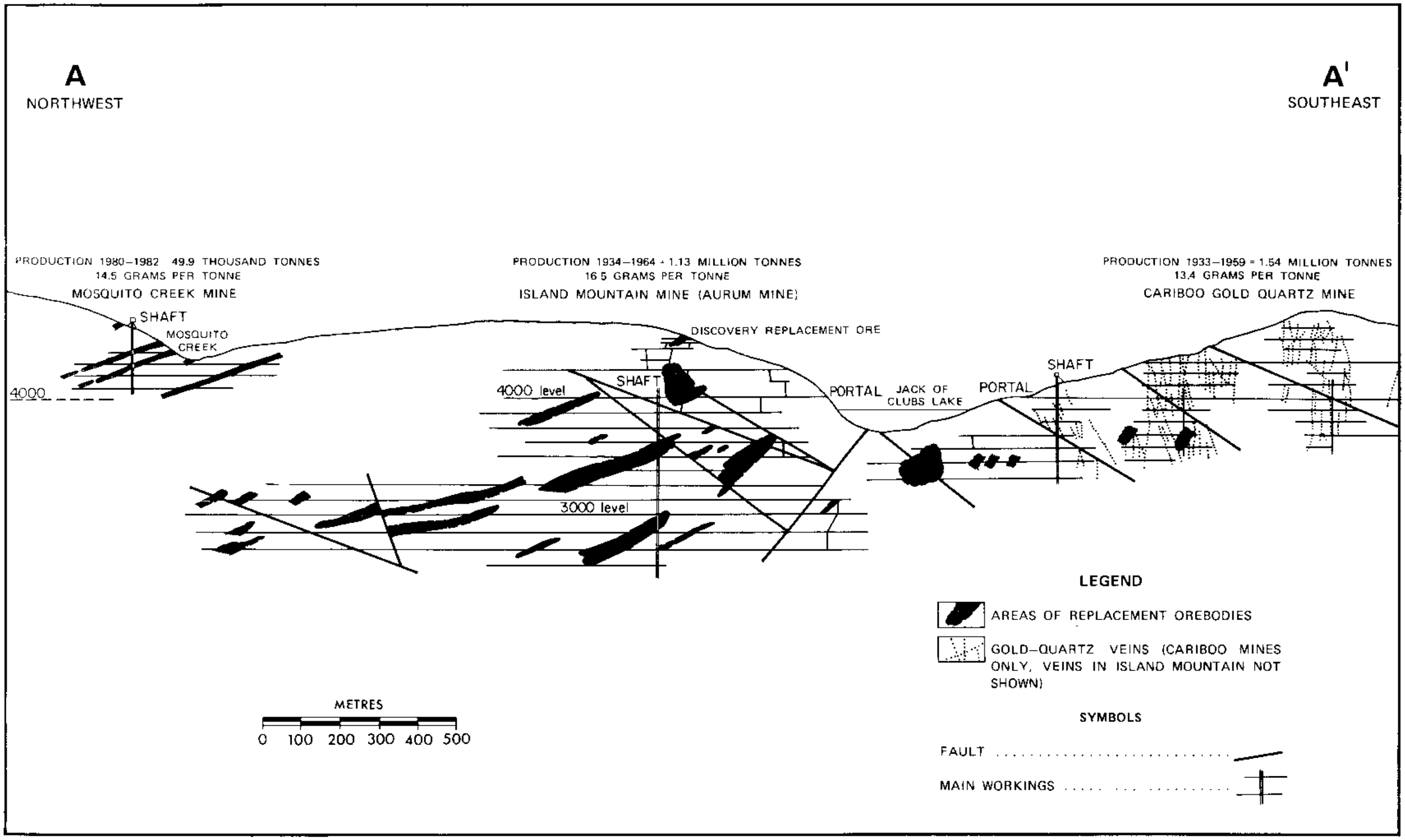


Figure 29. Longitudinal section. Projections of Mosquito Creek, Island Mountain, and Cariboo Gold Quartz mines (modified after Campbell, 1969).

produced a geological review of the Mosquito Creek mine for a field trip to the mine in May, 1983 before the annual GAC/MAC/CGU meeting in Victoria.

Sutherland Brown (1957) provides the most comprehensive description of mineral deposits in the region. For detailed information about the Mosquito Creek, Island Mountain, and Cariboo Gold Quartz mines, the reader is referred to Carlyle (in press), Benedict (1945), and Skerl (1948) respectively.

REGIONAL GEOLOGY

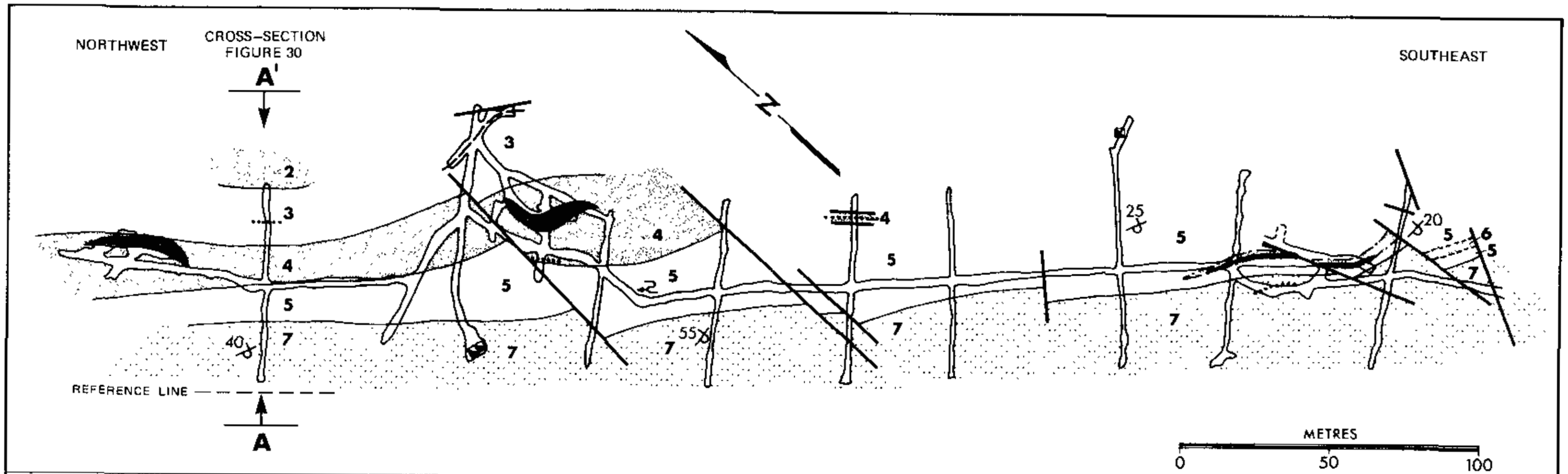
A simplified geological map of the Wells area is presented on Figure 28. The region is dominated by a thick, highly deformed sedimentary sequence of distinctive quartzites, conglomerates, grits, siltites, slates, phyllites, marbles, limestones, dolomites, amphibolites, and meta-tuff (?). From fossil studies Struik (1982b) ascribes an Upper Paleozoic age to the overall sequence. He assigned a Mississippian age to rocks of the Baker member in the Mosquito Creek mine based on an uncertain correlation of mine strata with a crinoidal limestone in the northwest corner of his map-area. Earlier, Struik (1981b) reported conodonts of Pennsylvanian to Lower Permian age from a bioclastic limestone bed in the Rainbow member.

The sedimentary sequence has been folded and regionally metamorphosed to greenschist facies. Small amounts of fine euhdral pyrite are disseminated through most of the rocks. Struik (1981a) inferred that the main folding event took place between Early Jurassic and Late Cretaceous time from stratigraphic and structural relationships throughout the region. Andrew (1982) obtained a Lower Jurassic (179±8 Ma) whole rock K/Ar date for a sample of phyllite from the Cariboo Gold Quartz mine. It is interpreted to be a metamorphic date.

Regional folds trend northwesterly and are overturned toward the southwest, with dips ranging between 40 and 55 degrees northeast. An important feature of this folding is the rhythmic development of minor folds down the limbs of the main folds. In the mine area these drag folds plunge 21 degrees at north 40 degrees west to north 50 degrees west; they host the majority of the ore zones.

LOCAL GEOLOGY

Figures 29 through 32 illustrate geological relationships in the Mosquito Creek mine. In the mine workings only the upper part of the pale-coloured Mississippian (?) Baker member and the lower part of the dark-coloured Pennsylvanian to Lower Permian Rainbow member are exposed.



LEGEND

STRATIGRAPHY

RAINBOW MEMBER (PENNSYLVANIAN/PERMIAN)

7 — DARK ARGILLACEOUS SEDIMENTARY SEQUENCE: PHYLLITE, ARGILLACEOUS QUARTZITES, BEDDED QUARTZITES, GRADED BEDS, INTERBEDDED QUARTZITE AND PHYLLITE, PEBBLE CONGLOMERATES, DOLOMITE, GREYWACKE, GRIT, TUFF(?)

BAKER MEMBER (MISSISSIPPIAN?)

6 — WHITE LIMESTONE; MASSIVE TO THICK-BEDDED, FINE-GRAINED TO SACCHAROIDAL, HOST ROCK FOR REPLACEMENT ORE

5 — LIGHT, THIN-BEDDED MICACEOUS SEDIMENTARY SEQUENCE: QUARTZITES, GRADED BEDS, PHYLLITES, INTERBEDDED QUARTZITE AND PHYLLITE, AND DOLOMITE

BAKER MEMBER (MISSISSIPPIAN?) *(CONTINUED)*

4 — DARK ARGILLACEOUS LIMESTONE: DARK GREY TO BLACK, MASSIVE TO THIN-BEDDED, WHITE CALCITE STREAKS AND BLEBS, MINOR PHYLLITE AND QUARTZITE HORIZONS, HOST ROCK FOR REPLACEMENT ORE

3 — LIGHT MICACEOUS SEDIMENTARY SEQUENCE: QUARTZITES, PEBBLE CONGLOMERATES, MINOR LIMESTONE BEDS, GREYWACKES

2 — DARK ARGILLACEOUS LIMESTONE: SIMILAR TO UNIT 4, MINOR SULPHIDE OCCURRENCES

SYMBOLS

SHAFT, MANWAY ....

DRIFT, CROSSCUT, STOPE ....

FAULT ....

GEOLOGIC CONTACT ....

BEDDING, OVERTURNED 40

DRAGFOLD ....

REPLACEMENT ORE ZONE ....

MINOR SULPHIDE OCCURRENCE: PYRITE, PYRRHOTITE, GALENA, SPHALERITE OR ARSENOPYRITE ....

MINERALIZED QUARTZ VEIN ....

Figure 30. Geology of the No. 2 Level, Mosquito Creek Gold mine.

The identification of many exposures of graded bedding in both Baker and Rainbow rocks was a key factor in establishing stratigraphic 'tops.' Most graded layers are less than 10 centimetres thick but individual beds are up to 2 metres thick. The graded beds generally consist of basal fine-grained white to buff quartzite that grades upward to black phyllite. Minor fine carbonate grains occur in both zones and the phyllite displays coarse rhombic dolomite crystals. The orientation of these beds indicates that the mine strata are overturned.

Workings on Level 3 of the mine expose a distinctive bed that is well up in the Rainbow member (unit 7, Fig. 30). The bed lies about 60 metres stratigraphically above the Rainbow-Baker contact and consists of dark greyish green, fine-grained, massive to faintly laminated rock with abundant fine pyrrhotite lamellae and rare scattered coarse pyrite crystals. While the euhedral pyrite is interpreted to be metamorphic, the distinctive pyrrhotite texture is thought to be primary. The rock is tentatively identified as metamorphosed tuff.

Lensing out of sedimentary strata made identification of key marker beds in the mine workings difficult. Virtually all lithologies are correlatable over short distances but few are continuous over the entire 500-metre length of the mine workings. Potentially useful units are: ore-hosting limestones, thin-bedded white quartzites, and orange to buff-weathering dolomite layers. All three lithologies are readily identifiable, even in intensely cleaved exposures. On Level 2 (Fig. 30) drag folding and intense faulting obscure the probable continuity of these beds near the southeastern limit of the mine workings. Any of these markers can be used as a prospecting guide in exploration programs in the area, and other units may prove useful locally.

Mine scale structural features are illustrated on Figures 29 through 32. Several minor folds were noted with an average plunge of 21 degrees toward north 45 degrees west. Orientation of strata on Figure 31 was determined from many well-exposed lithological contacts that strike north 50 degrees west with dips averaging 50 degrees northeast. Cleavage varies considerably in both orientation and intensity. Its development ranges from negligible to locally so intense that cleavage obscures rock textures and causes poor drill core recovery. Cleavage orientation roughly parallels the strike of rock strata but dips are shallower, ranging from 0 to 50 degrees and averaging 30 degrees northeast. The orientation of cleavage closer to horizontal than the dip of the rock strata supports the conclusion of overturned folds in the mine area. Prominent lineations throughout the mine parallel minor fold axes.

Faults abound in the mine. Most fall into two categories: north-south-striking, steeply east-dipping dextral faults (Fig. 30), and shallow, normal faults parallel to the cleavage (Fig. 31). The latter are abundant but often subtle, with little or no gouge. Benedict (1945) discusses them in some detail; they produce a limited but repetitive displacement which produces an overall apparent dip of 70 degrees northeast in the mine strata (Figs. 31 and 32).

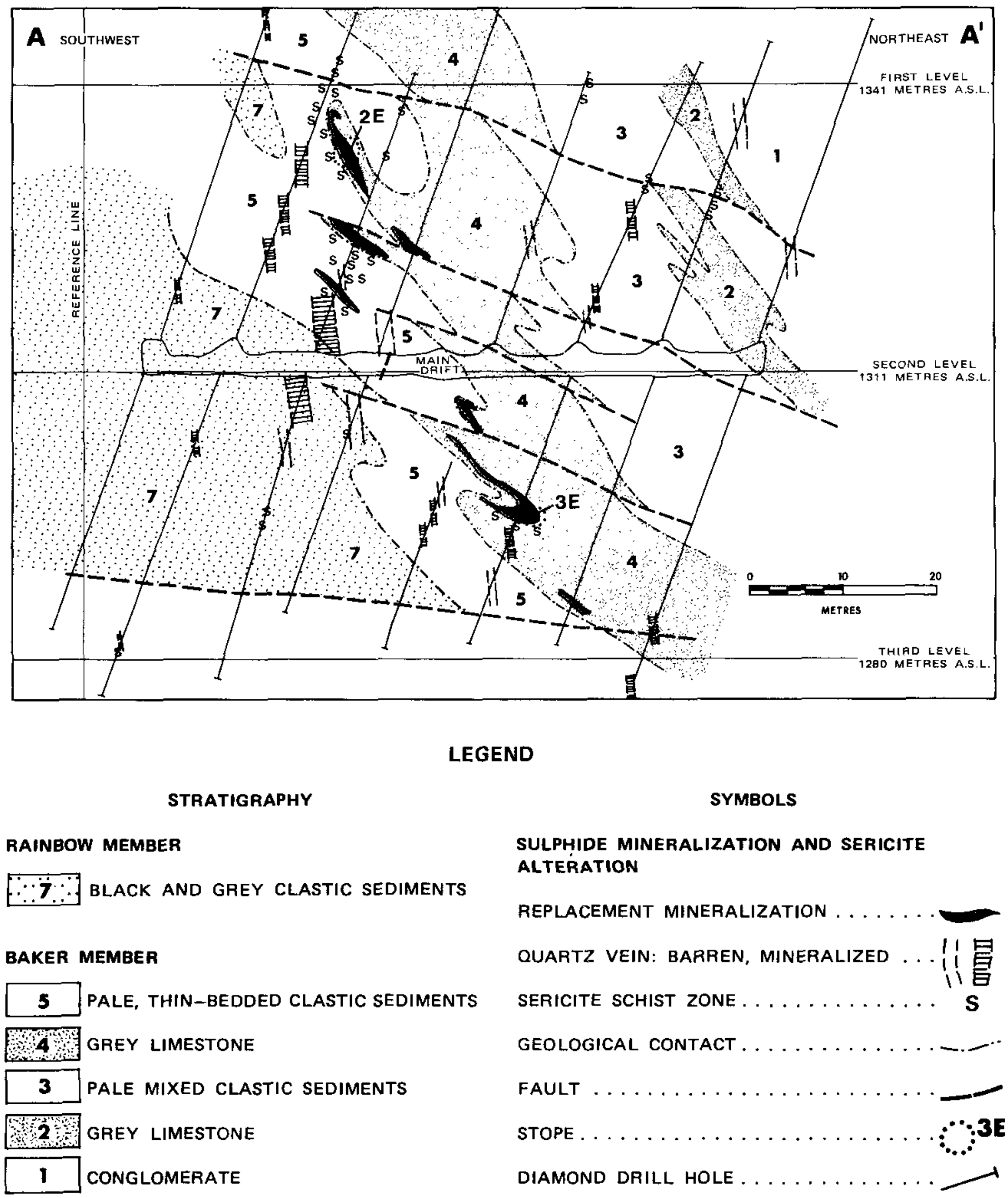


Figure 31. Geological cross-section of the No. 2 Crosscut West, No. 2 Level, Mosquito Creek Gold mine.

MINERALIZATION

Gold ore occurs in a large number of discrete, relatively small deposits along a total strike length of 45 kilometres that includes the Mosquito Creek, Island Mountain, and Cariboo Gold Quartz mines (Fig. 29) (Sutherland Brown, 1957). These occurrences consist of either auriferous pyrite in quartz veins in the Rainbow member (Fig. 33) or stratabound, massive auriferous pyrite lenses, termed 'replacement ore,' within and at the contacts of limestone beds of the Baker member (Fig. 31).

Quartz Vein Ore

The mine rocks are cut by numerous generations of intersecting quartz veins; the majority are barren. A minority of these veins carry coarse pyrite which is invariably auriferous. Ore-bearing quartz veins carry up to 25 per cent pyrite and grade up to 70 grams gold per tonne, although average production grades are considerably lower. Ore veins in Mosquito Creek mine reach 5 metres in width; the ultimate length and height of the near-vertical veins is still to be determined.

Mineralized quartz veins occurred in all three of the major mines at Wells. At Cariboo Gold Quartz, where total production was 1.54 million tonnes grading 13.4 grams gold per tonne from 1933 to 1959 (Carlyle, in press), the quartz veins were the main source of ore. At Mosquito Creek mine, during high metal price cycles, production has come from three quartz veins with grades ranging from 4.5 to 7.9 grams gold per tonne. These mineralized quartz veins at Mosquito Creek mine occur within Baker member rocks and accessory minerals in the veins are ankerite, galena, sphalerite, and sericite. However, Skerl (1948) also reports free gold, cosalite, argentite, and chalcopyrite from quartz veins at Cariboo Gold Quartz mine. Figure 33 is a sketch of a major quartz vein at Cariboo Gold Quartz mine. It shows that the vein is most extensively developed in Rainbow rocks but where the vein system continues into Baker member rocks it intersects and terminates in a 'replacement ore' lens.

Sericite from mineralized quartz veins at Cariboo Gold Quartz and Mosquito Creek mine has yielded Late Jurassic/Early Cretaceous K/Ar dates of 141 ± 5 (Andrew, 1982) and 139 5 (G. Klein, personal communication) respectively, from sites roughly 4 kilometres apart.

Replacement Ore

The historic term 'replacement ore' is used for the stratabound massive pyrite ore lenses despite its genetic implications. While quartz vein ore is most abundant in Rainbow rocks and only rarely occurs in Baker rocks, replacement ore occurs only within Baker rocks. Typically, replacement ore lenses occur within or at the contacts of the limestone lenses (Figs. 30 and 31). The ore lenses generally occur within 25 metres of the contact between dark Rainbow member beds and pale Baker beds.

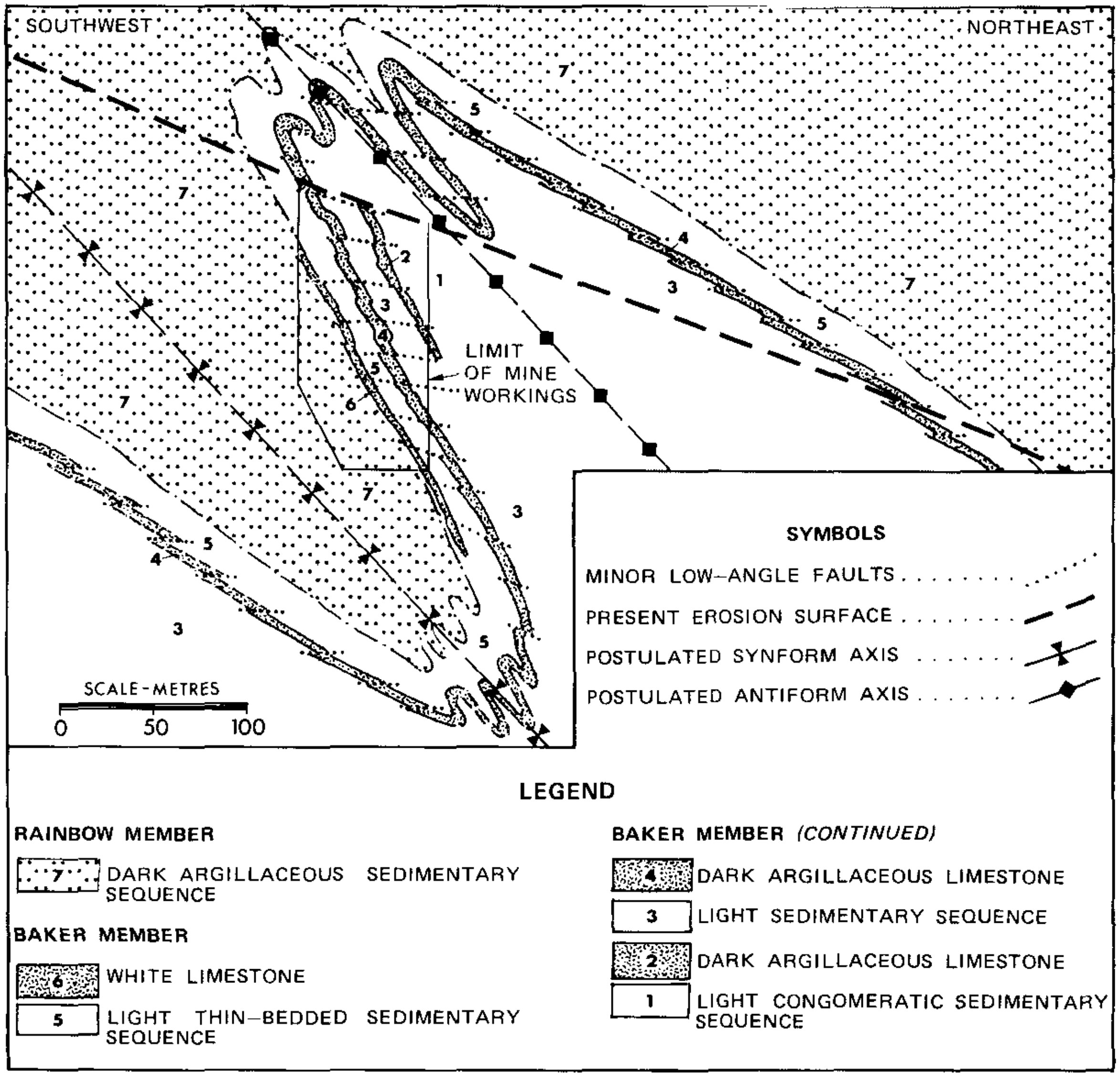


Figure 32. Idealized geological cross-section of the Mosquito Creek mine setting.

In addition to this lithologic association, most of the replacement lenses are structurally controlled. The massive pyrite lenses are commonly localized in the crests or noses of the minor folds and less frequently in fold troughs. However, significant tonnages of ore also occur in steeply dipping limbs of the main fold structure and in flat-lying tabular lenses where the limestones have 'rolled out' or flattened.

At Island Mountain mine ore lenses ranged from 500 to 35 000 tonnes, and averaged 2 000 to 7 000 tonnes. Typical dimensions are 2 to 3 metres thick, 6 metres wide, and from 30 to many hundreds of metres long down plunge. Replacement ore zones have average cross-section areas of 10 square metres, necessitating tight exploration drill spacing and careful study of peripheral alteration features in order to recognize 'near misses' in drilling.

The pyrite lenses are fine-grained and usually massive. Locally they display faint banding parallel to the host strata. The finest grained pyrite contains the highest gold values. Overall grades from 30 years of production at Island Mountain mine averaged 16.5 grams gold per tonne and 2.4′ grams silver per tonne (Carlyle, in press). However, grades from replacement ore alone, which supplied roughly 60 per cent of the production, averaged 23.0 grams gold per tonne and 3.4 grams silver per tonne. Overall grades at Mosquito Creek to December, 1982 mine averaged 14.5 grams gold per tonne from 49 940 tonnes of quartz vein and replacement ore combined.

Ore lenses have sharp hangingwall and footwall contacts; laterally they grade progressively into coarser barren pyrite with coarse arsenopyrite, minor amounts of disseminated galena, sphalerite and rare pyrrhotite, then into silicified limestone, sericitized limestone or sericite schist. The host rock is always limestone; dolomitized, silicified, or sericitized limestone; or sericite schist. In the schist, pervasive sericitization has obliterated the original lithology. One small replacement ore occurrence in sericite schist host rock is illustrated on Figure 31. Comparison with ore lenses in sericitized limestone suggests that the schists are derived from limestone as well. Carlyle (in press) noted that sericitization is most intense in the structural footwall of the pyrite lenses.

Short (2 to 4-metre), narrow (less than 5-centimetre) veins of massive galena and sphalerite mineralization occur in the hangingwall oriented at right angles to the ore lenses; similar veins occur, but are rare, in the footwall. Minor amounts of turquoise-green chromium-bearing mariposite characterize the hangingwall alteration zones. Recognition of these alteration features and peripheral accessory minerals at the mine enlarges 'targets' for exploration diamond drilling.

Some quartz veinlets show crosscutting relationships that clearly postdate the ore, but at least one major vein may be contemporaneous with a massive pyrite lens. In an excellent exposure in the 2E stope at

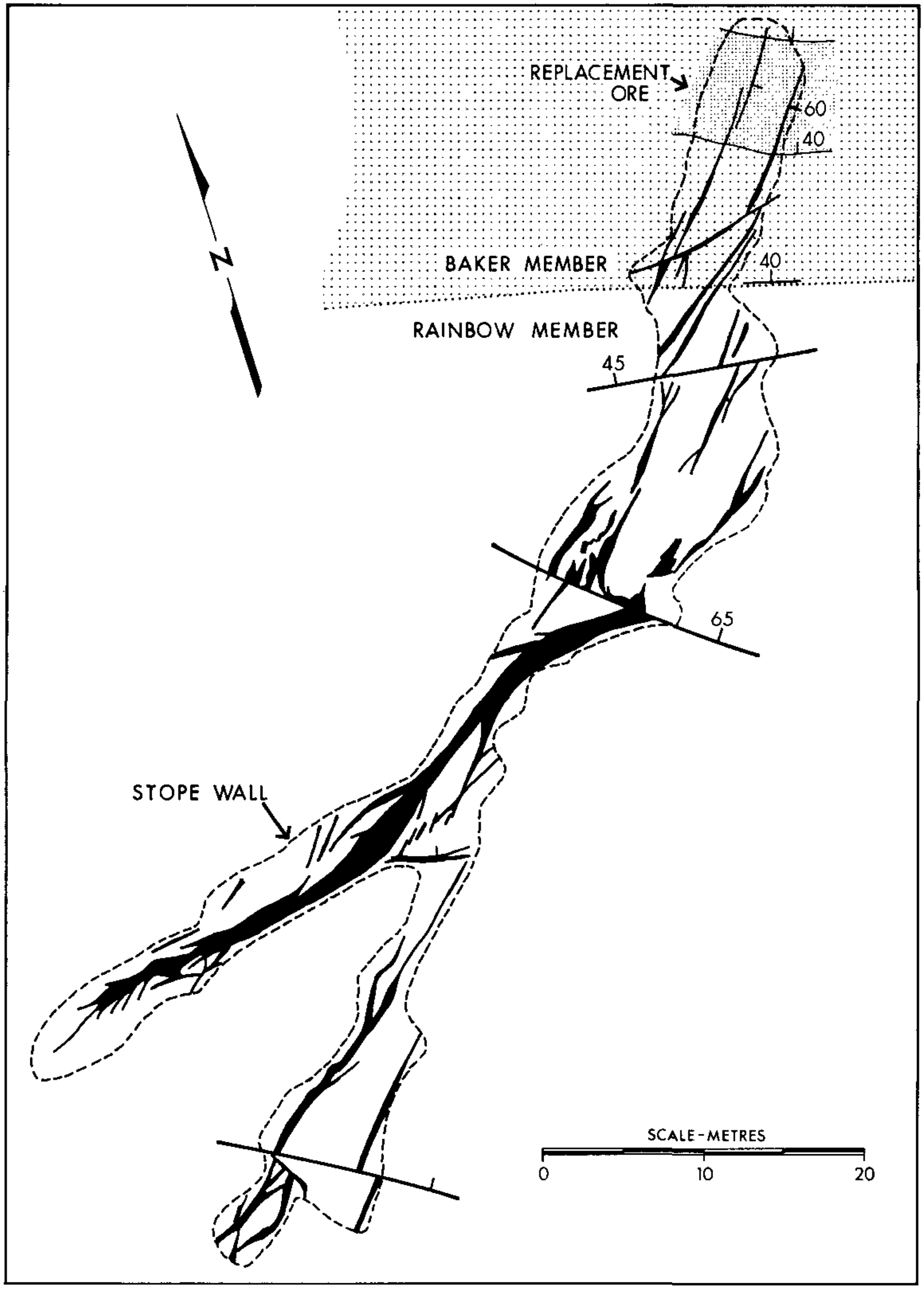


Figure 33. Plan of the 19-2 stope vein system, Cariboo Gold Quartz mine (after Skerl, 1948).

Mosquito Creek mine, a vertical 2-metre-wide barren quartz vein penetrates the massive pyrite lens and terminates abruptly at the hangingwall contact with sericite schists. The lateral margins of this massive white quartz vein are interlayered with stratiform silicified galena-sphalerite-pyrite mineralization which grades laterally into fine-grained massive pyrite of typical replacement ore.

GENESIS

Carlyle (in press) describes the three main genetic theories of mineralization developed since mining operations began in 1933:

(1) Metals were remobilized from the country rock during regional metamorphism and were reconcentrated in dilation zones, such as fold axes.

(2) Hydrothermal fluids rose from a deeply buried source along a complex fracture network of quartz veins and preferentially replaced the limestone beds.

(3) Hydrothermal fluids rose from a deeply buried source up the major north-striking faults and preferentially replaced limestone beds. Quartz vein ore then developed outward from the replacement ore lenses.

Recently developed metallogenic concepts of volcanic exhalative and/or sedimentary exhalative deposits were considered for this area but neither of the models fits well with observed data such as: quartz vein mineralization in the stratigraphic hangingwall; atypically high gold/base metal ratios; trace metal associations of arsenic, bismuth, tungsten; and Late Jurassic/Early Cretaceous radiometric dates for the quartz vein ore which contrast with Carboniferous fossil dates of the host rock.

Lead isotope analyses reported by Andrew, *et al.* (this volume) provide a Pb/Pb model age of 185±50 Ma for the lead mineralization which covers a broad enough range to be contemporaneous with regional metamorphism (K/Ar age of 179±8 Ma) or with post-tectonic magmatism (K/Ar age of 143±14 Ma) (Pigage, 1977). Andrew, *et al.* have concluded that the lead, and by inference the gold, in these deposits was derived from crustal rocks either by lateral secretion during Middle Mesozoic regional metamorphism or by hydrothermal leaching related to Late Jurassic/Early Cretaceous post-tectonic magmatism.

Given the distribution of all the known gold deposits over a 45-kilometre strike length along a single fold limb, a regional tectonic control for the mineralizing event seems necessary. The writer envisages the gold-bearing fluids were derived from the crustal rocks during regional metamorphism and emplaced late in the tectonic cycle during a period of fault readjustment (~140 Ma). The fluids penetrated the folded, overturned strata, precipitating mineralized quartz veins and reacting with carbonate beds when encountered. Fluids flowed along dilatant fold noses and troughs within the limestones, precipitating in massive sulphide lenses.

EXPLORATION

Successful exploration in the region has been based either on direct prospecting or on drilling near the critical Rainbow-Baker contact. Trenching has always been an essential part of the exploration programs because slopes throughout the area are steep and glacial overburden is deep.

The usefulness of geophysical methods such as IP, EM/VLF-EM, and SP is limited because trace disseminated pyrite is ubiquitous, carbon content is high in some strata, major fault zones are frequent, and typical orebodies are very small. A test induced polarization survey at Mosquito Creek mine delineated the contact between the Baker member and the highly carbonaceous Rainbow member. Resolution was sufficient to show displacement of the contact along by a major north-south fault. More useful results were obtained in a recent VLF-EM survey on the Mosquito Creek mines property where the Rainbow-Baker contact is delineated by bands of adjacent high and low anomalous values that follow the contact and show the same north-south fault displacement. The advantages of the VLF system over the IP technique lie in speed, simplicity, and lower cost. Correlation of filtered VLF results with property geology suggests that the anomalous VLF-EM lows or troughs may coincide with subcropping non-conductive limestone units.

Geochemical soil surveys in the region have produced gold anomalies and arsenic, lead, bismuth, silver, and copper are being used as pathfinder elements to avoid the problem of redistributed placer gold in the glacial till. Unfortunately, chemical metal dispersion, thick glacial overburden, soil creep, and small targets make spotting follow-up diamond-drill holes difficult. Follow-up of anomalies by trenching would probably be as cost-effective as drilling.

On a mine scale, systematic exploration for replacement ore at the Mosquito Creek mine involves establishing a regular spacing of exploraation crosscuts off the main southeast-northwest drift (Fig. 30) and a regular pattern of inclined drill holes from each crosscut (Fig. 31). This tight drill pattern is essential because ore zones and their alteration halos are small. Once ore is intersected, it is developed by mining along the plunge of the hosting minor folds (Fig. 29).

The exploration potential for more of these relatively small, but high grade gold deposits is excellent. Surface and underground exploration programs at Mosquito Creek mine have discovered additional reserves of replacement ore. Substantial reserves had been established at depth in the Island Mountain mine when it closed in 1967. Production from the

Cariboo Gold Quartz mine was predominantly from quartz vein ore in the Rainbow member (Figs. 29 and 33) while the existence and potential of the replacement ore within the Baker member was unrecognized. The mineral potential of minor limestone horizons within the Rainbow member rocks has yet to be evaluated.

CONCLUSIONS

The Cariboo Gold Belt is one of the major gold producing regions of the Canadian Cordillera. The Mosquito Creek mine produces ore from a number of deposits that are distributed along the strike extension of ore-bearing strata that yielded 37 697 kilograms of gold and 4 354 kilograms of silver since underground mining commenced in the area in 1933.

The many ore deposits of the belt occur in a structurally overturned metasedimentary rock sequence of the Carboniferous Cariboo Group. Lower Jurassic regional metamorphism produced greenschist facies mineralogy. Deformation produced regional, northwest-trending overturned folds with associated rhythmically spaced minor folds. Early Cretaceous lower grade quartz vein ore deposits are hosted predominantly in the dark carbonaceous rocks of the Pennsylvanian/Permian Rainbow member. Higher grade replacement ore deposits are hosted within and at the contacts of altered limestone horizons in the light-coloured Mississippian Baker member. The replacement ore deposits are localized by parasitic, minor folds and the crests and troughs of these folds may be continuously or discontinuously mineralized for many hundreds of metres down plunge.

The ore deposits are clearly epigenetic although the exact mechanism of their emplacement has still to be determined. The gold was likely derived from deeper crustal rocks.

The Cariboo Gold Belt offers excellent exploration potential within, between, and beyond the existing mine workings. An effective exploration program in this environment should combine detailed prospecting and geological mapping with soil geochemistry and VLF-EM geophysics. Initial work should be followed by an aggressive trenching program. The grade of replacement ore lenses and their orientation is so uniform and predictable that mining can be initiated directly from a subcrop exposure or a single drill hole intersection.

ACKNOWLEDGMENTS

The writer thanks the manager, R. R. Yarjau, and staff of Mosquito Creek Gold Mining Company Limited for their generous and willing cooperation. L. W. Carlyle, mine geologist, provided extensive discussions and excellent illustrations of many aspects of the mine stratigraphy and ore deposits.

This work has benefitted from discussions with L. C. Struik, J. Kelly, D. G. MacIntyre, and M. Guiguet. John Mawdsley and Mike Fournier ably and cheerfully assisted in the field.

REFERENCES

Andrew, A. (1982): A Lead Isotope Study of Selected Precious Metal Deposits in British Columbia, M.Sc. thesis, *University of British Columbia*, 80 pp.

Benedict, P. C. (1945): Structure at Island Mountain Mine, Wells, British Columbia, *C.I.M.*, Trans., Vol. 48, pp. 755-770.

Campbell, D. D. (1966): Potential of Ore Reserves and Production, Cariboo Gold Quartz Mine, Wells, British Columbia, unpub. company rept., 28 pp.

.... (1969): Surface Exploration and Production Potential of Cariboo Gold Quartz Mine, Wells, British Columbia, unpub. company rept. 24 pp.

Carlyle, L. W. (in press): Geological Summary of the Mosquito Creek Gold Mining Company Limited, *in* Field Guides to Geology and Mineral Deposits, Victoria 1983 Annual meeting, GAC/MAC/CGU.

Hanson, G. (1935): Barkerville Gold Belt, Cariboo District British Columbia, *Geol. Surv., Canada*, Mem. 181, 42 pp.

Pigage, L. C. (1977): Rb-Sr Dates for Granodiorite Intrusions on the Northeast Margin of the Shuswap Metamorphic Complex, Cariboo Mountains, British Columbia, *Cdn. Jour. Earth Sci.*, Vol. 14, No. 7, pp. 1690-1695.

Skerl, A. C. (1948): Geology of the Cariboo Gold Quartz Mine, Wells, British Columbia, *Econ. Geol.*, Vol. 43, pp. 571-597.

Struick, L. C. (1980): Geology of the Barkerville-Cariboo River Area, Central British Columbia, Ph.D. thesis, *University of Calgary*, 330 pp.

.... (1981a): Snowshoe Formation, Central British Columbia, *in* Current Research, Pt. A, *Geol. Surv., Canada*, Paper 81-1A, pp. 213-216.

.... (1981b): A Re-examination of the Type Area of the Devono-Mississippian Cariboo Orogeny, Central British Columbia, *Cdn. Jour. Earth Sci.*, Vol. 18, pp. 1767-1775.

.... (1982a): *Geol. Surv., Canada*, O.F. 858, Map Series.

.... (1982b): Snowshoe Formation (1982), Central British Columbia, *in* Current Research, Pt. B, *Geol. Surv., Canada*, Paper 82-1B, pp. 117-124.

Sutherland Brown, A. (1957): Geology of the Antler Creek Area, Cariboo District, British Columbia, *B.C. Ministry of Energy, Mines & Pet. Res.*, Bull. 38, 105 pp.

TELKWA COALFIELD, WEST-CENTRAL BRITISH COLUMBIA (93L)

By J. Koo

INTRODUCTION

The Telkwa Coalfield is situated a few kilometres southwest of Telkwa and 18 kilometres south of Smithers in west-central British Columbia. The Canadian National Railway line and Highway 16 run through the town of Telkwa to the port of Prince Rupert, 370 kilometres west of the Telkwa Coalfield.

After the initial discovery of coal about 1900 until the 1950's, exploration had been concentrated on the coal seams exposed along the valleys of the Telkwa River and Goathorn Creek (Dowling, 1915; Black, 1951) (Fig. 34). Telkwa coal measures crop out only in a few valleys that have cut deeply through the thick overburden. Volcanic or intrusive rocks underlie most of the higher ridges around the Telkwa Coalfield. The Telkwa basin lies near the southern boundary of Bowser successor basin north of Skeena Arch within the Intermontane Belt of the Canadian Cordillera (Tipper and Richards, 1976; Carter, 1981), and the Telkwa coal measures comprise part of a Mesozoic volcanic and sedimentary sequence cut by granitic intrusions of Late Cretaceous and Early Tertiary age.

In 1969, Canex Placer Ltd. conducted a drill program to explore the northern part of the coalfield. Since 1979, Crows Nest Resources Limited has conducted an extensive exploration program to delineate economic coal seams of the Telkwa Coalfield. Mining to date has consisted of relatively small scale underground and open pit operations in the valleys of the Telkwa River and Goathorn Creek. Growth in mining has been hampered by the limited geological understanding of the coal measures and their coal resource potential.

The present project was initiated in early August of 1982 with the following terms of reference: description of the stratigraphy, structural development, depositional environments, and geologic age of the Telkwa basin; the correlation of coal seams and their quality; definition of the areal extent of the coal measures, and their relationships to surrounding rocks. This report presents preliminary results of the fieldwork conducted between August and September of 1982. Geological mapping, conducted at scale 1:10 000, was based on investigation of outcrops and examination of drill cores. Fieldwork for the project will be completed during the summer of 1983.

STRATIGRAPHY OF THE TELKWA COAL MEASURES

The Telkwa coal measures can be subdivided into the Lower, Middle, and Upper units (Figs. 34, 35, and 36).

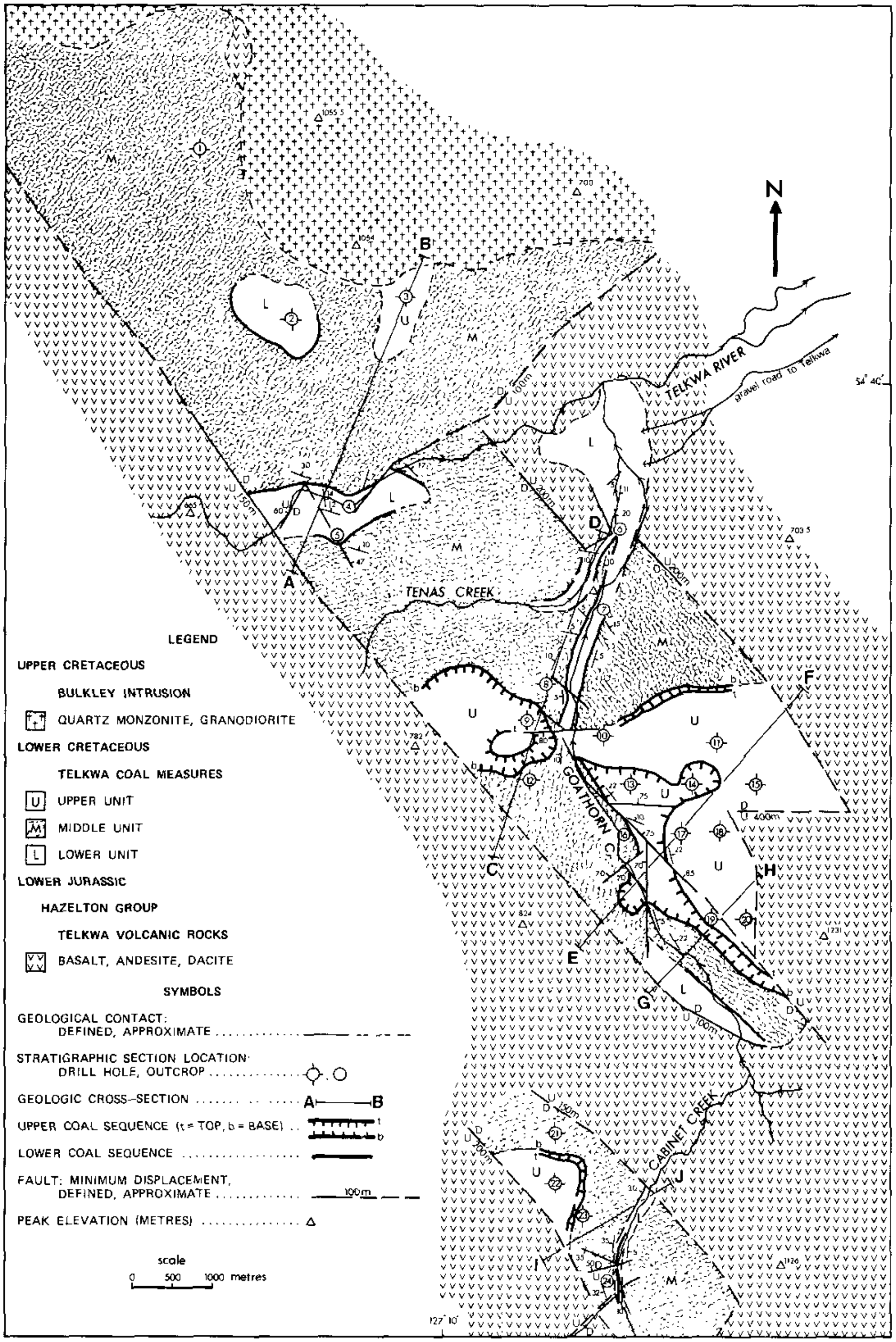


Figure 34. Simplified geology of the Telkwa Coalfield.

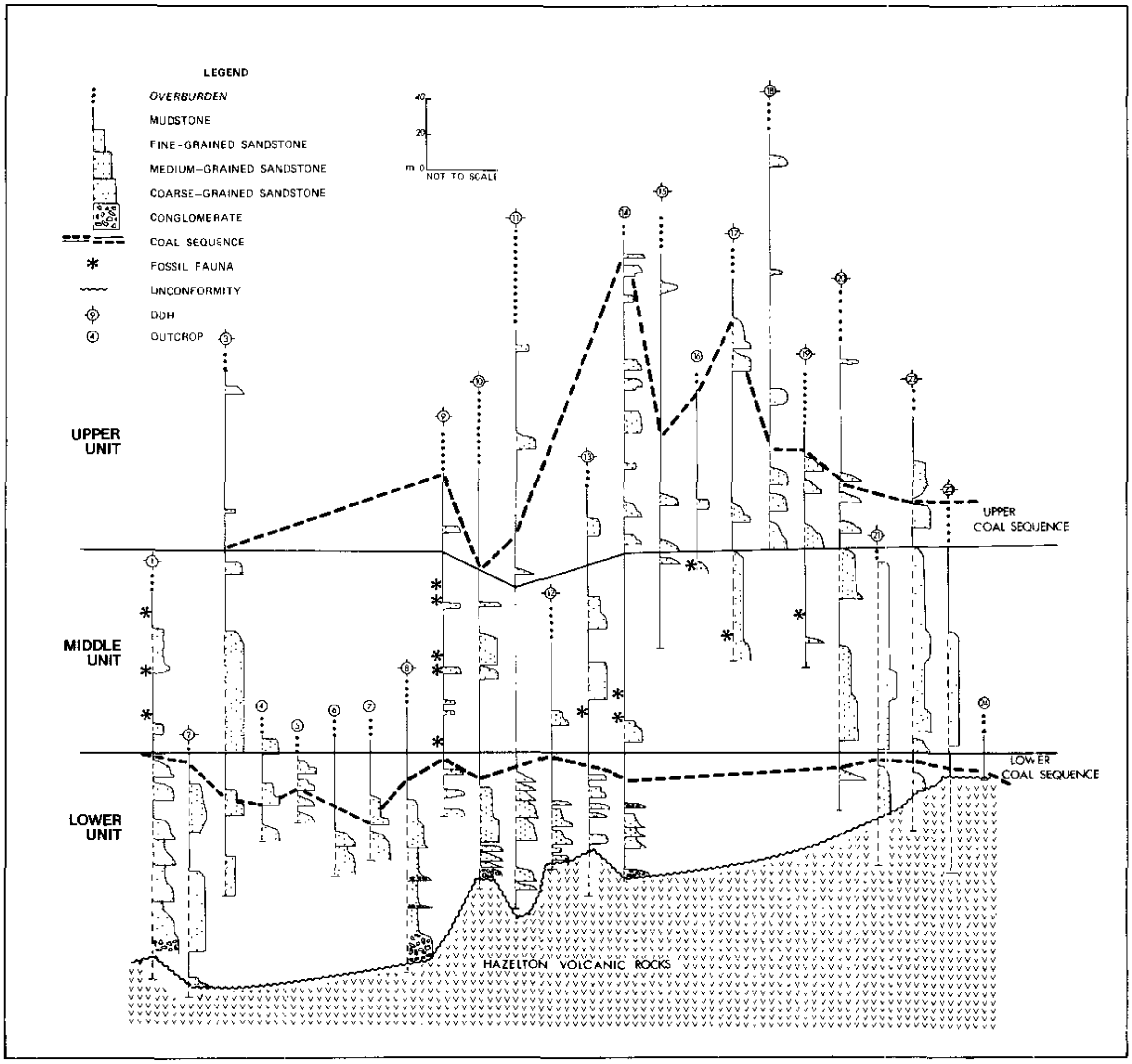


Figure 35. Geological cross-sections, Telkwa Coalfield.

The Lower unit consists of conglomerate, coarse to fine-grained sandstone, mudstone, and coal seams. This unit comprises the lower part of the Telkwa coal measures. Its thickness varies from 15 to 120 metres. Up to seven fining-upward rhythmites characterize vertical sections of this unit. Each rhythmite shows a gradual lithological variation up section from conglomerates or coarse-grained sandstone through medium-grained sandstone to fine-grained sandstone or mudstone. The individual rhythmites vary in thickness from 4 to 40 metres.

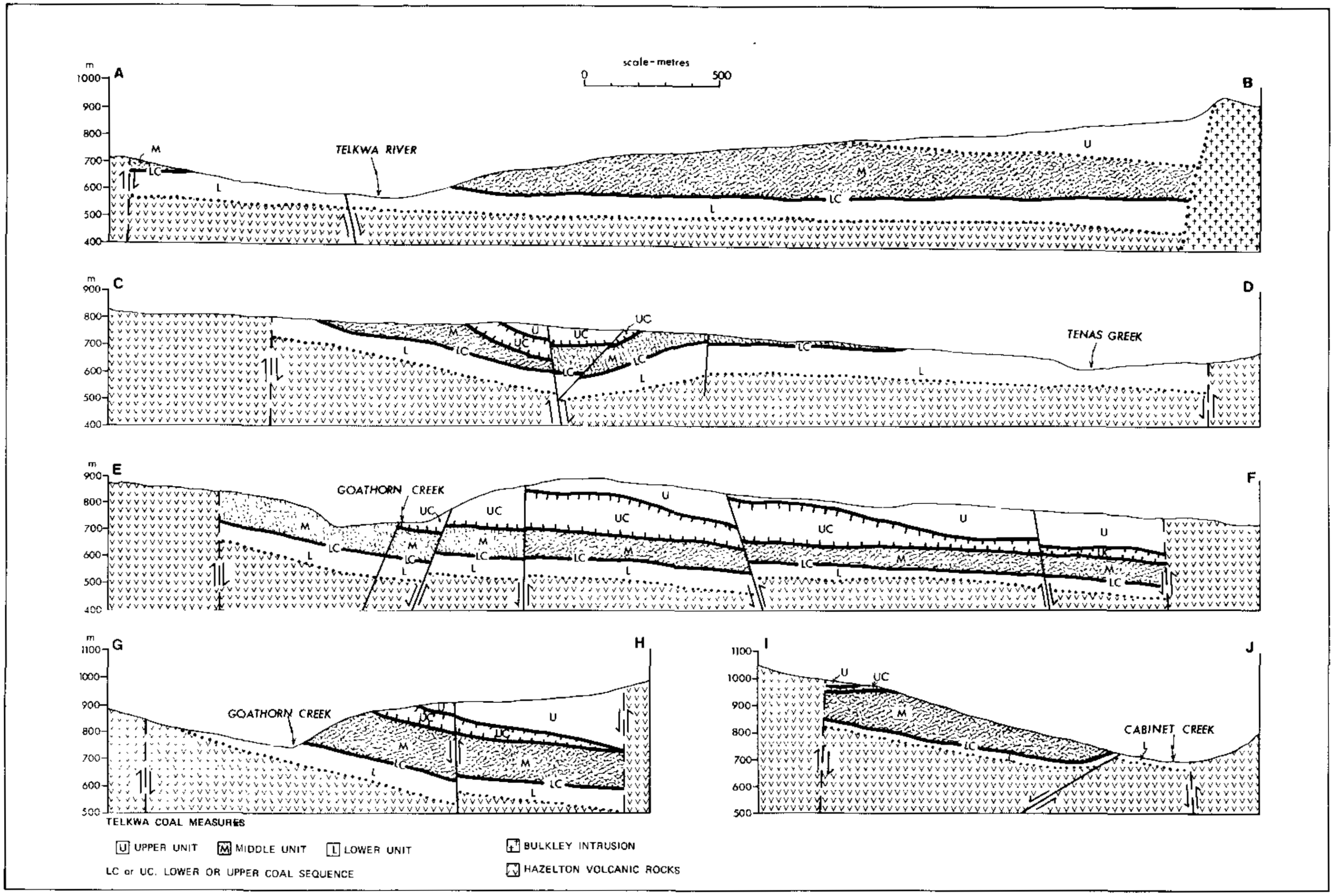


Figure 36. Stratigraphic cross-sections, Telkwa Coalfield.

Conglomerates occur in some of the fining-upward rhythmites, but only near the base of the Lower unit. Most conglomeratic layers consist of subangular to subrounded, relatively well-sorted clasts that decrease in size up section from cobbles through pebbles to granules. The conglomeratic layers vary in thickness from 50 centimetres to 15 metres. Most of the clasts originate from red, green, or grey volcanic flows, agglomerates and tuffs of basaltic, andesitic, or dacitic composition.

The coarse-grained sandstones are mainly maroon, purple, or grey. They are up to 10 metres thick and similar in composition to the conglomerates. The medium to fine-grained sandstones are purple, grey, or dark grey, and range up to 40 metres in thickness. The mudstones are grey, black, or brown and range from 2 to 25 metres in thickness. In the upper part of the Lower unit, mudstone layers at the tops of the fining-upward rhythmites are relatively thick. These mudstone layers are closely associated with coal seams. Coalified plant debris up to 15 centimetres long, 5 centimetres wide, and 2 centimetres thick are randomly scattered within the conglomerates and coarse to medium-grained sandstones.

The Lower unit typifies a fluvial clastic sequence. The conglomerate and commonly crossbedded, coarse to medium-grained sandstone layers are lenticular in shape with limited lateral extension, and represent relatively high-energy channel deposits. The fine-grained sandstones and mudstones form laterally extensive layers and represent relatively low-energy flood plain deposits.

The Middle unit consists of 90 to 140 metres of medium to fine-grained sandstones and mudstones. This unit comprises the middle strata of the Telkwa coal measures. The rocks are green, grey, or black. They form relatively thick and laterally extensive layers. Some of the layers are up to 100 metres thick and over 1 kilometre long in lateral extent. Locally, the Middle unit contains several 2 to 20-metre-thick fining-upward rhythmites. Each rhythmite begins with medium-grained sandstone and ends with fine-grained sandstone to mudstone. Although these rhythmic sequences represent fluvial deposits, local shallow marine incursions in the Middle unit are also signalled by the molluscan faunas that include brachiopods.

The Upper unit consists of more than 330 metres of sandstones, mudstones, and coal seams. This unit comprises the upper strata of the Telkwa coal measures. The lower part of this unit consists of up to 180 metres of medium to fine-grained sandstones, mudstones, and coal seams. This succession consists of up to eight fining-upward rhythmites that change from medium-grained sandstone through fine-grained sandstone to mudstone and coal seams. Individual rhythmites are 10 to 30 metres thick. Coalified plant debris up to 5 centimetres across are commonly scattered within the sandstones. The upper part of this unit is more than 150 metres in thickness, consisting of mudstone with subordinate amounts of fine-grained sandstone and marl. The rocks are greenish grey or dark grey.

The Upper unit is a fluvial clastic sequence consisting of much finer grained sedimentary rocks than those of the Lower unit. This unit represents relatively low-energy, recessive fluvial deposits.

Plant fossils are relatively abundant, and occur mainly in the Lower and Upper units. Hacquebard, *et al.* (1967) identified these fossil plants and determined them to be of Lower Cretaceous age. Concretions up to a few metres across are common in iron and carbonate-rich mudstones and sandstones of the Telkwa coal measures. Clay rip-ups, loading, slumping, flasers, convolution, thin laminations, scour filling, and bioturbation are also common in most mudstones and sandstones of the coal measures.

Erosion stripped off much of the Upper and Middle units in places from the Telkwa Coalfield (Figs. 35 and 36). Overburden ranges in thickness from a few metres to more than 100 metres outside major valleys in the coalfield.

HAZELTON VOLCANIC ROCKS

The Telkwa coal measures unconformably overlie a volcanic sequence composed of red, purple, green, or grey flow and pyroclastic rocks (Figs. 34, 35, and 36). These volcanic rocks are of dacitic, andesitic, or basaltic composition. The contact is clearly an unconformity that is marked by basal conglomerates or coarse-grained sandstones of the Telkwa coal measures that lie on the uneven, erosional surface of the volcanic sequence. Similar volcanic rocks occur outside the Telkwa Coalfield. They are of Lower Jurassic age (Sinemurian to earliest Pliensbachian) and comprise part of the Howson subaerial facies of the Telkwa Formation, a lower stratigraphic unit of the Hazelton Group (Tipper and Richards, 1976).

BULKLEY INTRUSIONS

A major intrusion of porphyritic granodiorite and quartz monzonite cuts the coal measures at the north end of the Telkwa Coalfield (Figs. 34 and 35). This stock is one of the Upper Cretaceous (70 to 84 Ma) Bulkley intrusions (Carter, 1981). Elsewhere, the coal measures are also cut by up to 10-metre-thick quartz porphyry dykes which are similar in composition to the major intrusion, and by up to 2-metre-thick mafic dykes of unknown age.

STRUCTURAL FRAMEWORK

The Telkwa coal measures dip mostly 5 to 15 degrees to the northeast or east (Figs. 34 and 35). However, faulting causes local variations due to drag folding or block tilting. These faults dip mostly at high angles ranging from 70 to 90 degrees and strike northwest, east-west, north-south, or northeast. Some created intensely brecciated and sheared zones up to 5 metres wide that commonly contain brecciated and sheared coal seam blocks. The high-angle faults show reverse or normal displacements of up to 30 metres (Figs. 34 and 35). Mafic dykes intruded along some of the northwesterly faults, and all mafic and felsic intrusions are at least partly fault controlled. The mafic dykes are intensely sheared and, locally, are altered to talc schist.

The coal measures appear to be bounded by a number of northwesterly trending high-angle faults that are parallel to faults within the coal-field. The net displacements on these boundary faults appear to be mainly vertical and range from 50 to 300 metres. The Telkwa coal basin has a horst and graben configuration that consists of two parallel, major grabens that contain coal measures separated by a central horst made up of Hazelton volcanic rocks.

COAL SEAMS

The coal in the Telkwa basin occurs in the Lower and Upper units (Figs. 34, 35, and 36). Coal seams, therefore, are classified as lower and upper sequences.

The lower sequence consists of up to four coal seams, 1 to 15 metres apart, that occur near the stratigraphic top of the Lower unit. Individual coal seams range from 1 to 6 metres and aggregate zones from 2 to 12 metres in thickness. The lower coal sequence extends continuously throughout the Telkwa Coalfield and varies from 2 to 40 metres in thickness.

Following infilling of the uneven, eroded surface of the older Hazelton terrane by fluvial deposits of the Lower unit of the Telkwa coal measures, an extensive flood plain developed and bogs persisted long enough for potentially economic coal seams to form. Periodic flooding and deposition of river muds occurred. The coal swamp and flood plain environment was altered and ended by marine incursions. Sediments deposited during a few short-term transgressions and regressions mark the end of the lower coal sequence.

The upper coal sequence consists of up to 13 coal seams. It lies in the lower part of the Upper unit. Potentially economic coal seams are closely associated with black mudstone layers at the tops of fining-upward rhythmites of fluvial clastic rocks. Intervals between individual coal seams range from 2 to 20 metres, almost the thickness of individual fining-upward rhythmites. Coal seams range in individual thickness from 1 to 5 metres and in aggregate thickness up to 26 metres.

The upper coal sequence occupies a stratigraphic interval of 20 to 170 metres. Evidently, eutropic coal swamps and flood plains developed again in a recessive, low-lying fluvial environment, following deposition of the Middle unit.

Both sapropelic and humic coals comprise the lower and upper coal seams. The sapropelic coal consists of black, dull canneloid type with vitrain stringers less than 1 millimetre thick and up to a few per cent of disseminated pyrite. This coal represents limnic gyttja deposits. The humic coal consists of alternating clarain and durain with occasionally abundant vitrain and fusain. This coal represents limno-telmatic reed moor deposits. The lower and upper coal seams have vitrinite reflectances ($\bar{R}_o$ max.) of 0.6 to 0.9 per cent. Although the Telkwa coal represents largely limnic to telmatic deposits, it may also contain paralic coal locally due to the marine incursions near the top of the lower coal sequence and near the base of the upper coal sequence.

Natural burning occurred in limited parts of some coal seams that crop out in the steep cliffs along Goathorn Creek. These burnt seams occur in zones that lie within 10 metres of the base of the overburden. The sedimentary sections with burnt coal seams show local collapse or crackle structures, red oxidation zones, melted rock fragments, and residual ash layers.

CONCLUSIONS

The Telkwa coal measures can be subdivided into three stratigraphically significant map units with respect to the potentially economic coal seams: the Lower unit, the Middle unit, and the Upper unit.

Maximum thickness of the coal measures succession reaches 400 metres. Stratigraphic columns show typical, vertically and laterally accreting, fluvial clastic sequences with periodic marine incursions. The fluvial sequences appear to comprise channel lag, point bar, braided bar, levee, crevasse-splay, and flood plain deposits.

Coal seams occur at the upper part of the Lower unit and at the lower part of the Upper unit. In each unit they occur near the tops of most fining-upward fluvial clastic rhythmites. The lower coal seams can be traced continuously throughout the Telkwa Coalfield within a relatively narrow stratigraphic interval. The upper coal seams are relatively thick and are best developed in the southern half of the coalfield.

The coal measures are probably of Lower Cretaceous age. They unconformably overlie Hazelton volcanic rocks, and Bulkley intrusions intrude them. The Telkwa Coalfield exists because the coal measures lie in two grabens and were protected from erosion.

ACKNOWLEDGMENTS

Thanks are extended to: F. Martonhegyi, D. Handy, S. Cameron, and K. Lendell of Crows Nest Resources Limited and L. Gething of Bulkley Valley Collieries for their willing cooperation, and I. Webster for his able assistance. The author thanks his colleagues in the Geological Branch for their helpful support in various aspects of this project.

REFERENCES

Black, J. M. (1951): Report on Goathorn Creek Coal *Area, B.C. Ministry of Energy, Mines & Pet. Res.*, Ann. Rept., 1951, pp. A291-A297.

Carter, N. C. (1981): Porphyry Copper and Molybdenum Deposits, West-Central British Columbia, *B.C. Ministry of Energy, Mines & Pet. Res.*, Bull. 64, 150 pp.

Dowling, D. B. (1915): Coalfields of British Columbia, *Geol. Surv., Canada,* Mem. 69, pp. 167-189.

Hacquebard, P. A., Birmingham, T. F., and Donaldson, J. R. (1967): Petrography of Canadian Coals in Relation to Environment of Deposition, *Energy, Mines & Res.*, Proc. of Symposium on the Science and Technology of Coal, Mines Branch, Ottawa, pp. 84-97.

Tipper, H. W. and Richards, T. A. (1976): Jurassic Stratigraphy and History of North-Central British Columbia, *Geol. Surv., Canada,* Bull. 270, 73 pp.

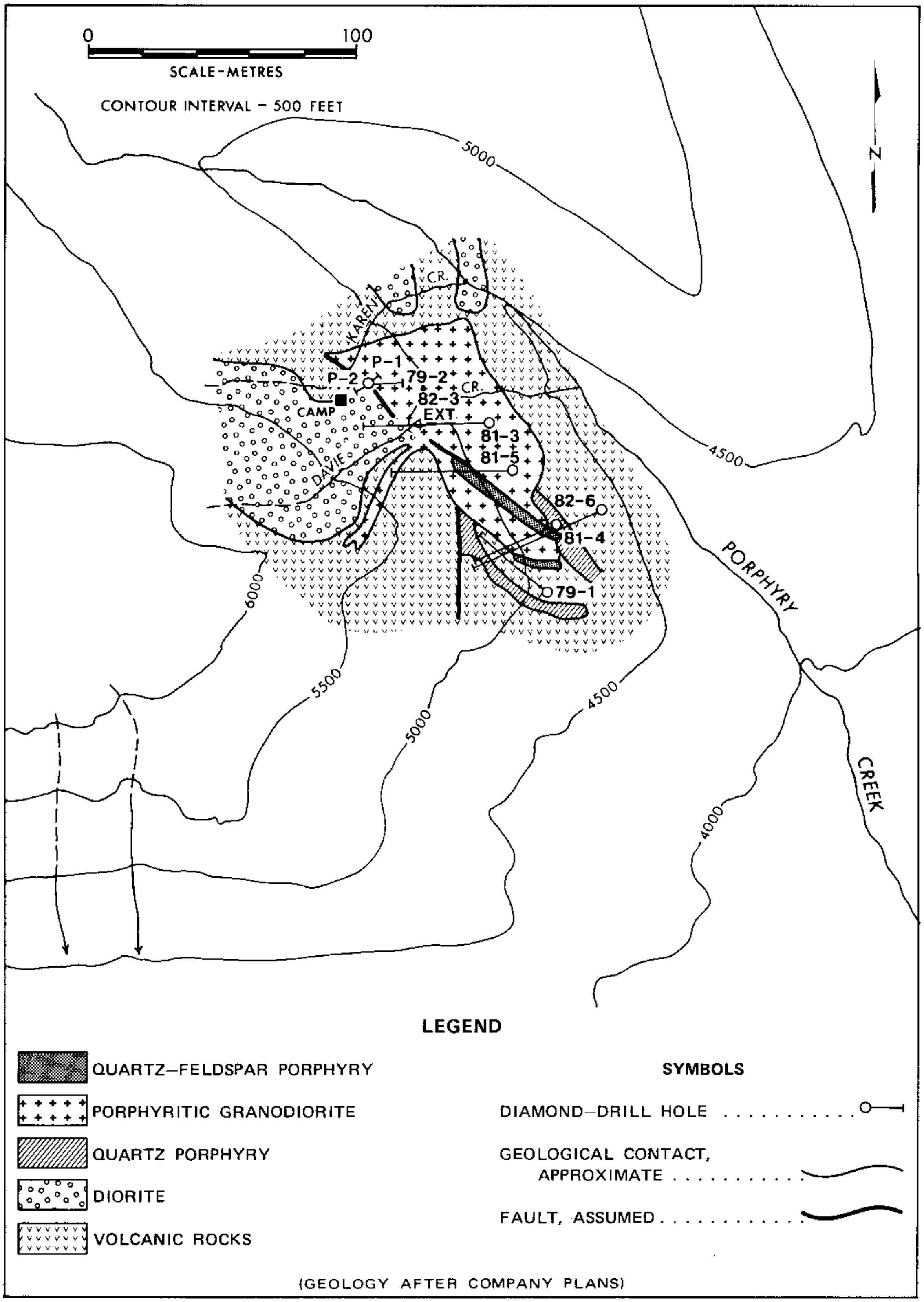


Figure 37. Geology of Porphyry Creek prospect.

PORPHYRY CREEK PROPERTY
(94D/8E)

By T. G. Schroeter

INTRODUCTION

On August 19th and 20th the writer visited the Porphyry Creek molybdenum property (MI 94D-113) located approximately 20 kilometres southeast of Johanson Lake. The property was being drilled by Getty Mines, Limited in an option agreement with Teck Corporation. Access was by helicopter from Johanson Lake.

GEOLOGY AND MINERALIZATION

Molybdenite rosettes and pyrite occur on fractures and in quartz veinlets within multi-phase dioritic to granodioritic intrusive rocks and host Takla Group andesitic rocks, which locally are hornfelsed and contain red garnet, epidote, and pyrite (Fig. 37). Magnetite is locally abundant and chalcopyrite is rare. The stock has been mapped along a northwesterly trend for 750 metres and is 250 metres wide. Alteration minerals include quartz, potash feldspar, sericite, epidote, and garnet.

Drill hole 81-3 was deepened from 242.9 to 457.2 metres and hole 82-6 was drilled to a total depth of 748 metres, bringing total 1982 drilling to 962.3 metres.

ACKNOWLEDGMENTS

The writer acknowledges the hospitality of Getty Mines, Limited and Bema Industries Ltd. during his visit to the property.

LAY CREEK PROPERTY
(94D/9E)

By T. G. Schroeter

INTRODUCTION

The Lay Creek property, consisting of the Breccia claims (60 units total), is located approximately 6 kilometres east of the south end of Johanson Lake, 210 kilometres north-northeast of Smithers. Access to the property is either by the Omineca Mining Road 170 kilometres from Germansen Landing or approximately 200 kilometres via fixed wing wheel or float-equipped aircraft from Smithers. A 2.5-kilometre road connects the showings with the Omineca Mining Road. The writer visited the property on August 20th.

GEOLOGY AND MINERALIZATION

Two main areas of surface mineralization and a third geophysical target were tested by diamond drilling with three drill holes totalling approximately 425 metres. The Breccia zone trends in a northwesterly direction apparently for a continuous length of 320 metres; dips range from 35 to 50 degrees southwest. The breccia is unusual in that it has a bedded or sheeted nature wherein angular thin plates to massive slabs of andesitic, dioritic, and pyroxenitic rock sit in a matrix of rhodochrosite, quartz, and chlorite with erratic clots and veinlets of chalcopyrite, pyrite, and minor amounts of magnetite. Chalcopyrite is also disseminated in the dioritic fragments.

The Contact zone occurs at the contact between granodiorite and breccia and contains chalcopyrite disseminated in granodiorite. Secondary minerals include malachite and azurite. There is also a distinctive orange-red amorphous 'stain' which is anomalous in copper.

ACKNOWLEDGMENTS

The writer acknowledges the hospitality of Silver Standard Mines Limited and Lornex Mining Corporation Ltd.

TOODOGGONE RIVER AREA
(94E)

By T. G. Schroeter

INTRODUCTION

The Toodoggone River area is situated approximately 300 kilometres north of Smithers (Fig. 38). Access to the area was by aircraft, mainly from Smithers.

The writer spent two weeks in the area, mainly north of the Toodoggone River. Work included fill-in geological mapping using a 1:25 000 scale topographic base, as well as detailed property examinations and core inspection. Particular attention was paid to structural controls, alteration zones, and mode and types of mineralization.

In addition, Andre Panteleyev and Larry Diakow conducted detailed stratigraphic studies in the area (*see* accompanying reports, this volume). It is hoped that a preliminary map of the Toodoggone area will be available in the spring of 1983 at a scale of 1:50 000.

WORK DONE

The following diamond drilling was completed in the Toodoggone during 1982:

(1) Kidd Creek Mines Ltd.

(a)	JD	1 445 metres	(4 739 feet)
(b)	Porphyry Pearl	498 metres	(1 632 feet)
(c)	Al	1 667 metres	(5 469 feet)
		3 610 metres	(11 840 feet)

Core from this program was briefly examined.

(2) SEREM Ltd. Approximately 3 597 metres (11 800 feet) of underground and surface drilling on the Amethyst gold breccia zone (Lawyers property).

Core from this program was not examined.

(3) Lacana Mining Corporation. Drilled 621 metres (2 038 feet) on the Metsantan gold breccia zone.

Core from this program was examined.

(4) Du Pont of Canada Exploration Limited. Approximately 915 metres (3 000 feet) was drilled on a 'new' (upper) quartz vein at Baker mine. Total drilling in the area was 8 743 metres (28 678 feet).

Core from this program was not examined.

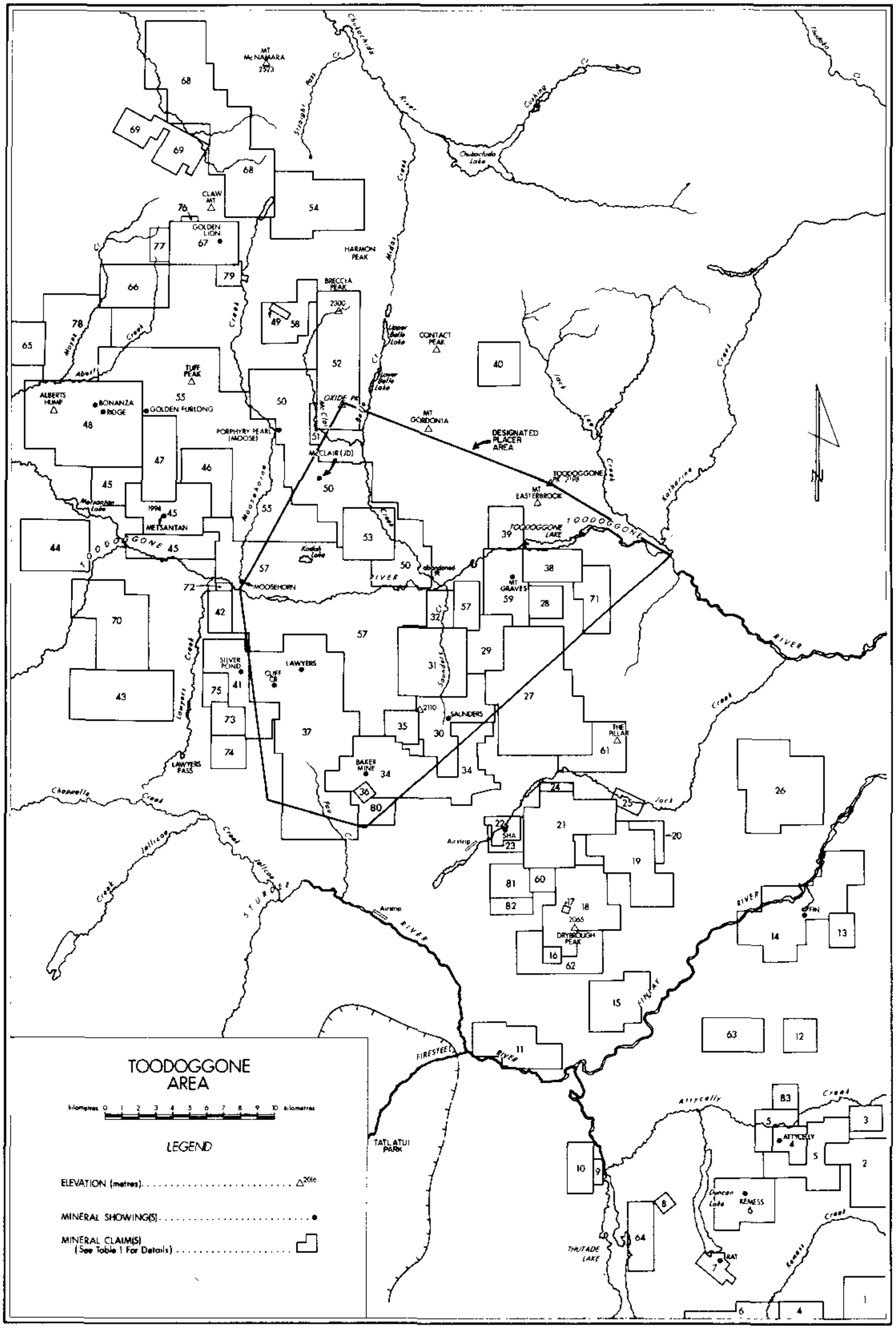


Figure 38. Toodoggone map-area.

TOODOGGONE RIVER AREA, MINERAL PROPERTIES

No.	Claim Name	MDI 94E	Operator
1	Aura	------	SEREM Ltd.
2	Mess 1-4	------	SEREM Ltd.
3	Audrey 1-2	------	Kidd Creek Mines
4	Audrey East, Audrey West	22	Kidd Creek Mines
5	Kem 1-9	------	Kidd Creek Mines
6	New Kemess 1-2	21	Kennco
7	Rat	25	Cominco Ltd.
8	Crown-granted claims	12, 13, 14	Cominco Ltd.
9	Atty	------	Taiga Cons.
10	Firesteel	2	SEREM Ltd.
11	Fire 1-3	------	Du Pont Expl.
12	Rich	------	Taiga Cons.
13	Mex	57	Cominco Ltd.
14	Fin 1-9	16	Brinco
15	Grace 1-4	47, 48, 49	D. MacQuarrie
16	Amigo	58	Cominco Ltd.
17	RN	3, 4, 5	Winderra Mines
18	Aca, Pul, Acapulco, Gotch 1-2	3, 4, 5	SEREM Ltd.
19	Jock 1-5	8	Taiga Cons.
20	Gossan 1-2	8	Lacana Mining
21	Jock 1-5	8, 39	SEREM Ltd.
22	Shas	50	International Shasta
23	Silver Reef	45, 50	C. Kowall
24	Pill	------	J. Weishaupt
25	Brenda	------	J. Weishaupt
26	Nub Mountain	63	SEREM Ltd.
27	Orange, Argus 1-4, Arg 1-2, OJ 1-4	28, 29, 42	SEREM Ltd.
28	To No. 2	------	Du Pont Expl.
29	GWP 200	7	Great Western Pet.
30	Golden Neighbour 1-4, Camp, Camp Fr., Jolly Roger, Artful Dodger	37	Lacana Mining
31	Saunders	40	Taiga Cons.
32	GWP 43	------	Great Western Pet.
34	Chappelle	26	Du Pont Expl.
35	Pel	26	Du Pont Expl.
36	Crown-granted claims	27	O. McDonald
37	New Lawyers 1-4, Law 1-3, Breeze, Road 1-111, Perry 1-2, Mason 1-2, GTW 1-3, plus fractions	64	SEREM Ltd.
38	Duke 1-2	------	SEREM Ltd.
39	To No. 1	------	Du Pont Expl.
40	Mui 1-2	52	Du Pont Expl.
41	Silver Pond, Silver Creek, Silver Peak, Silver Grizzly	17	Great Western Pet.
42	Kodah	17	SEREM Ltd.
43	Lass 1-4	------	Du Pont Expl.
44	Edo 1-4	------	Du Pont Expl.
45	Metsantan 1-9	65	Lacana Mining
46	Ant 1-3	------	Du Pont Expl.
47	Mets 1-2	------	Taiga Cons.
48	Al 1-8	66	Kidd Creek Mines
49	Har	53	Kennco
50	Scree 1-3, Moose 1-3, JM, JD, JB JR, McClair 1-5, plus fractions	31, 32	Kidd Creek Mines
51	Air 1-2	------	Du Pont Expl.
52	Poo, On, Lou, Oxide	------	SEREM Ltd.
53	Belle 1-2	------	Taiga Cons.
54	Moose 1-4	------	S. Young
55	Bert, Ernie, Winkle, Bull, Chute, Surprise, Gerome, Oscar Fr., Wankle Fr., Antoine Louis, Tour Sturdee, Big Bird, Kadah, Shodee, RJ Fr., JP Fr.	------	Kidd Creek Mines
57	GWP 1-43, Doug's Bear	------	Great Western Pet.
58	Gordon Davies, Gordon Davies 2	53	Lacana Mining
59	Graves 1-4	67	Great Western Pet.
60	Itsch	------	SEREM Ltd.
61	Hercules, Atlas	24	SEREM Ltd.
62	Star, Co, Sun	58	SEREM Ltd.
63	Wrich	------	SEREM Ltd.
64	Ron 1-6	13, 14	R. Wong
65	Adoo 1-2	------	Newmont Expl.
66	Hump 1-2	------	Newmont Expl.
67	Golden Lion 1-2	------	Newmont Expl.
68	QBX 1-12	------	Taiga Cons.
69	Claw	46	Umex
70	Xenos 1-4	------	Lacana Mining
71	Sun 1-2	------	Newmont Expl.
72	Kodah 2	------	SEREM Ltd.
73	Pipe	------	Kidd Creek Mines
74	Dream	------	Kidd Creek Mines
75	Asap	------	Great Western Pet.
76	Silver Lion	------	Newmont Expl.
77	Golden Lion 3	------	Newmont Expl.
78	Moyez 1-4	------	Newmont Expl.
79	Golden Lion 4	------	Newmont Expl.
80	Castle Mtn., Castle Mtn. Fr.	------	Dynamic Oil Co.
81	Foghorn	------	Kidd Creek Mines
82	Leghorn	------	Kidd Creek Mines
83	Awesome	------	Kidd Creek Mines

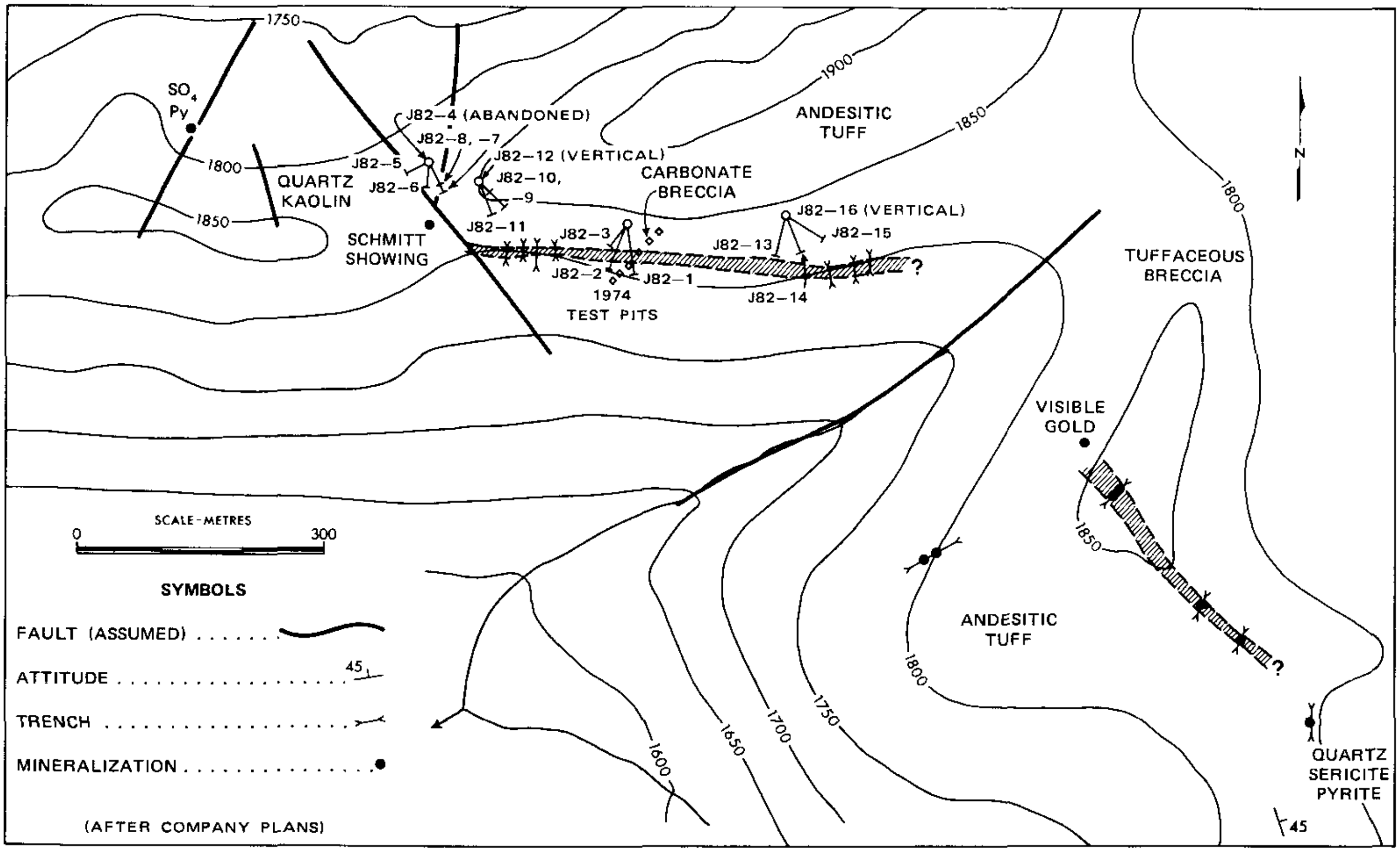


Figure 39. Geology of part of the JD property.

GEOLOGY

The regional geological setting is discussed in Geological Fieldwork, 1981 (Ministry of Energy, Mines and Petroleum Resources, Paper 1982-1, pp. 122, 123).

PROPERTIES

JD (MI 94E-32)

Sixteen diamond-drill holes were drilled by Kidd Creek Mines Ltd. to test the Schmitt and Carbonate breccia showings on the JD claim (*see* Fig. 39). A quartz-hematite-sulphide zone varying in width from approximately 1 to 4.6 metres was traced along a 600-metre strike length (105 degrees). Dips were north into the hill and varied from 23 degrees at the west end to 50 degrees at the east end. The mineralized zone is open to the east but is cut off to the west by a series of northwesterly and northeasterly trending faults near the Schmitt showing. A persistent gouge zone was intersected on the footwall, and minor quartz stringers were located in the hangingwall. The mineralized quartz structure occurs within a sequence of massive, green to maroon hornblende-feldspar porphyritic-andesitic flows and tuffs of the Toodoggone volcanic series. Locally, there are tuffaceous agglomerates and volcanic breccias. Alteration minerals include hematite, chlorite, and manganese oxide. Gangue minerals include amethystine to white quartz, calcite, and minor amounts of barite. Sulphide minerals include pyrite, chalcopyrite, acanthite, galena, and sphalerite. Approximately 100 metres to the southeast another strong quartz vein structure was traced by hand trenching. It may be an offset of the JD 'vein.' Native gold was recovered from this zone.

PORPHYRY PEARL (MI 94E-31)

Two drill holes were completed by Kidd Creek Mines Ltd. near the junction of Moosehorn and McClair Creeks (*see* Fig. 38). Pyrite, galena, sphalerite, and chalcopyrite occur as disseminations, fracture fillings, and in quartz ± carbonate ± anhydrite veins within a hypabyssal monzonite which has been altered in varying degrees to K-feldspar and sericite.

GOLDEN FURLONG

Two holes were drilled by Kidd Creek Mines Ltd. to test a fault-controlled zone of intensely silicified and kaolinized andesitic tuffs. The zone contains native gold in association with hematite (*see* Fig. 38). Finely banded pyrite with traces of chalcopyrite were found in quartz-rich zones which reach 35 metres in apparent thickness. Drusy, open cavities lined with quartz and/or hematite were common.

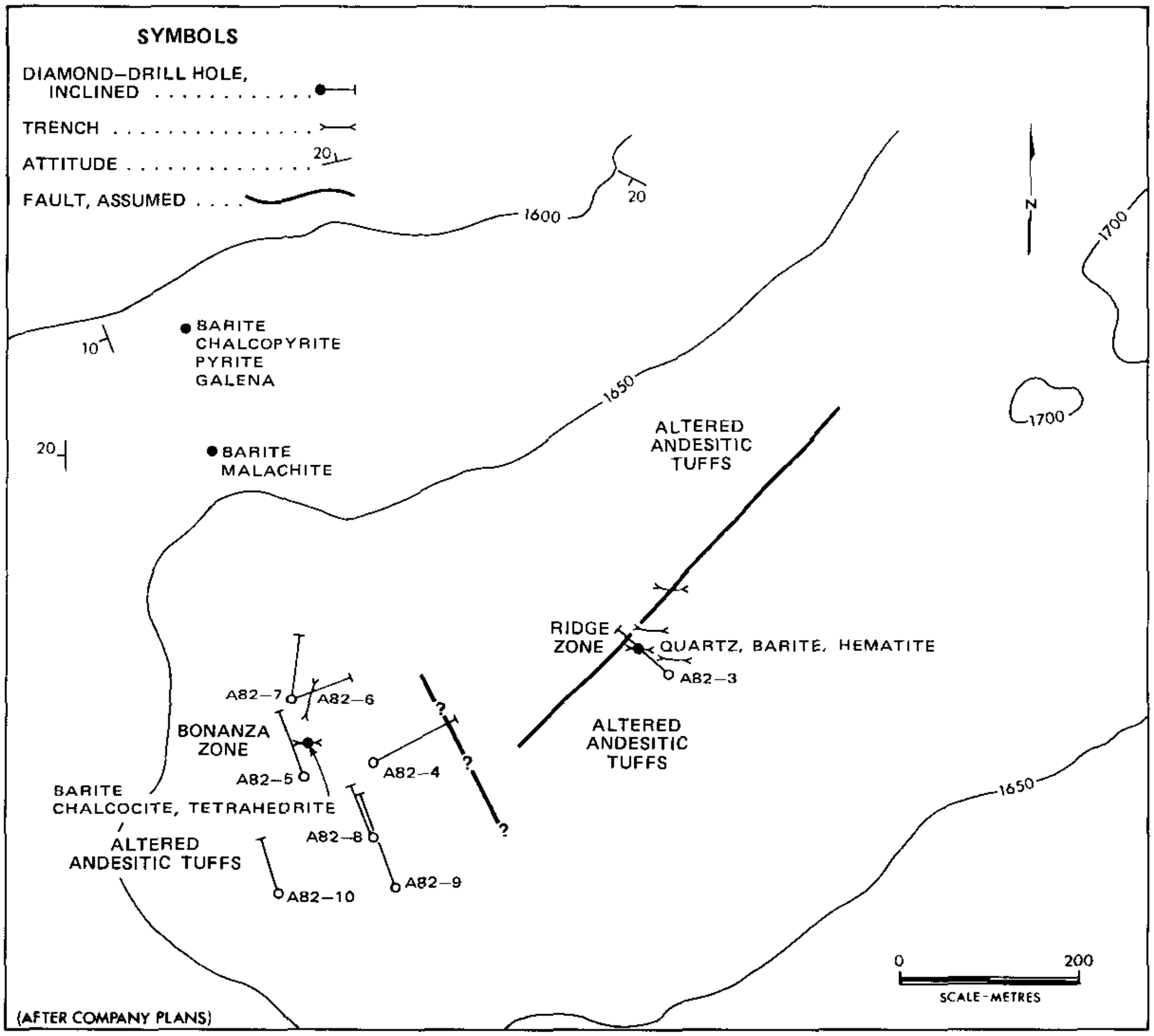


Figure 40. Setting of the Alberts Hump area.

RIDGE

Two diamond-drill holes were completed by Kidd Creek Mines Ltd. to test a highly altered structural zone located approximately 4 kilometres east along an open grassy ridge from Alberts Hump (*see* Figs. 38 and 40). Andesitic tuffs have been altered to quartz, chlorite, and hematite. Barite is a common gangue mineral. Sulphides encountered included pyrite and galena.

BONANZA

Six diamond-drill holes were completed by Kidd Creek Mines Ltd. to test the Bonanza zone and its relationship to the Ridge zone, which adjoins to the southeast (*see* Figs. 38 and 40). Andesitic ash tuffs have been altered to quartz, chlorite, and hematite. Malachite, azurite, pyrite, chalcocite, chalcopyrite, and sphalerite occur within silicified zones. Locally it appears that the pyrite was introduced as a fine-grained 'front', and lithic fragments have been replaced by pyrite. Chloritization of fragments is common.

ALBERTS HUMP

Two drill holes were completed by Kidd Creek Mines Ltd. to test a large zone of quartz ± alunite ± kaolinite alteration in andesitic to dacitic hornblende-feldspar crystal and lithic tuffs (*see* Fig. 38). Altered zones contain many vuggy sections. A hypabyssal intrusion was encountered at depth. Pyrite was the main sulphide mineral encountered.

METSANTAN (MI 94E-64) (Geological Fieldwork, 1981, Paper 1982-1, pp. 131, 132)

The Metsantan prospect is located on the southeast flank of 'Metsantan Mountain.' During 1982 Lacana Mining Corporation completed five diamond-drill holes on the Metsantan gold breccia zone (*see* Fig. 41). A weak quartz stockwork zone with minor amounts of galena, sphalerite, chalcopyrite, and pyrite cuts crystal to lithic tuff which is locally pervasively epidotized, especially feldspar crystals and lithic fragments.

GOLDEN LION

The Golden Lion prospects are located south of Claw Mountain, near the headwaters of Dedeeya Creek and north of Abesti Creek (*see* Fig. 38). During 1982 Newmont Exploration of Canada Limited conducted surface exploration on this large group of claims. On Golden Lion 1 claim, a zone trending 155 degrees has been traced 2.5 kilometres. Malachite, galena, sphalerite, pyrite, and chalcopyrite occur in a gangue of quartz-hematite-barite. The zone has been traced in talus and apparently has a width of 10 metres. The host rocks are 'Toodoggone' airfall hornblende-feldspar crystal to lithic tuffs.

On the Golden Lion 3 claim, a 600-metre by 75-metre alteration zone trends 340 degrees. Alteration minerals include quartz, hematite, and various clays (alunite ?). Bright green fluorite occurs, but no sulphides were observed.

LAWYERS (MI 94E-66) (Geological Fieldwork, 1981, Paper 1982-1, p. 130)

Underground and fill-in surface diamond drilling by SEREM Ltd. continued to define and develop ore zones on the Lawyers Amethyst gold breccia zone (*see* Fig. 38). In addition, the Cliff Creek breccia zone was explored by extensive surface trenching along a northwesterly length of approximately 1 000 metres. Locally, spectacular zones with amethyst were encountered.

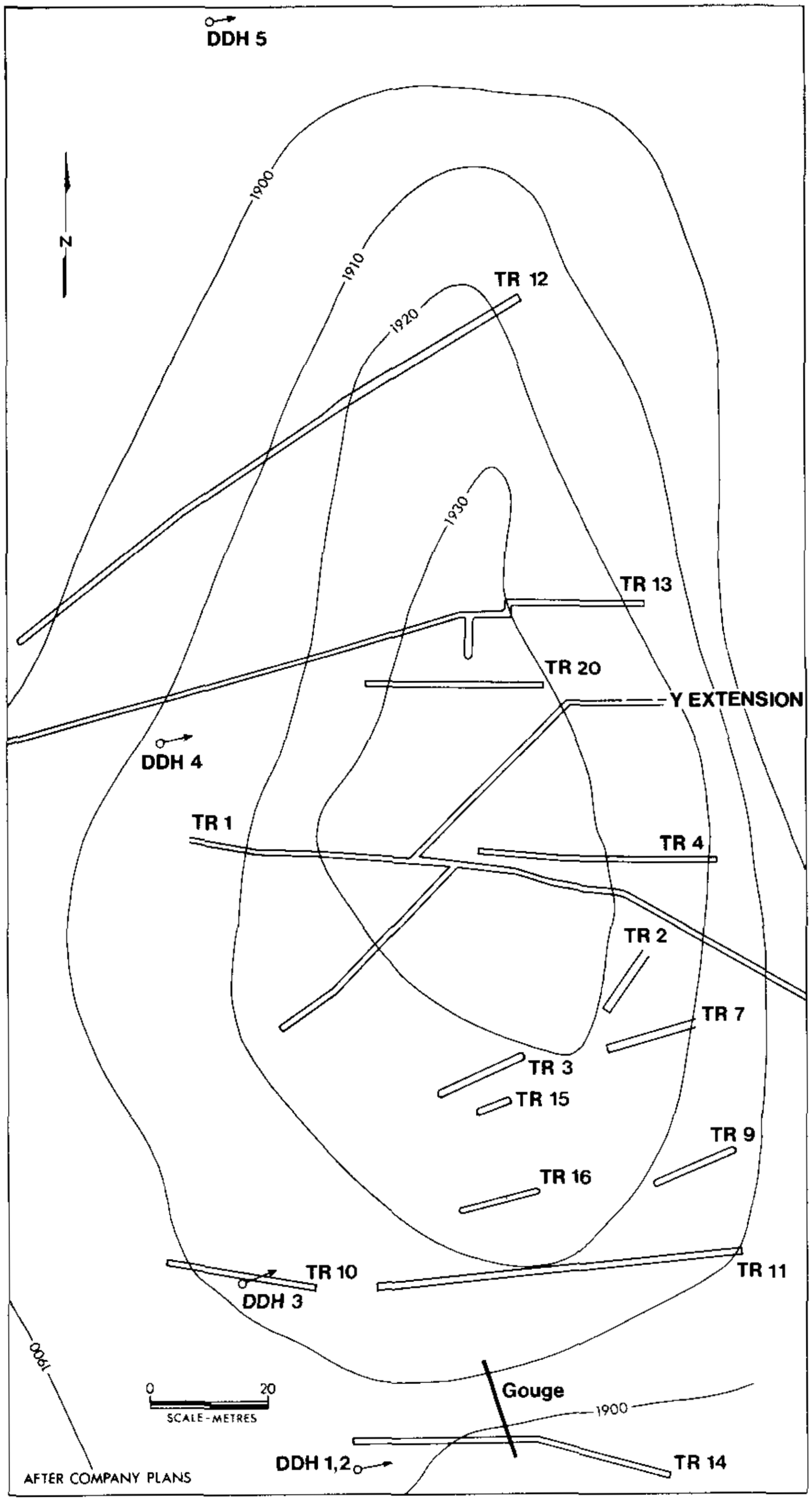


Figure 41. Setting of the Metsantan property.

BAKER MINE (MI 94E-26) (Geological Fieldwork, 1981, Paper 1982-1, pp. 129-132)

Mining continued at a rate of 90 tonnes per day on the A vein. A limited diamond-drill program comprising approximately 915 metres was undertaken to test a newly discovered quartz vein just north of A vein.

MOOSEHORN (Geological Fieldwork, 1981, Paper 1982-1, p. 132)

During 1982 Great Western Petroleum Corporation conducted a detailed chip sampling program on their Moosehorn prospect (*see* Fig. 38).

MOUNT GRAVES (Geological Fieldwork, 1981, Paper 1982-1, p. 132)

During 1982 Great Western Petroleum Corporation conducted a detailed chip sampling program on their Mount Graves prospect (*see* Fig. 38).

ACKNOWLEDGMENTS

The writer acknowledges the hospitality and logistical support offered in the field by the following companies: Kidd Creek Mines Ltd., Bema Industries Ltd., Du Pont of Canada Exploration Limited, SEREM Ltd., Central Mountain Air Services Ltd., Airlift Corporation, Lacana Mining Corporation, Newmont Exploration of Canada Limited, and Kelowna Flightcraft Ltd.

REFERENCE

Schroeter, T. G. (1982): Toodoggone River (94E), *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1981, Paper 1982-1, pp. 122-133.

A COMPARISON OF VOLCANIC STRATIGRAPHY, STRUCTURE, AND HYDROTHERMAL ALTERATION OF THE SILVER POND (CLOUD CREEK) AND WRICH-AWESOME CLAIM GROUPS, TOODOGGONE RIVER

(94E)

By L. J. Diakow

INTRODUCTION

The 'Toodoggone Volcanics' comprise a northwest-trending belt at least 90 kilometres long and 15 kilometres wide, located 300 kilometres north of Smithers. They are an Early Jurassic, predominantly subaerial, calc-alkaline suite probably deposited in an island-arc environment. The regional stratigraphic section includes a base of andesitic flows which interfinger with and are overlain by flows and pyroclastic rocks of andesitic to dacitic composition (Panteleyev, 1983, this volume). Silver and gold, principally as argentite and electrum (Schroeter, 1981), occur in discordant quartz veins and grossly stratabound stockworks. On the other hand, pervasive siliceous zones which are stratiform and stratabound appear to contain only minor amounts of precious metal mineralization although erratic high values are common. The vein and stockwork occurrences have sharp boundaries and narrow alteration halos; concordant siliceous zones are diffuse with extensive wallrock alteration characterized by clay minerals, alunite, and barite.

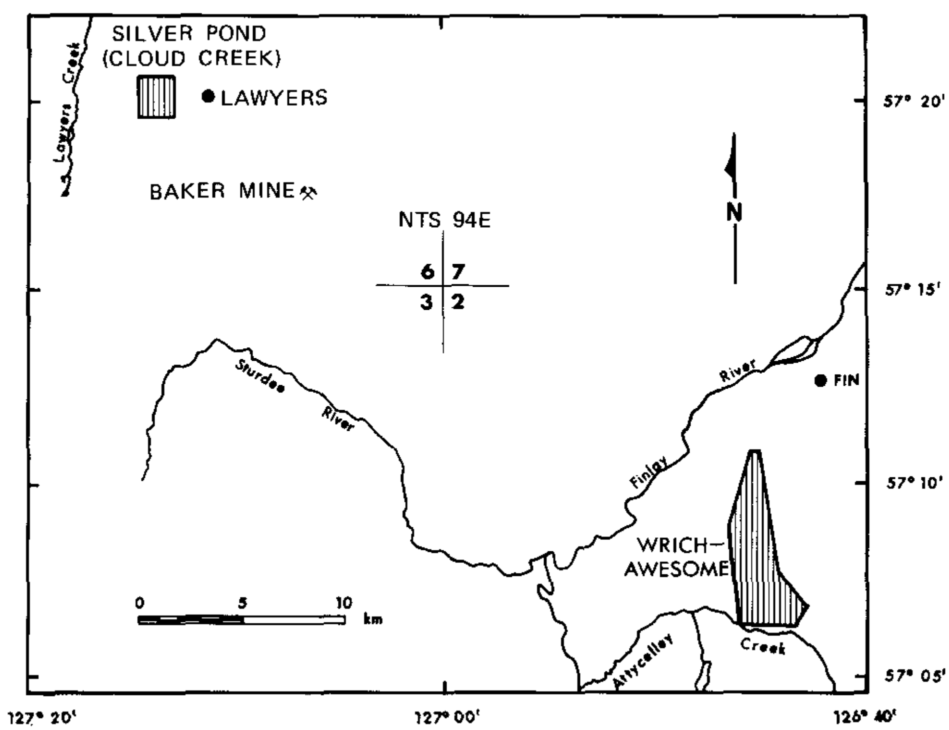


Figure 42. Location map for the Silver Pond (Cloud Creek) and Wrich-Awesome occurrences.

This research addresses the problem of distribution and variability in *morphology and wallrock alteration of these two types of silica* occurrences by analysing two occurrences. The Wrich-Awesome, which represents the vein and stockwork type, and Silver Pond (Cloud Creek), a pervasive siliceous zone (Fig. 42). Each area was mapped at 1:5000. Approximately 150 hand specimens of altered rock and 58 chip samples of siliceous rock were collected. The siliceous samples are currently being analysed for 16 elements including gold and silver; alteration assemblages are being defined by X-ray analysis.

This research constitutes part of a graduate thesis currently in progress at the University of Western Ontario; it is supported in part by the Ministry of Energy, Mines and Petroleum Resources.

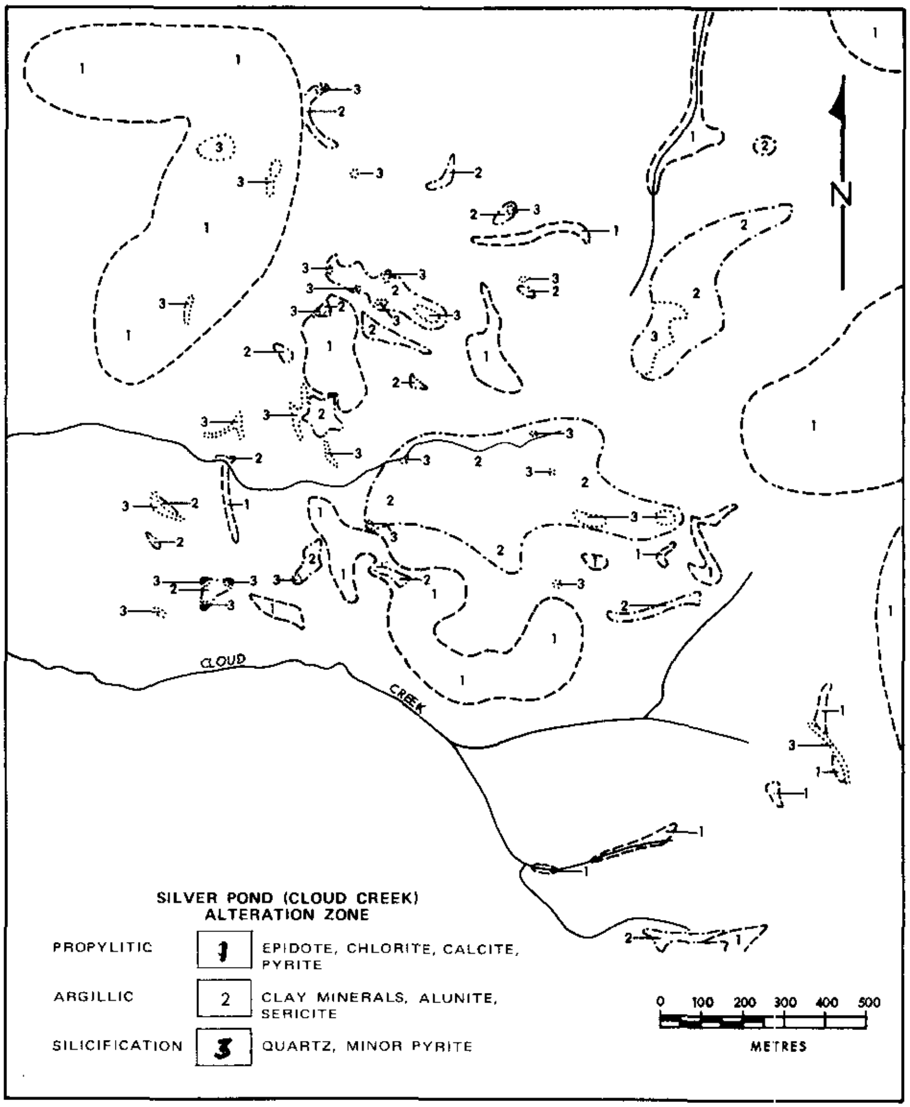


Figure 43. Alteration mineral zoning in the Silver Pond (Cloud Creek) area.

SILVER POND (CLOUD CREEK) AREA

LOCATION AND GENERAL GEOLOGY

The Silver Pond (Cloud Creek) occurrence (Silver Pond, Silver Sun, Silver Creek claims) is approximately 2 kilometres west of the Lawyers prospect. It is a 5-kilometre-square area of low relief that is underlain by porphyritic andesite with subordinate interbeds of lithic lapilli tuff and agglomerate. Attitudes measured from tuffaceous beds strike consistently northeast with dips of less than 20 degrees to the northwest. Exposures of agglomerate occur in only one fault block that is on the south-facing slopes immediately north of Cloud Creek.

The area is segmented by a network of faults which acted as channelways for hydrothermal fluids. Dykes of syenite offset the layered rocks and are locally altered; perhaps they occupy early faults which were reactivated later to provide access to hydrothermal fluids. A fresh syenite dyke dismembered by a series of *en echelon* faults indicates that more more than one phase of faulting affected the area.

ALTERATION

The Silver Pond (Cloud Creek) alteration zone is circular in outline with a diameter of 2 kilometres. A number of isolated 'patches' of intermediate-advanced argillic alteration and silicification occupy the central zone. Alteration grades laterally into an outer propylitic zone (Fig. 43).

INTERMEDIATE-ADVANCED ARGILLIC ZONE

In this zone secondary quartz, clay minerals, sericite, and alunite replace primary minerals in porphyritic andesites. Where microcrystalline quartz is most abundant there are low-lying mounds of undetermined thickness that are up to 150 metres by 50 metres in size. In these mounds the original porphyritic texture of the andesite is almost completely obliterated; only outlines of relict feldspar phenocrysts and biotite crystals remain. Pyrite is rare, occurring as fine, disseminated grains in quartz. Barite commonly occurs with quartz as crystal aggregates lining cavities or as irregular greasy white clots up to 3 centimetres across.

A recessive zone partially to completely encloses all siliceous occurrences. Typically these rocks are white with yellow-orange surface oxidation, display a remnant porphyritic texture, and are composed almost entirely of clay minerals. Dickite, kaolinite, montmorillonite, and illite are the primary constituents; alunite and sericite are subordinate. The stratiform nature of 'white' rocks with co-spatial pervasive silica occurrences suggests that a temporal relationship exists. This relationship might be due in part to primary bed porosity in underlying tuffs that enabled fluid movement along the base and through fractures in the porphyritic andesite. Red staining is imparted by hematite and goethite; commonly brilliant hues of irridescent green and blue occur on fracture surfaces.

A younger phase of silica emplacement formed discontinuous veins up to 2 centimetres wide that consist of terminated quartz crystals and lesser chalcedonic quartz. They cut both white rocks and syenite.

PROPYLITIC ZONE

This chlorite-carbonate-epidote alteration zone is widespread and extends beyond the boundary of the mapped area at Silver Pond. In the transitional area between the argillic and propylitic zones plagioclase phenocrysts show signs of corrosion and alteration to white clay and calcite, and amphibole is commonly replaced by chlorite. Fine-grained, disseminated pyrite and magnetite are ubiquitous within this transitional area, but each rarely constitutes more than 3 per cent of the rock.

Oxidation of pyrite and magnetite occurs throughout the alteration system but does not appear to penetrate deeply into the rocks. Further, in areas of propylitic chlorite-carbonate-epidote alteration, intensive 'bleaching' and replacement of the rock by clay minerals is absent. These observations suggest that the broad patterns of alteration observed in the Silver Pond area are hypogene.

WRICH-AWESOME AREA

LOCATION AND GENERAL GEOLOGY

The Wrich-Awesome area is 25 kilometres southeast of Baker minesite between Attycelley Creek and Finlay River (Fig. 42). Panteleyev (1982) presented a compilation of the regional geology south of Finlay River. The geology and distribution of known quartz stockwork and vein occurrences within the study area are shown on Figure 44. Porphyritic andesite flows with intervening beds of crystal lithic tuff underlie the majority of the mapped area. These rocks correspond with Panteleyev's map unit 5b and grade upward into quartzose tuffs that are similar to the overlying grey dacitic ash flow tuff (unit 6, Panteleyev, 1982). Takla Group pyroxene basalt, limestone, and chert crop out along the western margin of the map-area. A fault relationship between Takla and Toodoggone volcanic rocks is indicated. Takla chert beds outline chevron-style folds with amplitudes up to 7 metres and most Takla rocks dip steeply northeast as opposed to shallow westward dips in the nearby Toodoggone rocks. Takla rocks are also exposed in a fault-bounded wedge directly north of Attycelley Creek. Coarse-grained quartz monzonite is exposed where the overlying Toodoggone rocks have been removed by erosion in the northern part of the area.

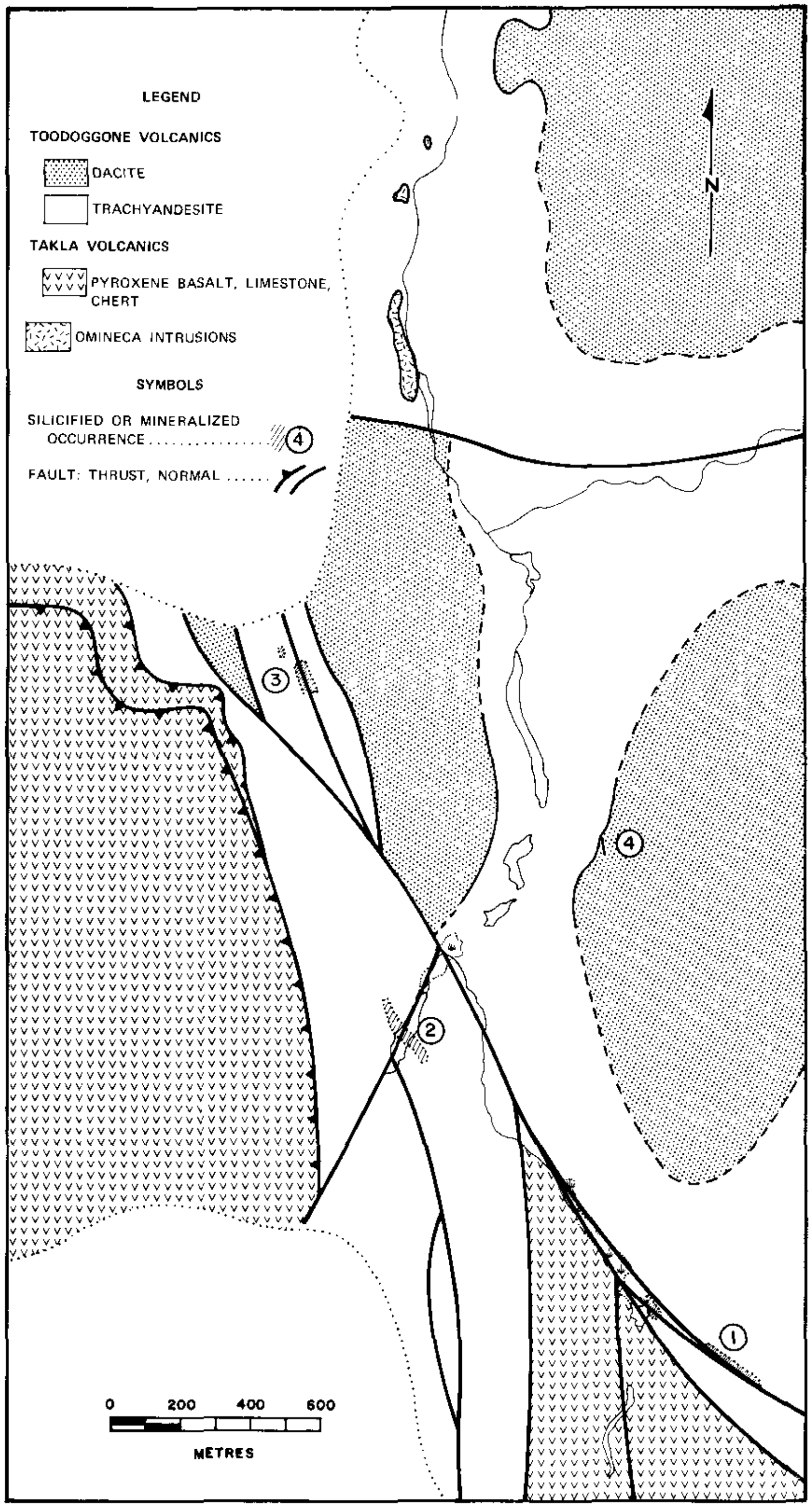


Figure 44. Geology and distribution of silica occurrences in the Wrich-Awesome area.

ALTERATION

A tabular, discontinuous zone characterized by silicification and clay minerals is aligned subparallel to a major northwest-trending fault zone (Fig. 44). Quartz stockwork and vein occurrences designated by numbers 1 and 2 on Figure 44, form narrow subvertical zones containing individual veins that are up to 4 centimetres wide in brecciated trachyandesite. Quartz in the veins occurs mainly as clear terminated crystals; there are lesser amounts of amethystine quartz. Chalcedonic silica, which is white or tinted to shades of red and green by hematite and chlorite, forms banded veins that crosscut the older, clear quartz veins. Calcite commonly fills voids within the clear crystalline veins.

A tabular zone on the Wrich claims (3 on Fig. 44), approximately 100 metres wide, is outlined by pale, clay-altered porphyritic rocks and confined to a fault-bounded area. The pale colour of these rocks reflects replacement of phenocrysts and matrix material in the host andesite by a mixture of white quartz and clay minerals. X-ray analysis showed that the white rocks contain kaolinite and minor amounts of pyrophyllite (Panteleyev, 1982). Widespread hematite and limonite impart a rusty colour to outcrop surfaces.

The quartz-kaolinite assemblage grades outward into a larger zone characterized by chlorite-calcite-epidote-pyrite alteration. This propylitic assemblage characterizes the entire trachyandesite unit and also occurs in the grey dacite. In the area mapped, the intensity of alteration decreases away from fault zones suggesting that it is fracture controlled. Pyrite occurs as fine-grained disseminations in the altered rocks; it averages 1 to 2 per cent generally but exceeds 5 per cent within one-half kilometre of intrusive rocks that lie to the north. Fine-grained disseminated magnetite is also present in trachyandesite and dacite. 'Reddening' of feldspar phenocrysts is a phenomenon that becomes more pronounced adjacent to vein and stockwork occurrences in the area. It might be caused by albitization and oxidation of magnetite or it might be alteration to K-feldspar.

MINERALIZATION

The only mineralization observed in the Wrich-Awesome area occurs within a narrow shear zone in grey dacite at location 4 on Figure 44. The occurrence consists of blebs of galena in a gangue of quartz, chlorite, epidote, and pyrite. Although this occurrence is small, it is important because it represents one of only two known mineralized occurrences in the grey dacite map unit.

SUMMARY

Hydrothermal fluids apparently travelled along fractured zones and altered surrounding volcanic rocks to produce two distinct types of silica occurrences in the Toodoggone belt. In the Wrich-Awesome area, quartz stockwork veins are related to a northwest-trending fault zone that appears to be an important control for silica-kaolinite-pyrophyllite and, to a lesser extent, chlorite-carbonate-epidote-pyrite alteration. In Silver Pond (Cloud Creek) area zones of silicification and kaolinite-dickite-alunite alteration appear to be localized at the base of a relatively flat-lying porphyritic andesite unit. Perhaps primary bed porosity governed the shape and distribution of alteration in this area.

Chip samples from 58 sites at Silver Pond (Cloud Creek) reveal consistently low gold values. Only 11 samples had detectable gold (greater than 20 ppb); four were in the 48 to 55 ppb range, and one was 164 ppb. The results are consistent with an acid-leached clay-silica capping containing the sulphate minerals alunite and barite. Other metals show little concentration in the altered zone with the exception of manganese which occurs consistently in the 600 to 800 ppm range and barium from 0.15 to 0.4 per cent. These values are consistent with results for a wide variety of elements reported by Schroeter (Geological Fieldwork, 1981, Paper 1982-1, pp. 126-128).

In the Wrich-Awesome area, four grab samples from silicified zones shown on Figure 44 give the following results:

	Au ppb	Ag ppm
Site 1 (Awesome)	24	1.25
Site 1 (Awesome)	<20	<0.4
Site 2	66	60.8
Site 3	<20	6.76

ACKNOWLEDGMENTS

The writer expresses his appreciation to the following companies for logistic support, discussion, and permission to examine their mineral prospects: Du Pont of Canada Exploration Limited, Great Western Petroleum Corporation, Kidd Creek Mines Ltd., Lacana Mining Corporation, Newmont Exploration of Canada Limited, and SEREM Ltd.

Thanks are extended to Dr. A. Panteleyev for his direction and helpful discussion during the field season. Shaun Pattenden and Mitch Mihalynuk provided cheerful, able assistance in the field.

REFERENCES

Panteleyev, A. (1982): Toodoggone Volcanics South of Finlay River, British Columbia, B.C. *Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1981, Paper 1982-1, pp. 135-141.

Schroeter, T. G. (1981): Toodoggone River, *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1980, Paper 1981-1, pp. 124-131.

.... (1982): Toodoggone River, *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1981, Paper 1982-1, pp. 122-133.

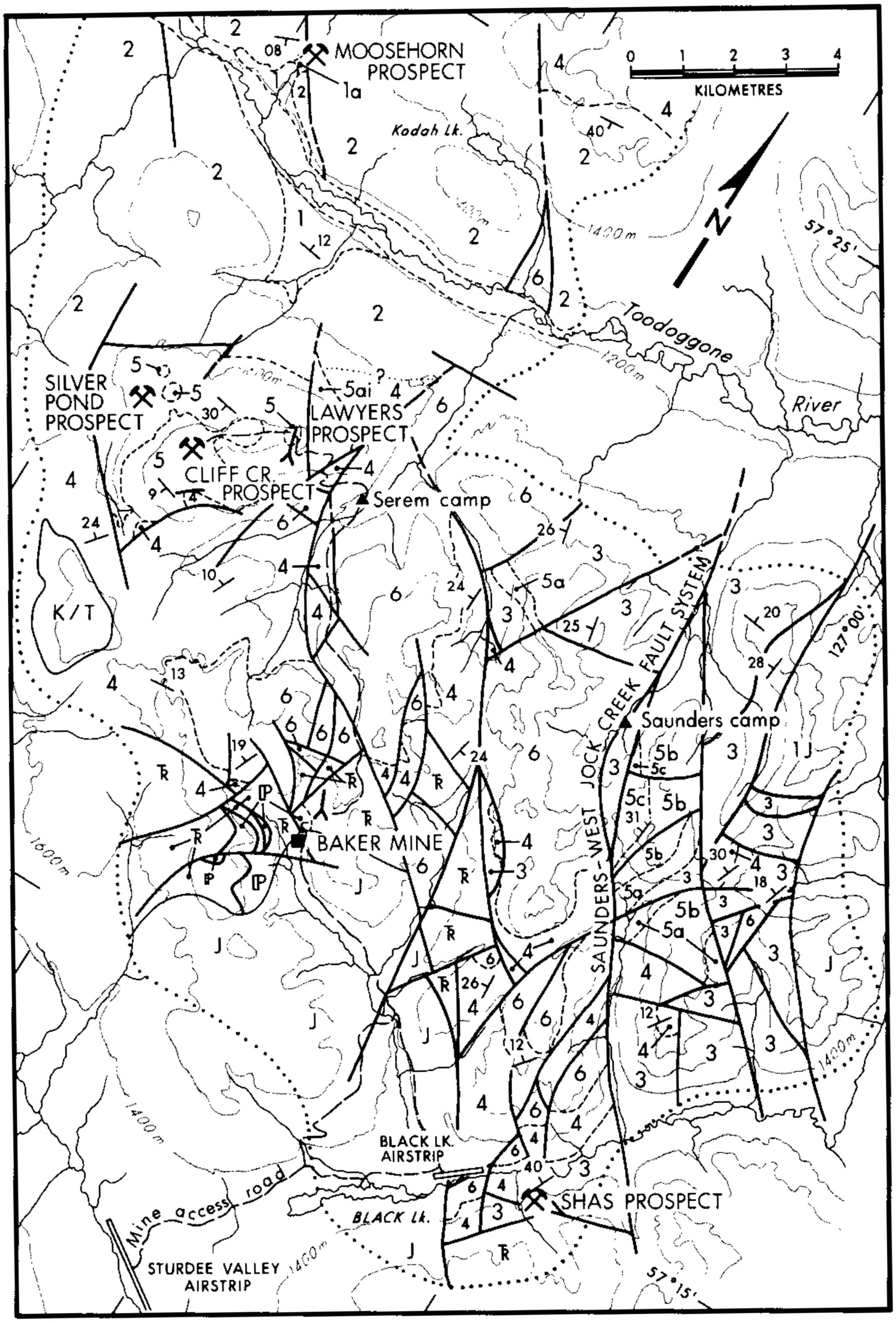


Figure 45. Geology between Toodoggone and Sturdee Rivers.

GEOLOGY BETWEEN TOODOGGONE AND STURDEE RIVERS (94E)

By A. Panteleyev

INTRODUCTION

Regional mapping in 'Toodoggone Volcanics' that was initiated south of Finlay River in 1981 was expanded in 1982 to cover the central portion of the volcanic belt between Toodoggone River on the north end and Sturdee River on the south. During 1982, 270 square kilometres was mapped as shown on Figure 45. The area is being actively explored for gold-silver deposits (*see* report by T. Schroeter, this volume).

Field mapping data was entered on Federal 1 inch to 1/2 mile (1:31 680) air photographs. The detailed information was subsequently transferred to 1:25 000 base maps prepared under contract and available from Burnett Resource Surveys Ltd. Final compilation was done on Federal 1:50 000 preliminary map sheets for NTS 94E/2, 3, 6, and 7. L. J. Diakow examined areas exhibiting hydrothermal alteration, notably silicification and clay-alunite development, as an adjunct to these regional studies. Two of the more economically interesting zones were studied in detail -- the Silver Pond (Cloud Creek) zone shown on Figure 45, and the Wrich-Awesome area, south of Finlay River. Diakow discusses both zones in a separate report in this volume.

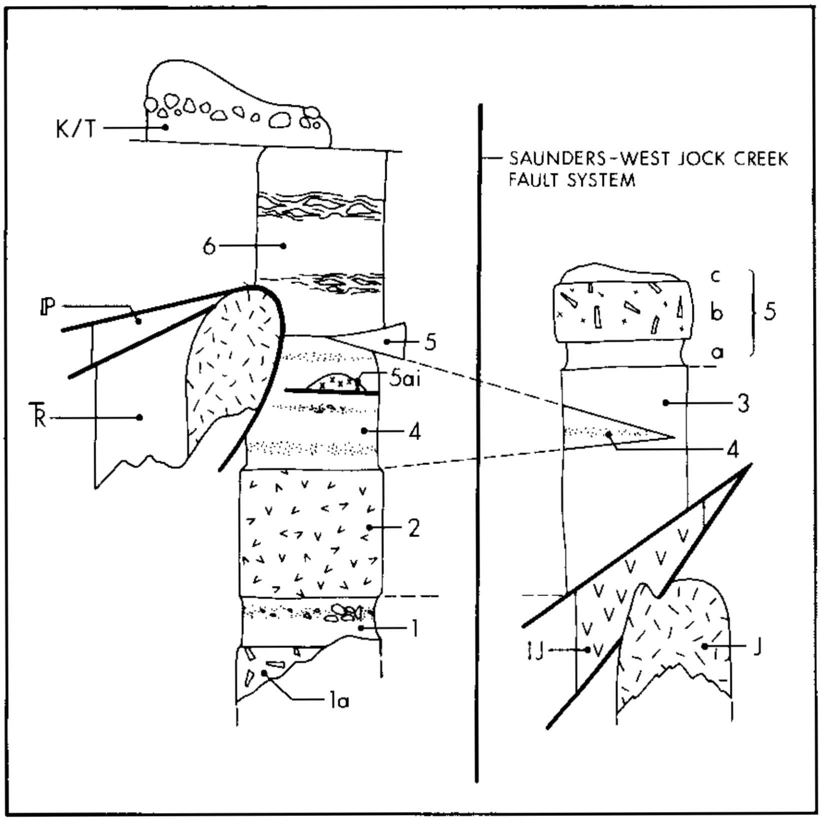
All mapping by Schroeter, Diakow, and this writer will be compiled in early 1983 and released as a preliminary map at scale 1:50 000.

GEOLOGY

Six major stratigraphic subdivisions were established as shown on Figures 45 and 46. The most widespread and continuous rock type in the Toodoggone volcanic belt is map unit 6, 'grey dacite.' The rock is distinctive in outcrop and hand specimen. The base of this unit provides the most useful stratigraphic datum plane in the map-area. The grey dacite is also the only clearly identifiable rock type that provides continuity between the 1982 map-area and the area south of Finlay River mapped in 1981 (*see* Panteleyev, 1982). Although other Toodoggone rocks that underlie grey dacite (map units 1 to 5) are lithologically similar north and south of Finlay River, the map units described in this report are not stratigraphic equivalents of those described in 1981.
The stratigraphic section between Toodoggone and Sturdee Rivers includes the following map-units as shown on Figure 45:

Unit 1

Tuff and tuffaceous sandstone 'red beds.' A well-layered sequence of graded, feldspathic crystal-lithic ash to dust tuffs or reworked (epiclastic) tuffs. Some coarse boulder conglomerate lenses.



LEGEND

CRETACEOUS/EARLY TERTIARY

K/T — SUSTUT GROUP: SANDSTONE, CONGLOMERATE

LOWER JURASSIC

"TOODOGGONE VOLCANICS"

6 — "GREY DACITE" ASH FLOW UNIT

5 — ANDESITE FLOWS, IN PART TRACHYANDESITE AND MINOR TUFF

5ai — PYROXENE BASALT (INTRUSIVE)

4 — QUARTZOSE ANDESITE PYROCLASTIC UNIT, PREDOMINANTLY CRYSTAL AND LITHIC-LAPILLI ASH FLOW TUFFS, WELL-LAYERED ASHFALL UNIT WITH MUCH CLAST SIZE RANGE, LESSER FLOWS, BRECCIAS, AGGLOMERATE, MINOR EPICLASTIC UNITS WITH LOCAL COARSE LANDSLIDE DEBRIS

2 — ANDESITE FLOWS, SOME BRECCIAS, MINOR TUFFS

1 — TUFFS, TUFFACEOUS SANDSTONE, CONGLOMERATE, "RED BEDS"

1a — FELDSPAR PORPHYRY FLOWS (TRACHYANDESITE)

5c — ANDESITIC BASALT, DUST TO COARSE LAPILLI LITHIC TUFFS

5b — BASALT/BASALTIC ANDESITE FLOWS

5a — BASALTIC TUFFS

3 — ANDESITE FLOWS, MEDIUM TO FINE GRAINED; TUFFS; INCLUDES SOME QUARTZOSE TUFF UNITS EQUIVALENT (?) TO UNIT 4

JURASSIC

V V — HAZELTON GROUP: ANDESITIC FLOWS, PYROCLASTIC ROCKS

J — OMINECA INTRUSIONS: GRANODIORITE

TRIASSIC

TR — TAKLA GROUP: PYROXENE BASALT FLOWS, TUFFS, BRECCIAS

PALEOZOIC

IP — ASITKA ? GROUP: LIMESTONE, IN PART MARBLE, SKARN; MINOR CHERT, ARGILLITE

Figure 46. Diagrammatic stratigraphic column, Toodoggone-Sturdee River area.

Unit 1a

Volcanic flow unit of undetermined extent, exposed only in Moosehorn Creek *and overlain by tuffaceous red beds (unit 1). The flows consist of* up to 15 per cent pink albitized plagioclase phenocrysts 3 to 6 millimetres in length in an aphanitic, dark green matrix that contains chloritized biotite and abundant very fine-grained magnetite.

Unit 2

Andesite flows -- medium-grained hornblende feldspar porphyry. Grey-green to purplish brown when fresh, pervasively oxidized to salmon pink or orange in weathered and hydrothermally altered outcrops. Sparse reddish brown apatite (?) grains to 1 millimetre in size are distinctive and characteristic of this rock type. Epidote alteration with minor amounts of associated pyrite is common. This is an extensive map unit derived from a homogeneous magma source. It consists mainly of massive flows, although some display trachytoid crystal alignment. Less common is flow breccia and there are minor amounts of pyroclastic breccia and tuff.

Unit 3

Andesite flows and tuffs -- a heterogeneous assemblage of flow and pyroclastic rocks -- predominantly hornblende feldspar porphyry flows and lithic ash tuffs. In the southeast corner of the map-area grey, fine to medium-grained crowded porphyry flows are common. Interspersed in at least three levels in the succession are quartzose lithic-crystal tuffs that are believed to be lateral equivalents to map unit 4. Map unit 3 appears to be a temporal equivalent of map unit 2 and probably interfingers with it.

Unit 4

Quartzose andesite pyroclastic rocks -- an extremely heterogeneous unit in terms of colour, clast size, and origin. Clasts range in size from dust to coarse blocks in breccia and compositions cover the spectrum from pure crystal tuff to solely lithic material. In detail, lava flows, breccia, agglomerate, thick crudely layered ash and blocky ash flows, occasional well-bedded ash fall deposits, and some reworked (epiclastic) units make up this map unit.

Unit 5

Andesite and trachyandesite flows -- a thin, dissected unit that caps pyroclastic rocks of map unit 4. It signals the end of explosive pyroclastic activity and the onset of lava eruptions. Flows of the bimodal suite -- andesite and trachyandesite -- are interlayered along with minor tuffs. The volume, regional extent, and significance of the alkaline rocks is not currently known.

Units 5a, 5b, and 5c

A basaltic sequence found only east of the major Saunders Creek-West Jock Creek fault system. The sequence contains well-layered ash tuffs (unit 5a), coarse-grained hornblende plagioclase porphyry flows (unit 5b), and mixed ash to coarse lapilli tuff beds (unit 5c). The rocks are strongly epidotized and, where oxidized, are stained a hematitic, deep purple ochre colour.

Unit 5ai

Pyroxene basalt intrusion -- possibly a laccolith or sill. The rock is made up of 5 to 10 per cent pyroxene phenocrysts in a matrix of plagioclase microlaths. It is generally unaltered but near the faulted western contact it is extensively zeolitized.

Unit 6

Grey dacite -- grey to grey-green rocks that weather dark grey to brown and form resistant, blocky-jointed scarps. The rocks contain up to 25 per cent biotite, hornblende, quartz, feldspar phenocrysts and abundant clasts of quartz feldspar porphyry. No internal banding is present in the unit but compaction, clast orientation, and locally developed welding impart a weak layering-foliation to outcrops. The base of the unit most commonly is a relatively clast-poor, chloritic, devitrified, vitrophyric crystal tuff. Locally it is a coarse fragmental ash flow with abundant, rounded clasts up to 10 centimetres in diameter. This coarse pyroclastic rock probably formed as a turbidity lag deposit that reflects turbulence developed by local topographic features along the base of an overall laminar ash flow.

AGE OF TOODGGONE VOLCANICS

Radiometric dates for hornblende and rubidium-strontium samples from volcanic and related intrusive rocks in the Toodoggone area range from 179 to 207 Ma (Gabrielse, *et al.*, 1980). A sample of alunite has been reported to be 190±7 Ma (Schroeter, 1982). A new date of 204 Ma is the first to be reported from biotite in Toodoggone volcanic rocks. The sample of biotite-bearing quartzose crystal ash tuff was collected south of Finlay River from rocks of Panteleyev's 1981 map unit 5a. These rocks are probably equivalent to map unit 4 in this report. The 204 Ma date corresponds to 202 and 207 Ma dates from nearby granitic intrusions at Kemess deposit (Cann and Godwin, 1980). Collectively, radiometric dates from south of Finlay River to the Stikine River suggest that Toodoggone volcanics were deposited over a 20-million-year period from approximately 200 to 180 Ma.

Sample Data:

Sample No.	Location	Material Analysed	% K	Ar^{*40}	% Rad. Ar^{*40}	Apparent Age (Ma)
81AP-T28	57°05'38"N 126°39'30"W	Biotite	6.87±0.02 (3)	25.743	97.5	204±7

NOTES

% K determined by the Analytical Laboratory, Ministry of Energy, Mines and Petroleum Resources; number in parenthesis refers to number of K analyses.
Ar determination and age calculation by J. E. Harakal, University of British Columbia.
Constants used: $\lambda = 0.581 \times 10^{-10} yr^{-1}$; λ^{6} $4.96 \times 10^{-10} yr^{-1}$; $K^{40}/K = 1.167 \times 10^{-4}$.

DISCUSSION

The volcanic assemblage mapped represents a subaerial, predominantly pyroclastic accumulation that was probably restricted to a relatively small island or island chain. Magma underwent little differentiation, judging from the preponderance of andesitic rocks. Some differentiation took place to produce quartzose andesitic rocks that are transitional to dacite. True dacite erupted only at the end of pyroclastic activity that produced the grey dacite ash flows. Small, probably isolated, individual magma chambers produced localized basaltic and trachytic volcanic rocks and small intrusions. No rhyolite has been found. Hydrothermal alteration produced pale, quartz-bearing, commonly banded rocks that resemble rhyolite. The altered rocks, which are composed of quartz grains, clay minerals, and alunite, are invariably localized in fault zones.

The grey dacite is interpreted to be a massive ash flow sheet or sheets that acted as a single cooling unit. It is at least 250 metres thick and covered an area at least 15 kilometres by 40 kilometres. The volume of the grey dacite sheet is a minimum of 125 cubic kilometres, which is equivalent to major ash flow sheets described in other volcanic fields (for example, *see* Steven and Lipman, 1976). Compared to ash flows in the San Juan volcanic region of Colorado, the grey dacite map unit ranks as a 'moderate volume ash flow.'

Sites of mineralization/alteration do not appear to have any simple lithologic control although mineralization tends to favour andesitic flows and flow contacts with tuffs rather than pyroclastic rocks. This is possibly a consequence of hydrothermal fluids being channeled by well-defined, long-lived fracture/fault systems in andesite. In contrast, hydrothermal fluids that entered pyroclastic units became dispersed and diffused by intergranular flow in the highly porous and permeable rocks. In addition, fluid-rock interaction in andesites was minimal as opposed to the strongly hydrothermally altered pyroclastic rocks where much alteration of glass shards and crystals took place to produce abundant clay minerals.

Volcanic-related hydrothermal activity was controlled by older faults and fracture zones; many of these trend northerly to north-northeasterly. The altered zones are independent of the predominantly northwesterly-southeasterly trending younger faults shown on Figure 45.

ACKNOWLEDGMENTS

Bema Industries Ltd. provided expert expediting services from Smithers. Central Mountain Air Services Ltd., Airlift Corporation, and Kelowna Flightcraft Ltd. provided air services. The writer acknowledges the courtesy and support by Du Pont of Canada Exploration Limited, SEREM Ltd., and Kidd Creek Mines Ltd. Mitch Mihalynuk and Shaun Pattenden ably assisted the writer; Larry Diakow was a capable senior assistant.

REFERENCES

Cann, R. M. and Godwin, C. I. (1980): Geology and Age of the Kemess Porphyry Copper-Molybdenum Deposit, North-Central British columbia, *C.I.M.*, Bull., Vol. 73, pp. 94-99.

Gabrielse, H., Wanless, R. K., Armstrong, R. L., and Erdman, L. R. (1980): *Isotopic Dating of Early Jurassic Volcanism and Plutonism* in North-Central British Columbia, *in* Current Research, Pt. A, *Geol. Surv., Canada,* Paper 80-1A, pp. 27-32.

Panteleyev, A. (1982): Toodoggone Volcanics South of Finlay River, *B.C. Ministry of Energy, Mines & Pet. Res.,* Geological Fieldwork, Fieldwork, 1981, Paper 1982-1, pp. 135-141.

Schroeter, T. G. (1982): Toodoggone River (94E), *B.C. Ministry of Energy, Mines & Pet. Res.,* Geological Fieldwork, 1981, Paper 1982-1, pp. 122-133.

Steven, T. A. and Lipman, P. W. (1976): Calderas of the San Juan Volcanic Field, Southwestern Colorado, *U.S.G.S.,* Prof. Paper 958, 35 pp.

A COMPARISON OF THE GEOLOGIC SETTING OF STRATIFORM MASSIVE SULPHIDE DEPOSITS OF THE GATAGA DISTRICT WITH THE MIDWAY AND WINDY-CRAGGY DEPOSITS, NORTHERN BRITISH COLUMBIA

(94F, L; 104O/16; 114P/12)

By D. G. MacIntyre

INTRODUCTION

A study of the stratigraphic and structural setting of sediment-hosted zinc-lead-barite deposits of the Gataga district of northeastern British Columbia was initiated in 1979 and continued through the 1980 and 1981 field seasons (*see* MacIntyre, 1980a, 1980b, 1981a, 1981b, 1982a, 1982b, 1982c; MacIntyre and Diakow, 1982). In 1982 further mapping in the Gataga district was curtailed due to budget restraints. However, a short visit to the Driftpile Creek property was made in late June to examine drill core. The scope of the Gataga project has been expanded; it is now a regional study of Paleozoic stratiform massive sulphide deposits in northern British Columbia. During 1982 geologic fieldwork was done on two such deposits, Midway (104O/16) and Windy-Craggy (114P/12E). If budgets allow and suitable logistical support can be obtained, additional work will be done on these deposits during 1983.

Paleozoic and particularly Late Devonian clastic sedimentary strata in northern British Columbia have tremendous resource potential for zinc-lead-barite deposits. Consequently, all areas underlain by these rocks are potentially important and will be studied to assess the potential and to provide a better understanding of the geologic setting and genetic controls for this important class of mineral deposits.

The purpose of this paper is to compare and contrast stratiform massive sulphide ± barite deposits of the Gataga district with the Midway and Windy-Craggy deposits. The paper will show that each of the three sedimentary ± volcanic terranes discussed host distinct types of stratiform massive sulphide ± barite deposits. Those of the Gataga district are barite rich, occur within a linear sedimentary trough, and have a very minor pre-ore volcanic component. Midway is a stratabound silver-rich massive pyrite-sphalerite-galena deposit within transgressive clastic rocks and platformal carbonates. Windy-Craggy is a thick cupriferous massive pyrrhotite ± pyrite deposit that is related to altered basaltic volcanic rocks.

GATAGA DISTRICT

The history, geology, and mineral deposits of the Gataga district have been discussed in previous reports and papers (for example, MacIntyre, 1982b). Figure 47 shows the setting of the Gataga district with respect to the Selwyn basin and Kechika Trough and Figure 48 shows locations of mineral deposits and the general geology of the district. An idealized stratigraphic column is shown on Figure 49 along with those for the Midway and Windy-Craggy areas.

Recent work by Gordey (1982), Gordey, et *al.* (1982), and Dawson and Orchard (1982) has helped to refine the stratigraphy of the Selwyn basin. The informal nomenclature proposed by these authors has been adopted for the Gataga district. That is, all rocks overlying Kechika Group and underlying Middle to Late Devonian siliceous clastic rocks are included with the Road River Group. Overlying Late Devonian to Mississippian transgressive 'black clastics' are included with the Earn Group. It should be noted that microfossil studies are continuing and hopefully

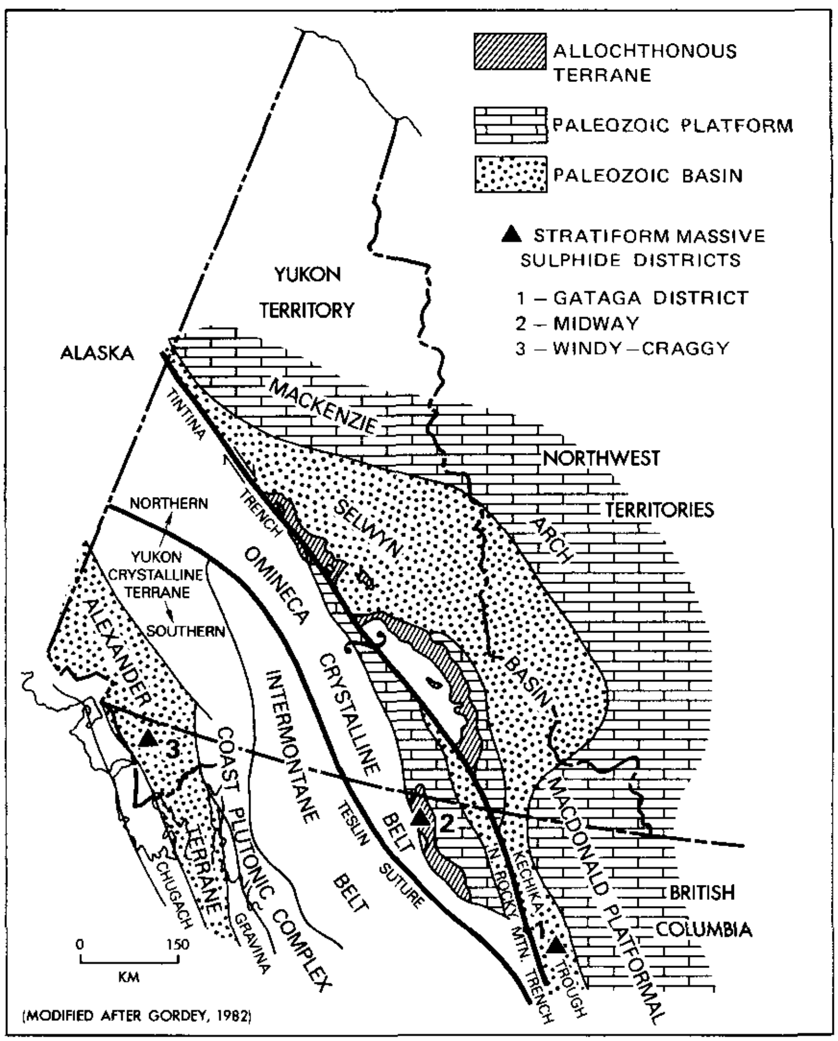


Figure 47. Tectonic subdivisions of the northern cordillera and location of the Gataga district (1), the Midway (2), and Windy-Craggy (3) deposits. Inset shows restoration prior to 450-kilometre right lateral displacement along Tintina and northern Rocky Mountain Trenches.

further refinement of age relationships will be possible when new data become available. Much uncertainty still remains about the exact ages of stratiform barite-sulphide deposits of the district; most ages are inferred by stratigraphic position rather than paleontological data.

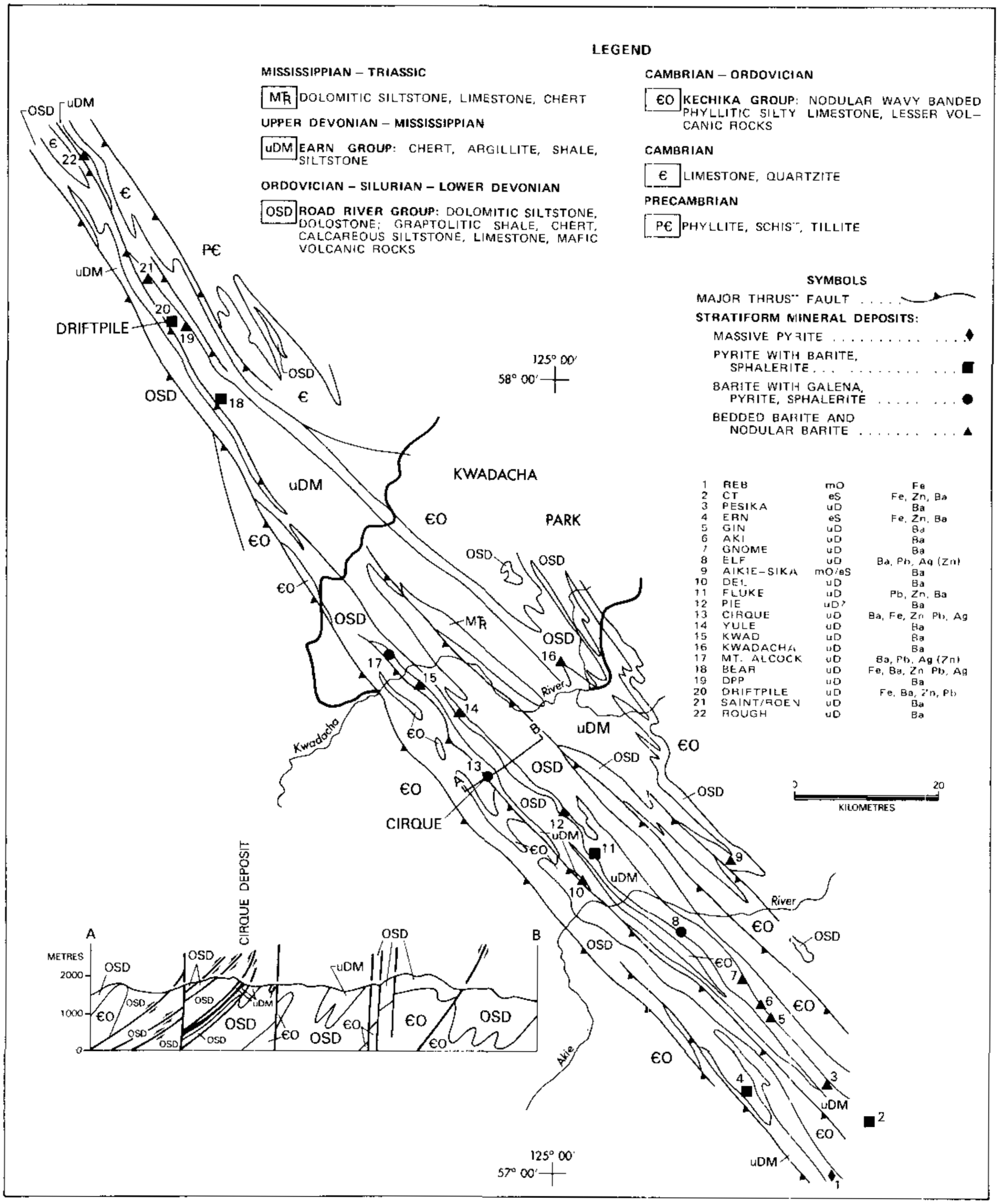


Figure 48. General geology and location of stratiform barite-sulphide deposits of the Gataga district.

As shown on Figure 49, stratiform barite-sulphide beds occur at several different stratigraphic levels within the basinal facies succession of the Gataga district. The oldest known deposits are late Middle to early Late Ordovician age as indicated by graptolite assemblages collected from hangingwall black shales (identification by B. Norford, Institute of Sedimentary and Petroleum Geology, Calgary). Both barren barite (for example, Aikie-Sika) and massive pyrite (for example, Reb) end members are present. The former occurs immediately above a quartz wacke turbidite unit and is located just outboard of the MacDonald platform; the latter occurs within an anomalously thick section of black shales and chert that probably represents a relatively deep water basin. Both deposits are overlain by a transgressive black shale unit. This unit diachronously onlaps platformal carbonates outside the district.

Stratiform barite-sulphide deposits of Early Silurian age have recently been discovered by Cominco Ltd. in the southern part of the Gataga district (for example, CT and ERN prospects). Footwall rocks are shallow water thin-bedded limestones, dolostones, and quartzites that are locally brecciated and mineralized with pyrite. Hangingwall rocks include calcareous siltstone, shale, and cherty mudstone. Mineralization varies up section from predominantly pyrite with variable amounts of sphalerite and minor galena to mainly barite. The stratigraphic succession suggests mineralization occurred during an Early Silurian marine transgression that was terminated by a major regression in Middle Silurian time. This regression resulted in erosion of Early Silurian and older rocks and partial filling of the Kechika Trough with dolomitic detritus. The stratigraphic setting of Early Silurian deposits in the Gataga district is strikingly similar to that of the Howard's Pass area of the Selwyn basin (Morganti, 1981).

The most important stratiform barite-sulphide deposits of the Gataga district occur within a 180-kilometre-long belt of black cherts, cherty mudstones, argillites, and siliceous shales and siltstones of the Middle to Late Devonian Gunsteel 'Formation' of the lower Earn Group. The deposits of the district can be fitted into a Meggan-type zoning model. In this model a central, vent proximal, massive pyrite zone with local high-grade sphalerite and galena concentrations grades outward into massive, barren bedded barite. The Driftpile Creek and Bear deposits would be examples of the massive pyrite zone, the Cirque, Elf, and Mount Alcock deposits appear to be at the transition from massive pyrite to barite and the Kwadacha, Pie, and DPP deposits are examples of the relatively barren bedded barite facies. Beds of nodular and thinly laminated barite at the Rough, Roen, Kwad, Yule, Gnome, Del, Aki, Gin, and Pesika properties may be the distal equivalents of the massive pyrite and bedded barite deposits.

Footwall rocks for the Late Devonian stratiform barite-sulphide deposits of the Gataga district are typically rhythmically bedded black cherts (porcellanites), cherty mudstones and argillites, siliceous shales, and lesser intercalated turbiditic siltstones. These rocks represent a starved basin regime with periodic turbidite sedimentation. Thickness of the footwall unit varies. It is relatively thin (10 to 20 metres) in the southern and eastern parts of the district where it onlaps slope and shelf carbonates and underlies massive barren bedded barite and laminated nodular barite occurrences (for example, Kwadacha, Pesika, Del, Gin, Aki, Gnome, Pie, Yule, Kwad, DPP). It is relatively thick (100 to 200 metres) with chert-rich sections where it underlies stratiform massive bedded barite-pyrite-sphalerite-galena deposits (for example, Elf, Fluke, Cirque, Mount Alcock) and laminated pyrite-sphalerite±barite deposits (for example, Bear, Driftpile Creek).

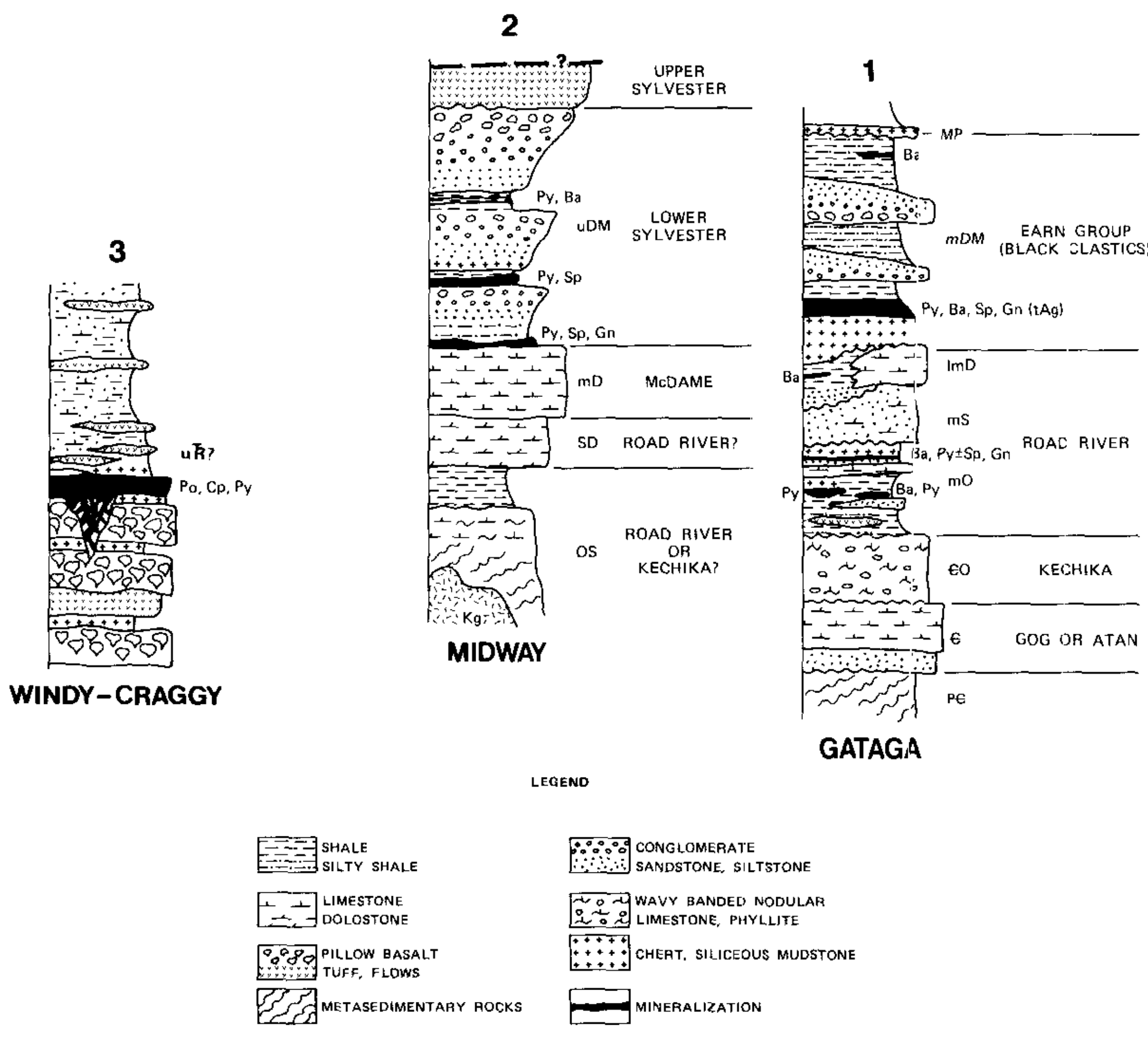


Figure 49. Stratigraphic columns for the Gataga district (1), the Midway (2), and Windy-Craggy (3) areas.

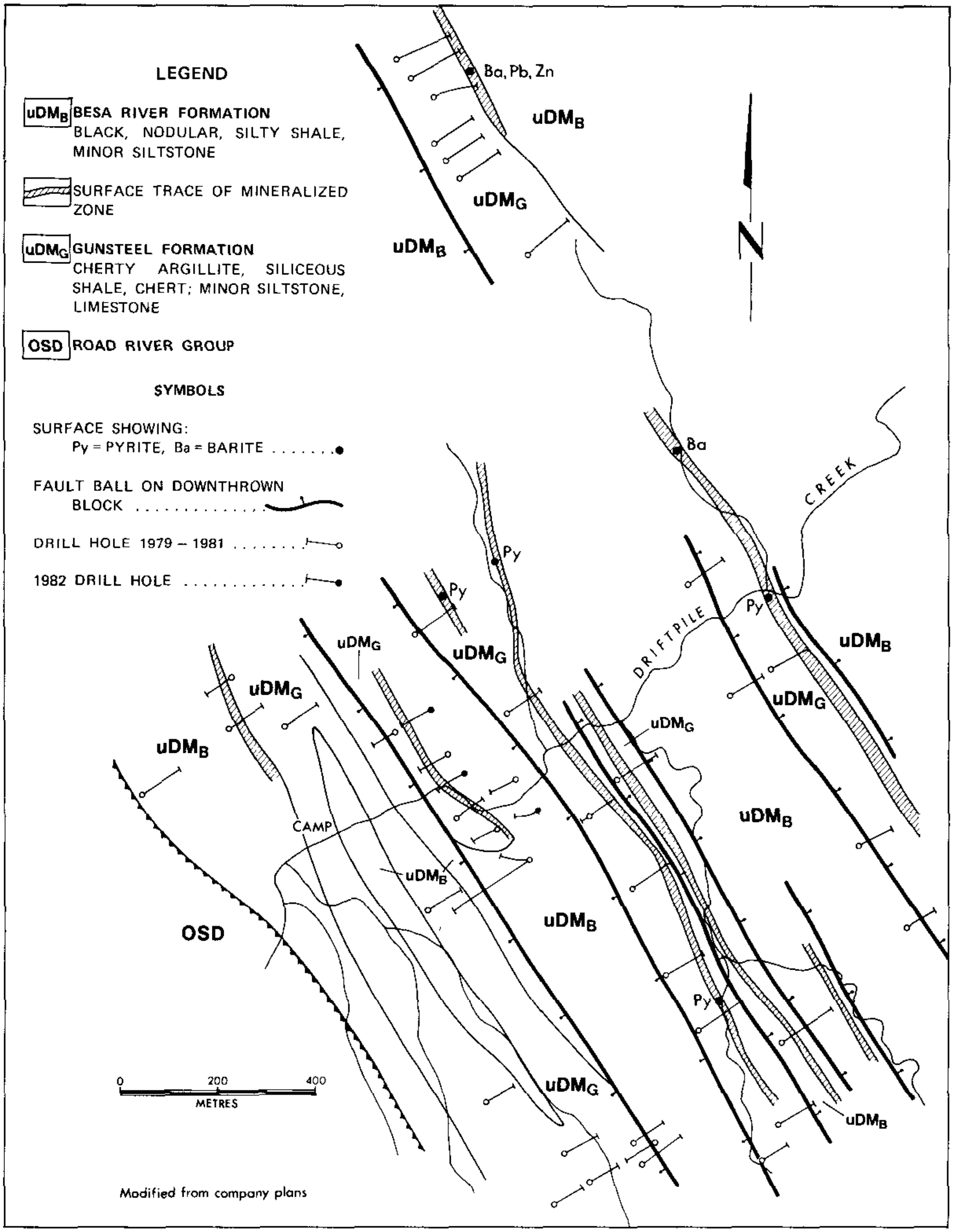


Figure 50. General geology and drill hole locations, Driftpile Creek property.

Siliceous to nonsiliceous pyritic black silty mudstones, argillites, and shales form the immediate hangingwall for the Late Devonian barite-sulphide deposits of the Gataga district. Calcareous 'nodules' and septarian concretions are common in hangingwall rocks at Driftpile Creek and the Bear. Some of the 'nodules' may be limy beds that were pulled apart during compaction. The shales are locally phosphatic and cherty and contain silty interbeds interpreted to be distal turbidites. In general, hangingwall rocks have a relatively high clastic component compared to footwall rocks. This suggests a more open marine environment with higher sedimentation rates followed formation of the deposits. This change coincides with a major eastward advancing Late Devonian marine transgression. Much of the clastic material deposited in the Kechika Trough at this time may have been derived from uplifted fault blocks to the west (Gordey, 1982).

DRIFTPILE CREEK

Driftpile Creek was the only property in the Gataga district that was visited during 1982. The following is a brief summary of the work done on this property to date. From 1978 to 1982 a total of 54 drill holes were completed at Driftpile Creek. Approximate location of these holes relative to the projected and known surface traces of the mineralized zone(s) are shown on Figure 50. The Gataga Joint Venture (Welcome North Mines Ltd., Chevron Canada Limited, Getty Mining Pacific Limited, and Canterra Energy Ltd.) has now earned a 50 per cent equity in the Driftpile property; Placer Development Limited and partners must now match the expenditures of the Gataga Joint Venture in order to retain their 50 per cent interest.

Drilling during 1982 (holes 51 to 54) further delineated a northwest-trending moderately east-dipping zone located approximately 300 metres east of the camp. This zone consists of laminated pyrite with local high-grade concentrations of galena and sphalerite; minor amounts of barite occur at the base of the pyritic interval. The section appears to be upright with stratigraphic tops to the northeast. The mineralized zone is underlain by typical banded cherty black mudstones and siliceous argillite of the Gunsteel Formation (uDM_G) and is overlain by nodular black silty shales that the author includes with the transgressive shales of the Besa River Formation (uDM_B). Both hangingwall and footwall rocks are considered part of the Late Devonian to Mississippian Earn Group (black clastics) following the recent usage of Gordey, *et al.* (1982) for the Selwyn basin.

Sparse outcrop and structural complexity have made delineation of mineralized zones difficult, even with relatively close spaced drilling. High-angle normal and reverse (thrust ?) faults are common and typically offset earlier developed fold structures.

It is still uncertain whether the baritic and pyritic mineralization intersected in drilling at Driftpile Creek is part of one laterally

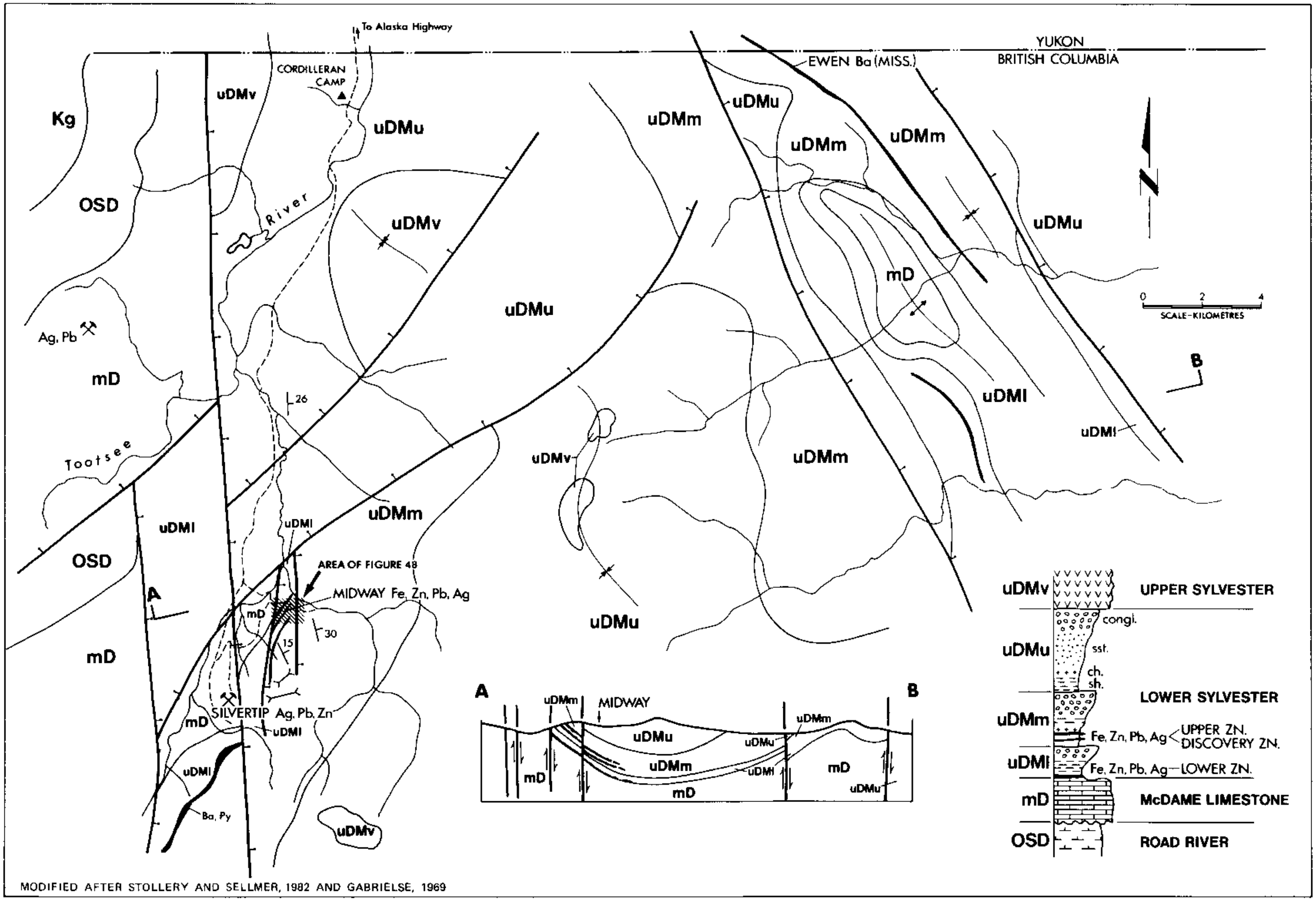


Figure 51. General geology in the vicinity of the Midway deposit.

continuous zone repeated by folding and faulting or actually represents several discrete mineralized zones at different stratigraphic levels. Recent biostratigraphic work by Dawson and Orchard (1982) in the Selwyn basin indicates both Middle Devonian and Mississippian (Osagean) barite deposits are present, in addition to the regionally extensive Late Devonian (Frasnian) barite-sulphide horizon. Apparently a similar time-stratigraphic distribution of deposits applies to the Driftpile Creek area (Gordey, 1982). However, the main sulphide-bearing zone at Driftpile Creek is most likely Frasnian in age, as it is in both the southern part of the Gataga district and MacMillan Pass area of Selwyn basin. Thin limestone interbeds collected from drill core at Driftpile Creek are currently being dissolved in the hopes of finding conodonts.

MIDWAY

The Midway deposit, which is situated within a broad synclinorium of Paleozoic platformal carbonates and transgressive clastic rocks immediately east of the Cassiar batholith (Fig. 47), was described in a previous report (MacIntyre, 1982c). Regional stratigraphy is summarized on Figure 49, and Figure 51 shows the geology in the vicinity of the deposit.

Six diamond-drill holes were completed on the Midway property at the end of the 1981 exploration program with encouraging results (Regional Resources News Release, November 23, 1981); 15 additional holes were drilled in 1982 (Fig. 52). The work done to date, which has been funded by Amax of Canada Limited and Procan Exploration Company with Regional Resources Ltd. as operator, has defined a high-grade stratabound zinc-lead-silver deposit in a block of moderately northeast-dipping Devonian to Mississippian carbonate and clastic rocks that are part of the McDame limestone and lower Sylvester Group respectively (Gabrielse, 1969). Massive stratabound pyrite-sphalerite-galena mineralization occurs at three different stratigraphic levels (Fig. 52). These levels are referred to as the Lower, Discovery, and Upper zones (Stollery and Sellmer, 1982). Several pyritic cherty exhalite beds also occur in a 50-metre section of argillites overlying the Upper zone.

The Lower zone occurs at the top of the Middle Devonian McDame limestone (Gabrielse, 1969). The mineralization is mainly hosted by the limestone which is locally strongly brecciated. Drilling indicates that the Lower zone is present in a subcircular area roughly 500 metres by 700 metres in size. The zone, which is locally very high grade, varies in thickness from less than 1 metre in its periphery to approximately 23 metres in diamond-drill hole 82-7 (Fig. 52). Combined lead+zinc grades vary from 2.65 to 32.75 per cent with 42 to 630 grams silver per tonne (George Cross News Letter, No. 188, September 30, 1982). The best intersection to date is in drill hole 82-8 with 2.6 metres averaging 21.61 per cent lead, 14.89 per cent zinc, and 1 371 grams silver per tonne. The lower zone is estimated to contain 2.7 million tonnes with 370 to 435 grams silver per tonne and 18 to 20 per cent combined zinc-lead (J. Stollery, personal communication). In addition, a weighted average of composite results from eight drill intersections contains 0.65 grams gold per tonne, 0.35 per cent copper, 0.14 per cent titanium, and 0.11 per cent bismuth (George Cross News Letter, November 25, 1982).

The Lower zone is overlain by an upward coarsening clastic sedimentary cycle that is approximately 100 metres thick. The cycle is characterized by increasing frequency, thickness, and coarseness of lithic wacke and pebble conglomerate intercalations up section.

The Discovery zone occurs approximately 100 metres up section from the Lower zone. The zone is well exposed by surface trenching (Fig. 52). The mineralization on surface consists of relatively coarse-grained pyrite intergrown with light-coloured sphalerite and lesser galena. The zone was intersected in all 1981 drill holes. Grades from 1981 drill holes ranged from 4.24 to 9.29 per cent lead-zinc with 62 to 99 grams silver per tonne. The Discovery zone apparently grades eastward into pyritic and baritic cherty exhalite.

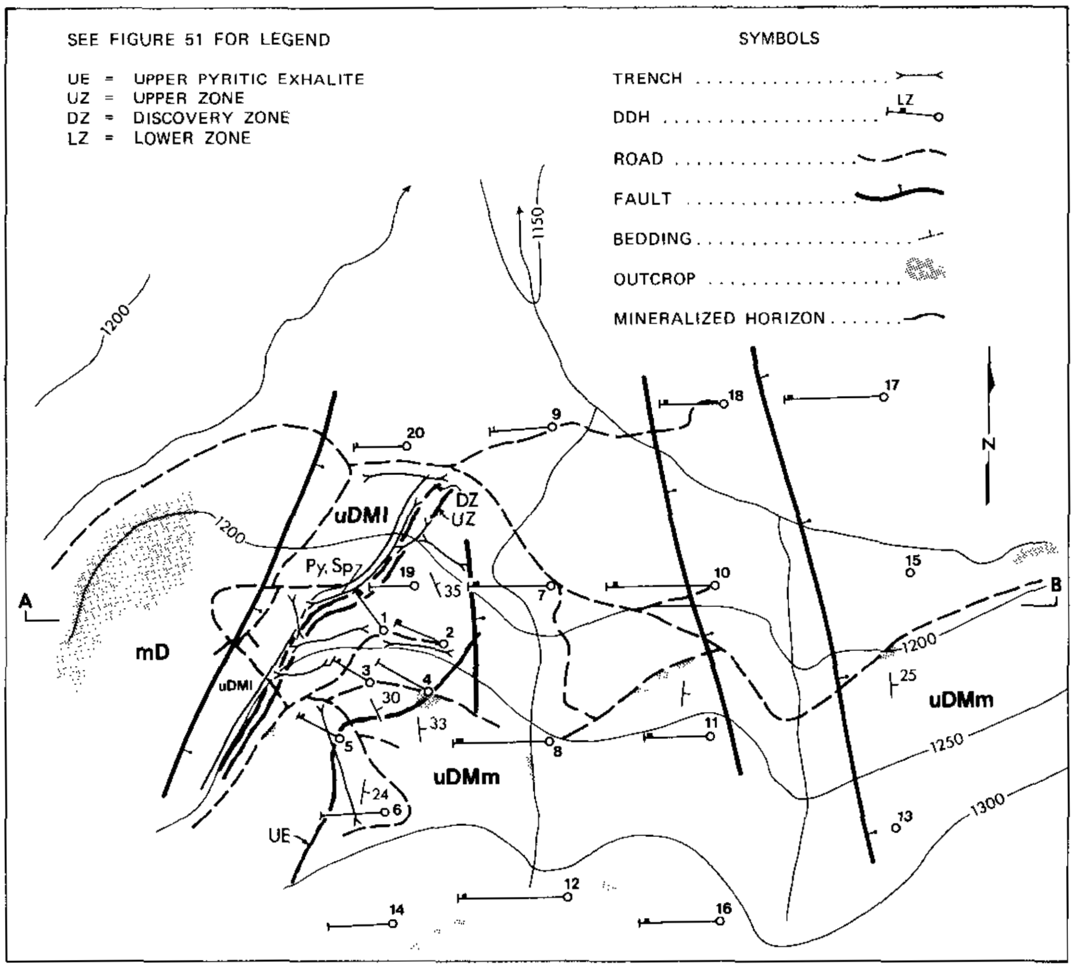


Figure 52. Geology and drill hole locations, Midway property.

The Upper zone occurs 10 to 20 metres above the Discovery zone. This zone, which was intersected in 1981 drill holes, is relatively thin (less than 3 metres) and lower grade than the Discovery and Lower zones.

Host rocks for the Discovery and Upper zones are cherty argillites and silty black shales at the base of the second coarsening-upward sedimentary cycle.

Mapping in the vicinity of the Discovery showing suggests that there are several pale-coloured pyritic cherty exhalite beds in rocks overlying the Upper zone (UE, Fig. 52). South of the Midway deposit cherty exhalite beds occur at a similar stratigraphic position (Fig. 51); these may represent the distal equivalents of the massive sulphide zones. A primary objective of our 1982 work on the Midway property was to collect samples from the exhalite horizons for lithogeochemical studies. Silt samples were also collected from drainages in the vicinity of the deposit, and all limestone and chert units were sampled for micropaleontological work. Results will be published when analytical work is completed.

The panel of rocks containing the Midway deposits is separated from McDame limestone by a high-angle fault of unknown displacement. The progressive downward displacement toward the east of the Lower zone suggests similar high-angle faults might also be present between drill holes 2 and 7, holes 9 and 18, and holes 18 and 17. Some small bedding plane shear zones were also noted in trenches on the property suggesting that some horizontal movement has also taken place.

The Midway is a new, economically significant example of a stratabound carbonate-hosted massive sulphide deposit that is overlain by clastic rocks *containing sedimentary-exhalative-type mineralization.* Unlike deposits of Selwyn basin and the Gataga district, which probably formed in starved third order basins, the Midway appears to have formed in a relatively shallow water platformal environment. Sulphide precipitation occurred during short-lived episodes of fine clastic sedimentation that preceded periods of coarse clastic deposition. The significance to exploration is that a starved basin environment is not necessary to form this type of deposit. Probably the most critical factor in determining where deposits of this type are formed is the location of hydrothermal vents, not host rock composition or sedimentary environment. Such vents are probably located along major crustal breaks; these can occur anywhere in a basin, slope, or platform environment. In the case of the Lower zone at Midway, karsting of the McDame limestone prior to clastic sedimentation might have established favourable sites for later sulphide deposition.

WINDY-CRAGGY

The Windy-Craggy stratiform cupriferous massive sulphide deposit is located in the Alsek-Tatshenshini River area of the St. Elias Mountains in the extreme northwestern corner of British Columbia. Because of the rugged and inaccessible nature of this area and extensive ice fields and glaciers, little is known about the stratigraphic relationships and mineral resource potential of the various geologic units present.

Regional 1:250 000 scale mapping by Campbell and Dodds (1979) defined several major fault-bounded geologic terranes within the Alexander allochthon (Fig. 47). The Windy-Craggy deposit occurs within a broad belt of volcanic and sedimentary rocks (Fig. 53) assumed to be largely Paleozoic in age. These rocks are intruded by intermediate to felsic plutonic rocks of Late Paleozoic to Tertiary age (unit MT_g, Fig. 53).

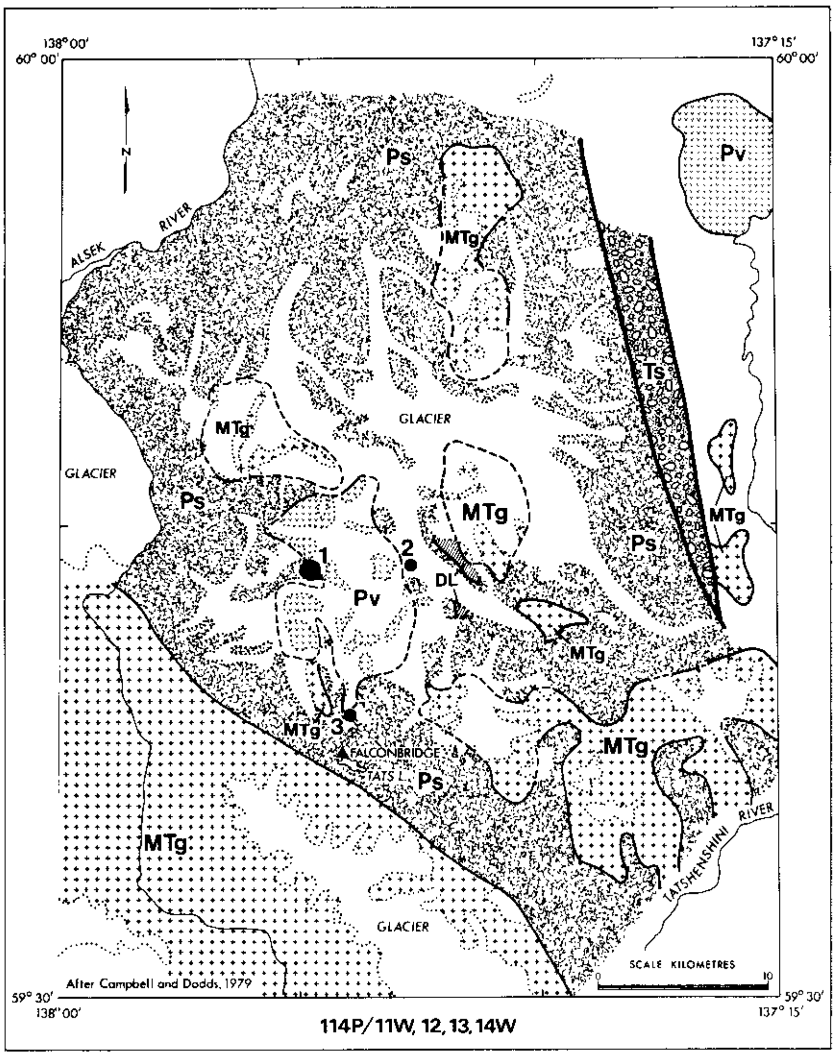


Figure 53. General geology in the vicinity of the Windy-Craggy deposit. Ps = predominantly sedimentary rocks; Pv = predominantly mafic to intermediate volcanic rocks; DL = Devonian limestone; MTg = Mesozoic to Tertiary intrusive rocks; Ts = Tertiary clastic rocks; 1 = Windy-Craggy deposit; 2 = Mus showing; 3 = Tats showing.

In the Windy-Craggy area the stratigraphic succession, which is informally called the Kaskawulsh Group (Campbell and Dodds, 1979), consists of a lower unit of intermediate to mafic locally pillowed flows and volcanic breccia of unknown age (unit P_V, Fig. 53). It is apparently overlain by intercalated calcareous and noncalcareous carbonaceous siltstones, greywackes, carbonates, and andesitic to dacitic tuffs and flows (unit P_S, Fig. 53). Mike Orchard (Geological Survey of Canada, Vancouver) has recently identified four Upper Triassic (Norian) and one Devonian conodont fauna from a thin limestone debris flow bed that presumably occurs at the base of this unit and in the immediate hangingwall of the Windy-Craggy deposit. The Devonian fauna is interpreted to be from Devonian limestone clasts in the debris flow. A limestone unit is present northeast of Windy-Craggy and contains Devonian macrofossils (unit D_L, Fig. 53).

The Windy-Craggy deposit and the Alsek (Tats) and Mus showings all occur at or near the contact between an altered pillow basalt unit and overlying interbedded tuff and calcareous siltstone units (Figs. 49 and 53). The mafic volcanic rocks appear to form the core of a major antiform of unknown complexity and attitude.

HISTORY

The Windy-Craggy gossan was first noted by J. J. McDougall of Falconbridge Limited while doing aerial reconnaissance of the area. A follow-up ground survey in 1958 resulted in discovery of the Windy-Craggy showing. The discovery showing is essentially a narrow gossan along the southern headwall of a cirque glacier. Packsack drilling in 1960 (11 holes totalling 240 metres) by Ventures Ltd. (later absorbed by Falconbridge Limited) intersected a massive sulphide body beneath the surface gossan. Three diamond-drill holes totalling 410 metres were completed in 1965 (65-1, 2, 3; Fig. 54), and an additional 10 holes totalling 2 250 metres were drilled in 1981.

In 1982 hole 1981-9 was extended and two new holes (11 and 12) were completed for a total of 1 364 metres of drilling. This work was financed by Geddes Resources Limited through a drilling fund; work on the property was managed by Falconbridge Limited. By spending $1 500 000 in 1981 and 1982, Geddes Resources Limited has now earned a 49 per cent undivided interest in the Windy-Craggy property.

DEPOSIT GEOLOGY

Surface geology and drill hole locations are shown on Figure 54. Drilling to date on the Windy-Craggy property has defined a concordant, tabular, steeply northeast-dipping pyrrhotite-chalcopyrite±pyrite massive sulphide body over 1 000 metres long and averaging approximately 100 metres in thickness. There are unknown extensions along strike and down dip. Copper grades are variable, ranging from less than 1 per cent up to

14 per cent in narrow high-grade supergene enriched intersections. The drill-indicated reserves of the best grade part of the massive sulphide zone are reported to be over 85 million tonnes averaging 3.04 per cent copper and 0.09 per cent cobalt within an overall inferred tonnage for the deposit of 300 million tonnes averaging 1.52 per cent copper and 0.08 per cent cobalt (Northern Miner, January 13, 1983).

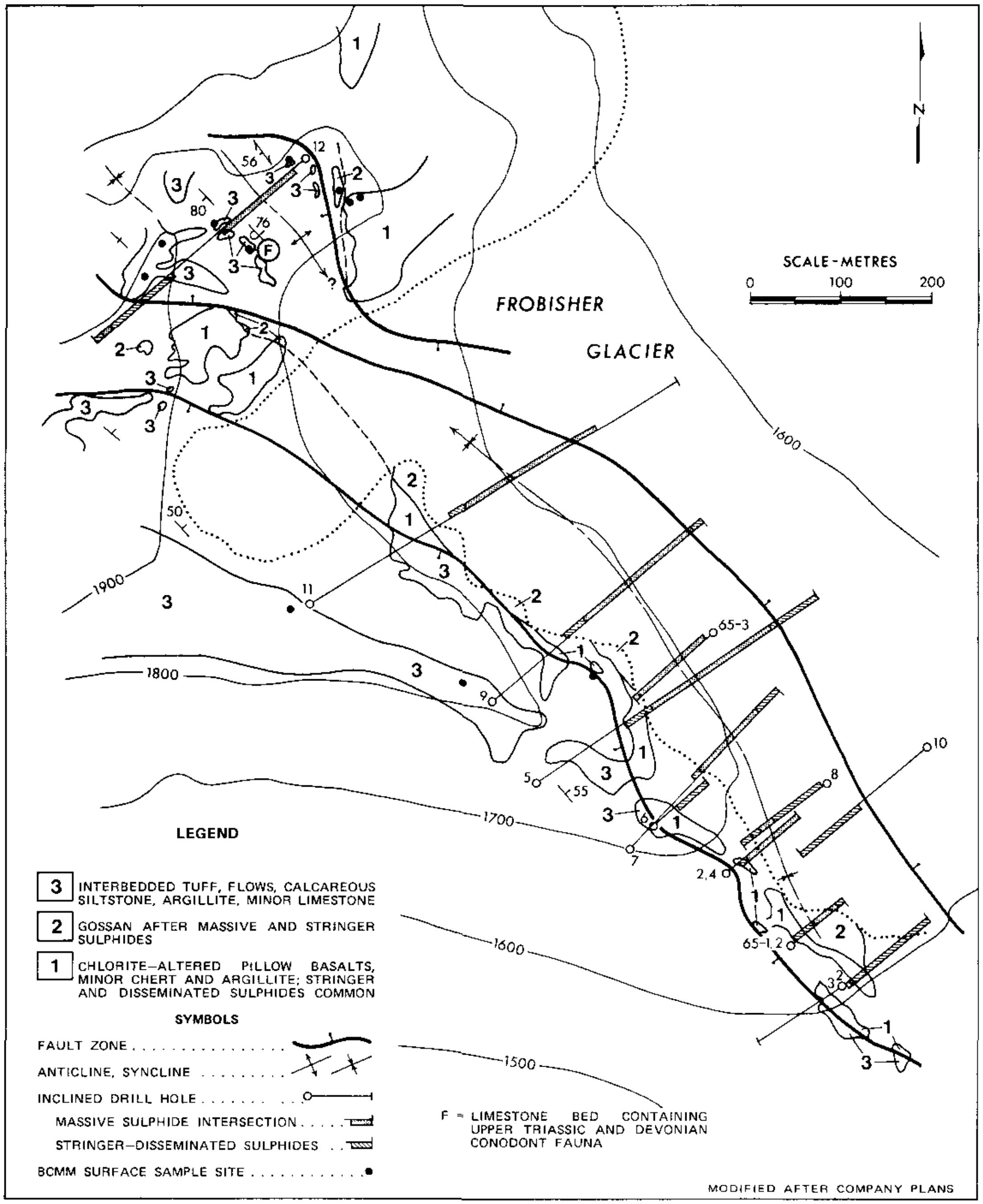


Figure 54. Geology and drill hole locations, Windy-Craggy deposit.

The most northerly drill hole, 82-12, intersected a predominantly massive pyrite zone from 24 to 187 metres that averaged 1.78 per cent copper (includes 53 metres averaging 3.09 per cent copper). The top 12.5 metres of this intersection also averaged 0.58 per cent zinc, 79 grams silver per tonne, and 1.34 grams gold per tonne, and the bottom 38.7 metres averaged 1.75 per cent zinc, 16.25 grams silver per tonne, and 0.47 grams gold per tonne. Concentrations of zinc, silver, and gold appear to increase toward the northern end of the deposit which is predominantly pyrite. Pyritic sections also tend to be coarser and more granular in texture and framboidal texture is locally well developed. Massive pyrrhotite sections are generally much finer grained. Stilpnomelane is a common accessory mineral in the massive sulphide zone, which is also locally magnetite rich. Pyrite and pyrrhotite bands and laminae also occur in argillites and cherts of the immediate hangingwall and footwall of the deposit. Small-scale fold structures are common in the banded and laminated sulphide zones.

One of the most interesting features of the Windy-Craggy deposit is the relatively high concentration of cobalt in massive pyrrhotite sections. Drill intersections averaging greater than 0.1 per cent cobalt are common; some short intersections contain greater than 0.2 per cent. The best cobalt grades do not necessarily correlate with better copper grades as shown on Figure 56. Falconbridge Limited research indicates no discreet cobalt mineral is present; cobalt is probably in solid solution with pyrrhotite and it might not be economically recoverable.

In addition to massive sulphide mineralization, a large zone with stringers and disseminations of pyrrhotite and chalcopyrite occurs in chlorite-epidote-serpentine altered pillow basalts, cherts, and argillites along both sides of the massive sulphide body. The grade of stringer mineralization generally averages 0.5 to 0.8 per cent copper with sporadic intersections up to 2 per cent. The stringer zone has relatively low cobalt, silver, and gold concentrations. A major northwest-trending fault zone separates stringer mineralization from relatively unaltered interbedded calcareous siltstones and andesitic to dacitic tuffs and flows southwest of the deposit. A similar fault may also be present below the glacier on the northeast side of the deposit as indicated by drill hole 81-10 (Fig. 56).

The mixed calcareous siltstone-volcanic unit is probably the stratigraphic hangingwall of the deposit. If altered mafic pillowed basalts and cherts with stringer sulphide mineralization comprise the stratigraphic footwall of the deposit, as they normally do in the classic volcanogenic massive sulphide model (Fig. 55), then drill hole data could be interpreted as shown on Figure 56. In this structural model the massive sulphide body is folded into tight anticline-syncline pairs that are separated and displaced by high-angle normal and reverse faults. In this model the best copper grades are located at the base of the massive sulphide body and in the immediate footwall.

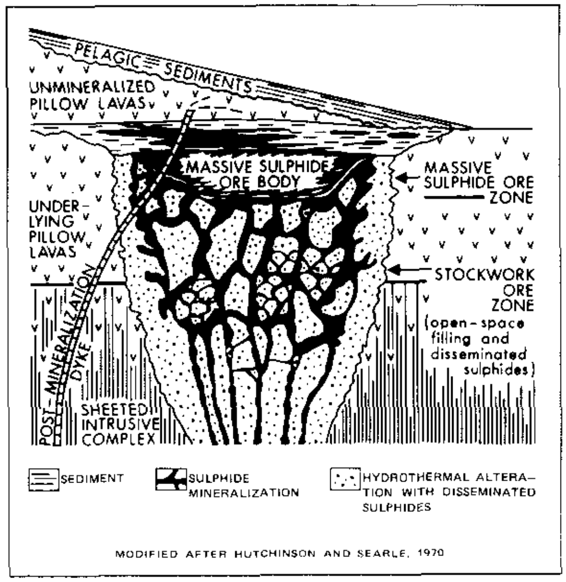


Figure 55. Model for Cyprus-type volcanogenic massive sulphide deposits. Modified after Hutchinson and Searle (1971).

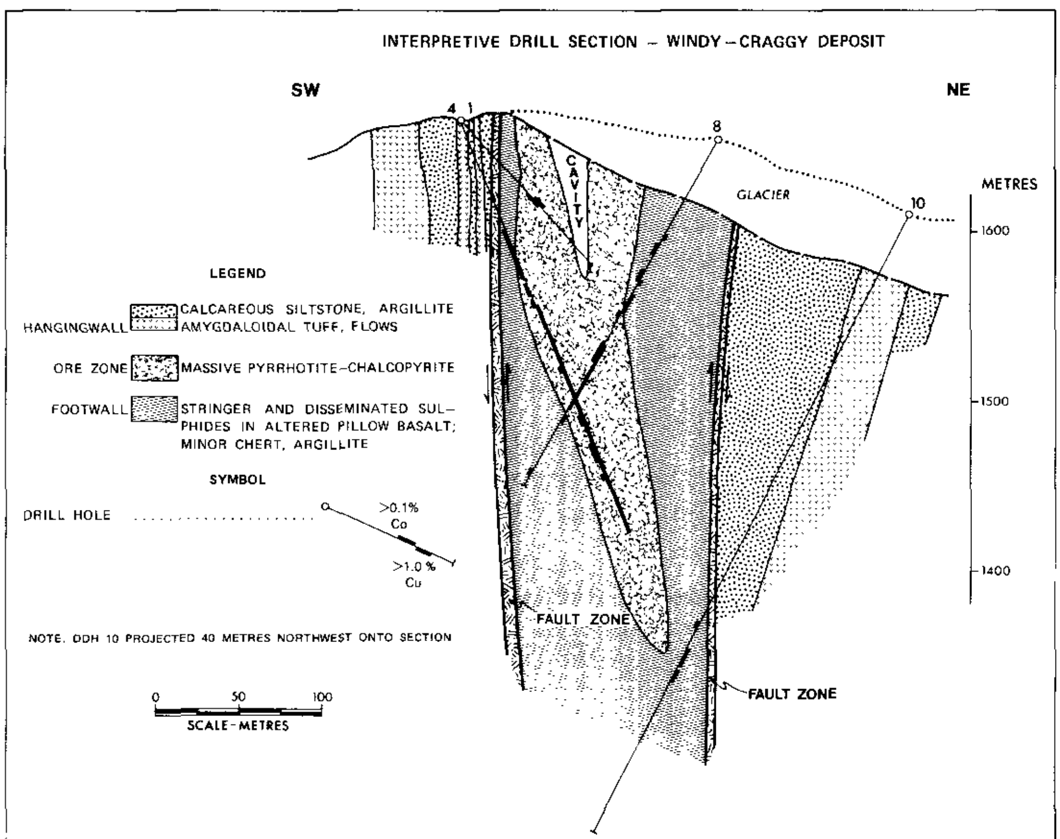


Figure 56. Interpretive drill section, Windy-Craggy deposit.

TABLE 1. COMPARISON OF GATAGA, MIDWAY, AND WINDY-CRAGGY DEPOSITS

	Setting	Pre-ore	Post-ore	Age(s)	Mineralogy
(1) Gataga	Continental margin basin or trough Fault bounded ?	Shallow marine shelf and slope to deep marine starved basin; proximal to distal turbidites near shelf; some volcanism (mO)	Transgressive open marine; distal turbidite Subsiding basin ? Active growth faults ?	(1) uD (2) eS (3) mO	Py, Sp → Ba, Py, Sp, Gn → Ba, Gn Ba Regional baritic horizon Ba, Py, Sp → Ba Py → Ba
(2) Midway	Shelf or platform along continental margin Fault bounded ?	Shallow marine carbonate buildup	Coarsening upward clastic sedimentary cycles; regressive distal to proximal turbidites going to subaerial volcanism Rising platform ?	uD-M M	Py, Sp, Gn → Ba, Py Regional pyritic-baritic exhalite horizons Ba (Ewen)
(3) Windy-Craggy	Back arc basin ? Sedimentary trough centred on spreading rift system ?	Submarine volcanic flows and tuffs; minor amounts of chert and clastic sedimentary rocks; pyritic exhalites	Distal turbidites, ash fall tuffs, flows, shallow water carbonate buildup ?	uTR ?	Po, Py, Cp (Sp, Mt) → pyritic exhalite ?

Ba - barite; Gn - galena; Po - pyrrhotite; Py - pyrite; Sp - sphalerite; Cp - chalcopyrite; → - lateral trend; Mt - magnetite; u - upper; m - middle; e - early; D - Devonian; S - Silurian; O - Ordovician; M - Mississippian; TR - Triassic

The massive sulphide intersection in drill hole 82-12 is bounded by interbedded volcanic rocks and calcareous siltstones but does not appear to come to surface. Perhaps the intersection is near the top of a tight anticlinal fold structure. As described previously, zinc concentration increases toward the 'upper' and 'lower' contacts of the massive sulphide intersection suggesting that zinc is enriched at the top of the massive sulphide body. This apparent zonation of copper and zinc within the Windy-Craggy deposit is consistent with that normally observed in volcanogenic massive sulphide deposits.

GENETIC MODELS

The three stratiform massive sulphide deposit types described in this paper have one unifying characteristic; they all formed by *in situ* precipitation of sulphides onto the seafloor, probably in close proximity to a hydrothermal vent. These vents or fumaroles were probably situated along major faults that provided escape conduits for heated formational waters and convectively circulating seawater. Differences in the metal content and mineralogy of the deposits (Table 1) can best be explained in terms of different temperature regimes as suggested by Finlow-Bates (1980), Large (1977), and others (Fig. 58).

Stratiform deposits of the Gataga district formed in a fault-controlled continental margin sedimentary basin or trough and typically have low temperature characteristics. That is, they have very low copper content, high barite content, and no appreciable footwall alteration or veining. The lack of coeval volcanic rocks in the section is consistent with the inferred low temperature environment of formation. In contrast, the Midway deposits formed both within platformal carbonates and in overlying transgressive clastic rocks. Periodic movements along nearby growth faults probably triggered episodes of coarse clastic sedimentation that produced the coarsening upward sedimentary cycles. Unlike deposits of the Gataga district, which grade outward into thin laminae of nodular barite, distal equivalents of the Midway stratiform massive sulphide zone are mainly pyritic cherty exhalites that have only minor amounts of intercalated barite. Mineralization on the Midway property is predominantly massive, locally recrystallized pyrite. It has local high-grade zinc, lead, and silver values but low barite concentrations. The Lower zone also contains copper with some gold, titanium, and bismuth. These features suggest the Midway deposits formed at slightly higher tempertures, and/or closer to hydrothermal vents than deposits of the Gataga district. A major high-angle fault occurs on the west side of Midway deposit; this fault might have been the main conduit for hydrothermal fluids, not only for Midway but also for the nearby Silvertip silver-lead-zinc vein system.

In contrast to the stratiform pyrite sphalerite barite±galena deposits of the Gataga district and the Midway deposit, the cupriferous massive sulphide deposit at Windy-Craggy is much like the Cyprus-type volcanogenic massive sulphide deposits. Cyprus deposits occur in a sequence of altered pillow basalts of ophiolitic affinity (Hutchinson and Searle, 1971). Typically they have a well-developed underlying stringer and disseminated sulphide zone. The massive cupriferous pyrite body is overlain by unaltered volcanic and pelagic sedimentary rocks (Fig. 55). All these features are present at Windy-Craggy.

The Cyprus deposits occur at the contact of the subcircular Troodos Igneous Complex which consists of an ultramafic base, a sheeted gabbroic dyke swarm, and upper altered pillow basalts. The complex is believed to have formed at a spreading rift system within continental crust. The Windy-Craggy deposit and other nearby stratiform massive sulphide occurrences of unknown significance also occur at the contact of a subcircular mass of mafic volcanic rocks (Fig. 53) and this mass may have an ophiolitic core similar to that of the Troodos Igneous Complex. Therefore a similar environment of formation might apply to the Windy-Craggy area, that is, a spreading rift system within continental crust, perhaps in a back arc basin setting similar to that of the present day Japanese Islands or Gulf of California (Fig. 57). The andesitic to dacitic tuffaceous rocks intercalated with sedimentary strata overlying the Windy-Craggy deposit may, in fact, represent fallout from an active volcanic arc that was located west of the basin. These ideas are speculative and require additional regional mapping to substantiate.

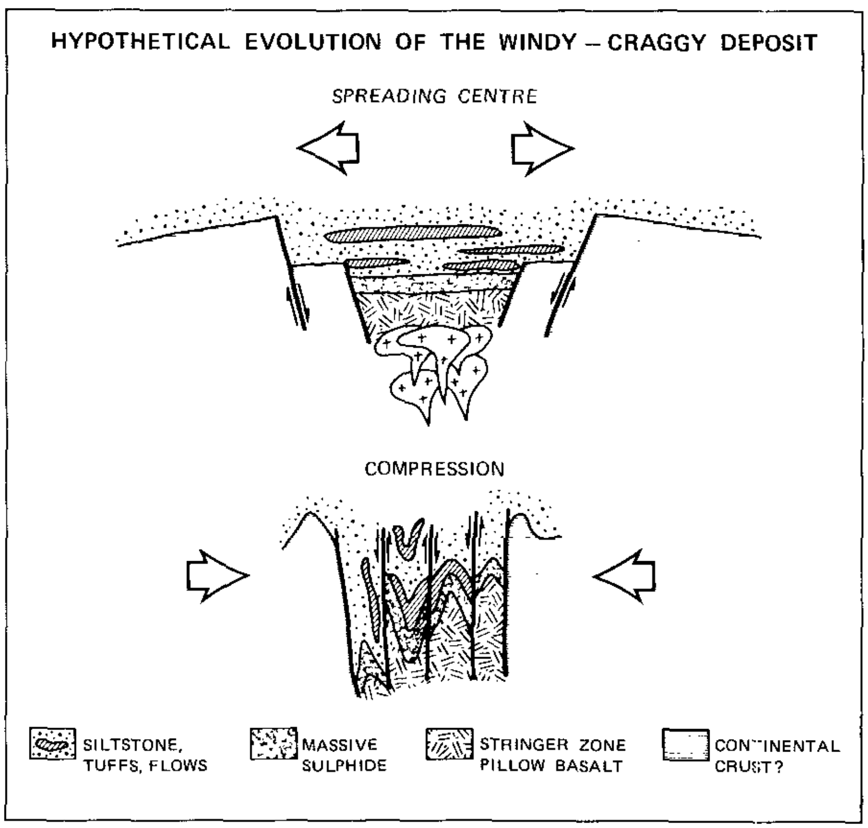


Figure 57. Hypothetical evolution of the Windy-Craggy deposit.

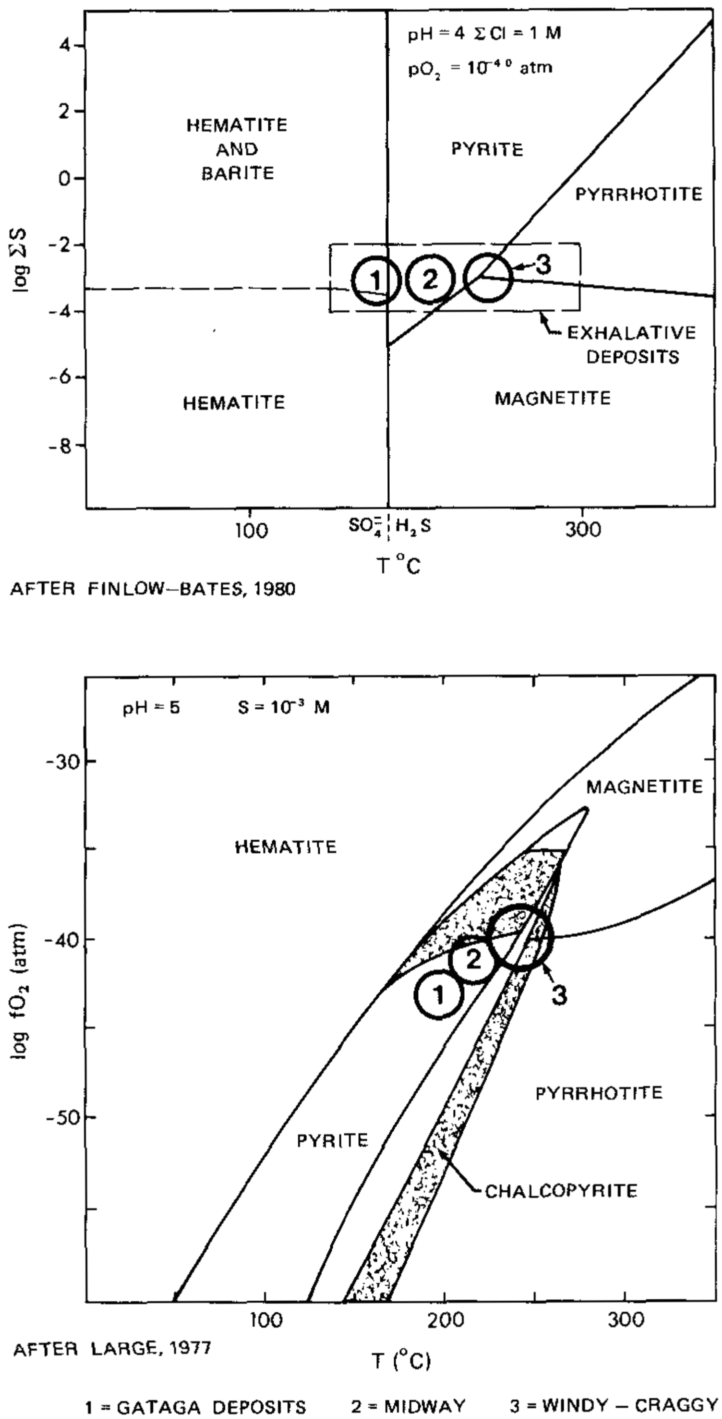


Figure 58. Log total sulphur-temperature and log oxygen fugacity-temperature diagrams and stability fields of phases common to exhalative deposits. Hypothetical fields of formation for deposits of the Gataga district and the Midway and Windy-Craggy deposits are also shown.

The high copper and anomalous cobalt content of the Windy-Craggy ore is consistent with a model of convective downward circulation of seawater and leaching of metals from a mafic to ultramafic volcanic pile in the manner described by Spooner (1980) for formation of the Cyprus deposits. Although Windy-Craggy has almost all the features of the Cyprus model, there is one very important difference -- size. The Windy-Craggy deposit has inferred reserves on the order of 300 million tonnes, which is much larger than the largest of the known Cyprus deposits (15 million tonnes). The discovery of a Cyprus-type deposit of this size and grade in this relatively unexplored area suggests that volcanic-sedimentary rocks of the Alexander terrane have a very high resource potential. In view of the deposit model presented in this paper, the contact between altered mafic volcanic rocks and overlying unaltered volcanic-sedimentary rocks would be a prime exploration target. The apparent Late Triassic age of the hangingwall rocks at Windy-Craggy should also be taken into consideration. If the mafic pillowed volcanic rocks are Paleozoic in age as inferred by the regional mapping of Campbell and Dodds (1979), then a major unconformity or thrust fault may exist between the mafic volcanic rocks and the overlying volcanic-sedimentary unit. Alternatively, the entire package might be Late Triassic in age and therefore correlate with other mafic volcanic units such as the Stuhini Group of the Intermontane Belt and the Karmutsen-Nikolai assemblage of the Insular Belt.

ACKNOWLEDGMENTS

The author would like to thank Rob Carne and Mike Philips of Archer, Cathro Holdings Limited, Brian Hall of Cordilleran Engineering Limited, and Terry Chandler and Jim McDougall of Falconbridge Limited for much valuable information and logistical support during visits to their respective properties. Mike Fournier provided able and cheerful assistance in the field.

REFERENCES

Campbell, R. B. and Dodds, C. J. (1979): Operation Saint Elias, British Columbia, *in* Current Research, Pt. A, *Geol. Surv., Canada,* Paper 79-1A, pp. 17-20.

Dawson, K. M. and Orchard, M. J. (1982): Regional Metallogeny of the Northern Cordillera: Biostratigraphy, Correlation, and Metallogenic Significance of Bedded Barite Occurrences in Eastern Yukon and Western District of Mackenzie, *in* Current Research, Pt. C, *Geol. Surv., Canada,* Paper 82-1C, pp. 31-38.

Finlow-Bates, T. (1980): The Chemical and Physical Controls on the Genesis of Submarine Exhalative Orebodies and their Implications for Formulating Exploration Concepts -- A Review, *Geol. Jb.,* Vol. 40, pp. 131-168.

Gabrielse, H. (1969): Geology of the Jennings River Map-Area, British Columbia, *Geol. Surv., Canada,* Paper 68-55, 37 pp.

Gordey, S. P. (1982): Devono-Mississippian ('Black Clastic') Sedimentation and Tectonism in the Northern Cordillera, *in* Program and Abstracts, *Geol. Assoc. Can.,* Cordilleran Section, Meeting, Vancouver, B.C., February 1982.

Gordey, S. P., Abbott, J. G., and Orchard, M. J. (1982): Devono-Mississippian (Earn Group) and Younger Strata in East-Central Yukon, *in* Current Research, *Geol. Surv., Canada,* Paper 82-1B, pp. 93-100.

Hutchinson, R. W. and Searle, D. L. (1971): Stratabound Pyrite Deposits in Cyprus and Relations to Other Sulphide Ores, *Soc. Min. Geol., Japan,* Special Issue No. 3, pp. 198-205.

Large, R. R. (1977): Chemical Evolution and Zonation of Massive Sulphide Deposits in Volcanic Terrains, *Econ. Geol.,* Vol. 72, pp. 549-572.

MacIntyre, D. G. (1980a): Driftpile Creek-Akie River Project, *B.C. Ministry of Energy, Mines & Pet. Res,* Geological Fieldwork, 1979, Paper 1980-1, pp. 55-67.

.... (1980b): Cirque Barite-Zinc-Lead-Silver Deposit, *B.C. Ministry of Energy, Mines & Pet. Res.,* Geological Fieldwork, 1979, Paper 1980-1, pp. 69-74.

.... (1981a): Akie River Project, *B.C. Ministry of Energy, Mines & Pet. Res.,* Geological Fieldwork, 1980, Paper 1981-1, pp. 32-47.

.... (1981b): Geology of the Akie River Barite-Lead-Zinc Mineral District, *B.C. Ministry of Energy, Mines & Pet. Res.,* Prelim. Map 44.

.... (1982a): Akie River Project, *B.C. Ministry of Energy, Mines & Pet. Res.,* Geological Fieldwork, 1981, Paper 1982-1, pp. 142-148.

.... (1982b): Geologic Setting of Recently Discovered Stratiform Barite-Sulphide Deposits in Northeast British Columbia, *C.I.M.,* Bull., Vol. 75, No. 840, pp. 99-113.

.... (1982c): Midway Occurrence, *B.C. Ministry of Energy, Mines & Pet. Res.,* Geological Fieldwork, 1981, Paper 1982-1, pp. 162-166.

MacIntyre, D. G. and Diakow, L. (1982): Kwadacha Barite Deposit, *B.C. Ministry of Energy, Mines & Pet. Res.,* Geological Fieldwork, 1981, Paper 1982-1, pp. 149-155.

Morganti, J. M. (1981): Sedimentary-Type Stratiform Ore Deposits: Some Models and a New Classification, *Geoscience Can.,* Vol. 8, No. 2, pp. 65-75.

Spooner, E.T.C. (1980): Copper-Pyrite Mineralization and Seawater Convection in Oceanic Crust -- The Ophiolitic Ore Deposits of Cyprus *in* The Continental Crust and Its Mineral Deposits, D. W. Strangway, editor, *Geol. Assoc. Can.,* Special Paper 20, pp. 685-703.

Stollery, J. W. and Sellmer, W. H. (1982): Midway, An Analysis of a New Massive Sulphide Discovery, *Cdn. Min. Jour.,* Vol. 103, No. 4, pp. 68-71.

BRUCEJACK LAKE (SULPHURETS) PROSPECT
(104B/8)

By T. G. Schroeter

INTRODUCTION

The Brucejack Lake (Sulphurets, MI 104B-118) precious metals epithermal prospect, located approximately 65 kilometres northwest of Stewart, was examined from August 3rd to 6th inclusive. Brucejack Lake, part of the larger Sulphurets property, is covered by the Red 1 Group mineral claims (Red River, Red River 2 to 7 inclusive, and Tedray 12). In total, the Sulphurets property consists of 240 units including three fractional claims and six two-post claims. It covers parts of 104B/8E, 8W, 9E, and 9W. The claims are held by Granduc Mines Limited, Esso Resources Canada Limited, and Sidney F. Ross. The property is being operated by Esso Resources Canada Limited under option from Granduc Mines Limited and Sidney F. Ross. Access is by helicopter from Stewart. During exploration, Esso Resources Canada Limited utilized a helicopter from their base camp located on the north side of Mitchell Creek, about 200 metres east of McTagg Creek.

GEOLOGY AND MINERALIZATION

Small precious base metal showings occur over a large area within altered Early Jurassic andesitic volcanic and sedimentary rocks (arenite and argillites) of the Unuk River Formation. The mineralization occurs in sericite schists that represent areas of moderate to intense wallrock alteration. Hornblende syenites and alkali feldspar syenites that intrude the sequence have also undergone local intense alteration. Numerous north-south to northwesterly faults cut across the property -- including the Brucejack fault. Middle Jurassic Betty Creek Formation rocks occur to the east. The dominant alteration products include sericite, K-feldspar, silica, carbonate, and chlorite. Sulphide mineralization, found in five separate mineralized zones spaced along a 7-kilometre belt, occurs as low-grade disseminations ('porphyry' gold), as veins (for example, Iron Cap), and as epithermal stockworks (for example, Brucejack Lake). Minerals include pyrite, chalcopyrite, molybdenite, ruby silver, stephanite, cerargyrite, electrum, native gold, tetrahedrite, freibergite, argentite, galena, sphalerite, and bornite in a gangue of quartz, barite, and calcite. Cerargyrite has been identified in a purple rind on silver-bearing veins in the Brucejack area (Dane Bridge, personal communication, 1982).

The main area of interest this year was Brucejack Lake where several showings of precious metal mineralization have been found and partially tested over a 2-square-kilometre area. At the time of the writer's visit, 120 short, hand-blasted trenches had been completed and diamond drilling was in progress.

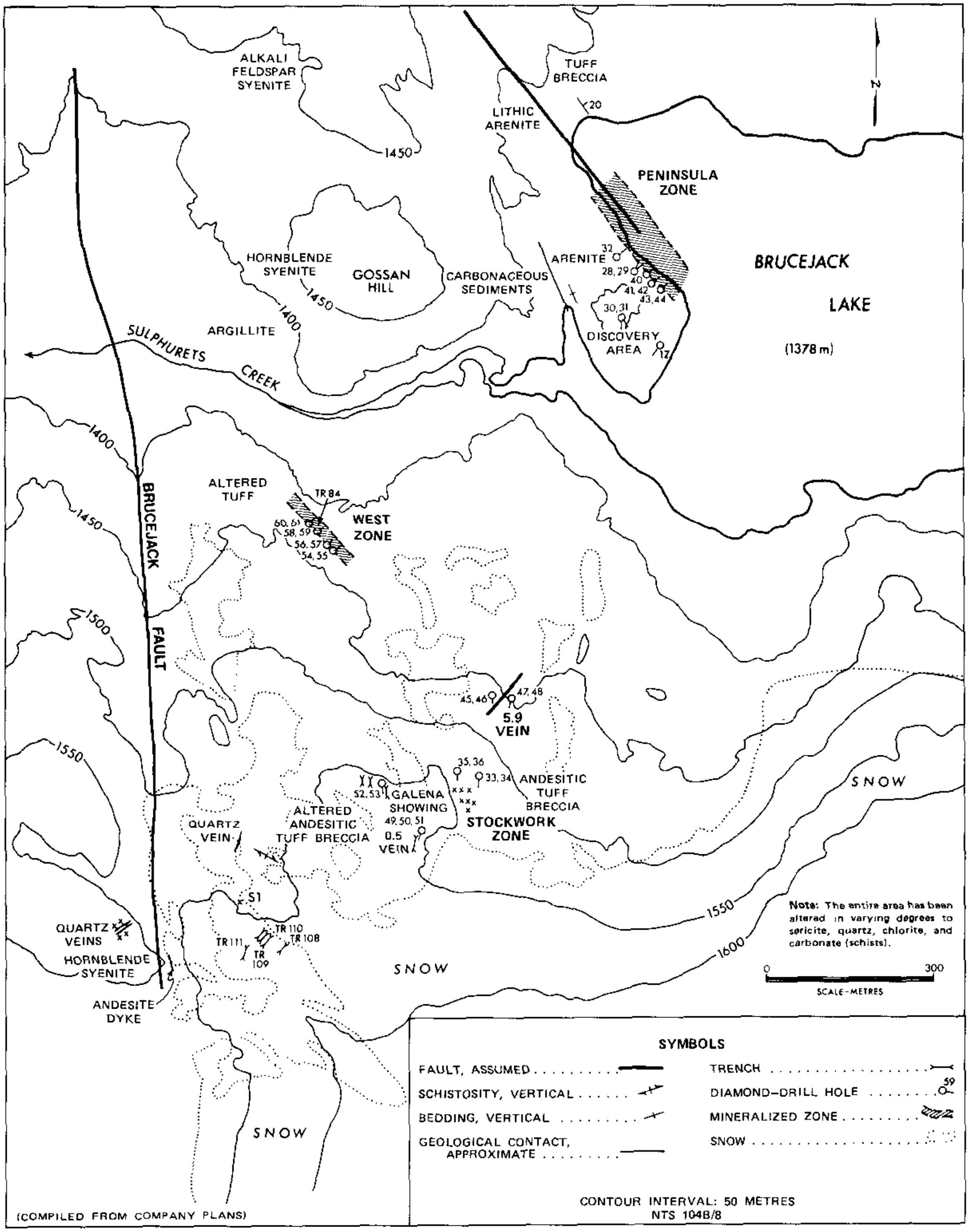


Figure 59. Brucejack Lake (Sulphurets) property (compiled from company plans).

During 1982, 53 diamond-drill holes totalling 4 633.4 metres were drilled on the Sulphurets property. On the Brucejack Lake prospect 1981 and 1982 drilling includes diamond-drill holes 28, 29, 32, 40 to 44 and 63 to 76 in the Peninsula zone; 54 to 62 and 80 to 91 in the West zone; 33 to 36 in the Stockwork zone; 52, 53 and 92 to 95 in the Galena showing; 45 to 48 in the 5.9 vein; and 17, 30 and 31 in the Discovery area on the peninsula.

Two principal zones have been identified:

(1) PENINSULA ZONE (Near Shore zone), which has been traced for 265 metres and to a depth of 140 metres by intersections in 22 drill holes. The zone is still open. Grab samples collected by the writer ranged in value from 0.1 ppm gold and 43 ppm silver up to 2 ppm gold and 2 924 ppm silver with lead and zinc values up to 1.49 per cent and 3.33 per cent respectively.

(2) WEST ZONE, which was tested by 21 drill holes along a length of 310 metres and to a depth of 60 metres. It is still open. True widths are estimated to range from 0.6 to 4.0 metres. Some very high grades over narrow widths have been obtained. Ruby silver, freibergite, electrum, native gold, stephanite, galena, pyrite, and sphalerite occur in a stockwork of quartz veinlets in sericitic andesitic tuff. Mineralized grab samples containing sulphides in quartz veinlets that the writer collected ranged in value from 4.8 ppm gold and several thousand ppm silver up to 275 ppm gold and 67 525 ppm silver. Copper ranged from 0.54 per cent up to 2.74 per cent, lead from 0.4 per cent up to 2.50 per cent, and zinc from 0.027 per cent up to 4.5 per cent.

Other showings or zones tested include (*see* Fig. 59):

(3) GALENA SHOWING -- galena, sphalerite, pyrite, chalcopyrite, and native gold occur in quartz and barite veinlets in sericite schist (altered andesitic tuff); grab samples collected by the writer ranged in value from 1 ppm gold and 69 ppm silver to 9.3 ppm gold and 1 276 ppm silver; copper values ranged from 0.02 to 0.52 per cent, lead from 0.04 to 7.7 per cent, and zinc from 0.02 to 4.78 per cent.

(4) TRENCH 108-111 RIDGE -- galena, tetrahedrite, electrum, argentite, sphalerite, pyrite, and chalcopyrite occur in a quartz stockwork in sericite schist (altered andesitic tuff); grab samples collected by the writer ranged in value from 0.3 ppm gold and 10 ppm silver to 56 ppm gold and 5 166 ppm silver; copper values ranged from 0.05 to 0.68 per cent, lead from 0.6 to 5.9 per cent, and zinc from 0.12 to 5.87 per cent.

(5) 0.5 VEIN -- sulphides in quartz veins in sericite schist; grab samples collected by the writer ranged in value from 16.5 ppm gold and 187 ppm silver to 36 ppm gold and 235 ppm silver; copper ranged

from 0.25 to 0.66 per cent, lead from 1.19 to 3.8 per cent, and zinc from 3.01 to 4.5 per cent.

(6) STOCKWORK ZONE -- pyrite, galena, and sphalerite in a quartz stockwork in sericite schist.

(7) 5.9 VEIN -- native gold, electrum, pyrite, galena, sphalerite, ruby silver in a quartz stockwork in sericite schist.

ACKNOWLEDGMENTS

The writer would like to acknowledge the cooperation and logistical support provided by Esso Resources Canada Limited.

MOUNT JOHNNY PROSPECT
(104B/11E)

By T. G. Schroeter

INTRODUCTION

On August 5th the writer made a brief visit to Skyline Exploration Ltd.'s Mount Johnny (Reg claims, MI 104B-77) massive sulphide property, which is located approximately 120 kilometres northwest of Stewart on the west flank of Mount Johnny (*see* Fig. 60). Access to the property, which consists of 172 units, is via helicopter from either Stewart or Eddontenajon.

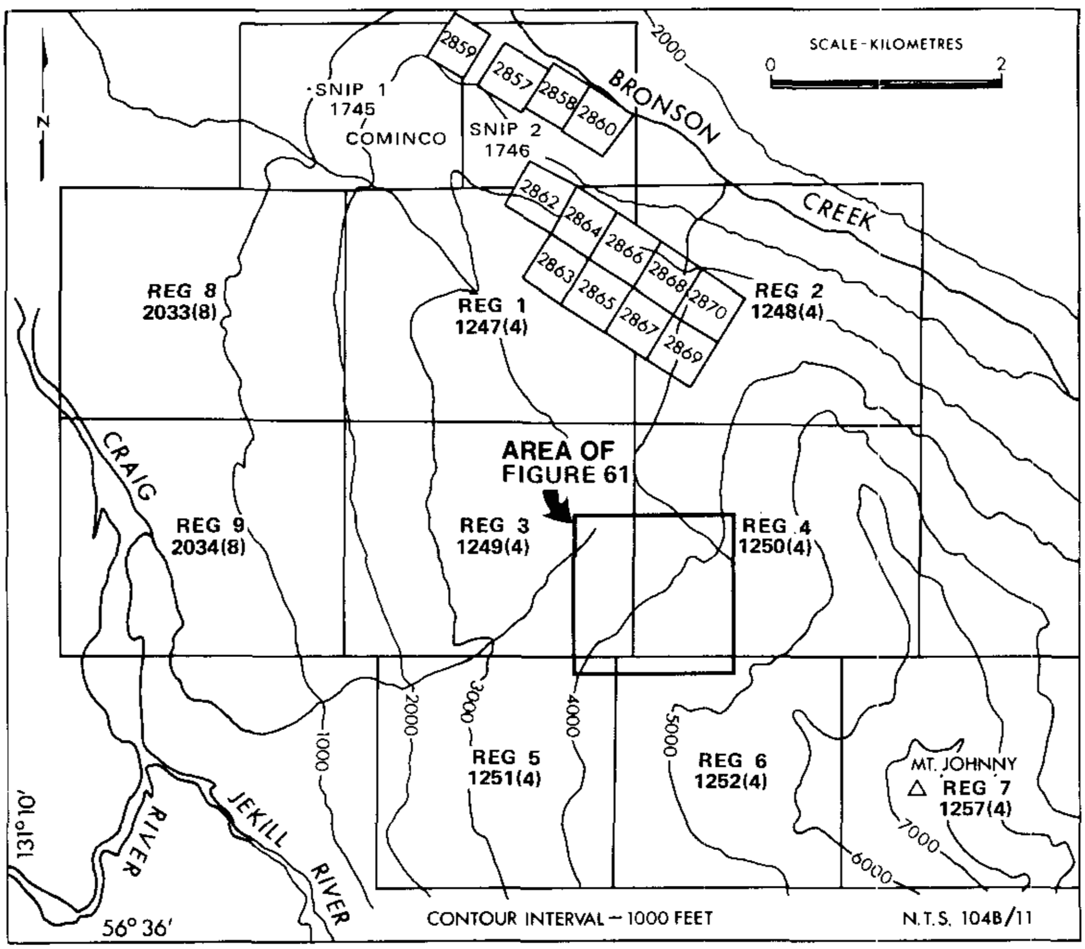


Figure 60. Location map, Mount Johnny prospect.

GEOLOGY AND MINERALIZATION

The base of Mount Johnny is underlain by intercalated phyllitic grits, siltstone, and an andesitic-rhyolitic sequence of Early Jurassic age (Unuk River Formation ?). The volcanic sequence locally shows persistent autometamorphic textures. A sequence of lower Middle Jurassic rocks (Betty Creek Formation ?) overlies the Early Jurassic rocks but are devoid of significant mineralization.

Copper-gold massive sulphide mineralization has been located in three zones: Pick Axe, Cloutier, and McFadden (*see* Fig. 61). The Pick Axe and Cloutier zones are localized in a sequence of rhyolitic tuffaceous rocks. Mineralization consists of near massive chalcopyrite and pyrite in quartz±carbonate gangue.

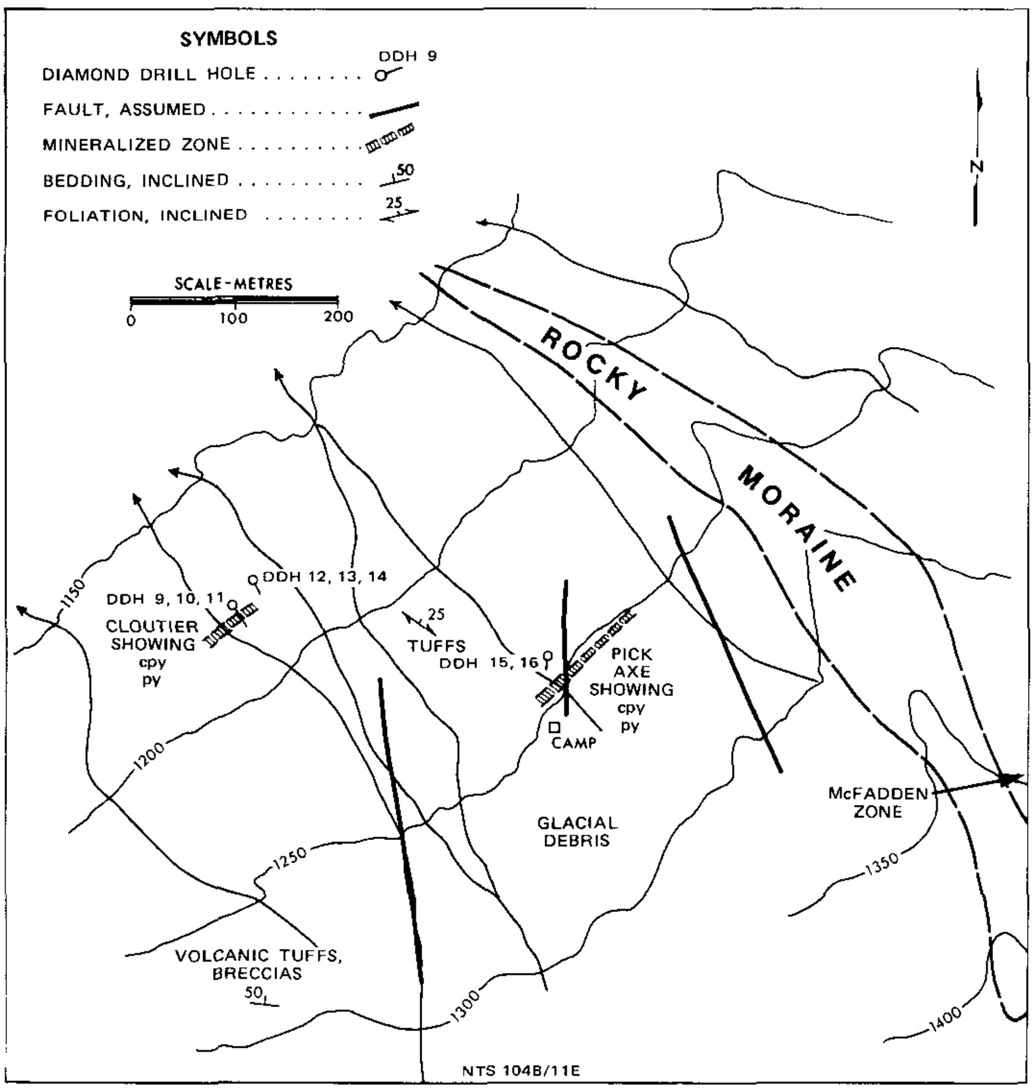


Figure 61. Mount Johnny prospect (Inset on Fig. 60) (based on company plans).

(1) Pick Axe Zone

Reportedly traced more than 1 000 metres, the zone has been confirmed by drilling along a length of 15 metres (George Cross News Letter, May 14, 1982). Assay results from grab samples collected by the writer are as follows:

Sample No.	Brief Description	Gold ppm	Silver ppm	Copper per cent	Lead per cent	Zinc per cent
JM-82-2	Massive chalcopyrite-pyrite	2	124	3.93	0.04	0.078
JM-82-3	Chalcopyrite-pyrite in quartz	2	90	3.57	0.02	0.078
JM-82-5	Chalcopyrite-pyrite in quartz	2.3	111	4.32	<0.02	0.043
JM-82-6	Chalcopyrite-pyrite in 'rhyolite'	0.7	255	3.42	<0.02	0.012
JM-82-8	Near massive pyrite and chalcopyrite	1	100	2.63	0.045	0.050

(2) Cloutier Zone

Apparently traced along a length of 490 metres (George Cross News Letter, May 14, 1982). Assay results for grab samples collected by the writer are as follows:

Sample No.	Brief Description	Gold ppm	Silver ppm	Copper per cent	Lead per cent	Zinc per cent
BJ-82-9	Chalcopyrite-pyrite in silicified tuff	1.7	19	1.37	0.03	0.03
BJ-82-11	Pyrite in silicified tuff	<1	<10	0.014	0.02	0.018
BJ-82-13	Near massive chalcopyrite-pyrite	2.3	19	2.1	<0.02	0.022
BJ-82-14	Chalcopyrite-pyrite in quartz	<1	35	5.40	<0.02	0.047
BJ-82-15	Near massive pyrite-chalcopyrite	3.4	140	6.50	<0.02	0.045
BJ-82-16	Massive pyrite-chalcopyrite	0.3	65	5.12	<0.02	0.017
BJ-82-17	Chalcopyrite-pyrite in quartz	0.3	45	4.15	<0.02	0.012

At the time of the writer's visit, drilling was in progress on diamond-drill hole 10. Diamond-drill hole 9 intersected a massive sulphide section from 35.8 to 38 metres.

(3) McFadden Zone

High-grade massive pyrite boulders were found in an area 245 metres by 45 metres (George Cross News Letter, May 14, 1982) that is located approximately 1 kilometre southeast of the Cloutier zone.

Diamond drilling exceeded 750 metres in eight holes, and geophysical surveys were carried out throughout the summer and fall. In mid-September, Placer Development Limited optioned the property from Skyline Explorations Ltd.

KUTCHO CREEK PROPERTY
(104I/1)

By T. G. Schroeter

INTRODUCTION

The part of the Kutcho Creek massive sulphide deposit (MI 104/I-60) owned by Sumac Mines Ltd. was visited on August 30th. It is located approximately 100 kilometres east of Dease Lake. During 1982, Sumac Mines Ltd. constructed a 12-kilometre tote road from the Kutcho airstrip to the property. The company then flew surface and underground equipment to Kutcho airstrip and moved it to the property.

Sumac Mines Ltd. completed a 218-metre crosscut into the ore zone for bulk sampling purposes and collected 145 tonnes of ore (*see* Fig. 62). They also conducted 1 525 metres of surface diamond drilling. This brings the total number of holes drilled by Sumac Mines Ltd. to 128 for approximately 21 335 metres in total. Esso Minerals Canada, owners of part of the massive sulphide mineralization, has also drilled 9 200 metres. Consequently, total drilling on the Kutcho Creek property exceeds more than 30 535 metres.

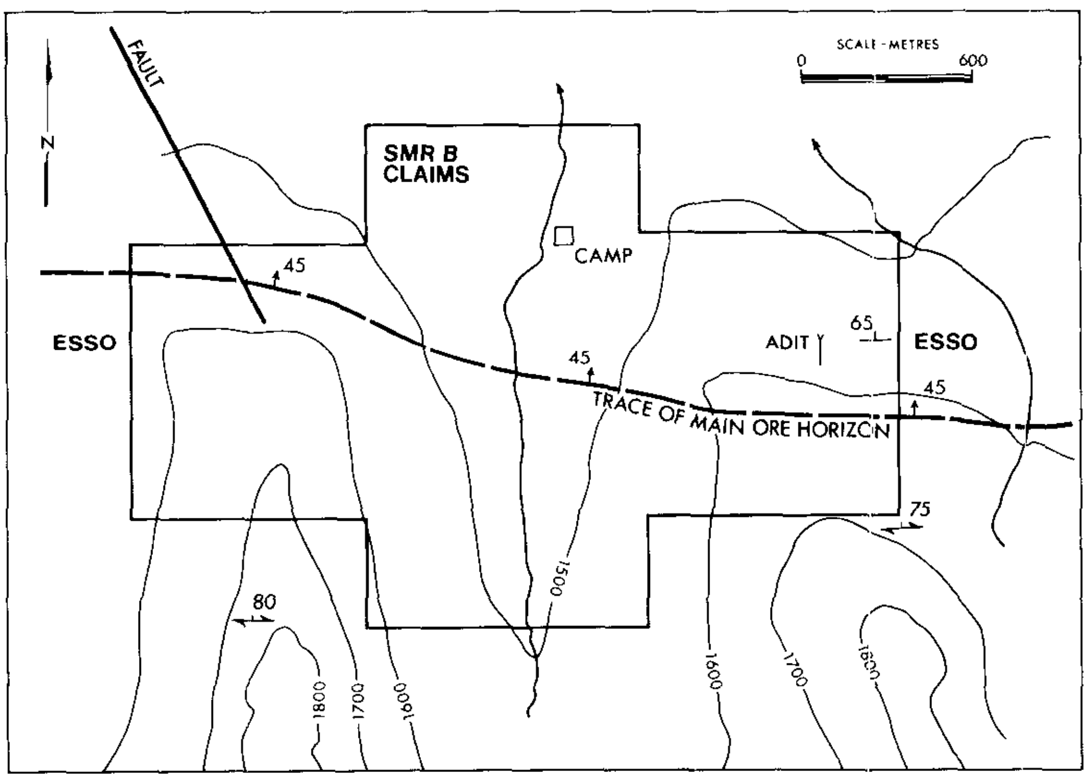


Figure 62. Sketch of Sumac Mines Ltd.'s Kutcho Creek property.

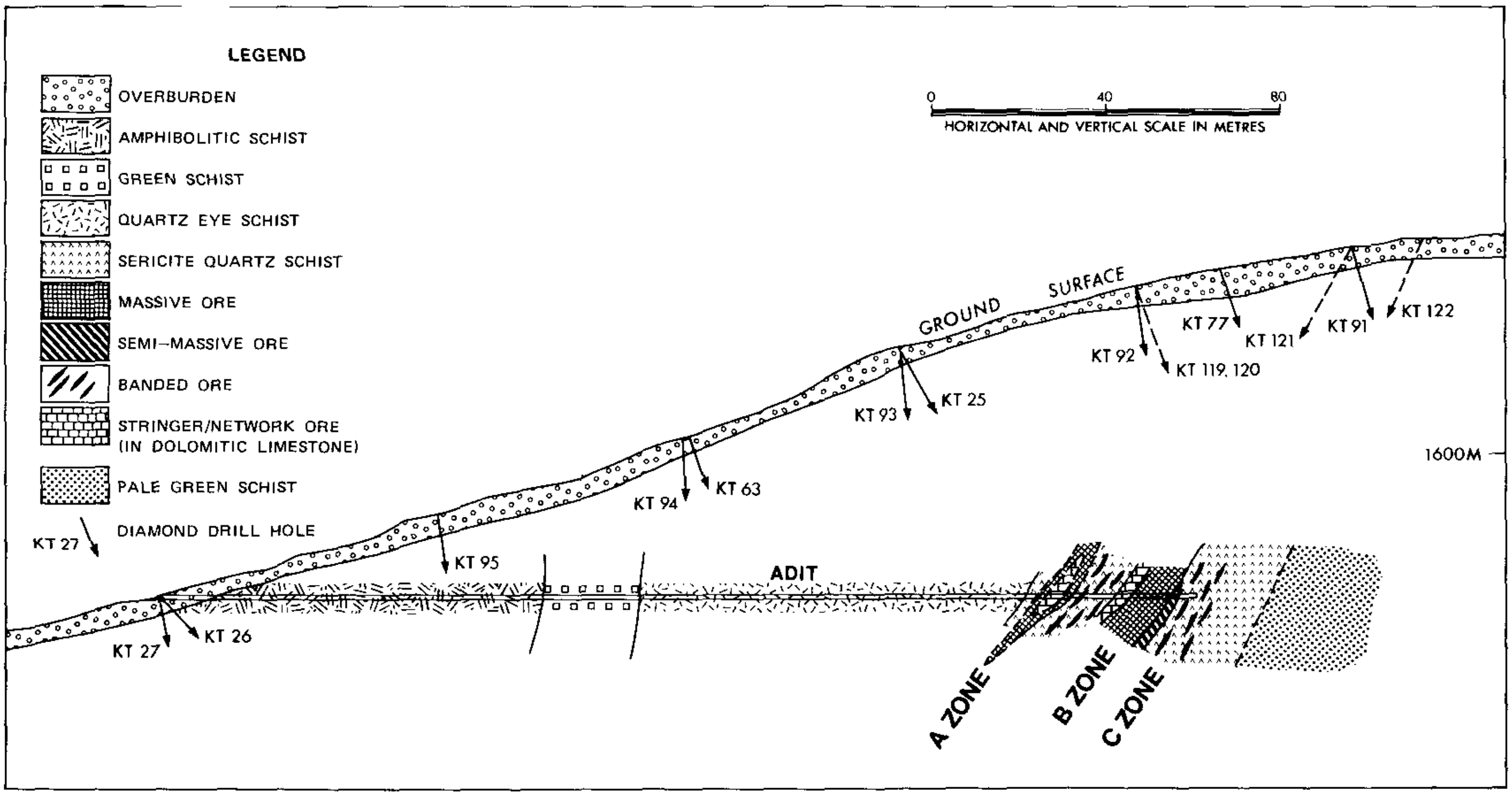


Figure 63. Cross-section along adit at 38232E, Kutcho Creek deposit, Sumac Mines Ltd. (after company plans).

Estimated reserves for the Sumac Mines Ltd. property are approximately 11 million tonnes grading 1.68 per cent copper, 2.14 per cent zinc, 25.23 grams silver per tonne, and 0.26 grams gold per tonne.

GEOLOGY AND MINERALIZATION

The geology of the crosscut is shown on Figure 63. Two main zones of massive sulphide ore mineralization consisting of chalcopyrite, pyrite, bornite, sphalerite, and minor galena and tetrahedrite were intersected in the crosscut. The first, A zone, is 4 metres wide, the second, B zone, is 13 metres.

In addition, a C zone was intersected below B zone and consists of greater than 80 metres of massive fine-grained pyrite (*see* Fig. 63). Metal zoning with a zinc-rich hangingwall appears to exist. The ore zones dip 45 degrees to the north and crosscut the enclosing rocks which have an average dip of 70 degrees to the north.

ACKNOWLEDGMENTS

The writer acknowledges the hospitality of Taiji Ueno, Roy Suzuki, and Ed Holt of Sumac Mines Ltd. while visiting the property.

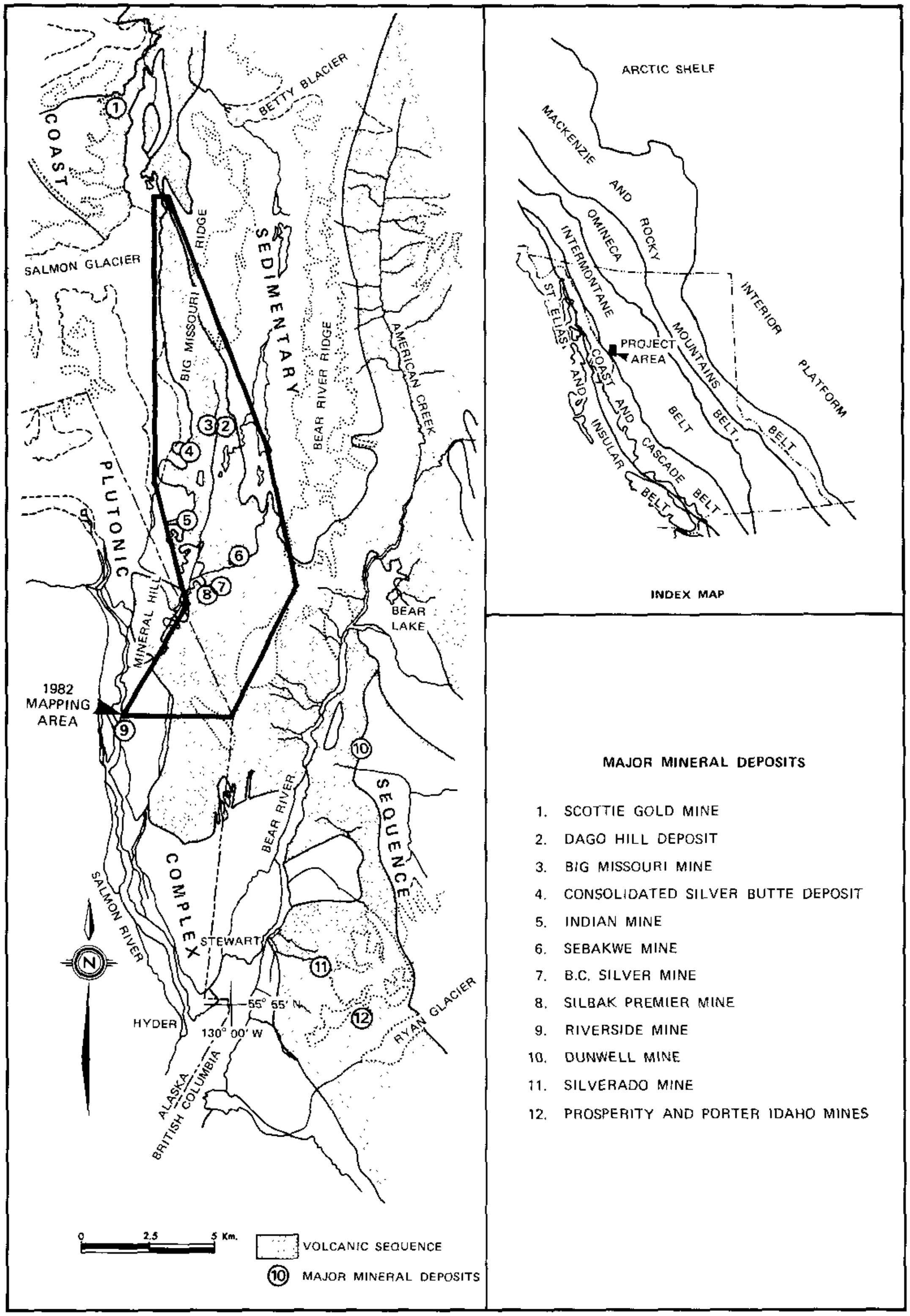


Figure 64. Regional geology and mineral deposits.

SALMON RIVER PROJECT, STEWART, BRITISH COLUMBIA (104B/1)

By D. J. Alldrick

INTRODUCTION

In July, 1982 the Ministry initiated a study of the geological setting of precious metal deposits in the Salmon River Valley which trends north from Stewart for 35 kilometres. The specific objectives are:

(1) Document structural and stratigraphic relationships of the host rock volcanic sequence and its contact relationships with adjacent terranes.

(2) Determine the evolution and depositional environment of the volcanic system from petrographic and geochemical studies of the sequence.

(3) Analyse the structural, stratigraphic, mineralogical, and trace element characteristics of the precious metal and base metal deposits of the area.

(4) Conduct metallogenic studies and define areas of high mineral potential.

(5) Sample for fossil and radiometric dating of the host rocks and ore zones and compare them with other volcanic terranes around the Middle Jurassic Bowser basin.

HISTORY AND PREVIOUS WORK

Prospectors began to explore the Stewart area in 1898 enroute to the Klondike. No major placer gold deposits were found but mineralized float led to the discovery of gold-quartz vein deposits. Continued prospecting located the gossan at Silbak Premier mine in 1910. Subsequently, the Stewart camp became the third greatest lode gold producing area in British Columbia. Between 1918 and 1968 the Silbak Premier mine production alone totalled 4.3 million tonnes grading 13 grams gold per tonne and 298 grams silver per tonne. Tipper and Richards (1976) outlined the tectonic evolution of the region. Major reports by Grove (1971) and Galley (1981) include historical reviews of geological studies in the area and extensive bibliographies. Barr (1980) provides a concise geological review of the Silbak Premier mining camp.

Exploration in the Stewart area during the past few years has been intensive. Companies are reassessing several known properties and testing interesting new prospects; for example, the Prosperity/Porter Idaho silver deposits; the Silbak Premier, Indian and Big Missouri mines;

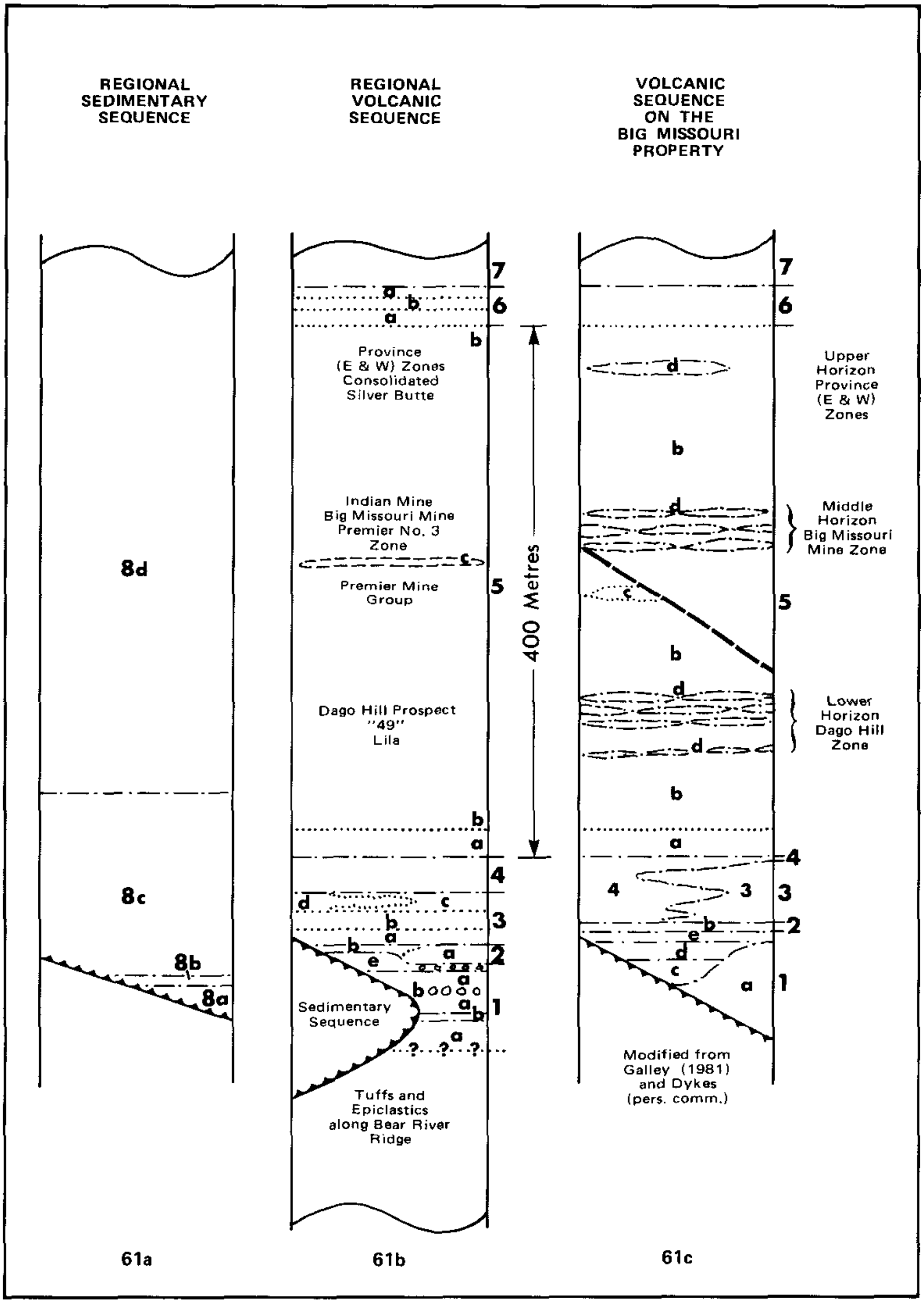


Figure 65. Schematic stratigraphic column.

the Consolidated Silver Butte Mines Ltd. deposit; and many scattered deposits in the Big Missouri claim group. There is also an ongoing exploration program around the producing Scottie Gold mine.

REGIONAL GEOLOGY

The north-northwest-trending belt of volcanic rocks (shaded on Fig. 64) through the central part of the project area is the focus of this study. It is bounded by a thick sedimentary sequence trending north-northwest along the eastern edge of the map-area and is cut off by a series of intrusive rocks to the west (Tipper and Richards, 1976).

All the major ore deposits and almost all the smaller mineral deposits of the area occur within the volcanic sequence. Hanson (1935) and Grove (1971) identified this sequence as 'Hazelton Group' and 'Hazelton Assemblage' respectively. They assumed that all the volcanic terranes of

LEGEND

(ALSO FOR FIGURES 66 AND 67)

SEDIMENTARY SEQUENCE

8a CONGLOMERATIC BLACK SILTSTONES AND SHALES
8b FOSSILIFEROUS LIMESTONE
8c BLACK TO GREY SILTSTONES
8d BLACK SILTSTONES AND PYRITIC SHALES

VOLCANIC SEQUENCE

7 BLACK SILTSTONE

INTERMEDIATE VOLCANIC ROCKS
6a BLACK TUFF
6b BLACK LAPILLI TUFF, BLEACHED FRAGMENTS
5a GREEN TUFF BRECCIA
5b GREEN TUFFS, LAPILLI TUFFS, AND FLOWS
5c PURPLE TUFF
5d CHERT–CARBONATE LENSES, ±SULPHIDES
4 PURPLE AND MAROON TUFF BRECCIA, LAPILLI TUFF, TUFF, AND EPICLASTIC ROCK

FELSIC VOLCANIC ROCKS
3 GRADED GREY TUFF:
3a TUFF BRECCIA
3b LAPILLI TUFF

FELSIC VOLCANIC ROCKS *(CONTINUED)*
3 GRADED GREY TUFF *(CONTINUED)*
3c TUFF, WITH LENSES OF 3d
3d MAROON TUFF
2a RHYOLITE ASH FLOW TUFF, HIGHLY PYRITIC, LIMESTONE BOULDERS, SCORIA FRAGMENTS
2b RHYOLITE ASH FLOW TUFF, MINOR OR TRACE PYRITE, FRAGMENTS OF 1e AND SCORIA
1a BLACK TUFF, FINE TO MEDIUM GRAINED
1b FOSSILIFEROUS LIMESTONE
1c PALE GREEN TUFF
1d GREY–GREEN TUFF
1e BLACK CARBONACEOUS LAPILLI TUFF, ABUNDANT PUMICE FRAGMENTS, LOCAL 1b NODULES, LOCAL PYRITE

SYMBOLS

LITHOLOGIC CONTACT ....
FAULT ....
LITHOFACIES CONTACT ....
THRUST FAULT ....

the region are contemporaneous with those of the type Hazelton area 200 kilometres to the southeast. Since fault and intrusive contacts border the volcanic sequence in the Stewart area, the correlation is tenuous. A richly fossiliferous limestone unit and fossiliferous limestone nodules occur in dark tuffaceous rocks of the sequence and may provide a definitive age for this metal-rich volcanic belt.

Throughout the area mapped this season, the sedimentary rocks were thrust westward over the volcanic rocks. The sedimentary sequence consists of black and grey siltstones and shales with basal conglomeratic horizons. A thin fossiliferous limestone crops out near the base of the sequence. Fossil age determinations completed in the mid-1960's (Grove, 1971) defined a broad Mesozoic age range. Grove assumed a Middle Jurassic age and identified these rocks as 'Bowser Assemblage.' Subsequently, Tipper and Richards (1976) described similar sedimentary sequences from the upper Hazelton Group. Consequently the exact age and correlation of this sedimentary sequence remains uncertain and the fossil horizon has been resampled for further macro and microfossil study.

A complex series of intrusive rocks along the western edge of the map-area define the eastern margin of the Coast Plutonic Complex. Based on limited K/Ar age dating by the United States Geological Survey, the various batholiths and smaller stocks range in age from Middle Jurassic to Middle Eocene (Grove, 1971). The compositions range from granodiorite to diorite. A wide variety of dyke rocks occur throughout the belt -- compositions range from aplite to gabbro. In some areas the intrusive rocks are spatially related to ore deposits, for example, at the Scottie Gold and Silbak Premier mines.

VOLCANIC STRATIGRAPHY

Volcanic units within the map-area (Fig. 66) strike north to north-northwest and generally dip to the west. Fragments of subjacent lithologies in tuff breccia, and grading in the thick ash flow of unit 3, suggest that stratigraphic tops are to the west. Galley (1981) identified graded beds in epiclastic rocks of unit 4 which also show that stratigraphic tops are to the west.

The overall thickness of the volcanic sequence must exceed 700 metres (Fig. 65) but total thickness cannot be estimated on the basis of this season's work. The siltstones of unit 7 may mark the top of the sequence. The lower part of the stratigraphic section has not been studied in detail but includes a thick section of tuffs, airfall tuffs, and epiclastic rocks (Fig. 65b). These are exposed along the Bear River Ridge south of Mount Shorty Stevenson.

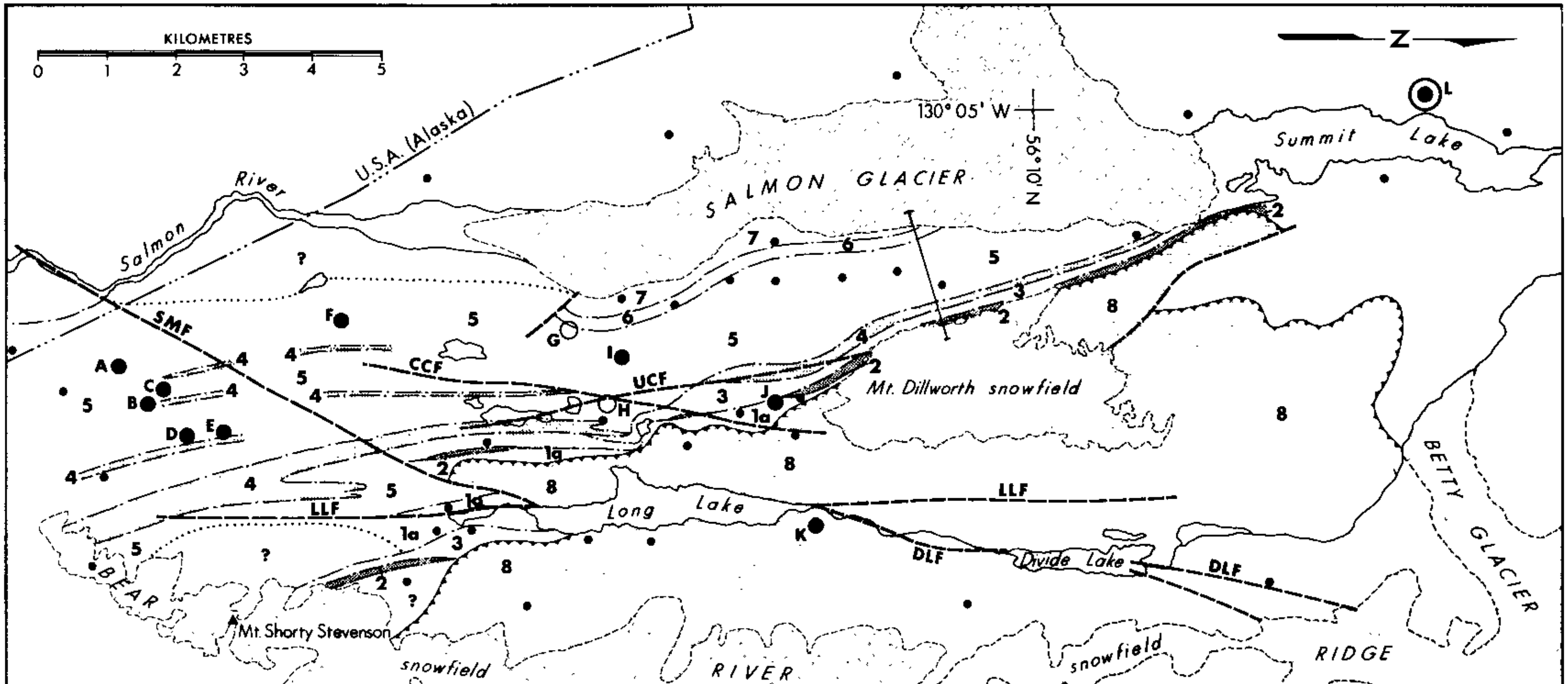
Galley (1981) developed a detailed type section of the stratigraphy on the Big Missouri property. The few modifications to Galley's work are based on excellent rock exposures along the west slope of Mount Dillworth beyond his map-area. Selected features of the stratigraphic sequence (Fig. 65) are described following.

A fossiliferous limestone band (1b) is interbedded with tuffs of unit 1a on the northwest edge of the Mount Dillworth snowfield. Nearby, large nodules of the same fossiliferous limestone, up to 0.5 metre across, are enveloped in black carbonaceous tuff (unit 1e). Textures suggest that the nodules were unlithified carbonate mud balls when incorporated into the tuff. The same carbonaceous tuff typically contains angular white pumice fragments and locally hosts blebs of pyrite up to 3 centimetres in diameter. Dykes (personal communication) traced unit 1e as far south as Fetter Lake beside Dago Hill. This horizon either underlies unit 2 directly or is separated from it by a thin layer of unit 1a tuff.

Various workers identified the rocks of unit 2 as rhyolite, chert, or exhalite, but the exact composition and origin has not been determined. Resistant rhyolite ash flow tuffs (facies 2a) weather to bright rusty red, nodular outcrops that form a continuous ridge along the western edge of Mount Dillworth. They extend from the Troy Flats to the Unicorn No. 3 workings south of Mount Dillworth where a gradual decrease in the density of fragments and in the pyrite content marks the change to facies 2b, which is exposed discontinuously as far south as Fetter Lake. One thin exposure of facies 2b occurs on the west side of Slate Mountain, and another exposure of this unit can be traced from southeast of Long Lake to the west slope of Mount Shorty Stevenson; southward it gradually changes to facies 2a. Facies 2a carries up to 20 per cent disseminated very fine-grained pyrite in a translucent grey siliceous matrix. Locally the pyrite occurs as massive blebs up to 20 centimetres long. One stratiform pyrite seam on Mount Dillworth is 8 centimetres thick and 6 metres long. This tuff contains numerous rounded carbonate boulders that are recrystallized (?) to coarse-grained calcite; locally there are abundant, large angular fragments of black scoria.

Unit 3 consists principally of grey tuff. The altered maroon facies (3d) is significant because it develops by progressive alteration of the green-grey fine-grained tuff of facies 3c. Oxidation may result from either subaerial exposure or passage of oxygenating fluids through the tuff.

With the exception of the Dunwell and Riverside mines, all the mineral deposits on Figure 64 are hosted within medium green andesitic volcanic rocks of unit 5. The rocks are crystal tuffs, lapilli tuffs, tuff breccias, and flows. They are characterized by plagioclase and, less commonly, hornblende crystals and crystal fragments. The basal tuff breccia contains fragments up to 1.5 metres in diameter and one intact hexagonal fragment of columnar andesite, 1.2 metres across, is exposed on Mount Dillworth. Galley mapped a thin, trough-like lens of pillowed andesites on the Big Missouri property. Intermittent exposures and rapid lateral facies changes in the tuffs prevent correlation of individual strata along strike. Perhaps the purple tuff facies in this sequence will provide time-stratigraphic markers of local and possibly regional significance to mapping and exploration programs.



SYMBOLS

- PRODUCING MINE
- PAST PRODUCING MINE
- MAJOR MINERAL DEPOSIT
- MINOR MINERAL DEPOSIT
- CROSS-SECTION (FIG. 63)
- AREA NOT MAPPED
- FAULT

PREMIER MINE GROUP

- A PREMIER BORDER SECTOR
- B B.C. SILVER SECTOR
- C PREMIER SECTOR
- D SEBAKWE SECTOR
- E BUSH WORKINGS
- F INDIAN MINE
- G CONSOLIDATED SILVER BUTTE DEPOSIT
- H DAGO HILL DEPOSIT
- I BIG MISSOURI MINE
- J SILVER TIP GROUP
- K SPIDER GROUP
- L SCOTTIE GOLD MINE

MAJOR FAULT ZONES

- SMF = SLATE MOUNTAIN FAULT
- LLF = LONG LAKE FAULT
- CCF = CASCADE CREEK FAULT
- UCF - UNION CREEK FAULT
- DLF = DIVIDE LAKE FAULT

Figure 66. Geology and mineral deposits of the central Salmon River Valley.

Intermittently mineralized lenses of chert, chert-carbonate, and limestone (unit 5d) comprise ore host rocks along Big Missouri Ridge. These rocks and their precious metal mineralization were the focus of Galley's petrographic and geochemical research and his results are summarized here. There are many of these lenses on the Big Missouri property but only a few are mineralized. The chert-carbonate zones can occur as individual lenses or as a series of two or three stacked lenses lying 2 to 20 metres apart. The individual lenses vary up to 7 metres in thickness and have been traced over a maximum strike length of 1.8 kilometres. Typically, they contain angular andesite fragments near their lower contacts; lenses lower in the sequence carry abundant finely disseminated carbon. The chert-carbonate lenses may grade into massive chert or massive carbonate zones along strike.

The contact between units 5 and 6 is gradational. The medium green fine-grained andesites of unit 5 gradually darken and give way to the black tuff of unit 6. Rock textures remain the same in both units and the gradational contact undulates through large outcrop exposures. The orientation of contacts between units 5 and 6 and also between units 6 and 7 are uncertain (Fig. 67).

Greenschist facies metamorphism affected the volcanic sequence throughout the map-area. However, there is no macroscopic evidence of extensive thermal metamorphism adjacent to major intrusive bodies.

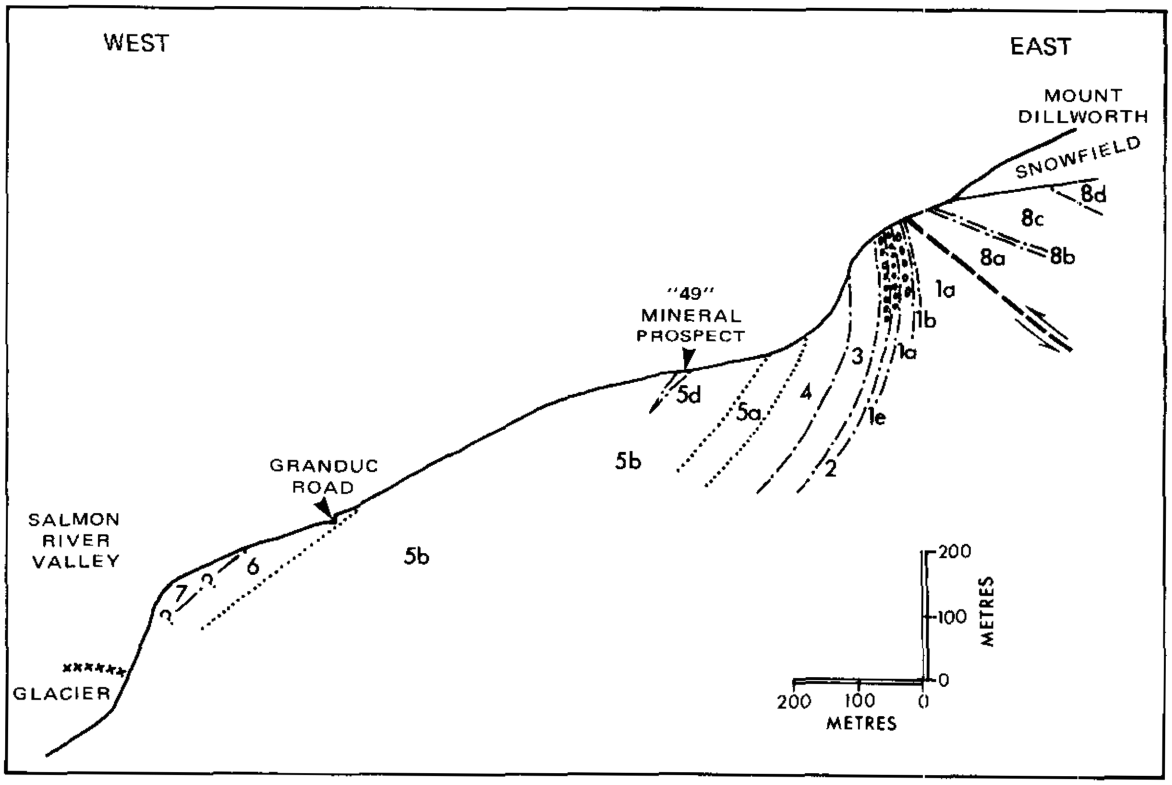


Figure 67. Geological cross-section on the west side of Mount Dillworth.

On a regional scale the volcanic sequence forms a west-dipping homocline averaging 50 degrees dip. Beds steepen to vertical and are locally overturned adjacent to the thrust fault contact (Fig. 67), but dips flatten on Mount Shorty Stevenson. Grove (1971) interpreted a major north-northwest-trending anticlinal axis east of Bear River Ridge. On property scale, gentle secondary warping has a 60-degree trend at Big Missouri (Galley, 1981).

Faulting within this terrane is common on both regional and local scales. Regional north-striking features form major topographic lineaments. One of these, the Long Lake fault, has strata down-dropped on the east side. Direction of movement along many of the faults has not been determined, but two northeast-trending fault zones have left lateral displacement and one major northwest-trending fault has relative right lateral movement.

Small-scale faulting is abundant throughout the area and creates difficulties both in correlating mineralized chert-limestone horizons and in estimating dilution factors for ore reserve calculations.

MINERALIZATION

Mineral deposits of the Salmon River Valley are categorized according to their structural settings as follows:

(1) Stratabound deposits (±mineralized wallrock veins)
   (a) Stratabound disseminated sulphide deposits:
      Big Missouri mine, Dago Hill prospect, Province East zone, Consolidated Silver Butte Mines Ltd. prospect (?)
   (b) Stratabound massive sulphide deposits:
      Creek zone, Martha Ellen zone, Province West zone, TBI-3 zone, Premier No. 3 zone, Silbak Premier mine (?)

(2) Massive sulphide vein deposits in major shear zones:
      Scottie Gold mine, Prosperity/Porter Idaho/Silverado mines, Indian mine

(3) Quartz/breccia fissure vein deposits:
      Outland Silver Bar, Lakeview, Spider, Unicorn No. 3, Silver Tip

There is insufficient data available to classify the important Silbak Premier mine and Consolidated Silver Butte Mines Ltd. prospect with any certainty. Galley (1981) provides detailed descriptions and illustrations of selected examples of type 1a, 1b, and 3 deposits.

The abundance and specific mineralogy of sulphides distinguish the two categories of stratabound deposits. However, both can occur in the same area, as at the Dago Hill prospect. The disseminated types typically carry higher grades of gold and silver in pyrite, minor amounts of associated galena and sphalerite, and negligible chalcopyrite. The massive sulphide types have typical polymetallic volcanogenic massive sulphide metal concentrations, that is, they have ore grade copper, lead and zinc sulphides with accessory but recoverable precious metals. Both styles of mineralization occur in chert-carbonate lenses (unit 5d); the massive sulphide types contain angular andesite fragments and underlie the cherty material. In contrast, in the Calcite Cuts showing near Dago Hill, disseminated sulphides are distributed through the hangingwall side of the chert but the lower half of the chert-carbonate lens is virtually barren.

Wallrock veins cut footwall strata or cut both hangingwall and footwall rocks in an area of stacked lenses. Disseminated coarse-grained pyrite, galena, sphalerite, and high precious metal values occur in blue-grey quartz-carbonate veins. If the vein density is high enough, the wallrock zone may constitute ore.

MASSIVE SULPHIDE VEIN DEPOSITS IN MAJOR SHEAR ZONES

These deposits have few features in common, but all are hosted within major fault/shear systems cutting through medium green andesite.

At Scottie Gold mine, ore-bearing veins are distributed along a conjugate shear system developed within and on the northern wall of a major southeast-trending fault. The high-grade gold mineralization occurs in a massive pyrrhotite zone up to 5 metres wide. This zone is symmetrically bordered by swarms of quartz-carbonate-pyrrhotite-base metal sulphide veins which envelope wallrock fragments that have been intensely hematized, silicified, and carbonatized (Williams, personal communication). Both the massive pyrrhotite core vein and the bordering vein swarms bear gold -- entire stopes with up to 60 grams gold per tonne have been produced from this structure. Average production grades to September, 1982 have been 17.5 grams gold per tonne. Overall gold/silver ratios are about 2 to 1.

Access to the mine workings is from an adit developed in the steep hillside overlooking Summit Lake, and exploration work has outlined additional ore grade material both above and below the present mining levels. To the southeast, the mineralization and the shear system feather out; to the northwest, toward the Summit Lake diorite stock, the shear and vein continue but precious metal values drop and base metal grades of the vein increase.

High-grade silver deposits of the Prosperity/Porter Idaho mine are 4 kilometres southeast of Stewart. Mineralization is localized in a series of at least six parallel shear zones. The shear zones trend 165 degrees, dip 60 degrees westward, and are roughly 175 metres apart. To the south, the shears terminate at, or are displaced by, a major north-dipping east-west fault zone. To the north, the shears are believed to continue under the permanent snowcap of Mount Rainey for more than 2.5 kilometres to the Silverado mine workings where sporadic mineralization is hosted by parallel shear zones of identical orientation. Mineralization pinches and swells with the width of a shear zone, resulting in well-mineralized zones that are up to 11 metres wide, 250 metres long, and extend to at least 175 metres depth where old mine workings end, still in mineralization. The zones are complex, consisting of one or typically two central massive sulphide bands each about 60 centimetres wide but locally converging and swelling to 2 metres in width. This massive sulphide core is composed of argentiferous galena and lesser sphalerite; it provided 29 000 tonnes of direct shipping ore with an average grade of 2 500 grams silver per tonne (Grove, 1971). The wallrock adjacent to the massive sulphide veins carries an average grade of 686 grams silver per tonne over typical widths of 5 to 6 metres on both sides of the vein. These mineralized borders consist of intensely sheared country rock that is altered to quartz, buff carbonate, abundant manganese oxide, and sulphides. Early workers reported a mineral suite consisting of galena, sphalerite, native silver, ruby silver, freibergite, and minor amounts of pyrite, chalcopyrite, and argentite. Gold is conspicuous by its absence in this deposit -- typical assays are 0.17 grams gold per tonne.

At the Indian mine, mineralization is localized in part of a major, vertical, 155-degree-trending shear and fault zone. Mineralization exposed in the dumps, trenches, and old workings consists of massive, fine to coarse-grained galena with minor amounts of pyrite and sphalerite. Quartz with minor amounts of carbonate and chlorite are gangue minerals. The sulphides are banded and brecciated -- features that are attributed to post-mineralization movement along the fault zone. Major slickenside surfaces are exposed at the Galena Cuts zone where massive sulphide mineralization is 3 metres wide. The mine produced 13 000 tonnes of ore grading 120 grams silver per tonne, 3 grams gold per tonne, 4.4 per cent lead, and 5.5 per cent zinc (Grove, 1971). Esso Minerals Canada traced the fault structure for more than 1 200 metres north of the mine workings (McGuigan, personal communication).

QUARTZ/BRECCIA FISSURE VEIN DEPOSITS

Deposits of this type are abundant in the Salmon River Valley but have low tonnage potential and consequently are of lesser economic importance. The veins cut volcanic, sedimentary, and intrusive rocks, thus they represent a very late-stage mineralizing event.

The veins consist primarily of quartz but carry angular wallrock fragments plus scattered coarse crystals and fine-grained blebs and pods of sulphide minerals. Wallrock fragments within the veins are commonly silicified, but vein walls are sharp with little or no silicification of the wallrock. Drusy vugs are common. Sulphide minerals occur as euhedral crystals and as crystal aggregates of pyrite, sphalerite, galena, chalcopyrite, chalcocite, and freibergite; there is minor associated native silver. The sulphides are typically concentrated near the centre of the quartz vein and sulphide crystals may be up to 3 centimetres across. These vein deposits were extensively prospected and locally mined for their silver content. Galley (1981) reports gold values in the sulphides where fissure veins intersect a stratabound, sulphide-bearing chert-limestone horizon, and Grove (1971) noted free gold in the Silver Tip workings.

EXPLORATION

All the mineral discoveries in the region can be attributed to intensive prospecting. The recent discovery of a precious metal deposit by Esso Minerals Canada on the Consolidated Silver Butte Mines Ltd. property (Northern Miner, November 4, 1982) resulted from an aggressive trenching program. The showing area has widespread, pervasive sericitic alteration with zones of abundant barren pyrite mineralization which had been trenched and sampled by previous workers.

The general sequence of exploration programs in the region can be summarized as follows:

(1) Regional reconnaissance mapping to locate bleached and altered andesitic volcanic rocks, chert-carbonate zones, or sulphide mineralization in veins or fractures.

(2) Detailed follow-up mapping and prospecting.

(3) Intensive trenching and sampling.

(4) Tightly spaced diamond-drill holes.

Geophysical test surveys have been completed over stratabound mineralized zones with moderately encouraging results (Dykes, personal communication). Electromagnetic surveys produce anomalous responses over the massive sulphide zones but abundant minor faulting that is common throughout the area creates problems. Water-saturated fault gouge produces anomalies and fault offsets disrupt the continuity and intensity of the anomalous response from a conductive massive sulphide lens. Induced polarization shows more promise as an exploration tool because it appears to discriminate between stratabound disseminated sulphide zones (strongly anomalous) and zones of disseminated pyrite in the altered host rocks (moderately anomalous). The cost of reconnaissance induced polarization surveys in this rugged terrane would be prohibitive, but the technique might be applied effectively over small grids as a prelude to trenching in areas of widespread or deep overburden.

GENESIS

The vein deposits of the area are clearly epigenetic, but the process of formation of the stratabound deposits is less obvious. Stratigraphic relationships suggest that the chert-carbonate lenses are synvolcanic. A volcanic exhalative genesis can be argued for the banded massive sulphide lenses which have 'normal' precious metal concentrations but the formaation of disseminated precious metal-rich stratabound deposits may be more complex.

CONCLUSIONS

The Salmon River Valley is one of the most active exploration areas in British Columbia and represents a distinct metallogenic province in the region. The precious metal deposits occur in a variety of structural settings but all the major deposits are hosted within one thick andesitic unit in a differentiated volcanic sequence. The deposits can be classified according to their geologic setting as (1) stratabound deposits of undetermined origin and (2) epigenetic vein deposits. Major exploration programs and prospect evaluation are expected to continue throughout the belt in 1983.

ACKNOWLEDGMENTS

It is a pleasure to acknowledge the generous hospitality and logistical support of Esso Minerals Canada, Pacific Cassiar Limited, Scottie Gold Mines Ltd., and Westmin Resources Limited during visits to their operations. I am indebted to Dane Bridge, Shaun Dykes, John Greig, Mike Kenyon, Paul McGuigan, and David Williams for discussions about many aspects of the geology and mineral deposits of the region.

John Mawdsley provided able assistance in the field.

REFERENCES

Barr, D. (1980): Gold in the Canadian Cordillera, *C.I.M.*, Bull., Vol. 73, No. 818, pp. 59-76.

Dykes, S. M., Meade, H., and Galley, A. (1982): Geology of the Big Missouri Deposit with Reference to Premier Silbak, *G.A.C.*, Annual Meeting of the Cordillern Section, February 19, 1982.

Galley, A. (1981): Volcanic Stratigraphy and Gold-Silver Occurrences on the Big Missouri Claim Group, Stewart, British Columbia, *University of Western Ontario*, M.Sc. thesis, 181 pp.

Grove, E. W. (1971): Geology and Mineral Deposits of the Stewart Area, *B.C. Ministry of Energy, Mines & Pet. Res.*, Bull. 58, 219 pp.

Hanson, G. (1935): Portland Canal Area, British Columbia, *Geol. Surv., Canada*, Mem. 175, 179 pp.

Northern Miner, Esso Makes Impressive Discovery on Silver Butte's Missouri Claims, 1982, Vol. 68, No. 35, p. 1.

Tipper, H. W. and Richards, T. A. (1976): Jurassic Stratigraphy and History of North-Central British Columbia, *Geol. Surv., Canada*, Bull. 270, 73 pp.

White, W. H. (1939): Geology and Ore Deposition of Silbak Premier Mines Ltd., *University of British Columbia*, M.A.Sc. thesis.

MAPPING OF SILICA OCCURRENCES IN BRITISH COLUMBIA

By Z. D. Hora

This project was started in 1981 and continued during the 1982 field season. The following properties not included in the 1981 survey were examined for information on size and quality:

(1) QUARTZITE UNITS

EK (82E/3E, 49°00.5'-119°06')

About 5 kilometres southwest of Bridesville fine-grained cherty quartzite crops out on several small knolls over an area 200 metres by 100 metres. The quartzite is mostly massive but has local quartz cemented breccia zones. The surrounding rocks are dominated by phyllitic slate; however, siliceous bands and, less commonly, zones of fine-grained massive greenish grey volcanic rock occur. The rocks are part of the Permo-Triassic Anarchist Group.

WIN (93O/2W, 55°02'-122°54')

The quartzite from this property, which is a medium grained buff to white rock, is 150 metres wide and has been traced for about 700 metres along the strike. It crops out in the northern part of the summit of Mount Chingee, approximately 15 kilometres southeast of the Hart Highway between Fort McLeod and Mackenzie. Numerous coarse-grained, massive white quartz veins of varying widths that strike mainly north-south cut the quartzite. The surrounding rocks are black slates and brown schistose greywacke of the Cambrian (?) Misinchinka Group.

NONDA QUARTZITE (94H/14W, 53°57'-121°27')

About 100 kilometres east of Prince George a thick band of pure white orthoquartzite crops out approximately 3 kilometres north of the town of Longworth on the north side of the Fraser River. The quartzite is massive and consists of well-sorted, well-rounded quartz grains in a siliceous matrix. Two parallel bands, each 100 to 250 metres thick, are separated by a 300 to 500-metre-thick sequence of carbonate rocks. The carbonates are mainly limestone, but dolomite is also present. Outcrops of the lower band lie at elevations between 1 000 to 1 150 metres, while the higher band is exposed in the upper part of the slope between 1 300 and 1 650 metres. Outcrops occur for several kilometres. The quartzite is part of the Silurian Nonda Formation.

ROUNDTOP MOUNTAIN (93A/14E, 52°55'-121°18')

A 300 to 500-metre-wide quartzite band extends in a northwest-southeast direction from Roundtop Mountain in the Cariboo Lake area. The quartzite is predominantly medium to fine grained and consists of well-rounded grains. It is white to buff-weathering with mica flakes on foliation planes. The band continues for at least 15 kilometres along strike, mostly at elevations between 1 000 and 1 700 metres. The quartzite is part of the Hadrynian/Cambrian Yanks Peak Formation.

YANKS PEAK (93A/14W, 52°51'-121°26')

A folded band of massive, white, fine-grained quartzite crops out on Yanks Peak, 12 kilometres northwest of Cariboo Lake. The rock is composed of well-sorted and rounded quartz grains in a siliceous matrix; tiny flakes of muscovite occur rarely. The quartzite, which is exposed over the area of approximately 300 metres by 500 metres, is apparently Hadrynian (?).

MARYSVILLE (82G/12W, 49°36'-115°57')

Medium to coarse-grained massive quartzite 90 to 100 metres thick is exposed in the Perry Creek area, 2 kilometres south of Marysville. The range of quartzite colours is from white to green and brown. White and light pink rocks that constitute the upper part of the quartzite sequence consist of well-rounded, moderately sorted grains in a siliceous matrix. The quartzite is part of the Cambrian Cranbrook Formation.

(2) DYKE AND VEIN OCCURRENCES

SWAN (82E/12W, 49°43'-119°54')

Quartz on this property forms part of a pegmatite body that is exposed in scattered outcrops, road cuts, and trenches over an area of approximately 60 metres by 120 metres. The property lies 27 kilometres northwest of Summerland at an elevation of 1 475 metres. The showing is on a steep northeast-facing slope and the vertical exposure of the pegmatite body is approximately 75 metres. In exposed areas, pure quartz constitutes approximately 25 per cent of the pegmatite body; the rest is either contaminated by muscovite (10 per cent), intergrown with feldspar (55 per cent), or composed of massive feldspar (10 per cent).

FS (82L/13W, 50°49'-119°49')

A milky white quartz vein crops out in two locations on Nisconlith Creek, approximately 10 kilometres west of the town of Chase. A white massive quartz vein from 3.5 to 15 metres wide, which is exposed over the length of about 110 metres, comprises the southern outcrop of the north-south-striking vein. Occasionally, crystals developed that are up to 30 centimetres long and 15 centimetres in diameter. The quartzite in this area is quarried for industrial uses. The northern outcrop is about 400 metres from the southern outcrop. The outcrop is dome shaped and consists of leucocratic granitic rock cut by quartz stockwork veining and a 20-metre-wide quartz vein. The outcrop is 120 metres by 200 metres.

CAMPANIA ISLAND (103H/3W, 53°05'-129°25')

The silica prospect is 160 kilometres south of Prince Rupert on the west side of Campania Island, about 1 kilometre from the coast. The main showing is a quartz outcrop 105 metres by 35 metres in size that rises 20 metres above the surrounding terrane. The main component is milky white quartz; occasional fragments of granitic host rock occur along the southern and northern margins of the quartz exposure. Granitic inclusions are estimated to be less than 5 per cent. A smaller, parallel quartz vein is exposed 160 metres east of the main showing. The vein is exposed in three north-south outcrops and is apparently 10 metres in width.

BANKS ISLAND (103G/8E, 53°28'-130°02')

A number of outcrops of pure white quartz occur near Patsy Cove south of Prince Rupert. The outcrops are part of a northeastly trending body that is at least 20 to 30 metres wide. At the southwestern end of these outcrops the quartz is exposed in a 10-metre cliff. The quartz is massive, coarse grained, and milky white. The quartz body is in Coast granodiorite intrusions, but the contact is not exposed so its real size and orientation are uncertain.

GLACIER CREEK (103P/13W, 55°59'-129°55')

Quartz veins 3 to 9 metres wide are reported from several old properties about 5 kilometres northeast of Stewart. Our reconnaissance study concentrated on veins intersected in Dunwell Mines Limited No. 4 adit and in the Silver Princess adit north of Glacier Creek. However, veins in the area are zones of predominantly quartz-argillite breccia, rather than pure quartz.

MORRIS SUMMIT (104B/1E, 56°13'-130°05')

'A huge quartz lode' was reported at a site 110 metres north of Scottie Gold Mines Ltd.'s 1 097 metre adit about 35 kilometres north of Stewart. The exposure consists of quartz vein breccia with many altered, rusty orange rock fragments.

MAPLE BAY (103P/5W, 55°25'-130°00')

This area provided a significant tonnage of quartz flux for the Anyox smelter during the years of its activity. Maple Bay is located on the east shore of Portland Canal about 56 kilometres south of Stewart. Nine major veins crop out east and northeast of Maple Bay; they contain variable amounts of sulphides. The Friday vein occurs 25 kilometres north of Maple Bay, about 500 metres from the shoreline. It consists of coarse-grained, milky quartz, is 4 to 5 metres wide and is at least 50 metres long.

Fieldwork was carried out by Z. D. Hora and Jennifer Pell with Gabrielle Sutton as a field assistant. Analysis of data collected during the summer is currently in progress.

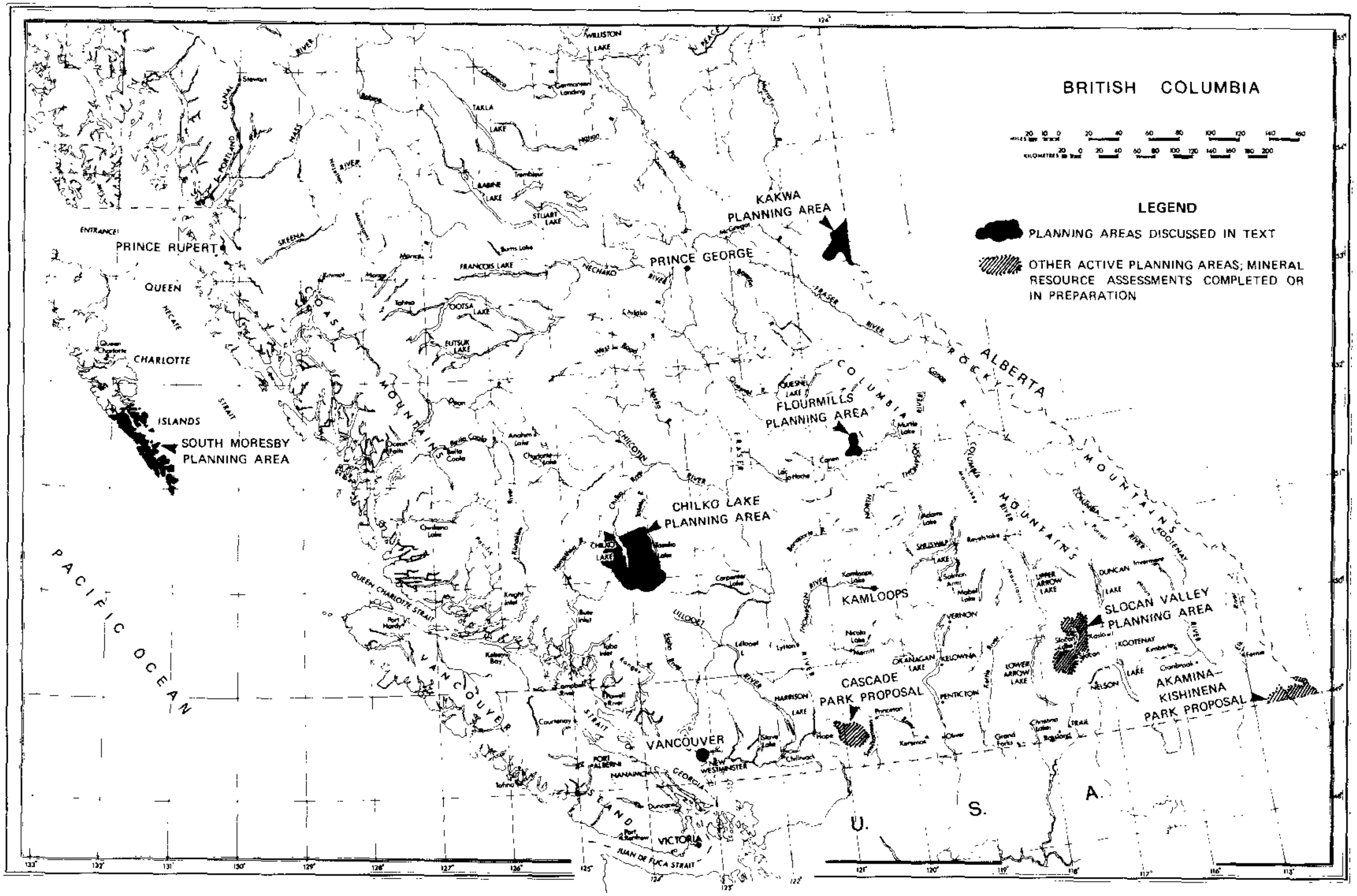


Figure 68. Location map.

OTHER INVESTIGATIONS

RECENT MINERAL RESOURCE ASSESSMENT STUDIES IN BRITISH COLUMBIA

By K. E. Northcote
K. E. Northcote & Associates Ltd., Agassiz, British Columbia
and
W. R. Smyth and H. R. Schmitt
B.C. Ministry of Energy, Mines and Petroleum Resources

INTRODUCTION

A number of mineral resource assessment studies were undertaken in 1982 to assist government planning and decision making on land use issues. They were conducted in response to specific requests from Lands, Parks and Housing to create provincial parks, and from Forests and Municipal Affairs for coordinated land use planning programs. The aim of the studies was to identify areas favourable for mineral deposit discoveries and to ensure that the planning process does not alienate such areas from exploration and mining. Summaries of four assessments are presented because they might be of use to the exploration industry in identifying and rating exploration target areas. Figure 68 also shows the location of other planning areas for which assessment reports are in preparation.

All the studies were office-based and carried out by K. E. Northcote under contract to the Ministry of Energy, Mines and Petroleum Resources. Since their completion, two of us (W. R. Smyth and H. R. Schmitt) joined the Ministry and have revised and added to the original reports. The reports will be released as open files after they have been submitted to the planning teams.

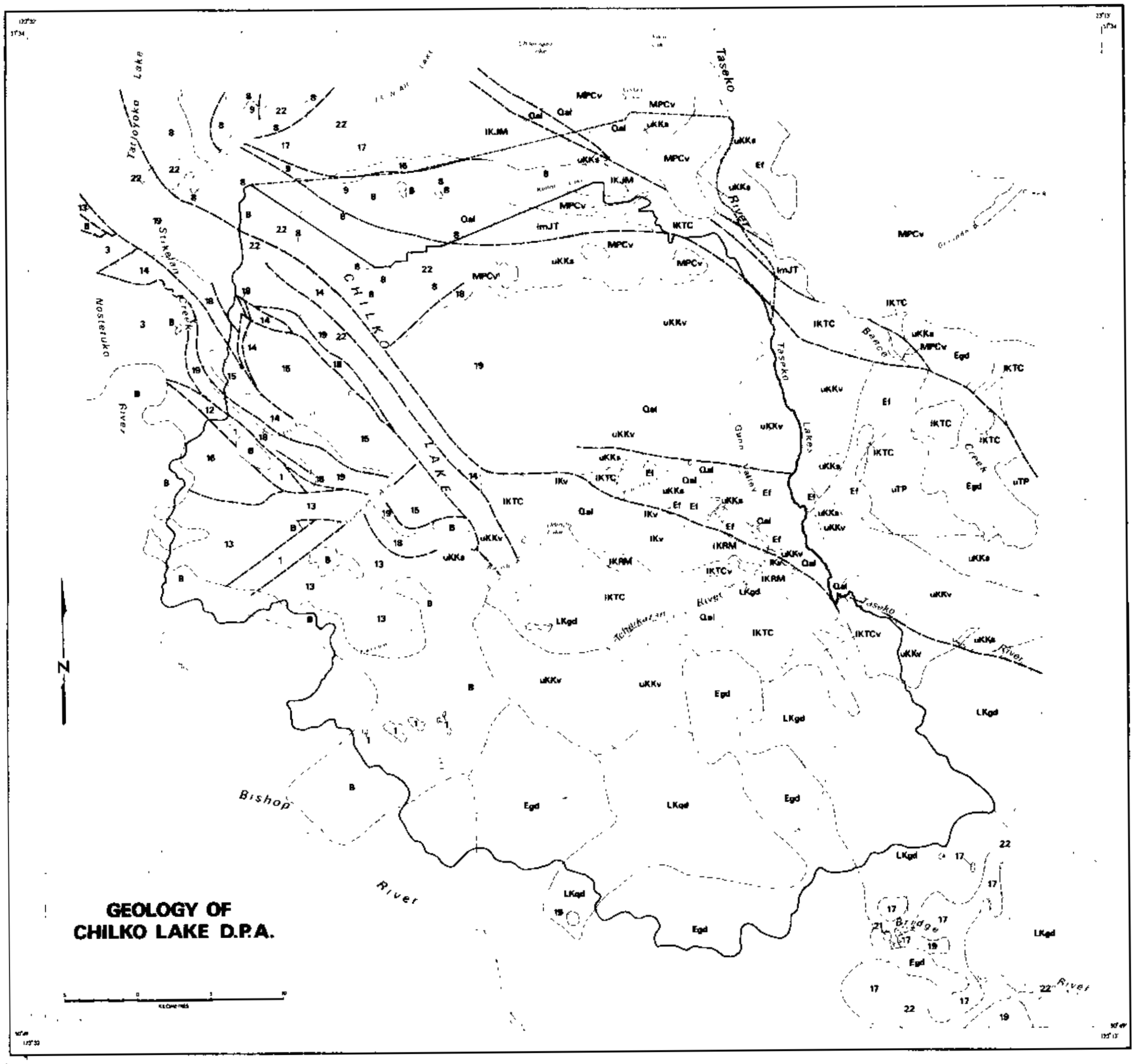
METHODS

Mineral potential assessments of the planning areas are qualitative. Mineral potential ratings ranging from high (1) to low (5) were assigned to the different geological units or packages in a study area. The rating of each package was based on the occurrence of known mineral deposits and its perceived potential for hosting undiscovered mineral resources. The types of mineral deposits that may be found are discussed in the text and their potential values estimated.

Parameters used to classify mineral potential include:

(1) Favourable geological environments for mineralization.

(2) Production history of properties in the area and/or in similar geologic environments elsewhere.



GEOLOGY SIMPLIFIED FROM:

Cummings, J. M. (1939). Reconnaissance along Proposed Tunnel from Chilko Lake to Bishop River, *B.C. Ministry of Energy, Mines & Pet. Res.*, Property Files.

Tipper, H. W. (1969). Mount Waddington, *Geol. Surv., Canada*, Paper 68–33, 1:126 720.

Tipper, H. W. (1978). Taseko Lakes, *Geol. Surv., Canada*, Open File Map 534, 1:250 000.

Woodsworth, G. J. (1977). Pemberton, *Geol. Surv., Canada* Open File Map 482, 1:250 000.

Figure 69. Geology of Chilko Lake Deferred Planning Area.

ROCK UNITS OCCURRING IN CHILKO LAKE D.P.A.

	GEOLOGICAL SURVEY OF CANADA, OPEN FILE 534, NTS 92O		*GEOLOGICAL SURVEY OF CANADA, PAPER 68-33, NTS 92N*
	QUATERNARY PLEISTOCENE AND RECENT		PLEISTOCENE AND RECENT
Qal	TILL, GRAVEL, SAND, CLAY, SILT	**22**	TILL, GRAVEL, SAND, ALLUVIUM
	CENOZOIC UPPER MIOCENE AND/OR PLIOCENE CHILKOTIN GROUP		
MPCv	VOLCANIC ROCKS		
	MESOZOIC UPPER CRETACEOUS (CENOMANIAN) KINGSVALE GROUP		UPPER CRETACEOUS (CENOMANIAN AND (?) LATER KINGSVALE GROUP
uKKv	VOLCANIC ROCKS	**19**	VOLCANIC ROCKS
uKKs	SEDIMENTARY ROCKS	**18**	SEDIMENTARY ROCKS
	LOWER CRETACEOUS (APTIAN AND ALBIAN) TAYLOR CREEK GROUP		LOWER CRETACEOUS (APTIAN) TAYLOR CREEK GROUP
lKTC	SEDIMENTARY ROCKS	**16**	SEDIMENTARY ROCKS
lKTCv	VOLCANIC ROCKS		
	LOWER CRETACEOUS (APTIAN AND ALBIAN) JACKASS MOUNTAIN GROUP		LOWER CRETACEOUS (ALBIAN) JACKASS MOUNTAIN GROUP
lKJM	SEDIMENTARY ROCKS	**17**	SEDIMENTARY ROCKS
	LOWER CRETACEOUS (HAUTERIVIAN)		CRETACEOUS (HAUTERIVIAN AND (?) YOUNGER)
lKv	*VOLCANIC ROCKS*	**15**	*VOLCANIC ROCKS*
		14	SEDIMENTARY ROCKS
		13	VOLCANIC ROCKS
		12	SEDIMENTARY ROCKS
	JURASSIC AND CRETACEOUS RELAY MOUNTAIN GROUP *(BERRIASIAN TO BARREMIAN)*		LATE JURASSIC TO EARLY CRETACEOUS *(OXFORDIAN TO BERRIASIAN)*
lKRM	SEDIMENTARY ROCKS	**9**	SEDIMENTARY ROCKS
	UPPER TRIASSIC TO MIDDLE JURASSIC *(SINEMURIAN TO MIDDLE BAJOCIAN)*		(HETTANGIAN (?), SINEMURIAN, BAJOCIAN, AND *CALLOVIAN)*
lmJT	SEDIMENTARY ROCKS	**8**	SEDIMENTARY ROCKS
			BAJOCIAN AND (?) CALLOVIAN
		7	VOLCANIC ROCKS
	UPPER TRIASSIC (KARNIAN AND (?) NORIAN) PIONEER FORMATION		TRIASSIC (KARNIAN (?) AND EARLY NORIAN)
uTP	VOLCANIC AND SEDIMENTARY ROCKS	**3**	*SEDIMENTARY ROCKS*
			(KARNIAN)
		1	VOLCANIC ROCKS
	PLUTONIC ROCKS		
	TERTIARY		
LKgd	GRANODIORITE	**B**	
LKqd	FELSITE FELDSPAR PORPHYRY		
	LATE CRETACEOUS AND/OR EARLY TERTIARY COAST PLUTONIC ROCKS		
Egd	GRANODIORITE	**8**	
Ef	QUARTZ DIORITE		

(3) Known mineral occurrences, regardless of present economic viability, because:
    (a) overburden may cover the best mineralized zones
    (b) mineralization is three-dimensional; higher grade mineralization may occur at depth

(4) Past and present mining exploration activity; this is shown by the number and location of present and former mineral claims, Crown grants, placer leases, etc.

The size of known and potential deposits in each rating class is expressed on the basis of estimated total value of contained metal. Classifications are as follows: (A) large (greater than $1 billion); (B) medium ($50 million to $1 billion); (C) small ($1 million to $50 million).

Each report includes the following:

(1) A geological compilation map at 1:250 000 scale or smaller.

(2) A mineral occurrence map constructed from the Ministry's MINFILE, which categorizes occurrences according to size and type of minerals present.

(3) A map showing the distribution of mineral claims that are in good standing.

(4) A mineral potential map.

(5) A bibliography of regional and economic geology reports for the study area.

(6) A discussion of the geology of the area with emphasis on major map units, structural features, and geological environments perceived to have metallogenic significance.

(7) A discussion of the potential types of mineral deposits expected in each unit and estimates of their potential values.

(8) Depending on the options available to the planning team, recommendations for future fieldwork.

CHILKO LAKE PLANNING AREA (92N, O)

INTRODUCTION

The Chilko Lake Deferred Planning Area (DPA on figures) lies at the eastern edge of the Coast Range approximately 240 kilometres north of Vancouver and 150 kilometres southwest of Williams Lake (Fig. 68). The area extends from Stikelan Creek on the west to Taseko Lakes on the east and from the north end of Chilko Lake southward to Stanley Peak (Fig. 69). It encompasses more than 2 000 square kilometres with parts accessible by gravel road from the Chilcotin Highway to the north.

GEOLOGY

The planning area straddles the boundary between the Coast Plutonic Complex on the southwest and the Intermontane Belt on the northeast. Figure 69 is a compilation of the geology of the planning area after Tipper (1969, 1978) and Woodsworth (1977). The Intermontane Belt in the area consists of three, northwest-southeast-trending, fault-bounded blocks of Triassic to Cretaceous sedimentary and volcanic rocks. Andesitic flows and associated tuffs and breccias constitute the bulk of the volcanic rocks and these are intercalated with waterlain tuffs, siltstones, shales, minor sandstone, and carbonate rocks. These are unconformably overlain by scattered outliers of Miocene and Pliocene plateau lavas. Plutonic rocks emplaced in Cretaceous and Tertiary times are granodiorite, quartz diorite, and diorite. They form the main mass of the Coast Mountains and lie mainly southwest of the study area. However, throughout the area related dykes, stocks, and sills intrude the volcanic and sedimentary rocks.

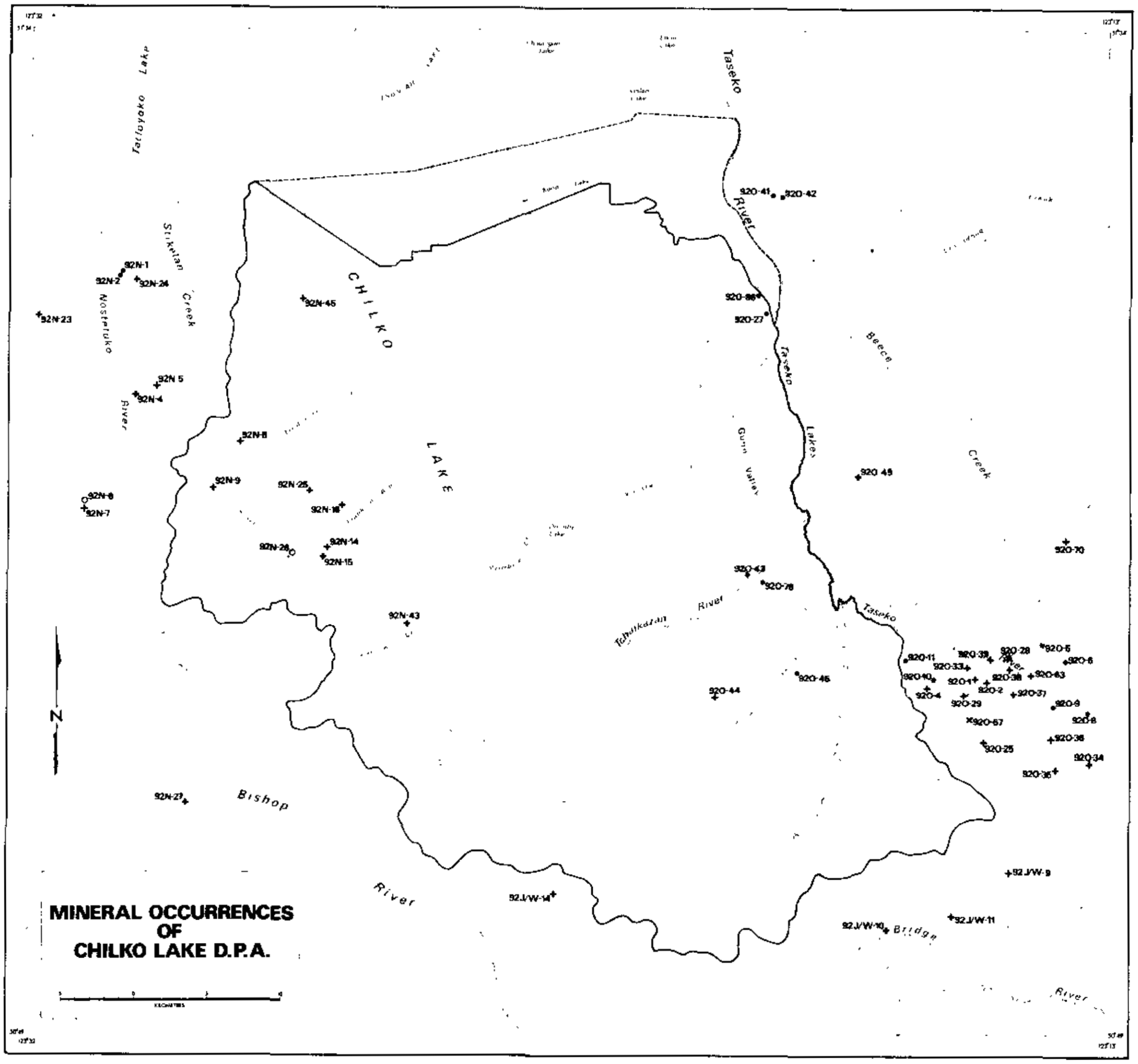
MINERALIZATION

Most of the known mineral occurrences (Fig. 70) are found in volcanic and sedimentary rocks at or close to plutonic contacts and within the plutons. A significant porphyry-type copper-molybdenum prospect is hosted by a granodiorite intrusion and adjacent volcanic rocks at Tchaikazan River in the southeast part of the planning area. The volcanic rocks structurally above this pluton are cut by quartz veins that host free gold and telluride minerals. These veins were discovered by H. Warren in 1945 and have been re-examined and drilled on many occasions since. The Pellaire prospect (Fig. 70), located about 7 kilometres southeast of the Tchaikazan property, consists of pyrite, chalcopyrite, gold, silver, and bornite mineralization in shattered quartz veins that cut a granodiorite intrusion.

A number of molybdenum and tungsten occurrences have been known since 1910 at the northwest end of Franklyn Arm of Chilko Lake. Skarn-type mineralization occurs in Triassic limestones and limy sedimentary rocks near contact with granodiorite intrusions. The best known is the Daisie prospect (92N/2b, Fig. 70) which contains chalcopyrite, pyrrhotite, molybdenite, silver, and scheelite mineralization.

MINERAL DEPOSIT MODELS AND MINERAL POTENTIAL RATINGS

Several geologic environments identified in the planning area are favourable hosts for a variety of mineral deposits.



MINERAL OCCURRENCES

NTS 92O

Mineral Occurrences Within Chilko Lake Deferred Planning Area

NO 92O-	NAME	PRODUCT(S)
27	VICK CASH	Au, Cu, Ag
43	EGGS TCHAIKAZAN CHARLIE	Cu Mo Au, Ag
44	ZEN REX	Cu Mo
45	HI DO (PELLAIRE)	Au Ag Cu
76	WARREN CHARLIE	Au, Ag Cu
86	TASEKO RIVER	hydromagnesite

Mineral Occurrences Outside Chilko Lake Deferred Planning Area

1	MOHAWK TASEKO	Cu Mo, Au, Ag, Zn Pb
2	MOTHERLODE, TASEKO MOHAWK	Cu, Au, Ag
4	SPOKANE TASEKO	Cu, Ag, Au
5	BATTLEMENT CREEK	Fe
6	RAE CREEK	Fe
8	DENAIN CREEK	Fe
9	FORREST WHALE MTN	Fe
10	LIMONITE McCLURE MTN	Fe
11	CHILCOTIN McCLURE MTN	Fe
25	ROWBOTTOM, NW BILL	Cu Mo
28	TAYLOR WINDFALL BUZZER	Au Ag, Cu, Pb Zn talc
29	PHAIR	Cu, Ag, Au
33	EMPRESS TASEKO SPOKANE MOHAWK	Cu, Au
34	MM, TAYLOR MOUNTAIN, MAD MAJOR	Cu Mo
35	MM WESTSIDE MAD MAJOR	Cu Mo
36	MM CANYON	Cu Mo
37	TOP	Mo Cu
38	BUZZER TASEKO	Cu Au Mo
39	BUR TASEKO 49 KM GRANITE	Cu Mo
41, 42	FISH LAKE [illegible] 69 VICCAL - MARY STUART	Cu, Au
49	BANNER CHITA	Cu Mo
63	TEEK ARD	Cu
67	MASSENA	Au Ag
70	GRAB (VIC ?)	Cu Pb Zn

NTS 92N

Mineral Occurrences Within Chilko Lake Deferred Planning Area

NO 92N	NAME	PRODUCT(S)
8	RUM 66	Cu Mo
9	RUM 2	Cu Mo
14	NORFA 18	Cu Mo
15	NORFA 20	Cu Mo
16	CINDY	Cu
25	Occurrence	Cu
26	DUCHARME COPPER QUEEN, DAISIE RONCAN	Cu Mo Zn W, Ag
43	Occurrence	Cu
45	ALEXIS	Cu Hg

Mineral Occurrences Outside Chilko Lake Deferred Planning Area

1	SPOKANE	Cu
2	MORRIS MINE	Au Ag Sb
4	BEN 37	Cu Mo
5	BEN 28	Cu Mo
6	BLUE 33 38	Cu Mo
7	BLUE 32	Cu, Mo
23	HOM	Cu
24	ICT	Sb Ag Au
27	SG SAM	Cu

NTS 92J

Mineral Occurrences Outside Chilko Lake Deferred Planning Area

NO 92J	NAME	PRODUCT(S)
9	NICHOL RAELODE	Cu Mo
10	BR	Cu
11	GRISWOLD RUSSNOR MEL	Cu Ag Au Mo
14	AUTUMN	Cu, Mo

ABBREVIATIONS

Ag	silver	Mo	molybdenum
Au	gold	Pb	lead
Cu	copper	Sb	antimony
Fe	iron	W	tungsten
Hg	mercury	Zn	zinc

Figure 70. Mineral occurrences of Chilko Lake Deferred Planning Area.

(1) Porphyry Copper-Molybdenum (Gold) Deposits

Based on the Tchaikazan River prospect and the presence of other porphyry-type prospects that occur in geologically similar environments adjacent to the area, parts of the study area are judged to have high potential for porphyry-type deposits. The Fish Lake deposit, 6 kilometres to the northeast of the study area, contains 180 000 000 tonnes of 0.25 per cent copper and 0.51 grams gold per tonne (Wolfhard, 1976) and the Poison Mountain prospect, 56 kilometres to the east, contains 170 000 000 tonnes of 0.34 per cent copper and 0.016 per cent molybdenum, and 0.34 grams gold per tonne (Seraphim and Rainboth, 1976). The most likely areas for porphyry-type mineralization are within, at the margins, and adjacent to post-tectonic intrusions. In the study area, units displaying these characteristics have been assigned a 2B rating (Fig. 71), the highest assigned in the area.

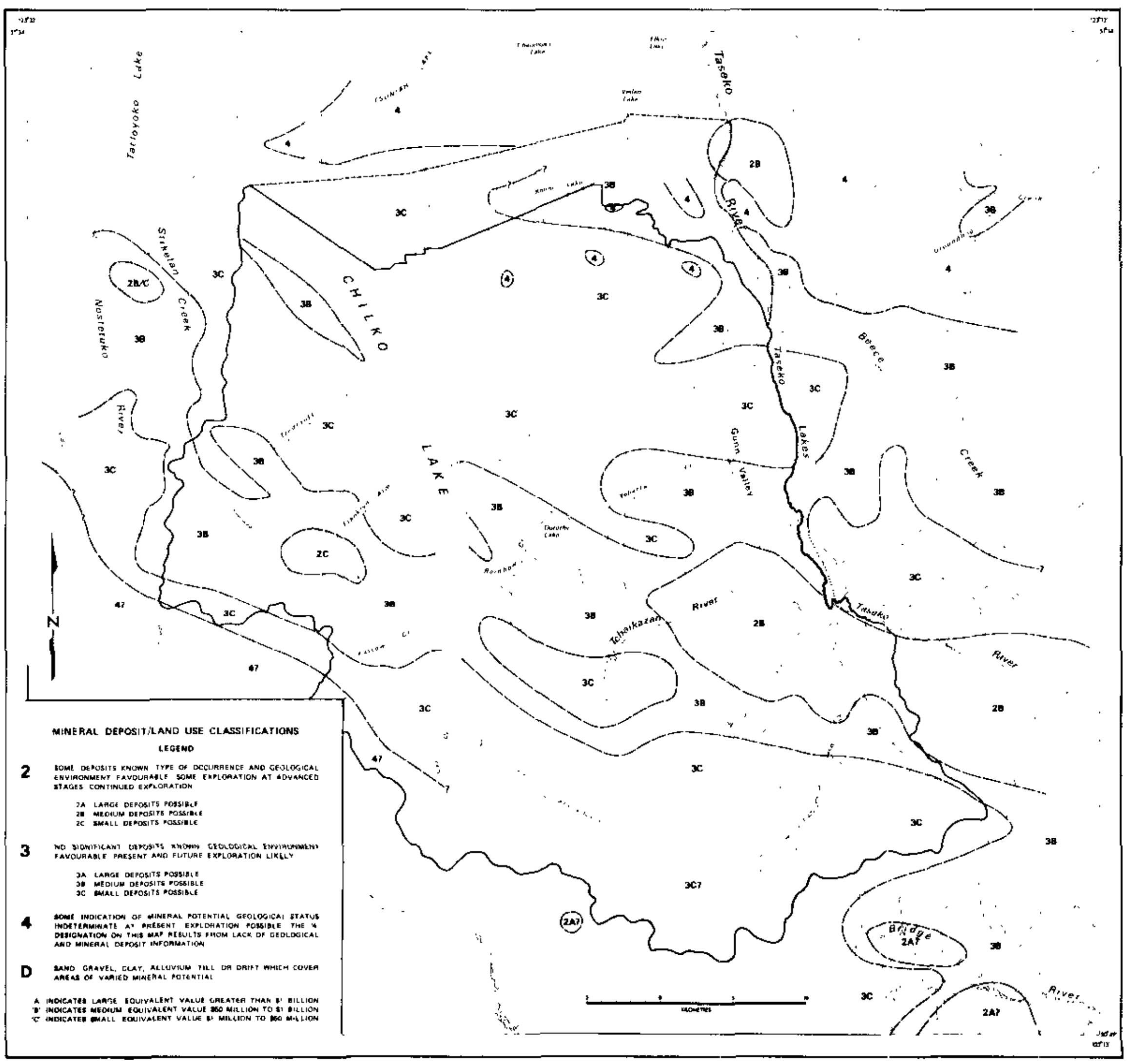


Figure 71. Mineral potential of Chilko Lake Deferred Planning Area.

(2) Gold-Silver Epithermal Vein Deposits

The Warren-Charlie prospects on Tchaikazan River are examples of epithermal gold-silver vein deposits related to intrusions of the Coast Plutonic Complex. Precious metal vein deposits of volcanogenic origin are in calc-alkalic volcanic sequences in other areas, particularly close to faults and siliceous volcanic centres. Most of the study area is underlain by volcanic rocks with this favourable geologic environment but because occurrences of this type are unknown in the area, these units are assigned a moderate (3B or 3C) potential.

The Alexis occurrence, located on the west side of Chilko Lake (Fig. 70), is a limonitic breccia stained with malachite in volcanic rocks close to a major fault. The trace of the fault zone is assigned a moderate (3B) potential for precious metal vein deposits (Fig. 71).

(3) Skarn Deposits

Areas containing carbonate-rich rocks have moderate potential for discovery of additional copper, molybdenum, tungsten, silver, and gold contact metasomatic deposits of the Daisie type. However, outside of the Franklyn Arm area existing geological maps do not report other areas of limestone in proximity to intrusions. Consequently only the Franklyn Arm area is assigned a high (2C) potential.

(4) Others

Areas of Tertiary volcanic rocks are assigned a low (4) mineral potential. Environments may exist for epithermal vein deposits or for basal-type uranium deposits at erosional unconformities below the volcanic rocks but no such deposits are known. Suitable environments may also exist for Carlin-type gold deposits associated with carbonate-bearing sequences. There is no information to support this possibility but it should be borne in mind while conducting mineral exploration in the area.

KAKWA PLANNING AREA (93H, I)

INTRODUCTION

The Kakwa Planning Area, located along the eastern slope of the Rocky Mountains, is bounded on the east by the Alberta border and on the south and west by the drainage divide between the Arctic and Pacific drainage systems (Fig. 68). The area covers approximately 33 750 hectares. A road built in 1982 to gain access to a quartzite prospect at Babette Lake is the only road into the area. The area is characterized by high rugged mountains, glaciers, and rockwalls interspersed with wooded valleys and small glacial lakes.

GEOLOGY

The planning area lies within the Rocky Mountain Fold and Thrust Belt and is characterized by a thick sequence of Late Precambrian to Lower Cretaceous miogeoclinal and platformal carbonate and clastic rocks (Fig. 72). The clastic rocks include conglomerates through sandstones and quartzites, and siltstones to shales and argillites with some carbonaceous and coaly members in the upper part of the sequence. The carbonate rocks range from calcareous shales to shaly limestones, and massive limestones to dolomites. The rock units have been compressed and displaced northeastward by a series of thrust faults.

Exploration companies have not been active in the area, partly because of poor access and partly because the geology is known only on a regional basis from reconnaissance mapping by the Geological Survey of Canada (Campbell, *et al.*, 1973; Taylor and Scott, 1979). From these surveys the geology appears to be typical of the Rocky Mountain Fold and Thrust Belt. Without the benefit of mineral exploration reports on the area, the following discussion on the mineral potential relies heavily on comparisons with analagous geological settings outside the planning area that host mineral deposits.

METALLIC MINERAL DEPOSIT MODELS AND MINERAL POTENTIAL RATING

(1) Carbonate-Hosted Lead-Zinc Deposits

A major lead-zinc deposit (Robb Lake) and 16 smaller occurrences have been discovered in platformal carbonate rocks of the Rocky Mountain Fold and Thrust Belt in northeastern British Columbia. These deposits occur in Devonian dolomites and limestones at a facies change or 'shale out' from massive carbonate rocks in the southeast to shaly carbonate rocks in the northwest (Macqueen and Thompson, 1978). In the Kakwa Planning Area the upper Devonian Palliser Formation undergoes a similar change and, by analogy, is an excellent reconnaissance target. The Robb Lake deposit, which occurs in a similar geologic environment 360 kilometres to the northwest, contains approximately 6.1 million tonnes of 7.3 per cent combined lead and zinc, giving a gross value of about $350 million. For this reason, the Palliser Formation is designated as 3B on the mineral potential map (Fig. 73), indicating moderate potential for finding a medium-sized deposit.

Potential also exists for Mississippi Valley-type lead-zinc deposits in the massive carbonate rocks that crop out extensively in the study area. Although the Cambrian Mural Formation hosts lead-zinc mineralization outside of the study area, no metallotects have been recognized in the area for this type of deposit. Consequently the carbonate units are designated as moderate potential (3) with no size classification.

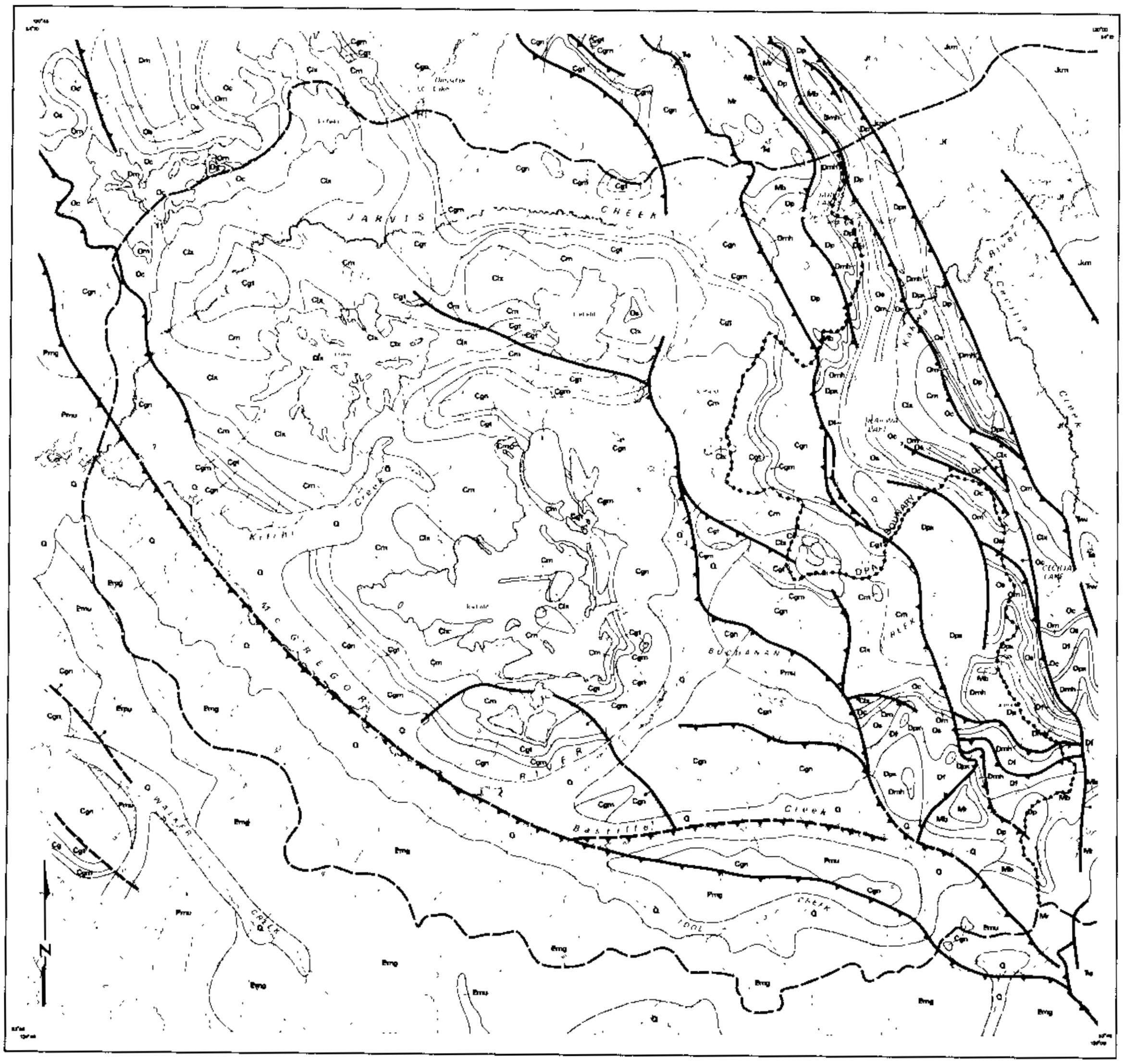


Figure 72. Geology of Kakwa Lake Deferred Planning Area.

(2) Clastic-Hosted Sulphide Deposits

Barite-lead-zinc deposits hosted by Devonian-Mississippian clastic rocks are a major type of deposit in the miogeoclinal rocks of the Rocky Mountain Fold and Thrust Belt (MacIntyre, 1982). Although known deposits in the Kechika Trough of northeastern British Columbia are restricted to the western half of the Rocky Mountain Fold and Thrust Belt, potential exists for discovering this type of deposit in the shale units of the study area. By analogy with the age of the host rocks of the known deposits, Devonian shales in the study area are assigned a moderate potential (3); other shales are assigned a lower designation (4) (Fig. 73).

Much of the western part of the study area is underlain by Cambrian quartzites and sandstones of the McNaughton and Mahto Formations. Although these and other quartzites in the study area are assigned a low potential (4), stratabound lead-zinc-silver mineralization occurs in rocks of similar age and setting in other mountain belts, for example, Laisvall, Sweden (Rickard, *et al.*, 1979).

INDUSTRIAL MINERAL AND MATERIAL POTENTIAL

(1) Quartzite

Good quality quartzite for industrial use for building stone and as a source of silica occurs in the McNaughton Formation throughout the study area. The quartzite is massive with uniform beds up to 8 metres thick. A quartzite quarry at Wishaw Lake near Babette Lake is under development. This site was chosen largely because it is more accessible than many other prospective sites. Preliminary market surveys by the developer indicate that the quartzite has many desirable and aesthetic properties for use as building stone.

(2) Gypsum

Good quality gypsum 15 metres thick occurs in the middle part of the Whitehorse Formation 7 kilometres east of the planning area (Govett, 1961). This formation crops out at the eastern margin of the planning area around Cecilia Lake; its gypsum potential is untested.

(3) Phosphate

Phosphate deposits were discovered recently about 30 kilometres northeast of the study area in the Triassic Sulphur Mountain Formation (Heffernan, 1980). This formation extends into the study area where its potential is unknown.

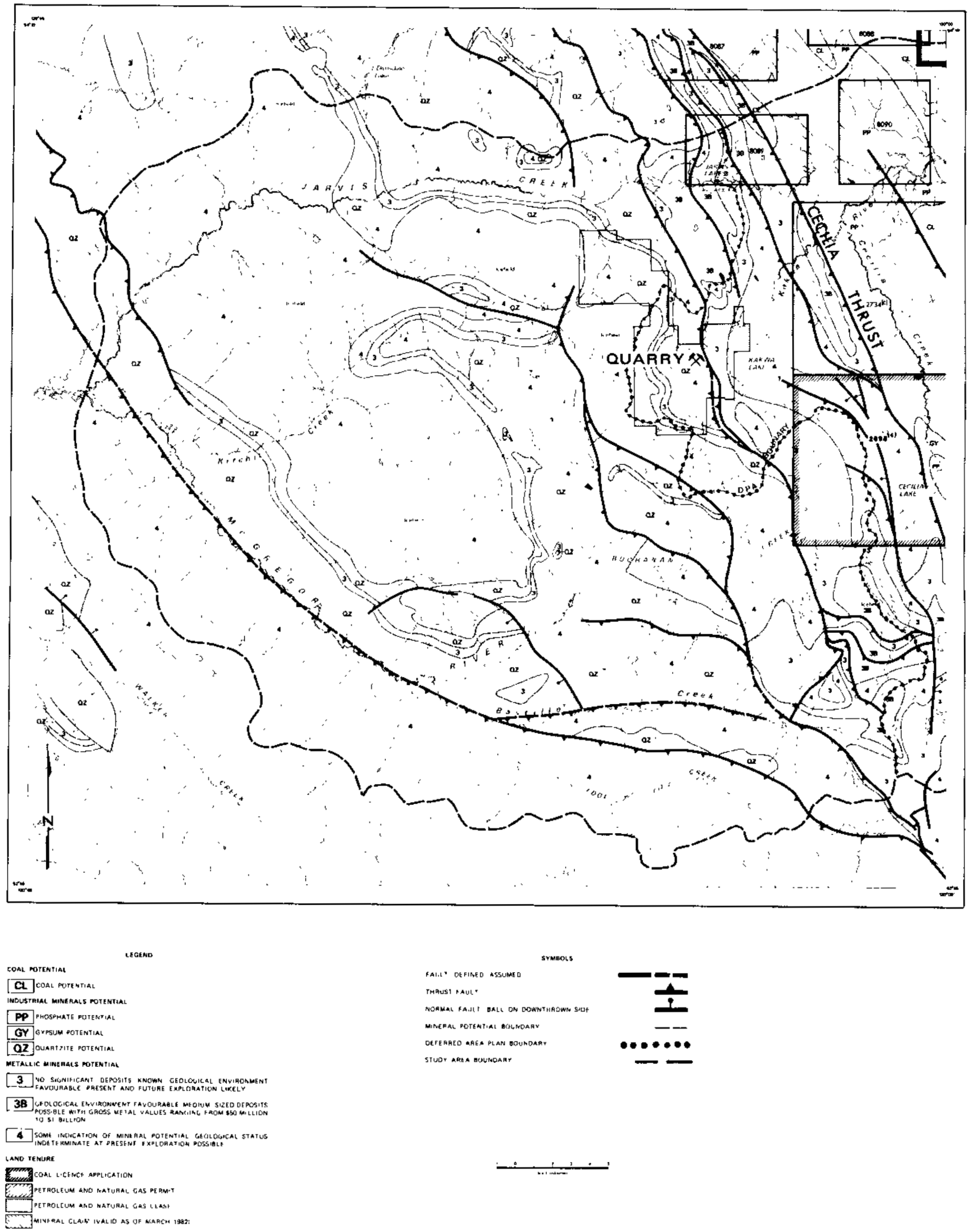


Figure 73. Mineral potential of Kakwa Lake Deferred Planning Area.

ENERGY RESOURCE POTENTIAL

The Petroleum Resources Division assessed the energy resource potential of the study area in a separate report that is summarized briefly here.

(1) Petroleum and Natural Gas

Favourable areas for petroleum and natural gas accumulations occur in the Fernie Group and under the Cecilia Thrust Plate. In the Kakwa Planning Area, leases and permits partly cover areas of interest but detailed exploration has yet to be undertaken.

(2) Coal

The southern limit of the Peace River Coalfield, currently under development to the northwest, crosses the northeast corner of the planning area. Coal licences extend from the study area northwestward along strike (Fig. 73). Detailed exploration has yet to be undertaken on licences adjacent to and in the study area but it is underlain by the coal-bearing Minnes Group.

SUMMARY

The Kakwa Planning Area presents a good example of the difficulties involved in assessing the mineral potential of an area with only a broad regional geological data base and no detailed private exploration reports. In this case the Ministry of Energy, Mines and Petroleum Resources recommended to the planning team that a ground assessment of the mineral potential (mapping, stream geochemistry, lithogeochemistry) should be carried out prior to any land use decision that would withdraw land from exploration and mining.

FLOURMILLS PLANNING AREA (93A/1W, 92P/16W)

INTRODUCTION

Flourmills Deferred Planning Area (Fig. 68) centres on latitute 52 degrees 06 minutes north and longitude 120 degrees 20 minutes west. The planning area encompasses 9 000 hectares of the southern portion of the Quesnel Highlands, a highly dissected plateau of moderate relief. It is bounded to the north, east, and south by Wells Gray Provincial Park, and on the west by Spanish Creek. Elevations range from 1 100 metres along Spanish Creek to more than 2 100 metres on Wells Gray Provincial Park boundary. Pleistocene glaciation rounded peaks and left extensive valley bottom till deposits. Several well-preserved, post-glacial volcanic cones, cinder deposits, and flows that lie near the eastern boundary of the planning area provided the impetus for a proposal by the Ministry of Lands, Parks and Housing to annex all, or part of, the planning area to Wells Gray Provincial Park.

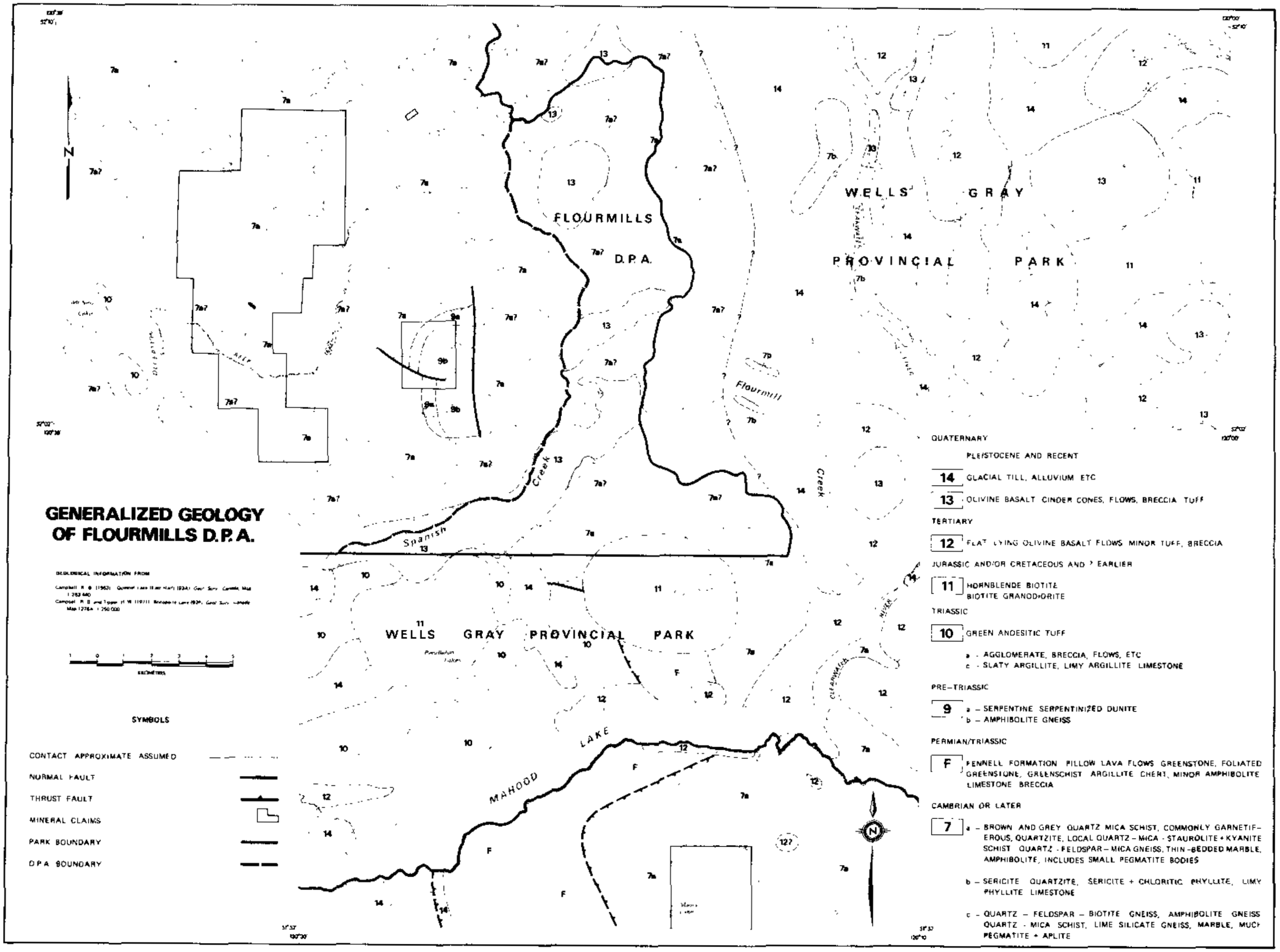


Figure 74. Generalized geology of Flourmills Deferred Planning Area.

GEOLOGY

Figure 74 is a generalized geologic map of the region surrounding the Flourmills Deferred Planning Area. The area is underlain predominantly by Lower Cambrian and younger metamorphosed rocks of the Snowshoe Formation of the Cariboo Group (unit 7a). Dominant lithologies are brown and grey quartz-mica schist, quartzite, thin-bedded marble, quartz-feldspar mica gneiss, and amphibolite pegmatite (Campbell, 1963; Campbell and Tipper, 1971). Along the southern boundary, these rocks and a minor area of Triassic Nicola Group metasedimentary rocks are intruded by Jurassic and/or Cretaceous monzonite to granodiorite plutons, which, by proximity, might correspond to the nearby Raft and Baldy batholiths. Superimposed on the general geologic pattern just described are Miocene to Recent volcanic flows culminating in a number of well-preserved cones and blocky lava flows. These are found in the northwest and central to southwestern part of the planning area. Pervasive glacial deposits and recent alluvium limit rock exposures.

MINERALIZATION

There are no metallic mineral occurrences in the Flourmills Deferred Planning Area. Scoria and ash deposits were investigated by a private company, Tri-Ag Resources Ltd., but no results are documented to provide an indication of economic value. A mica deposit associated with pegmatites of the Snowshoe Formation adjacent to the northwest boundary was investigated in 1930, but has received little recent attention.

MINERAL DEPOSIT MODELS

By analogy with geological environments and mineral deposits adjacent to the planning area, a variety of mineralization possibilities exist for Flourmills Deferred Planning Area:

(1) Porphyry-style molybdenum or copper mineralization related to Jurassic/Cretaceous plutons.

(2) Tungsten-bearing skarn mineralization associated with Snowshoe Formation-hosted Jurassic/Cretaceous plutons.

(3) Disseminated gold mineralization in iron-carbonate-rich Triassic phyllites. These rocks may extend southeast from the Crooked Lake-MacKay River Valley.

MINERAL POTENTIAL

Figure 75 shows mineral potential for the region surrounding Flourmills Deferred Planning Area. Mineral potential was considered to be low prior to about 1980. Regional exploration work, initiated after publication of Federal-Provincial regional geochemical silt sample data for NTS 92P and 93A, raised the designation of mineral potential from low to moderate.

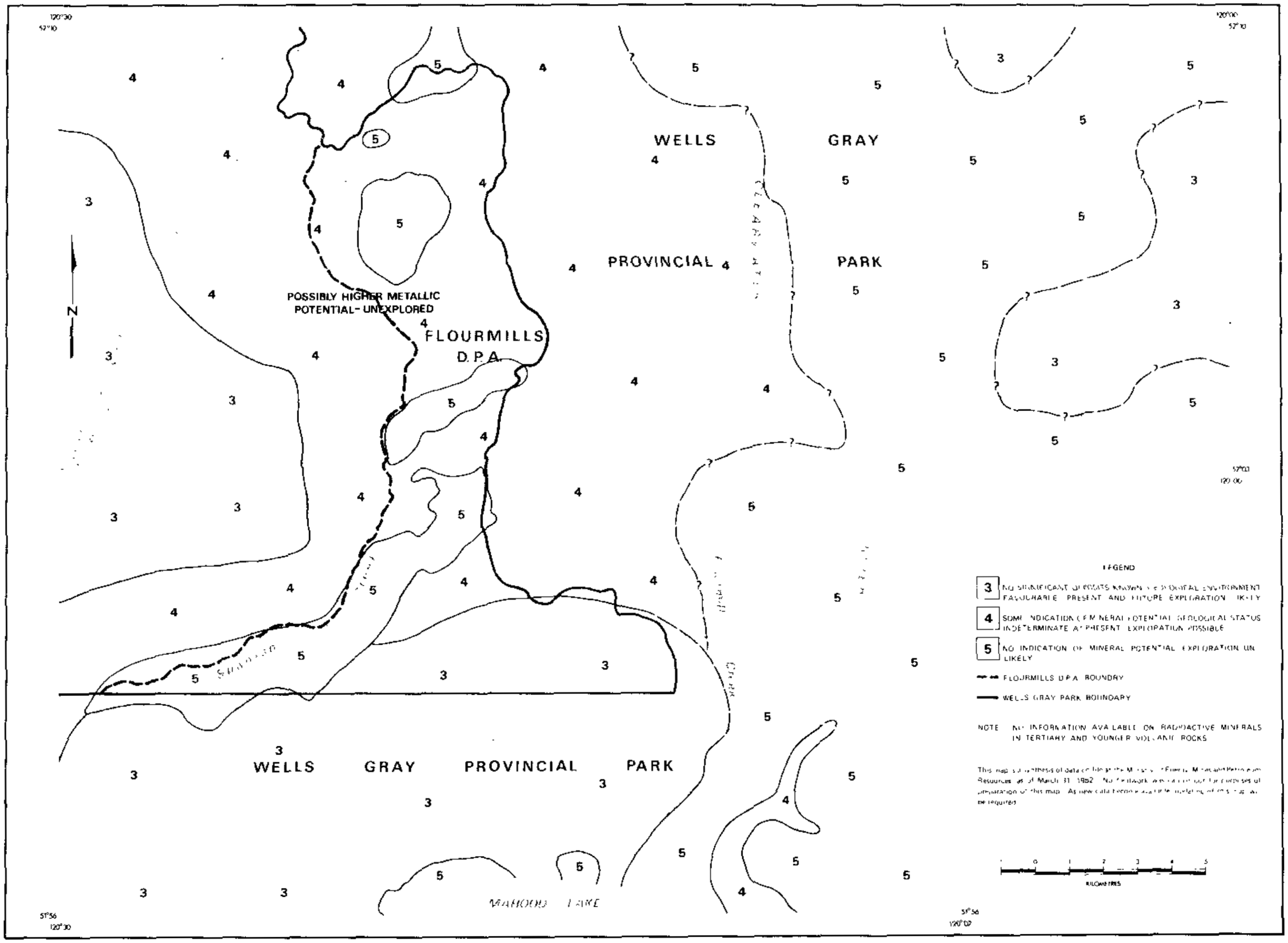


Figure 75. Metallic mineral potential of Flourmills Deferred Planning Area.

Highest mineral potential for porphyry and skarn mineralization exists in the south where a number of stocks intrude the Snowshoe Formation. Central and northern parts of the planning area that are underlain by Snowshoe Formation require detailed geologic mapping to determine whether gold-bearing geologic environments extend southeast from Crooked Lake-MacKay River into the planning area. Consequently, these rocks are designated as having indeterminate mineral potential. Areas covered by post-glacial volcanic cones and lava flows are considered to have low metallic mineral potential.

GEOTHERMAL POTENTIAL

Exploration for geothermal resources is in its infancy in British Columbia; the Flourmills area has not been investigated. Deep-seated structures controlled Tertiary to Recent volcanism in the area. Therefore, while geothermal energy potential presently is unknown, it could be high.

SUMMARY AND RECOMMENDATIONS

Flourmills Deferred Planning Area covers 9 000 hectares of relatively unexplored land in the southern Quesnel Highlands. Recent exploration adjacent to the planning area indicates that mineral potential may be considerably higher than previously thought. Untested mineralization possibilities include molybdenum-copper porphyries, tungsten-bearing skarns, and disseminated stratabound gold.

Industrial mineral potential is mainly for scoria, ash, and mica. The economics of these commodities, particularly scoria and ash, are dependent on proximity to ready markets.

Geothermal energy potential, which is generally high in areas of recent volcanic activity, is untested but may prove to be significant.

At present, it is strongly emphasized that the current level of geologic knowledge for the Flourmills Deferred Planning Area needs enhancement by more detailed geological, geochemical, and geothermal surveys to permit consideration and endorsement of proposals to alienate land from exploration and development.

SOUTH MORESBY PLANNING AREA (103B, C; 102O)

INTRODUCTION

The South Moresby Planning Area is located on the Queen Charlotte Islands approximately 200 kilometres southwest of Prince Rupert. The planning area covers 145 270 hectares and includes all land and adjacent islands south of an east-west-trending boundary south of Tangil Peninsula. The

Queen Charlotte Ranges are the dominant physiographic unit, with the San Christoval Ranges forming the major subdivision. Elevations range from sea level to more than 1 100 metres. Alpine conditions extend locally to near sea level.

During the Pleistocene, Moresby and adjacent islands were intensively glaciated as evidenced by widespread and varied glacial features in mountainous areas. Some paleoecologists think there were glacial refugia because nunataks existed even during the maximum stage of glaciation.

Daily flights from Vancouver to Sandspit and twice-weekly ferry service from Prince Rupert provide access to the Queen Charlottes. Access to the planning area is by boat, seaplane, or helicopter. Limited access by logging roads is available on parts of Lyell Island and old mining roads and trails are still discernible near Jedway.

The Environment and Land Use Committee (ELUC) initiated the South Moresby Resource Planning Program in 1979 in response to numerous proposals by public interest groups for establishment of a large wilderness park, and in response to native Haida concerns about proposed logging on Burnaby Island. The Environment and Land Use Committee terms of reference called for a five-year multiple land use allocation plan to be produced. Mineral resources were among the many issues that the planning team addressed. The Ministry of Energy, Mines and Petroleum Resources' major input to the planning program during the last two and one-half years consisted of the following:

(1) District Geologist or Mineral Land Use Geologist participated in monthly meetings.

(2) Mineral Potential Evaluation Report (1981) prepared by K. E. Northcote of Bema Industries Ltd.

(3) Mineral Resources Technical Report, including an economic evaluation, written by K. E. Northcote of K. E. Northcote & Associates Ltd., and Resource Data and Analysis Division.

(4) Close liaison kept with mining companies actively working in the area and the British Columbia and Yukon Chamber of Mines.

(5) Proposals for one sizeable and two small ecological reserves evaluated.

The planning program meetings will conclude in early 1983. Following a final set of public meetings, a series of land use options supported by extensive resource evaluations will be presented to the Environment and Land Use Committee. A policy decision will follow.

GEOLOGY

A. Sutherland Brown, from 1958 to 1963, geologically mapped the Queen Charlotte Islands at a scale of 1:125 000. The results of his work, which are documented in Bulletin No. 54, are the basis for all subsequent geological studies and mining exploration on the islands. Recent exploration for gold deposits that are similar to the Cinola deposit on Graham Island provide further detailed geologic data.

The stratigraphic section on Moresby Island is fairly complete and similar to that of the other Queen Charlotte Islands. Three major periods of volcanic activity are separated by four periods of deposition of fossiliferous marine sedimentary rocks. Two periods of plutonism are present, Late Jurassic syntectonic intrusions and Late Tertiary post-tectonic intrusions. Volcanic and plutonic rocks have evolved with time, from basic to acidic, from quartz poor to quartz rich (Sutherland Brown, 1968).

A continuous linkage of northwestward-trending fault systems dissects the islands. These major crustal fractures dominated the tectonic development and control the distribution of rock types. The Rennell-Louscoone fault zone, active predominantly from Late Jurassic to Cretaceous time, extends throughout the planning area from Lyell Island in the north to Kunghit Island in the south (Fig. 76).

A diversity of geologic environments for mineral deposit formation exist. The wide variety of volcanic and sedimentary rocks; the syntectonic and post-tectonic plutons, dykes and sills; and the large deep-seated faults on Moresby and adjacent islands can all create environments favourable for mineral deposition.

MINERALIZATION AND MINERAL DEPOSIT MODELS

Francis Poole discovered chalcopyrite and magnetite mineralization in South Moresby Planning Area in 1862 in the vicinity of Skincuttle Inlet. For the next 80 years exploration intensity fluctuated and there was limited production of primarily copper-bearing ores.

(1) Contact Metasomatic Deposits

From the late 1940's to 1970 attention focused on exploration and development of contact metasomatic (replacement) iron-copper deposits with accompanying gold and silver values. The following features typify these deposits:

(a) Proximal to the contact of massive limestone of the Kunga Formation with altered basalts of the Karmutsen Formation.
(b) Adjacent to a plutonic body.
(c) Faulting, pre-ore diorite porphyry and abundant post-ore dykes.
(d) Brecciation and common presence of a skarn envelope.
(e) Orebodies occur in tabular-lensoid to pipe-like deposits that are concordant or discordant to bedding and consist of massive magnetite with variable amounts of chalcopyrite, pyrite, and pyrrhotite.

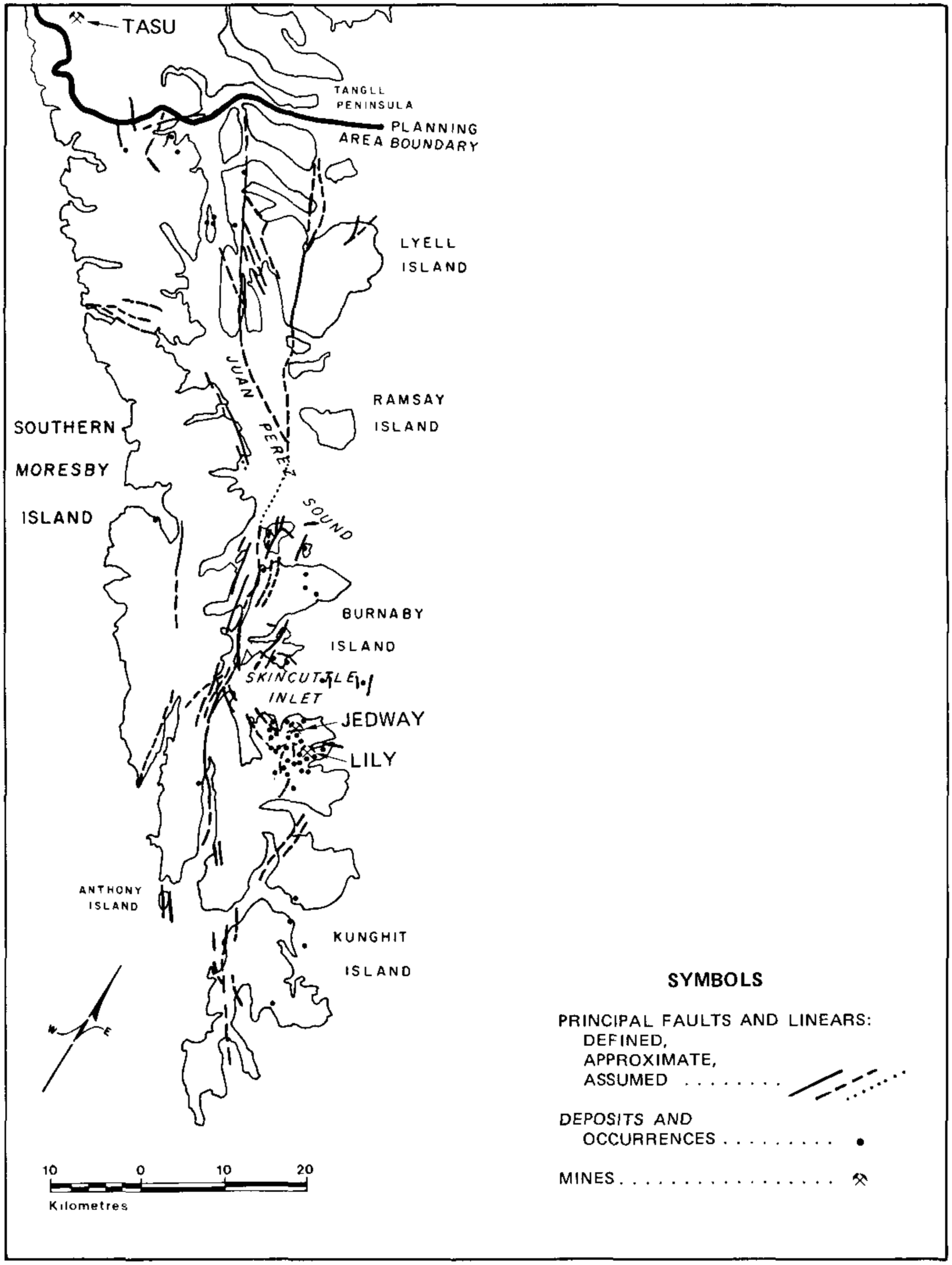


Figure 76. Major faults and linears showing relationship to known mineral deposits and occurrences, South Moresby Planning Area.

Jedway, the best known of these deposits inside the planning area, produced over 2 million tonnes of iron concentrate from 1962 to 1968 with a value of more than $21 million and provided direct employment for up to 150 workers. Significant reserves remain in other nearby deposits.

(2) Gold Deposits

The discovery of the Cinola gold deposit on Graham Island by Efrem Specogna and John Trico in 1970 stimulated a widespread search for similar deposits. They occur in silicified deep-seated faults and shear zones and are interpreted as variations of the Carlin Nevada-type of deposit. Exploration concentrated first on Graham Island around the original discovery and then, predictably, spread to similar geologic environments on Moresby and adjacent islands.

The Cinola gold deposit is located on the west side of the Sandspit fault where Haida sandstone and shale are structurally overlain by Early Tertiary volcanic rocks. Poorly lithified Mio-Pliocene sandstone, shale, and conglomerate of the Skonun Formation occur on the east side of the fault. Rhyolite porphyry crosscuts sedimentary units. Gold and silver mineralization is localized in intensely silicified rocks and quartz veins that appear to be spatially related to the rhyolite porphyry. Barr (1980) published estimates of reserves that ranged up to 22 million tonnes averaging 2.49 grams gold per tonne; recent company reports state reserves in the order of 41 million tonnes with 1.9 grams gold per tonne.

Gold exploration in the planning area involves a fairly wide variety of rock types but a narrow range of mineralizing environments. The following are significant as exploration guides:

(a) Silicification and quartz veining accompanied by sulphides proximal to deep-seated faults, shear zones, and major fault splays. Major fault systems traverse the Queen Charlotte Islands from northwest to southeast (Sutherland Brown, 1968).

(b) Silicification and sulphide mineralization that is associated with Tertiary (?) andesitic to rhyolitic dyke swarms.

(c) Silicification in brecciated rhyolitic rocks near eruptive or collapse centres; these likely targets are areas of Tertiary (Massett) volcanism. Dyke swarms within these volcanic rocks might also be significant.

Companies discovered significant mineralization on northern Lyell Island and on Moresby Island north of Bigsby Inlet. Some mineralized zones may extend more than 1 kilometre along well-defined fault structures. Exploration for gold deposits in the planning area is in its early stages; we anticipate much more to follow.

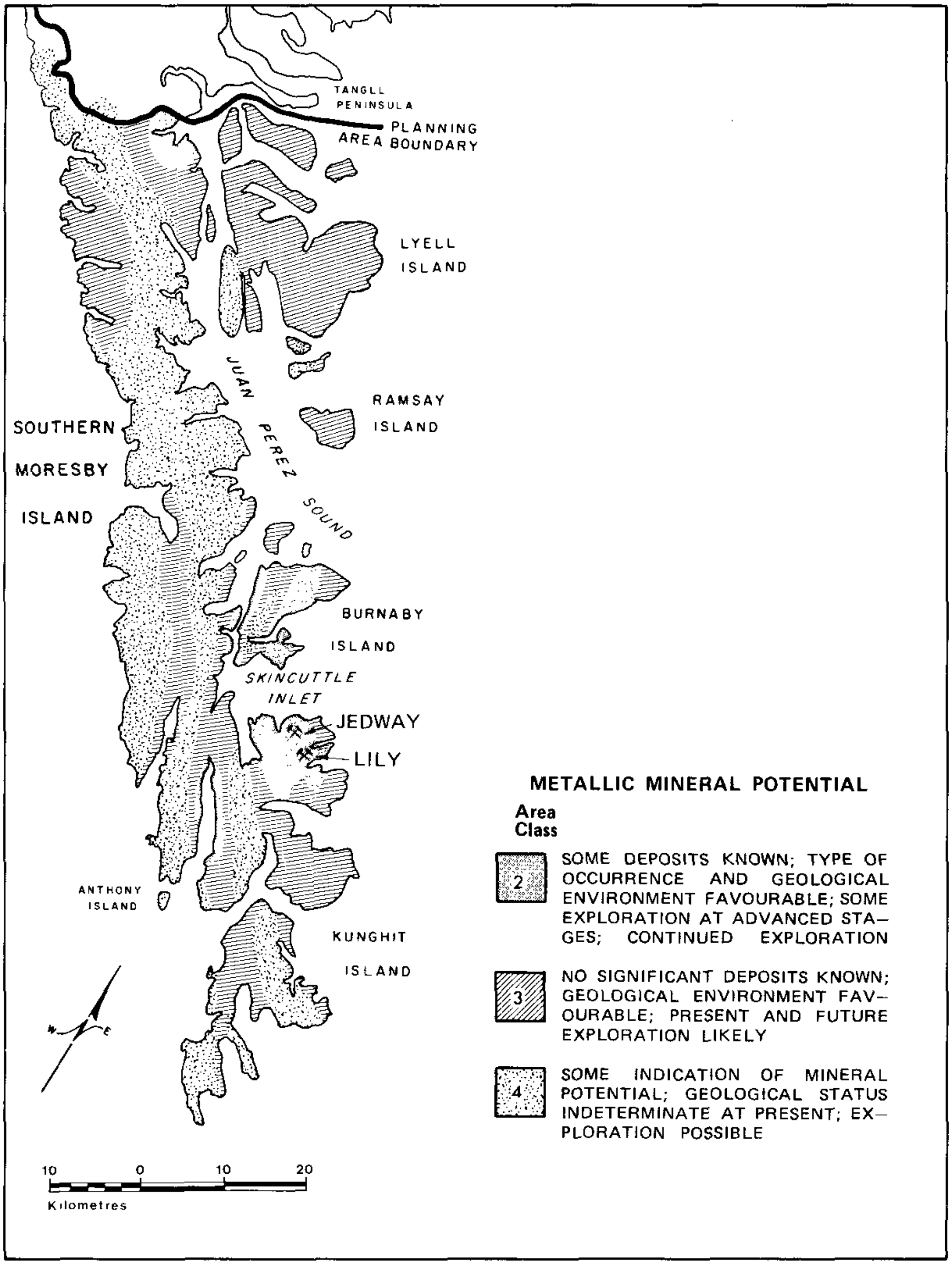


Figure 77. Metallic mineral potential of South Moresby Planning Area.

(3) Volcanogenic Massive Sulphide Deposits

Massive volcanogenic sulphide deposits and gold mineralization may occur in the predominantly acid submarine volcanic sequence of the Yakoun Formation. This possibility remains virtually untested, partly because areas underlain by the Yakoun Formation are not extensive.

(4) Post-Tectonic Porphyry Systems and Gold-Bearing Veins

Post-tectonic intrusions merit exploration for differentiated copper and molybdenum porphyry systems as well as gold deposits. The Catface porphyry copper-molybdenum deposit and Zeballos gold-bearing quartz veins on Vancouver Island are examples of mineralization related to similar post-tectonic intrusions in a similar geologic terrane.

(5) Other Possibilities

Other potentially economic types of mineralization include copper and lesser vanadium in amygdules in the tops of Karmutsen volcanic flows, and paleoplacer deposits proximal to areas of gold mineralization.

MINERAL POTENTIAL

In 1981, under contract to the Ministry, K. E. Northcote, then with Bema Industries Ltd., prepared a mineral potential map at scale 1:125 000 for the planning area. The map was compiled from Ministry files and information provided by industry. General concepts of mineral potential outlined earlier were utilized. A reduced, slightly modified version of this map is presented on Figure 77.

Mineral potential is summarized as follows:

(1) All areas where Kunga or interlava limestones are in contact with Karmutsen volcanic rocks, and are cut by or are close to intrusions, are considered to be areas of high (2) potential for iron, copper, gold, and silver mineralization in the form of contact meta-somatic deposits.

(2) Areas that are underlain by any of the features described previously under 'Gold Deposits' are classified as having high to moderate potential (3 to 2) for gold deposits. Ongoing exploration will necessitate periodic map revisions; some Class 4 areas will become Class 3, and some Class 3, Class 2.

(3) Areas underlain by the Yakoun Formation and post-tectonic intrusions are classified as having moderate potential (3) for volcanogenic massive sulphide deposits and porphyry systems respectively. Syntectonic intrusions are assigned low mineral potential (4). Deep emplacement and lack of differentiation make them unfavourable exploration targets.

SUMMARY AND RECOMMENDATIONS

For 120 years the South Moresby Planning Area has experienced varying intensities of mineral exploration and production of ore. Prior to 1980 most of the mineral exploration concentrated on searching for contact metasomatic (copper, iron, gold, and silver) deposits. Exploration for these kinds of deposits has reached a mature stage, as attested by the number of known properties in this geologic environment. Even now, considerable scope exists for expanding known reserves. In the early 1960's more than $1 million was spent exploring for such deposits in the Skincuttle Inlet area and culminated in the mining of the Jedway iron deposit. It is probable that producers will develop new mines from these kinds of deposits on southern Moresby Island or Burnaby Island in the future. Geologic environments which may host contact metasomatic deposits should, therefore, be protected from alienation.

Discovery of Cinola (gold) deposit on Graham Island stimulated exploration in similar geological environments in the planning area. Work is in its initial stages but results obtained to date in areas such as Lyell Island, have proved encouraging. Exploration in the near future will likely be focused on areas close to the major fault systems that extend southeasterly through the length of the planning area.

The South Moresby Planning Area program presented a major resource planning challenge. Many areas of high mineral potential and undeveloped deposits coincide with areas of high scenic, ecological, and core recreation potential. The main thrust of this Ministry's involvement has been to document resource values, analyse conflicts with other resources, and ensure that mineral resources are fully considered in the range of options presented for a decision.

REFERENCES

Barr, D. A. (1980): Gold in the Canadian Cordillera, *C.I.M.*, Bull., Vol. 73, No. 18, pp. 59-76.

B.C. Ministry of Energy, Mines & Pet. Res., Assessment Repts. 271, 3131, 3271, 3319, 3427, 3507, 3948, 3949, 5357, 5719, 7156, 7574, 8295, 8682, 9231; Revised Mineral Inventory Map 93A (MI), Quesnel Lake.

Belik, G. C. (1981): Geological and Geochemical Report on the Frasergold Property, Cariboo Mining Division, British Columbia, 93A/7E, Keron Holdings Ltd., *B.C. Ministry of Energy, Mines & Pet. Res.,* Assessment Rept. 9751.

Campbell, R. B. (1963): Geology, Quesnel Lake (East Half), British Columbia, *Geol. Surv., Canada,* Map 1-1963.

Campbell, R. B., Mountjoy, E. W., and Young, F. G. (1973): Geology of McBride Map-Area, British Columbia, *Geol. Surv., Canada,* Paper 72-35.

Campbell, R. B. and Tipper, H. W. (1971): Geology of Bonaparte Lake Map-Area, British Columbia, *Geol. Surv., Canada,* Mem. 363.

Chevalier, A. (1981): Assessment Report on the Rock Sampling Survey of the Three Mineral Claim Groups in the Eureka Property, Cariboo Mining Division, 93A/7, Umex Inc., *B.C. Ministry of Energy, Mines & Pet. Res.*, Assessment Rept. 9786.

Davis, N.F.G. (1930): Clearwater Lake Area, British Columbia, *Geol. Surv., Canada*, Summ. Rept., 1929, Pt. A, pp. 274A-296A.

Fahrni, K. C. (1961): Exploration and Reserves, Jedway Iron-Ore Ltd., Harriet Harbour, Queen Charlotte Island, unpub. rept., 9 pp. and maps.

Govett, G.J.S. (1961): Occurrence and Stratigraphy of Some Gypsum and Anhydrite Deposits in Alberta, *Research Council, Alberta*, Bull. 7.

Heffernan, K. J. (1980): Report on Geological Mapping, Sampling and Drilling, WAPITI 1-25 Claims, Liard Mining Division, *B.C. Ministry of Energy, Mines & Pet. Res.*, Assessment Rept. 8407.

Holland, S. S. (1964): Landforms of British Columbia, A Physiographic Outline, *B.C. Ministry of Energy, Mines & Pet. Res.*, Bull. 48.

MacIntyre, D. G. (1982): Geologic Setting of Recently Discovered Stratiform Barite-Sulphide Deposits in Northeast British Columbia, *C.I.M.*, Bull., Vol. 75, No. 840, pp. 99-113.

Macqueen, R. W. and Thompson, R. I. (1978): Carbonate-Hosted Lead-Zinc Occurrences in Northeastern British Columbia with Emphasis on the Robb Lake Deposit, *Cdn. Jour. Earth Sci.*, Vol. 15, No. 11, pp. 1737-1762.

Mellin, R. G. (1930): Report on the Clearwater Mica Mine, *B.C. Ministry of Energy, Mines & Pet. Res.*

Northcote, K. E. (1981): Mineral and Exploration Potential, Moresby Island and Adjacent Islands, Queen Charlotte Islands, British Columbia, *Bema Industries Ltd.*

.... (1982a): Mineral Resources and Potential of the Chilko Lake Deferred Planning Area, *B.C. Ministry of Energy, Mines & Pet. Res.*, Tech. Rept., 21 pp.

.... (1982b): Mineral Resources and Potential of the Kakwa Lake Deferred Area Plan, *B.C. Ministry of Energy, Mines & Pet. Res.*, Tech. Rept., 16 pp.

.... (1982c): Flourmills Deferred Planning Area, *B.C. Ministry of Energy, Mines & Pet. Res.*, Tech. Rept., 16 pp.

Rickard, D. T., Willden, M. Y., Marinder, N. E., and Donnelly, T. H. (1979): Studies on the Genesis of the Laisvall Sandstone Lead-Zinc Deposit, Sweden, *Econ. Geol.*, Vol. 74, pp. 1255-1285.

Seraphim, R. W. and Rainboth, W. (1976): Poison Mountain, *in* Porphyry Deposits of the Canadian Cordillera, *C.I.M.*, Special Vol. 15, pp. 323-328.

Sutherland Brown, A. (1968): Geology of the Queen Charlotte Islands, *B.C. Ministry of Energy, Mines & Pet. Res.*, Bull. 54.

Taylor, F. G. and Stott, D. F. (1979): Geology of Monkman Pass (93I), Map-Area, Northeastern British Columbia, *Geol. Surv., Canada*, Open File Map 630.

Tipper, H. W. (1969): Mount Waddington, *Geol. Surv., Canada,* Paper 68-33.

.... (1978): Taseko Lakes (92O) Map-Area, *Geol. Surv., Canada,* Map 534.

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

Woodsworth, G. J. (1977): Pemberton (92J) Map-Area, *Geol. Surv., Canada,* Open File 482.

Young, F. G. (1978): The Lowermost Paleozoic McNaughton Formation and Equivalent Cariboo Group of Eastern British Columbia, Piedmont and Tidal Complex, *Geol. Surv., Canada,* Bull. 288.

SILVER-GOLD ZONATION IN THE LASS VEIN SYSTEM, BEAVERDELL CAMP, SOUTH-CENTRAL BRITISH COLUMBIA (82E/6E)

By P. H. Watson
Indian and Northern Affairs Canada, Whitehorse, Yukon Territory
and
C. I. Godwin
Department of Geological Sciences, The University of British Columbia

INTRODUCTION

The Beaverdell silver, lead, zinc (gold) vein camp (Fig. 78), in the southern part of the Omineca Crystalline Belt in south-central British Columbia, has been a silver producer since the turn of the century. In recent years some gold has been reported in the eastern, and deeper, end of the Lass vein system (Lower Lass mine; B. Goetting, personal communication, 1979). This study was initiated to examine the distribution of major and minor elements in the Upper (Highland) Lass and Lower Lass vein system and to describe the zoning patterns, with emphasis on the economically important gold and silver.

The area is underlain by granodiorite of the Westkettle batholith, which has been intruded by the Beaverdell quartz monzonite stock (Fig. 78). The granodiorite contains remnant pendants and/or screens of metamorphosed volcanic and sedimentary rocks of the Wallace Formation (Reinecke, 1915; Christopher, 1975a, 1975b, 1976). A detailed summary of the geology is given by Watson (1981) and Watson, *et al.* (1982).

GEOLOGY

Mineralization is found in a northeast-trending 3-kilometre by 0.8-kilometre belt, referred to as the Beaverdell mine area, on the west slope of Wallace Mountain (Kidd and Perry, 1958). From west to east, the major producing mines were: Wellington, Sally, Bell, Highland Lass (Upper Lass), and Lower Lass (Fig. 78). The Upper and Lower Lass mines are presently being operated by Teck Corporation Ltd., and the samples collected for this study are from these and related workings.

Most of the veins are hosted in the Jurassic Westkettle granodiorite. Some mineralization is also found in the older Permian (?) Wallace Formation gneissic rocks, which overlie the batholith at the eastern end of the mine area, although structures tend to horsetail and disperse in these gneisses (Goetting, personal communication, 1979). Despite the apparent lack of mineralization in the younger, Tertiary, Beaverdell stock, which intrudes the batholith at the western end of the complexly faulted mine area, K/Ar and galena-lead isotope studies demonstrate that the veins are genetically related to the Beaverdell stock (Watson, 1981; Watson, *et al.*, 1982). Propylitic alteration is found in the wallrock up to 8 metres from the veins (R. Verzosa, personal communication, 1979) and thin sections of this altered granodiorite show amphiboles almost entirely converted to chlorite, and feldspars replaced by clay and calcite.

The mineralized veins occupy fissures along east-trending faults in the western part of the mine area and along northeast-trending faults in the eastern portion of the system (part of Bell, Upper Lass, and Lower Lass). Veins range from a few centimetres to a metre in width, and average 0.3 metres (White, 1949) but are rarely continuous for more than 5 to 10 metres without offset. However some ore shoots show only minor offset over horizontal distances up to 150 metres (White, 1949). The extensive faulting has been classified by White (1949). The most important type of post-ore faulting is high angle and normal. A series of widely spaced, north to northeast-striking, southeast-dipping faults divide the mineralized system into large blocks, often with up to 100 metres of vertical displacement between them. The West Terminal fault, separating the Bell and Lass mines, and the East Terminal fault, separating the Upper and Lower Lass mines, are of this type (Figs. 78 and 79). The veins are chopped into small segments by northeast-striking, closely spaced normal faults, which flatten the dip of the vein from 50 to 34 degrees (White, 1949). These faults dip to the northwest, and generally show less than a metre displacement.

Major metallic minerals in the veins are galena, sphalerite, and pyrite, with lesser amounts of arsenopyrite, tetrahedrite, pyrargyrite, chalcopyrite, polybasite, acanthite, native silver, and pyrrhotite (Reinecke, 1915; Staples and Warren, 1946a, 1946b; Watson, 1981; Watson, *et al.*, 1982). The gangue material is mainly quartz, with some altered wallrock fragments included in the vein; small concentrations of calcite and fluorite are also found occasionally. Some supergene silver mineralization is present, chiefly as native silver wires and plates. However, most of the mineralization is of hypogene origin (McKinstry, 1928; Staples and Warren, 1946a, 1946b). Supergene material is not considered in this study.

DATA COLLECTION AND ANALYSIS

Bulk chip and hand samples of vein material within the granodiorite were collected from 209 locations in the Lass system (Fig. 79). A systematic sample spacing was not possible due to vein geometry, so vein material was chip sampled wherever accessible in the workings. Samples from mined-out areas were taken from the edges of ore shoots.

Samples were analysed by atomic absorption spectrophotometry at the Department of Geological Sciences, The University of British Columbia for zinc, lead, iron, copper, cadmium, silver, calcium, magnesium, manganese, cobalt, and nickel. Gold, arsenic, mercury, and antimony were analysed for by Min-En Laboratories Ltd., North Vancouver, British Columbia. Results are in Table 1. Duplicate analyses of samples were evaluated using the method of Thompson and Howarth (1978). The following indicate the precisions for each element (at average concentrations) determined by this method: (1) between 5 and 10 per cent: copper, cadmium, antimony, arsenic, and manganese; (2) between 10 and 20 per cent: zinc, lead, calcium, and magnesium; (3) between 20 and 30 per cent: silver; and (4) between 40 and 45 per cent, gold. Precision for elements estimated as the mean relative error rather than as a function of concentration as in the Thompson and Howarth method are: nickel, 10 per cent; iron, 35 per cent; cobalt, 38 per cent; and mercury, 120 per cent.

The true spatial relationship between samples at the time of emplacement cannot be seen using the mine plan view because of post-ore faulting. Therefore, the veins were palinspastically reconstructed by removing the movement along major faults. Since most mining was carried out on the fault-bounded segments of the vein, the ore encountered along a drift could represent either a series of parallel veins or progressively lower sections of the same vein. Within the fault-bounded, major sections, therefore, it is assumed that successive samples represent a general continuation of the major vein system, down dip. This reconstructed plane may be up to 100 metres thick in some areas, because not all movement has been removed and the mineralization probably occurs within a series of subparallel veins. In this study, however, this plane is considered to represent a single vein, or a series of veins for which an overall zoning pattern can be examined. Figure 79 shows the sample locations on the composite plan of the workings. The reconstructed plans, used for all subsequent interpretations, are shown on Figures 80 to 84. Changes in element content down the dip of the vein can be examined by projecting all points onto an east-west line (approximately down dip), and plotting value versus distance along this line. These plots, called section plots, are shown with reconstructed plans on Figures 80, 81, and 84.

INTERPRETATION AND DISCUSSION

Histograms show that all elements have lognormal distributions. Nickel and cobalt are often not present in detectable quantities and will not be considered further. Poor reproducibility for mercury analyses makes their use suspect, but mercury will be discussed because of its importance in many ore-forming environments.

Each element can be partitioned into populations using lognormal probability plots as outlined in Sinclair (1976). Three populations can be defined for silver and lead, and one for mercury and calcium. All other elements can be partitioned into two populations. The means, standard deviations, and population proportions are listed in Table 2. In this table elements are grouped on the relative proportions of anomalous population (A) and background populations (B and B'). The lower two silver populations show a split similar to zinc and cadmium, while the most anomalous population is proportionately similar to copper and arsenic. This suggests that the most anomalous silver values may be associated with copper and arsenic minerals such as sulphosalts, while the moderately anomalous concentrations of silver are associated with base metal minerals such as galena and sphalerite. Gold does not have population proportions similar to any other elements (Table 2). It is possible that only one gold population is present and that the 10 per cent background population represents a bottom truncation of the data due to the detection limits of the analytical equipment used (Sinclair, 1976), rather than a second population.

Correlations are generally only applicable to single population variables. The large amount of overlap (estimated 30 to 70 per cent) among populations for most of the elements, however, allows the use of correlations to show approximate relationships. A correlation matrix of log transformed data (Table 3) shows strong correlations at the 0.1 significance level between the elements zinc, lead, iron, copper, cadmium, silver, gold, and antimony. The gangue elements, manganese, magnesium, and calcium, show strong correlations with each other. Calcium shows negative correlations with silver and arsenic, while magnesium correlates negatively with copper, antimony, arsenic, and gold. Ranked on strength of correlation, silver correlates with lead, zinc, copper, iron, antimony, gold, cadmium, and arsenic. For gold, the strongly correlated elements are, in order: iron, lead, zinc, copper, cadmium, antimony, arsenic, and silver. This suggests that silver is associated with galena and sphalerite and, to a lesser extent, with antimony sulphosalts. Gold correlates most strongly with iron minerals, followed by the major sulphides, galena and sphalerite. Thus, gold is primarily associated with pyrite and/or chalcopyrite; arsenic and antimony minerals, while significant, appear to be less important. Correlations for the three indicator elements, mercury, arsenic, and antimony are: (1) mercury correlates with antimony, copper, zinc, lead, and cadmium; (2) arsenic correlates with antimony, gold, iron, silver, and lead; and (3) antimony correlates with iron, lead, copper, zinc, gold, mercury, arsenic, cadmium, and silver. From this, it appears that antimony is the most dominant of these three indicator elements. Because much of the correlation matrix simply shows the affinity of all the sulphides for each other, some correlations would be expected even if the minerals they represent were not contemporaneous. Antimony, however, seems to correlate with all ore-forming elements and was a more significant element than arsenic in the vein-forming solutions. Detailed studies of the mineralogy (Staples and Warren, 1946a, 1946b; McKinstry, 1928) show that pyrargyrite and tetrahedrite (antimony end members) are the common forms of their respective solid solution series in this vein system. Arsenopyrite probably formed earlier than other ore minerals such as galena and sphalerite (Watson, 1981).

Spatial relationships among populations can be seen when the assay values (Table 1) are computer-drawn, using different symbols for background and anomalous values, on the reconstructed plan and section plots of Figures 80 to 84. Anomalous values for silver occur mainly in the central, western portion of the mine. By comparison, the 10 per cent of the values which form the background population for gold lie mainly in the western part of the mine (Figs. 81 and 83).

Differences in values between the upper, western and lower, eastern parts of the mine are clear on Figures 82 and 83. The highest values (approximately one-quarter of the sample points) for zinc, lead, and gold are in the eastern part of the vein system. Plan and section plots on Figure 84 show that ratios of gold to silver are dramatically different in the two parts of the vein system; 17 of the highest 20 values for gold/silver are in the eastern section, and the highest 50 values for silver/gold are in the western part of the mine.

The two segments, defined previously, were split into two equal sections (based on distance down dip) to see if smaller subdivisions in the zoning pattern were present. Means, with standard errors, for the four subdivisions are plotted on Figure 85 along with the same statistics using only two subdivisions of the vein. Three of the four elements (lead, silver, and gold) show level sections and sharp changes indicating that values within each of the two major sections are similar, but that major changes occur between the two sections. Thus, Figure 85 is consistent with only two major zones in the mine.

A north-trending line between high silver, moderate lead and zinc in the west, and low silver, high gold, and moderate to high lead and zinc in the east is drawn on Figures 80 to 85. This line is placed near the central part of the mine, about 120 metres east of the East Terminal fault. Figure 86 summarizes the changes across the line as noted above or as detailed in fluid inclusion, mineralogy, and geometry studies by Watson (1981).

Because of the difference in the number of samples on either side of this dividing line ($N = 159$ to the west and $N = 42$ to the east), t-tests and F-tests were performed to determine if, indeed, the two populations are significantly different ($\alpha = 0.05$). The following elements (logrithmic) have significantly different geometric means (t-test) and variances (F-test) in the two parts of the mine: gold, zinc, lead, cadmium, and mercury. Vein thickness (arithmetic) also has significantly different means and variances on either side of the dividing line. Gold, zinc, lead, cadmium, and vein thickness means are higher in the eastern part of the mine while silver and mercury means are higher in the west.

CONCLUSIONS

The presence of silver-gold zonation in the Lass vein system has been known to exist for several years (B. Goetting, personal communication, 1979; Christopher, 1975a, 1975b). This study has examined the major and minor element distribution patterns in samples from the Lass vein system hosted in the Westkettle granodiorite. The vein system was palinspastically reconstructed into a single plane by removing the movement along major post-ore faults to examine the original element zoning. Fifteen elements have been studied (zinc, lead, copper, iron, manganese, cadmium, calcium, magnesium, cobalt, nickel, gold, silver, mercury, arsenic, and antimony), all of which can be partitioned into 1, 2, or 3 lognormally distributed populations. The correlation matrix of elements indicates that silver associates with galena, sphalerite, and antimony sulphosalts, but that gold associates with pyrite and chalcopyrite.

The four major economic elements, zinc, lead, silver, and gold, have been considered in detail. Plan views show a series of ore shoots, elongate along strike, *en echelon* down the dip, in the upper part of the vein system. Metal zoning and mineral deposition are related to depth and reflect changes in temperature or vein configuration at specific elevations.

Two zones of distinctive mineralization are recognized in the Lass vein system. The boundary between these two zones trends north-south and lies within the Lower Lass mine, about 120 metres east of the East Terminal fault. In contrast to the lower, eastern part, the upper, western portion of the vein system is characterized by high silver and moderate zinc and lead values, more gangue, and thinner veins within multiple vein and stringer zones. The lower, east end of the vein system, however, contains high gold, moderate to high zinc and lead, and low silver values. The elements copper, calcium, magnesium, and arsenic show consistent values throughout the mine.

Gold values are concentrated at depth and in several small zones along the footwall of the system. Silver values are highest in the upper parts of the system, centrally between the footwalls and hangingwalls. Using information from a fluid inclusion study (Watson, 1981), the gold mineralization can be related to solutions of higher temperature, salinity, and pressure. This model postulates that groundwater mixing occurred above a throttling point, resulting in lower temperature, lower salinity, and lower pressure solutions that deposited the silver mineralization. A model for element zonation in this system, based in part on the fluid inclusion studies, is shown on Figure 86. This model accounts for: (1) the presence of only two zones (above and below the throttle point), and (2) the variations in thickness, gangue, and mineralogy due to temperature, pressure, and salinity changes. Deposition of copper, calcium, magnesium, and arsenic was apparently not affected by the changes occurring in the ore fluids. Gold solubilities, however, are greatly affected by these variations (Helgeson and Garrels, 1968), so the deposition of gold would decrease after the solutions have passed the throttle point.

This model suggests that high gold values could continue eastward at depth, given continuation of vein structures. Silver values would probably also continue to the east at their moderate to low values.

Additional areas of high silver values are unlikely east of the present workings and at depth in the system and will only be found in those areas that were above the throttle point (in the western part of the mine).

ACKNOWLEDGMENTS

The writers thank Teck Corporation for financial support for this work. B. Goetting, B. Bergey, R. Verzoza, the staff at the Beaverdell operation, P. Christopher, and A. Sinclair helped in this study. Shen Kun, visiting scholar from China, did much of the excellent polished section and fluid inclusion work referred to in this paper. J. Newlands did most of the draughting.

REFERENCES

Christopher, P. A. (1975a): Highland Bell (Beaverdell) Mine (82E/6E), *B.C. Ministry of Energy, Mines & Pet. Res.*, Geology, 1975, pp. G30-G33.

.... (1975b): Carmi-Beaverdell Area (82E/6, 11), *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1974, Paper 1975-1, pp. 27-31.

.... (1976): Beaverdell Area (82E/6E), *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1975, Paper 1976-1, p. 15.

Helgeson, H. C. and Garrels, R. M. (1968): Hydrothermal Transport and Deposition of Gold, *Econ. Geol.*, Vol. 63, pp. 622-635.

Kidd, D. F. and Perry, O. S. (1958): Beaverdell Camp, B.C., in *Structural Geology of Canadian Ore Deposits, Vol. II, 6th Commonwealth and Metallurgical Congress, Canada, 1957, C.I.M.*, pp. 136-141.

McKinstry, H. E. (1928): Silver Mineralization at Beaverdell, British Columbia, *Econ. Geol.*, Vol. 23, pp. 434-441.

Reinecke, L. (1915): Ore Deposits of the Beaverdell Map Area, *Geol. Surv., Canada,* Mem. 79, 178 pp.

Sinclair, A. J. (1976): Applications of Probability Graphs in Mineral Exploration, *Assoc. Explor. Geochem.*, Special Vol. 4.

Staples, A. B. and Warren, H. V. (1946a): Minerals from the Highland-Bell Silver Mine, Beaverdell, British Columbia, *University of Toronto,* Geol. Ser. 50, pp. 27-33.

Staples, A. B. and Warren, H. V. (1946b): Mineralogy of the Ores of the Highland-Bell Mine, *Western Miner,* Vol. 19, May, 1946, pp. 38-43 and June, 1946, pp. 54-58.

Thompson, M. and Howarth, R. J. (1978): A New Approach to the Estimation of Analytical Precision, *Jour. Geochem. Expl.*, Vol. 9, pp. 23-30.

Watson, P. H. (1981): Genesis and Zoning of Silver-Gold Veins in the Beaverdell Area, South-Central British Columbia, M.Sc. thesis, *University of British Columbia,* 156 pp.

Watson, P. H., Godwin, C. I., and Christopher, P. A. (1982): General Geology and Genesis of Silver and Gold Veins in the Beaverdell Area, South-Central British Columbia, *Cdn. Jour. Earth Sci.,* Vol. 19, No. 6, pp. 1264-1274.

White, W. H. (1949): Beaverdell, *B.C. Ministry of Energy, Mines & Pet. Res.,* Ann. Rept., 1949, pp. 138-148.

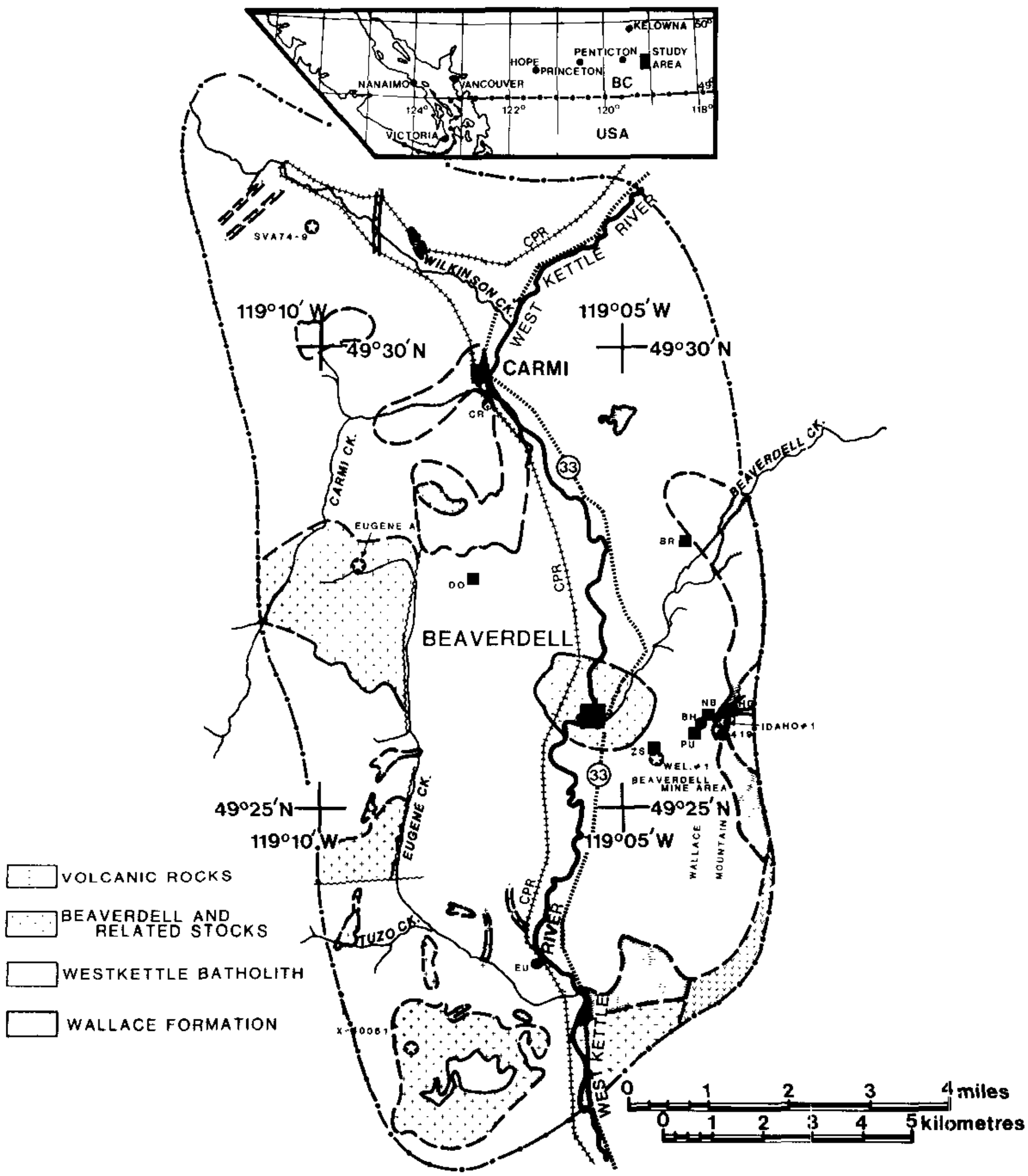


Figure 78. Regional geology with locations of major mines in the Beaverdell mine area, south-central British Columbia. Modified from Reinecke, 1915 and Christopher, 1975a, 1975b, and 1976.

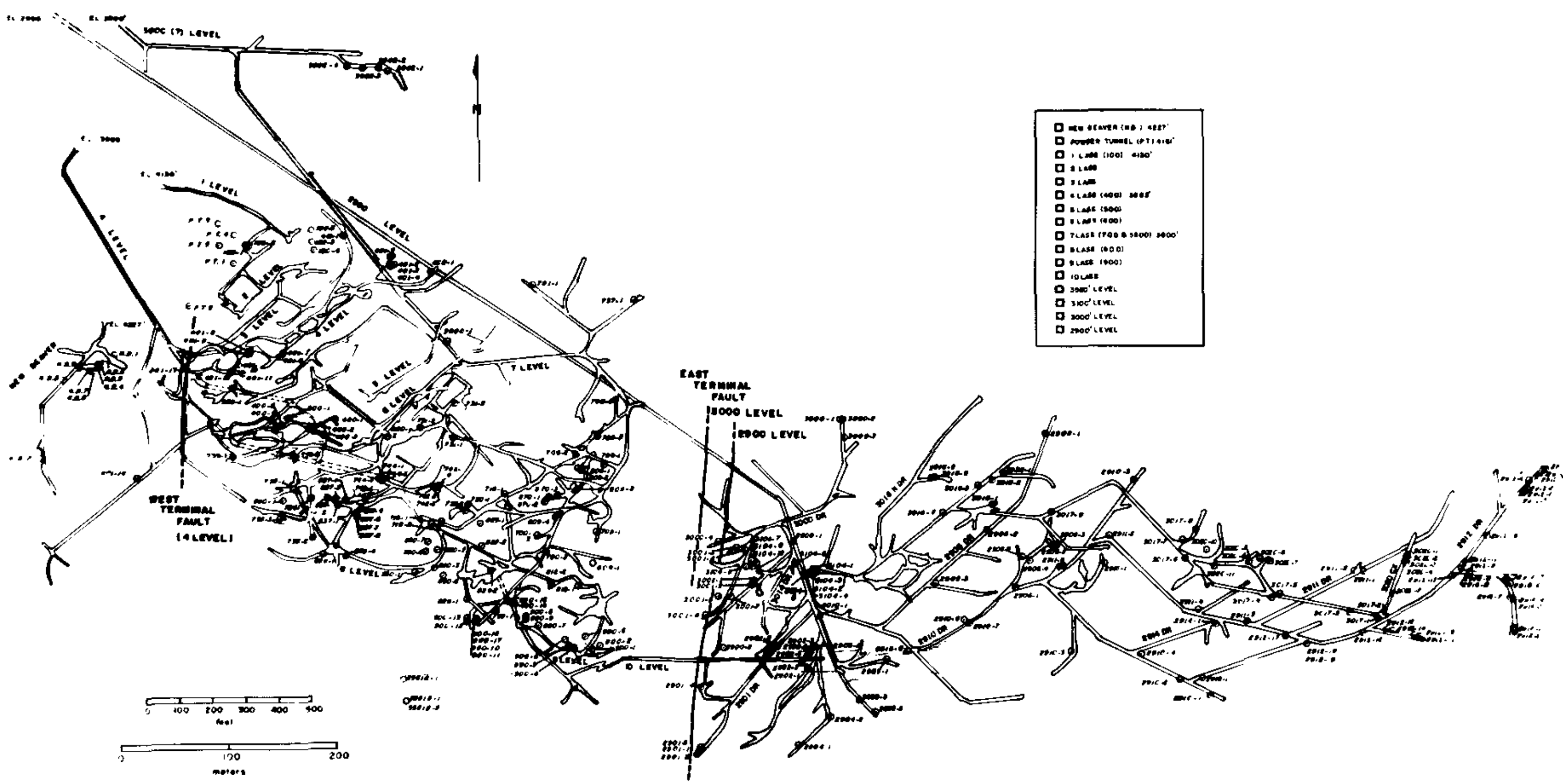


Figure 79. Sample locations (data in Table 1) on the composite plan view of the Upper and Lower Lass vein system, Beaverdell area. Mine drifts, stopes, and the West and East Terminal faults are located.

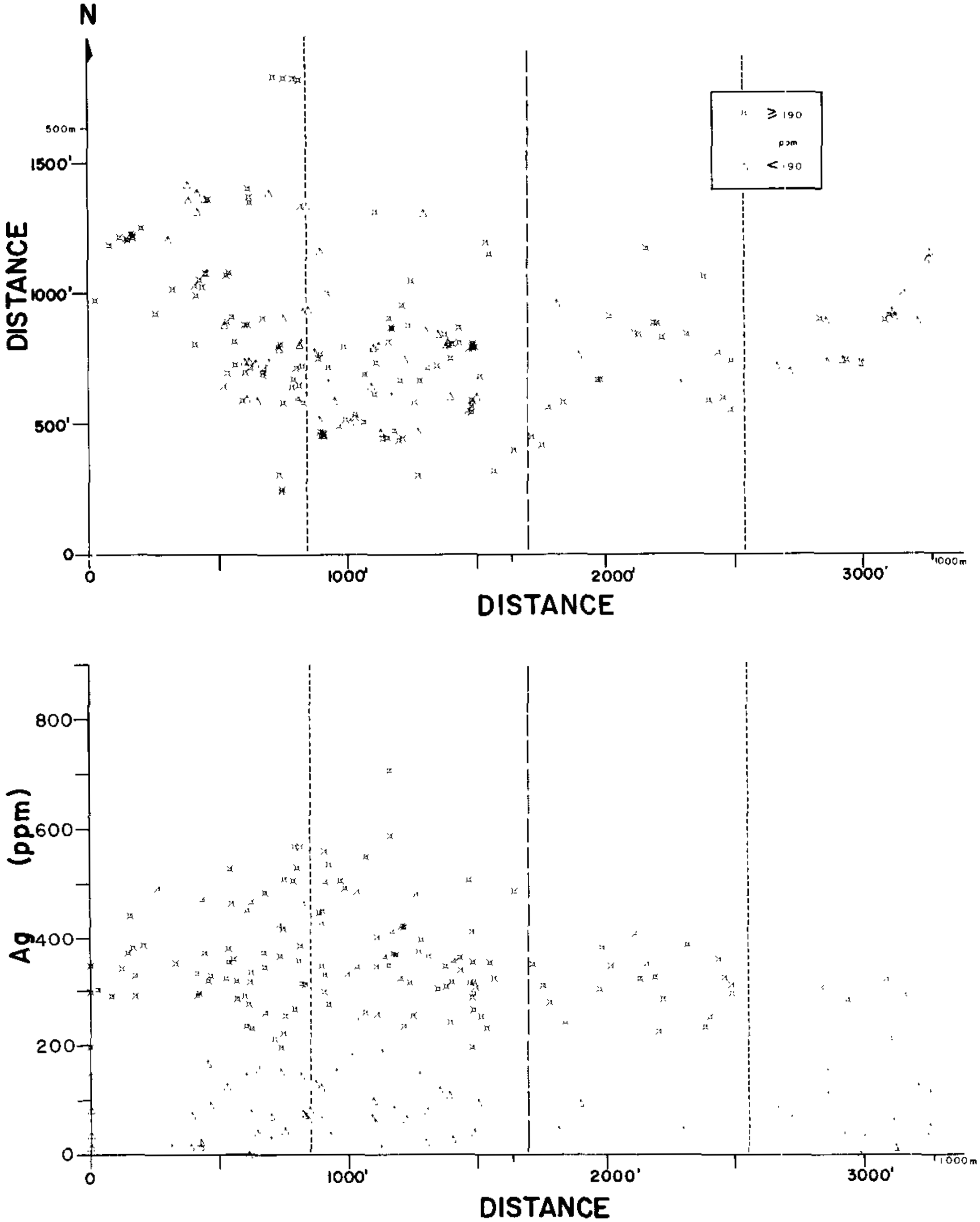


Figure 80. Reconstructed plan and 'section' plot of the Lass vein system, Beaverdell mine area. Silver analyses are separated into background and anomalous populations as noted in the legend. Long dashed line marks the boundary between the silver and gold-rich sections of the mine, and short dashed lines indicate the divisions for calculations of four-way means (see Fig. 85).

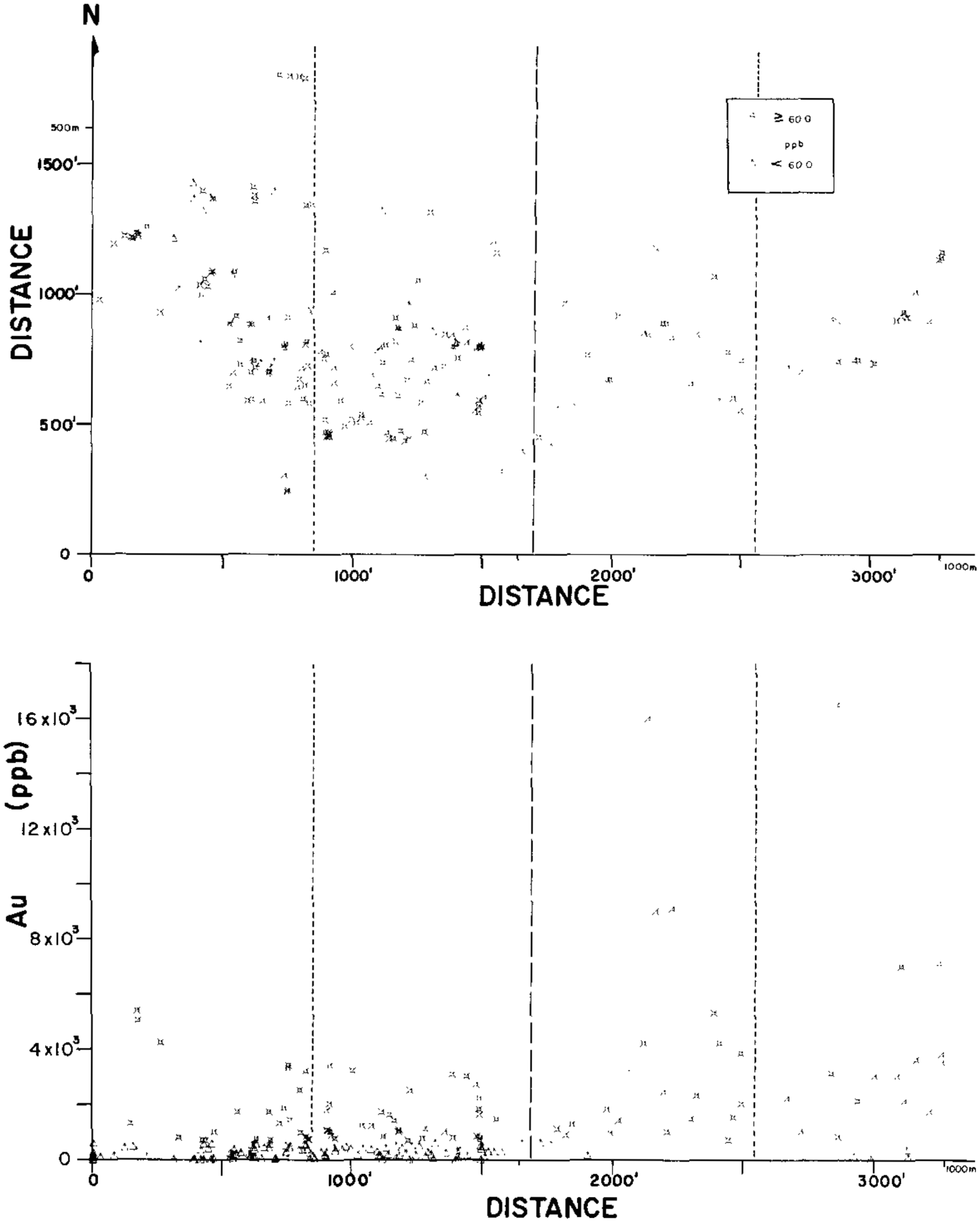


Figure 81. Reconstructed plan and 'section' plot of the Lass vein system, Beaverdell mine area. Gold analyses are separated into background and anomalous populations as noted in the legend. Long dashed line marks the boundary between the silver and gold-rich sections of the mine, and short dashed lines indicate the divisions for calculations of four-way means (see Fig. 85).

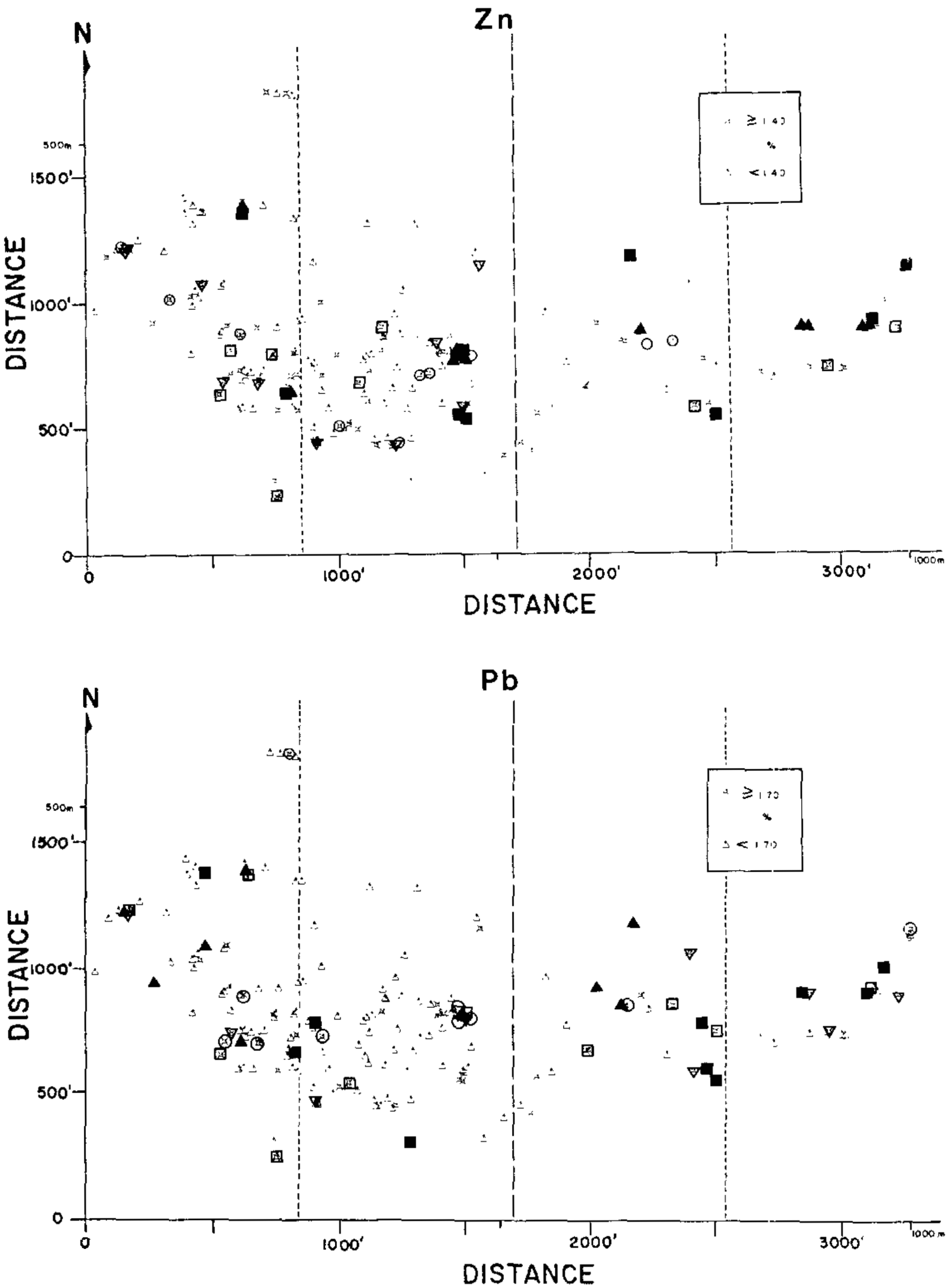


Figure 82. Reconstructed plans of the Lass vein system, Beaverdell mine area. The highest 50 analyses for zinc (top) and lead (bottom) are plotted using the following: solid square, first 10; solid triangle, second 10; open square, third 10; open triangle, fourth 10; and open circle, fifth 10.

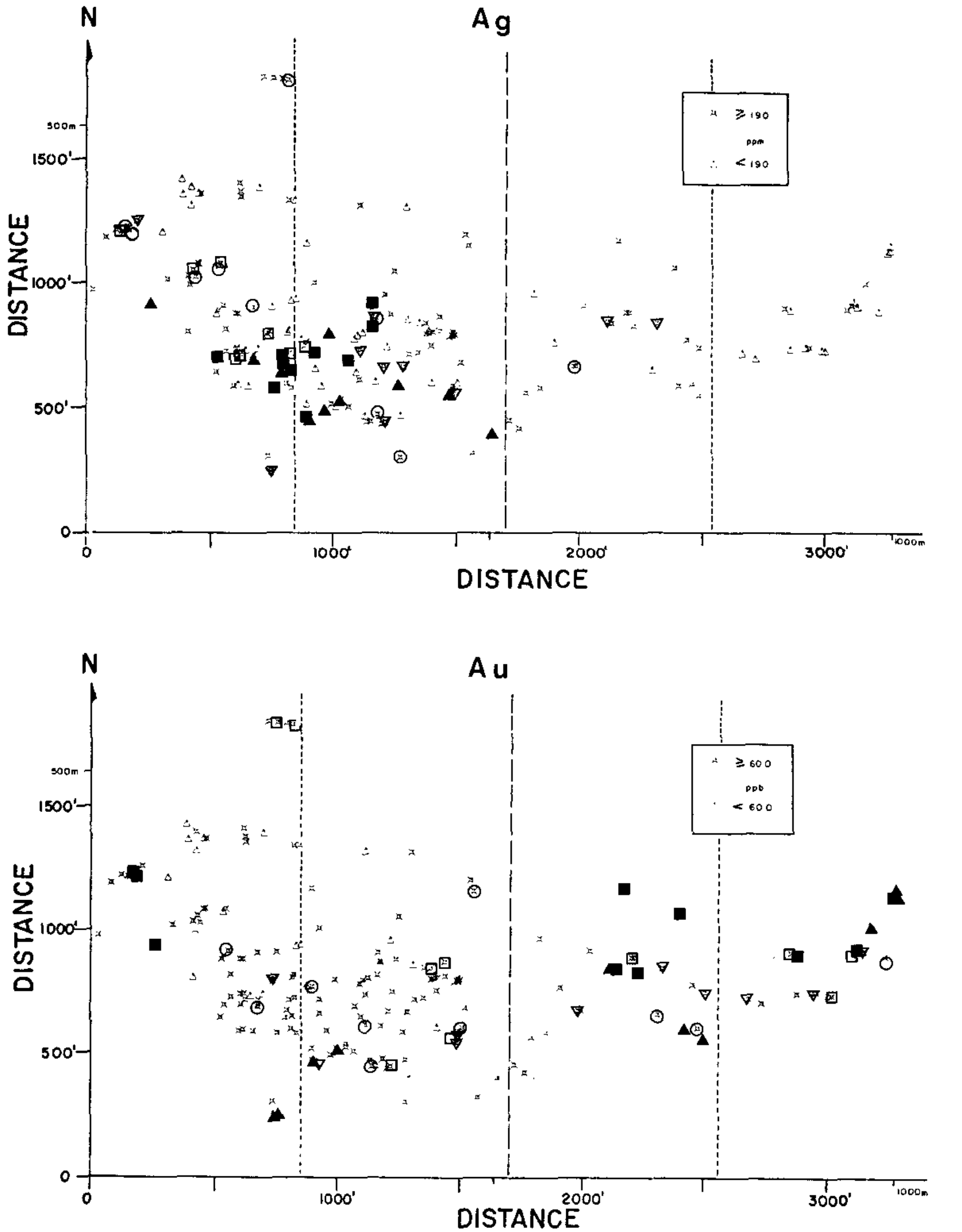
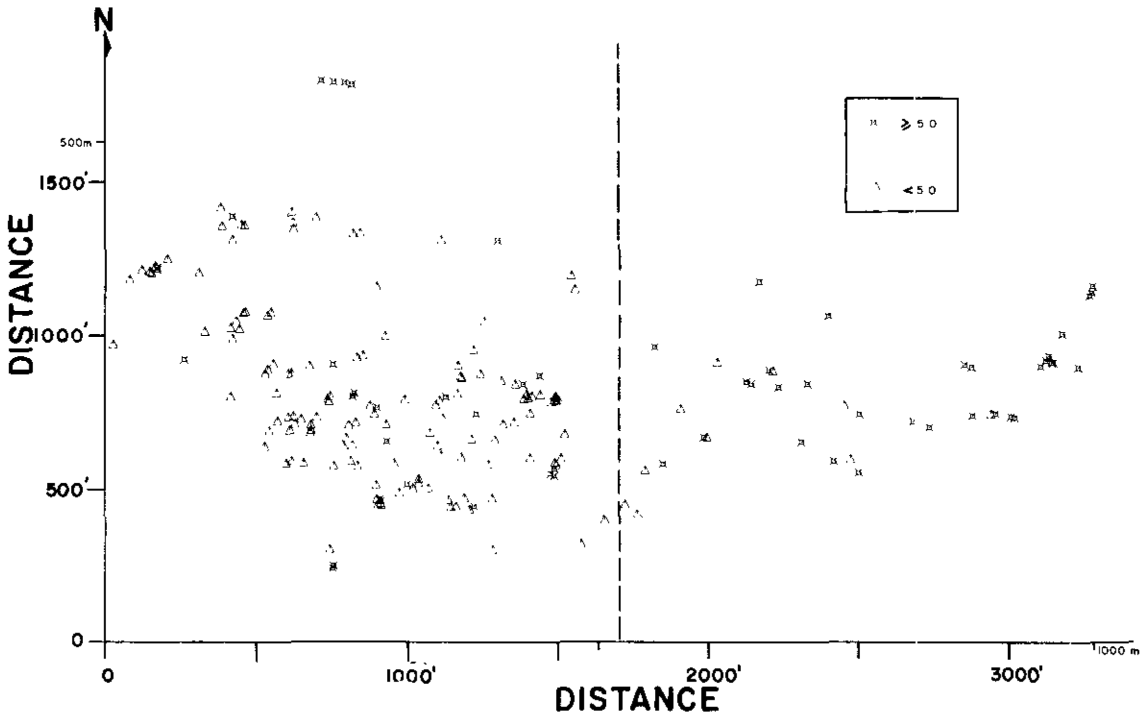


Figure 83. Reconstructed plans of the Lass vein system, Beaverdell mine area. The highest 50 analyses for silver (top) and gold (bottom) are plotted using the following: solid square, first 10; solid triangle, second 10; open square, third 10; open triangle, fourth 10; and open circle, fifth 10.



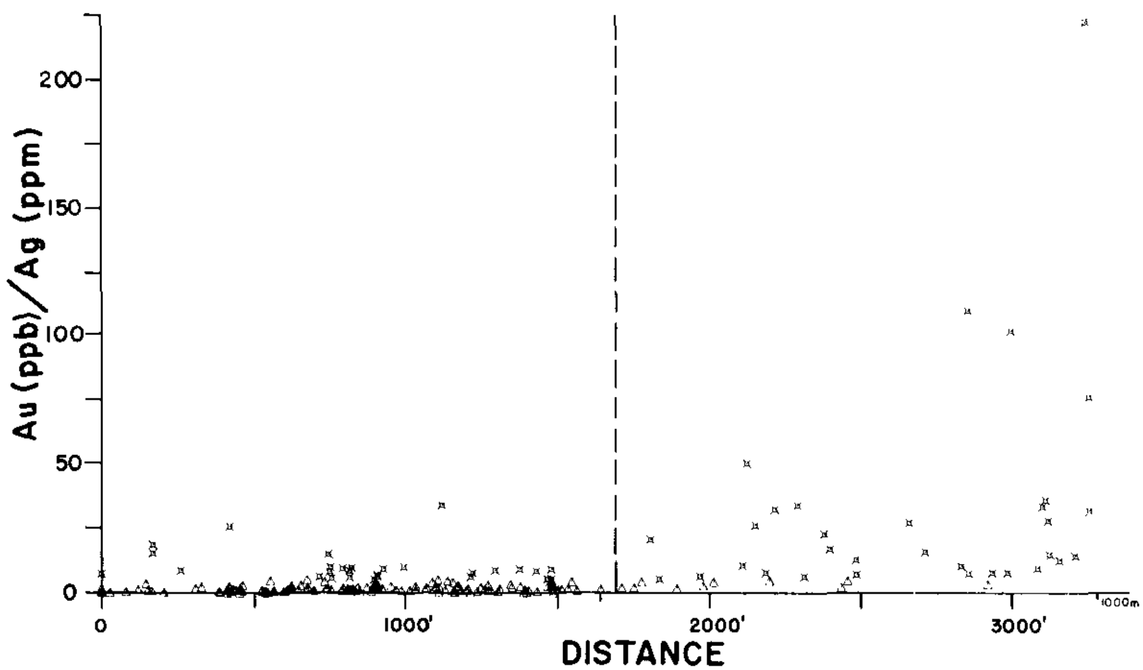


Figure 84. Reconstructed plan and 'section' plot of the Lass vein system, Beaverdell mine area. Gold (ppb)/Silver (ppm) values are separated into two populations, above and below a ratio of 5. Long dashed line marks the boundary between silver and gold-rich sections of the mine.

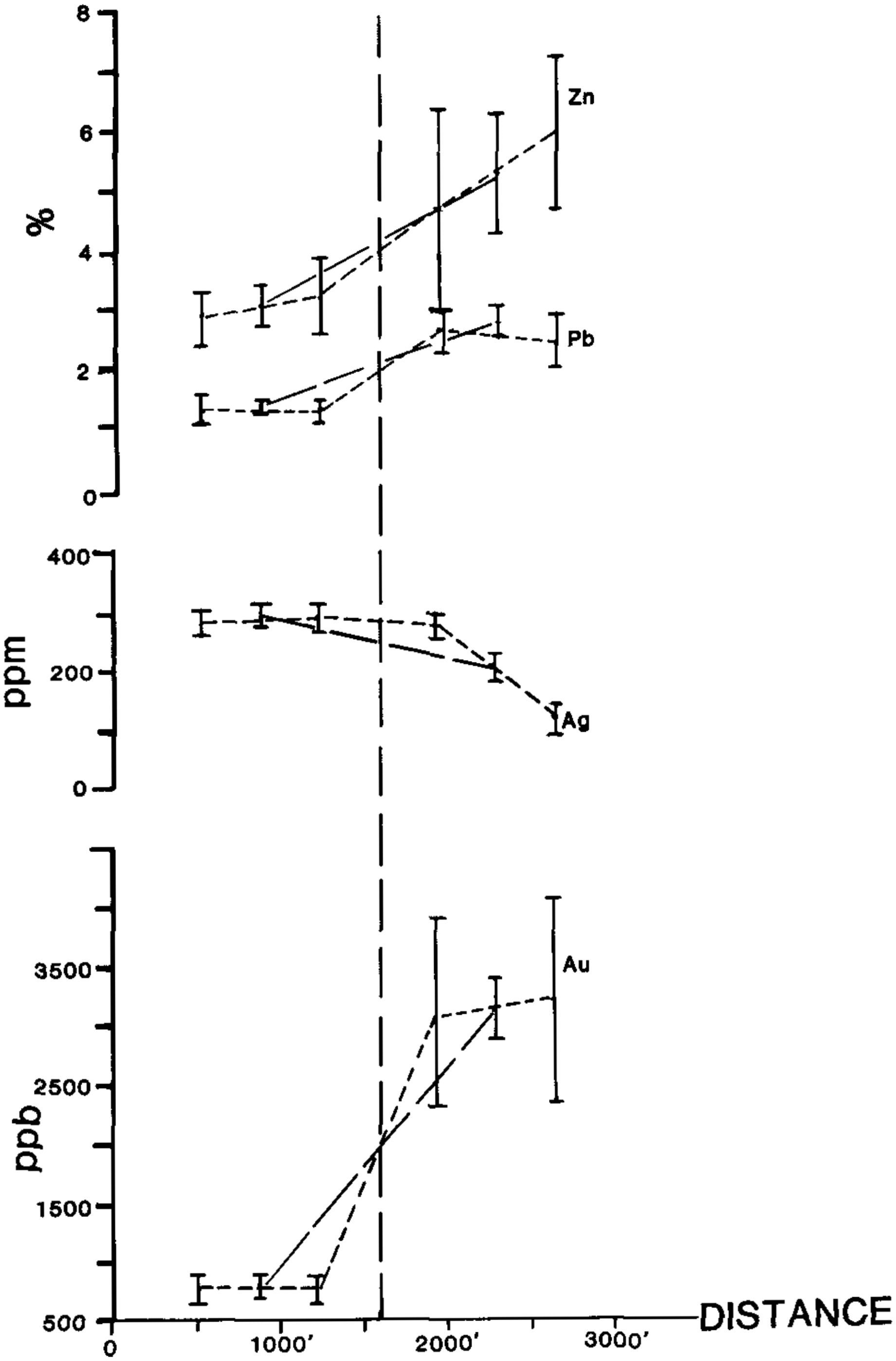


Figure 85. Plot of arithmetic means and standard errors of the mean for gold, silver, lead, and zinc, after division of the Lass vein system, Beaverdell area, into two and four sections (see Figs. 81 to 84). Left-hand side of the plot is uppermost, western section of the vein system; the right-hand side is down dip, deepest, and easternmost section of the mine. Distance is measured along the reconstructed plane of the vein.

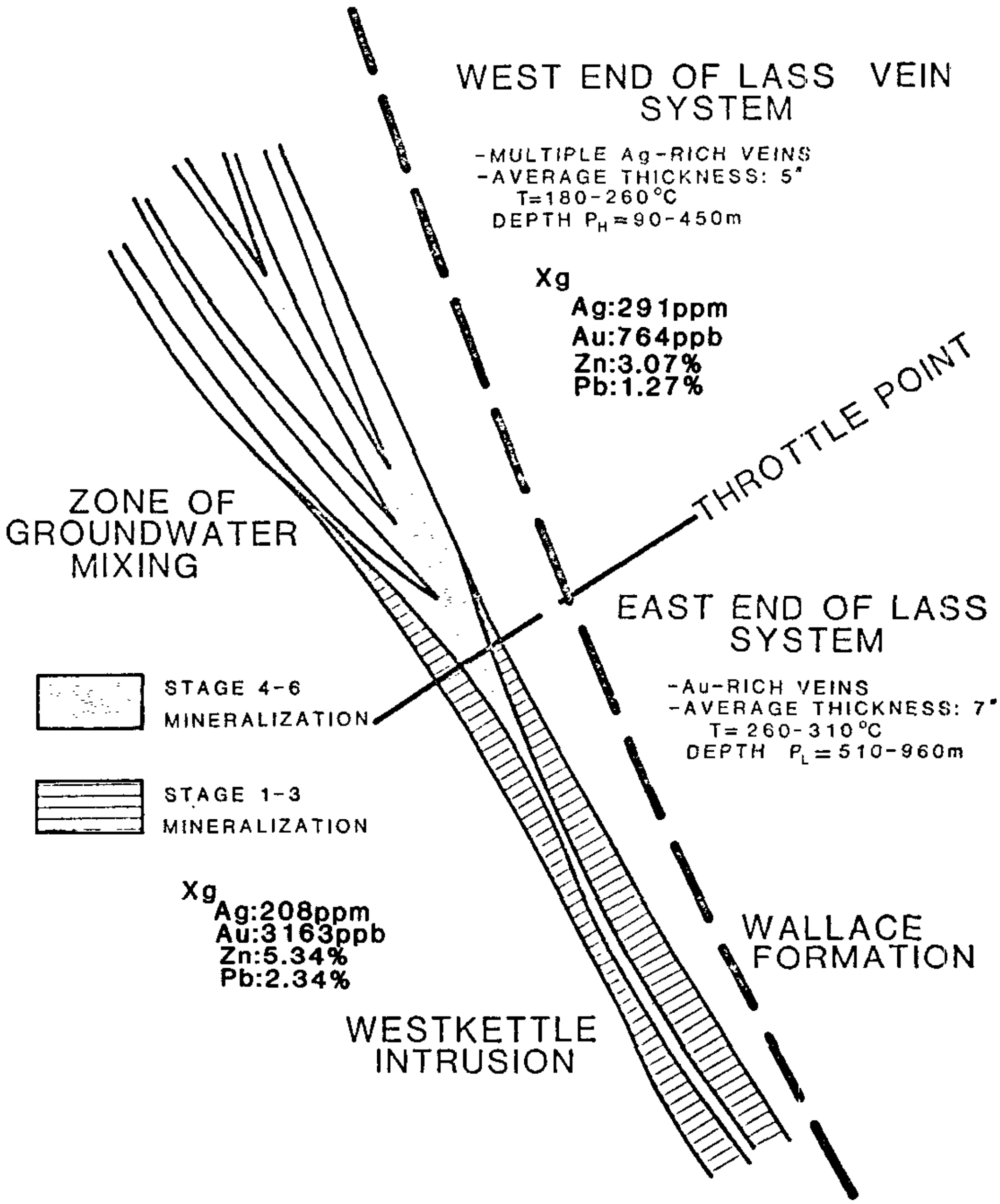


Figure 86. Model of the Lass vein system, Beaverdell area. The vein is divided into an upper, silver-rich part and a lower, gold-rich part. Average values for key elements and vein thicknesses are noted on the model. Mineralization stages and temperature and depth (P_H = hydrostatic pressure, P_L = lithostatic pressure) estimates are from fluid inclusion studies (Watson, 1981).

TABLE 1. Atomic Absorption Spectrophotometry Analyses from 209 Chip Samples (Located on Fig. 79) of Granodiorite-Hosted Vein Material from the Lass Vein System, Beaverdell Camp, B.C.

SAMPLE	ZN%	PB%	CU PPM	FE%	MN PPM	CD PPM	CA PPM	MG%	CO PPM	NI PPM	AU PPB	AG PPM	HG PPB	AS%	SB PPM
BSTH-1	0 099	0.021	35.	4 028	8986.	14.	193.	0.224	1.	0	260.	36.	50.	1.350	75.
SFCE-7	1.650	0.205	343.	2.222	1057.	173.	1640.	0.226	4.	0.	610.	346.	100.	0.112	35.
BSTH-2	0.068	0.025	36.	4.328	6902.	0.	9697.	0.519	54.	0.	5.	15.	25.	0.032	45.
HC-2	0.744	0.168	97.	2.630	4323.	79.	5360.	0.281	4.	0.	70.	146.	10.	1.020	60.
JSON-1	0.347	0.122	67.	2.248	2514.	41.	18663.	0.613	8.	0.	15.	83.	25.	0.058	25.
HC-1	2.996	1.001	726.	4.188	10690.	339.	6694.	0.260	0.	0.	100.	298.	50.	1.320	380.
BSTH-3	8.346	0.460	306.	3.111	6313.	1070.	298.	0.175	5.	0.	155.	198.	405.	1.190	80.
SFCE-6	0.044	0.045	46.	1.030	1398.	0.	36730.	0.098	0.	0.	25.	37.	10.	0.100	30.
NB-2	0.275	0.330	100.	3.046	10076.	35.	4430.	0.461	0.	0.	110.	302.	480.	1.090	110.
NB-3	1.750	0.483	218.	2.134	2044.	198.	6005.	0.254	4.	0.	160.	290.	50.	0.550	50.
NB-9	0.380	1.137	325.	3.715	1213.	48.	3535.	0.241	3.	0.	440.	342.	25.	0.920	230.
NB-7	2 157	3.674	955.	14.492	609.	270.	802.	0.105	0.	0.	1300.	372.	110.	0.260	1000.
NB-8	4.485	4.056	2577.	12.883	563.	593.	2436.	0.109	0	0.	475.	443.	62.	0.500	5650.
NB-6	1.589	0.539	244.	2.608	1664.	18.	3074.	0.331	6.	0.	325.	383.	18.	0.234	25.
NB-4	6.564	2.457	1175.	10.844	973.	817.	2250.	0.105	0.	0.	5050.	329.	170.	0.170	150.
NB-5	6.359	3.090	1423.	8.064	954.	790.	2853.	0.150	3.	0.	5400.	290.	90.	0.152	130.
NB-1	0.930	0.560	166.	2.542	1492.	111.	22009.	0.226	0.	0.	125.	388.	50.	0.096	65.
401-14	1.625	4.110	1158.	9.680	5324.	194.	22430.	0.557	5.	0.	4250.	493.	200.	1.090	170.
PT-2	0.167	0.041	42.	3.289	2031.	10.	3693.	0.308	8.	11.	25.	14.	18.	0.200	50.
401-13	5.323	1.056	940.	5.035	2051.	690.	863.	0.175	5.	0.	800.	351.	6.	1.210	110.
PT-3	0.887	0.032	1686.	0.956	255.	293.	7598.	0.082	12.	0.	10.	15.	50.	0.015	30.
PT-5	0.048	0.136	70.	0.845	754.	0.	10607.	0.149	9.	0.	15.	72.	270.	0.027	20.
401-12	2.087	0.404	226.	3.834	2855.	266.	900.	0.221	6.	0.	350.	291.	6.	0.700	70.
739-1	0.080	0.163	295.	2.840	1634.	0.	7838.	0.687	25.	8.	10.	332.	18.	0.072	50.
500-1	0.422	0.172	104.	3.728	1317.	47.	139.	0.150	2.	0.	710.	296.	18.	1.310	60.
PT-1	0.083	0.103	56.	1.763	869.	0.	16021.	0.527	3.	0.	10.	16.	30.	0.064	40.
PT-4	0.020	0.102	27.	5.051	17699.	0.	27273.	0.651	0.	0.	580.	23.	120.	1.390	120.
401-10	0.402	0.257	82.	3.282	1140.	50.	67.	0.132	0.	4.	690.	473.	2.	1.360	160.
401-11	0.496	2.036	756.	4.153	1392.	44.	417.	0.223	4.	0.	400.	372.	2.	0.680	100.
100-1	0.635	0.324	96.	2.505	7853.	82.	10051.	0.505	4.	0.	25.	168.	780.	0.910	80.
401-8	6.641	4.290	688.	5.040	3311.	860.	252.	0.176	5.	0.	580.	319.	18.	1.090	155.
401-9	1.157	0.216	313.	2.831	4569.	153.	1927.	0.324	6.	0.	65.	91.	2.	0.106	40.
100-2	0.868	5.557	623.	6.884	3043.	146.	1019.	0.258	4.	0.	1000.	328.	910.	1.140	150.
735-3	7.319	3.303	626.	8.432	5069.	926.	3402.	0.355	5.	0.	235.	324.	140.	0.950	185.
400-4	0.953	0.122	133.	3.051	7901.	115.	3355.	0.257	0.	0.	120.	126.	30.	1.110	30.
400-5	1.159	0.381	157.	3.654	3596.	143.	266.	0.228	6.	0.	185.	354.	18.	0.910	45.
401-6	0.030	0.036	4301.	2.265	400.	13.	47.	0.048	7.	0.	35.	381.	2.	0.084	55.
890-1	5.346	2.908	613.	10.312	1801.	685.	238.	0.192	4.	0.	360.	529.	180.	0.220	120.
401-7	1.195	2.151	213.	5.310	7041.	148.	645.	0.245	7.	0.	180.	466.	10.	1.300	160.
600-1	3.527	2.443	3372.	8.521	5986.	487.	1343.	0.210	3.	0.	1700.	360.	90.	1.410	1550.
739-2	7.375	0.667	1242.	5.260	1024.	1030.	280.	0.066	4.	0.	250.	319.	405.	0.960	360.
735-1	1.982	3.890	1080.	8.130	1505.	1224.	4841.	0.177	5.	0.	230.	286.	240.	0.550	205.
839-1	0.650	0.284	110.	3.743	1124.	77.	1766.	0.429	5.	0.	190.	290.	2.	0.140	45.
400-2	2.955	1.159	511.	3.449	13091.	347.	1404.	0.303	4.	0.	140.	236.	240.	0.970	70.
837-2	3.235	0.171	372.	3.205	4037.	419.	10284.	0.429	7.	0.	85.	144.	62.	0.260	30.
735-4	3.621	4.604	301.	4.261	3080.	470.	10243.	0.271	4.	0.	520.	454.	62.	0.144	90.
400-3	4.437	2.549	437.	8.784	32605.	666.	1140.	0.546	3.	0.	440.	275.	80.	1.300	190.
735-2	0.161	0.104	64.	1.886	2570.	31.	3833.	0.192	4.	0.	75.	0.	25.	0.840	35.
100-5	1.531	0.312	127.	6.726	2958.	167.	1182.	0.275	6.	0.	360.	316.	40.	1.390	175.
837-3	0.050	0.058	40.	1.457	984.	0.	20797.	0.075	0.	0.	75.	77.	60.	0.840	40.
100-3	9.834	4.230	1720.	9.490	7140.	1454.	6125.	0.254	3.	0.	585.	334.	120.	1.340	1100.

100-4	19.244	3.289	1885.	12.971	3021.	2411.	243.	0.227	0.	0.	565.	233.	670.	1.170	1450.
837-1	3.839	0.751	438.	4.757	1693.	464.	1191.	0.140	3.	0.	740.	467.	100.	0.880	65.
837-4	0.162	0.101	63.	2.522	1558.	17.	807.	0.228	5.	0.	40.	41.	40.	0.256	35.
850-4	0.288	0.186	41.	4.190	1712.	32.	1814.	0.195	4.	0.	430.	158.	10.	1.660	65.
400-1	2.244	0.345	180.	4.266	3918.	253.	21942.	0.252	0.	0.	420.	372.	10.	1.190	80.
837-7	6.387	2.798	571.	14.934	727.	806.	479.	0.124	0.	0.	1700.	345.	200.	0.510	205.
837-6	3.365	1.390	412.	8.610	1495.	352.	79.	0.223	4.	0.	690.	485.	50.	1.200	125.
837-5	3.913	1.586	494.	4.939	7460.	479.	8719.	0.776	7.	0.	550.	261.	90.	0.880	40.
742-1	0.290	0.052	45.	4.665	7737.	41.	90542.	0.740	2.	0.	20.	28.	18.	0.056	85.
401-1	0.715	0.240	133.	1.343	738.	103.	3345.	0.148	2.	0.	50.	70.	6.	0.046	10.
3802-4	2.342	0.652	366.	8.674	1073.	273.	1600.	0.181	5.	0.	1300.	212.	12.	0.790	75.
744-3	9.256	1.958	1525.	10.744	676.	1238.	672.	0.055	0.	0.	1850.	425.	110.	1.380	2450.
744-2	0.722	0.471	325.	4.106	6511.	105.	28169.	0.427	6.	0.	240.	153.	25.	1.290	110.
3561A-1	1.710	1.040	237.	5.140	4643.	197.	7506.	0.625	6.	0.	500.	366.	2.	0.890	85.
744-1	0.472	0.363	102.	2.948	2040.	57.	1269.	0.264	4.	0.	280.	197.	18.	1.200	75.
3561B-2	3.859	3.327	719.	9.748	4267.	470.	30754.	0.343	6.	0.	3300.	224.	950.	0.144	90.
3561B-1	7.312	1.399	923.	7.840	9138.	874.	29014.	0.714	7.	0.	3400.	420.	6.	0.178	80.
600-2	0.830	0.160	87.	3.283	2186.	102.	39992.	0.299	8.	0.	430.	45.	18.	1.280	90.
850-1	4.161	1.939	651.	3.696	1721.	431.	3050.	0.084	2.	0.	500.	510.	120.	1.480	375.
3802-3	0.933	0.713	156.	7.795	4157.	126.	1071.	0.376	9.	0.	1400.	255.	2.	0.880	75.
850-6	18.244	0.606	877.	8.248	1716.	2115.	253.	0.072	7.	0.	360.	507.	270.	0.500	950.
3802-2	2.398	2.542	525.	9.853	1513.	238.	353.	0.297	3.	0.	2500.	268.	2.	0.340	85.
850-7	2.260	1.682	309.	6.377	400.	265.	0.	0.037	4.	0.	970.	570.	90.	1.580	465.
718-1	3.777	0.665	403.	3.765	1345.	498.	417.	0.073	3.	0.	350.	530.	18.	1.150	65.
850-3	1.114	0.137	139.	3.320	562.	128.	0.	0.060	3.	0.	560.	357.	18.	1.580	50.
850-5	13.703	4.774	1010.	8.519	679.	1708.	612.	0.069	0.	2.	530.	568.	260.	1.010	1200.
3802-1	1.014	1.517	256.	9.317	1500.	136.	148.	0.195	8.	0.	3200.	387.	2.	1.450	105.
742-2	1.600	0.546	195.	6.522	1238.	186.	630.	0.298	3.	0.	820.	144.	30.	0.790	105.
401-5	0.814	0.370	193.	4.582	1741.	87.	5772.	0.184	0.	0.	370.	313.	2.	1.330	110.
742-4	0.611	0.210	146.	3.322	829.	79.	120.	0.064	0.	5.	730.	76.	25.	1.360	85.
718-2	2.113	1.990	292.	5.190	727.	94.	100.	0.097	0.	0.	720.	466.	50.	1.320	630.
731-2	0.082	0.093	503.	2.616	923.	14.	4028.	0.115	31.	13.	35.	73.	50.	0.128	35.
850-2	2.456	1.579	356.	2.863	1578.	323.	3478.	0.078	0.	0.	230.	312.	90.	1.260	60.
402-1	0.064	0.059	80.	2.283	1124.	8.	837.	0.085	4.	0.	135.	65.	2.	1.260	55.
731-1	0.093	0.114	352.	2.174	1417.	25.	12913.	0.667	12.	0.	50.	82.	50.	0.052	18.
742-3	0.196	0.106	164.	3.190	1032.	39.	994.	0.152	0.	0.	280.	130.	50.	0.178	55.
720-2	0.320	0.170	117.	3.327	2488.	42.	1818.	0.288	5.	0.	185.	448.	40.	1.280	55.
3800-1	0.681	0.324	144.	2.787	6135.	80.	39996.	0.827	7.	0.	90.	65.	30.	0.790	50.
829-1	0.083	0.091	40.	3.064	672.	17.	2738.	0.084	0.	0.	280.	123.	40.	1.280	65.
900-13	5.628	2.146	589.	6.782	1885.	693.	1543.	0.169	3.	0.	1050.	430.	270.	1.380	240.
720-1	0.870	4.690	678.	10.116	651.	126.	106.	0.086	0.	0.	1750.	347.	80.	1.390	2100.
900-12	2.591	1.172	167.	3.142	885.	63.	256.	0.072	0.	0.	1050.	452.	100.	1.350	110.
900-16	1.024	3.753	617.	7.905	358.	141.	413.	0.044	3.	0.	2000.	297.	140.	1.390	495.
900-17	1.394	0.843	1748.	6.090	1018.	107.	245.	0.256	5.	0.	3400.	561.	140.	1.360	1050.
900-10	0.790	0.373	166.	4.366	821.	84.	1066.	0.074	0.	5.	1020.	329.	110.	1.360	130.
900-11	2.902	1.280	476.	3.678	808.	248.	3077.	0.070	0.	0.	840.	504.	195.	1.350	215.
731-3	1.958	0.720	207.	6.857	1772.	217.	650.	0.306	3.	0.	450.	276.	62.	1.390	95.
825-1	3.010	2.280	354.	8.560	1170.	370.	692.	0.138	3.	0.	750.	536.	110.	1.340	1350.
825-2	0.170	0.092	55.	2.366	505.	12.	3589.	0.073	2.	9.	320.	36.	25.	1.310	60.
829-2	0.274	0.076	69.	4.375	1000.	21.	0.	0.152	5.	0.	390.	151.	50.	1.380	90.
700-1	0.506	1.315	315.	7.284	2704.	61.	836.	0.391	5.	11.	460.	507.	2.	0.120	115.
716-1	3.476	0.303	362.	4.893	1183.	435.	183.	0.190	8.	5.	380.	493.	80.	1.540	80.

900-15	4.919	2.057	1028.	8.907	1331.	633.	94.	0.172	0.	0.	3200.	330.	110.	0.780	95.
900-14	3.003	0.749	343.	2.578	2446.	373.	1432.	0.177	5.	0.	160.	180.	50.	1.110	35.
900-8	3.094	2.240	1277.	4.870	4022.	374.	5340.	0.541	10.	6.	1200.	486.	240.	0.104	70.
900-9	3 752	2.924	531.	4.303	4323.	477.	21003.	0.367	7.	7.	390.	344.	180.	0.114	80.
900-7	1.743	0.357	223.	4.942	2566.	241.	5749.	0.292	6.	0.	360.	261.	80.	0.800	65.
700-3	7.926	1.268	2264.	19.210	294.	1106.	665.	0.044	2.	0.	1200.	550.	300.	0.345	4950.
870-2	0.116	0.087	77.	2.507	169.	13.	0.	0.029	3.	0.	280.	68.	2.	1.470	30.
700-2	0.026	0.055	65.	2.948	428.	0.	38.	0.041	3.	10.	150.	99.	2.	1.460	45.
870-1	0.046	0.078	54.	2.208	480.	0.	0.	0.039	4.	0.	140.	60.	2.	1.440	30.
812-1	2.444	0.988	534.	3.814	976.	302.	2637.	0.145	2.	0.	1700.	346.	62.	0.146	50.
701-1	0.508	0.163	84.	2.022	3843.	52.	24169.	0.644	8.	0.	25.	258.	2.	0.098	50
809-4	3.812	1.055	456.	7.327	1009.	483.	186.	0.144	4.	0.	820.	403.	100.	1.380	165.
870-3	0.078	0.028	21.	3.134	478.	22.	0.	0.042	0.	0.	420.	13.	2.	1.560	45.
900-6	0.949	0.386	260.	1.798	1506.	126.	8526.	0.291	4.	0.	170.	188.	195.	0.084	30.
900-3	1.733	1.591	804.	3.843	1928.	243.	882.	0.320	5.	0.	1600.	364.	6.	0.126	50.
900-4	0.517	0.441	150.	9.442	977.	73.	252.	0.073	9.	9.	1400.	347.	300.	1.390	150.
809-3	2.114	2.408	662.	4.816	1613.	269.	0.	0.142	8.	0.	500.	707.	110.	1.320	800.
708-2	8.258	0.405	288.	8.623	1317.	981.	260.	0.140	8.	0.	70.	588.	240.	1.620	110.
809-1	0.200	0.420	272.	6.246	1426.	21.	3693.	0.138	4.	0.	1000.	415.	50.	1.190	100.
812-2	0.367	0.120	50.	3.140	924.	53.	301.	0.083	0.	0.	150.	84.	40.	0.860	45.
809-2	1.492	1.589	601.	8.293	2289.	170.	463.	0.317	8.	0.	1050.	371.	100.	0.880	110.
900-5	0.431	0.286	155.	3.087	1666.	28.	73.	0.188	4.	0.	430.	369.	62.	0.910	45.
900-1	4.805	0.428	293.	2.105	942.	599.	2286.	0.069	1.	0.	230.	323.	10.	0.210	20.
808-1	0.616	0.487	177.	4.365	1969.	50.	548.	0.198	3.	0.	680.	425.	62.	1.360	75.
708-3	0.825	0.510	131.	4.922	12797.	59.	4136.	0.588	10.	0.	5.	236.	2.	1.410	80.
900-2	5.508	2.395	752.	3.897	1050.	637.	8441.	0.121	0.	0.	2500.	423.	18.	0.194	40.
709-1	0.058	0.030	61.	3.315	725.	0.	48.	0.081	3.	0.	500.	66.	2.	1.580	45.
708-1	0.173	0.242	96.	4.685	1830.	23.	690.	0.183	10.	0.	180.	315.	2.	1.510	70.
708-4	0.646	0.982	210.	6.613	985.	58.	4359.	0.238	6.	0.	500.	255.	2.	0.260	65.
2900-2	0.720	0.795	601.	4.631	1451.	90.	162.	0.322	5.	0.	750.	482.	6.	0.980	75.
2901-1	0.970	5.350	290.	7.679	1928.	143.	1120.	0.214	0.	0.	1100.	375.	2.	0.680	90.
2901-4	0.493	0.318	71.	2.971	2846.	70.	102.	0.217	10.	0.	130.	146.	2.	0.670	35.
3001-6	1.001	0.292	167.	3.422	938.	87.	7082.	0.412	6.	0.	290.	400.	8.	0.850	35.
737-1	0.170	0.080	40.	2.077	7161.	17.	10175.	0.207	0.	0.	200.	24.	40.	1.320	55.
3000-4	0.476	0.132	86.	1.918	1155.	60.	2416.	0.081	0.	0.	50.	81.	10.	0.970	25.
3001-5	4.281	0.378	265.	6.854	794.	540.	777.	0.054	0.	0.	600.	366.	18.	1.250	90.
3001-7	5.291	1.586	731.	7.036	711.	650.	90.	0.085	0.	0.	1000.	304.	25.	0.230	65.
3001-3	0.164	0.660	50.	3.008	1520.	15.	1009.	0.083	9.	0.	260.	118.	6.	0.860	30.
3001-4	1.789	1.730	616.	4.933	1206.	230.	437.	0.078	0.	0.	3100.	345.	18.	1.260	95.
3104-9	4.533	2.819	1006.	18.831	606.	600.	610.	0.140	0.	0.	790.	307.	6.	1.160	365.
3104-7	0.301	0.227	83.	1.609	823.	38.	5099.	0.267	4.	0.	5.	110.	2.	0.096	35.
3104-10	0.702	0.314	257.	4.450	617.	32.	1012.	0.098	0.	0.	310.	244.	2.	1.340	75.
3001-2	0.963	1.052	207.	5.300	1261.	121.	7202.	0.154	5.	0.	110.	317.	20.	0.940	165.
2901-5	0.063	0.038	64.	1.292	452.	0.	10871.	0.382	4.	10.	5.	28.	2.	0.020	15.
3104-8	2.360	3.527	472.	9.224	713.	305.	2425.	0.099	3.	0.	330.	356.	6.	0.780	165.
2900-1	7.171	0.771	1171.	5.120	2743.	862.	9762.	0.410	0.	0.	3000.	362.	6.	0.120	60.
3104-6	0.731	0.595	235.	4.783	854.	86.	481.	0.107	5.	0.	150.	339.	10.	1.420	160.
2902-2	27.271	1.767	427.	11.024	1087.	273.	1405.	0.169	5.	0.	2700.	508.	2.	1.340	140.
3104-5	2.517	2.816	800.	11.887	1801.	320.	142.	0.186	4.	0.	820.	315.	25.	0.272	145.
2902-5	0.362	2.258	1113.	11.735	1235.	49.	200.	0.138	0.	0.	1800.	197.	2.	1.340	190.
3104-1-1	11.723	3.955	2517.	11.521	858.	1330.	582.	0.039	0.	0.	700.	288.	240.	1.220	3600.
2902-1	27.522	1.870	347.	12.355	1196.	349.	710.	0.236	5.	0.	2200.	413.	2.	1.370	135.

2902-3	6.693	0.669	367.	11.841	1077.	829.	945.	0.188	10.	0.	1600.	354.	6.	1.360	145.
3104-3	12.301	2.771	2291.	15.742	787.	1453.	1086.	0.046	0.	0.	800.	295.	340.	1.370	2550.
3104-1	14.625	3.731	1036.	9.411	1786.	1831.	6851.	0.179	5.	0.	480.	265.	40.	1.240	165.
3104-4	16.902	3.248	1624.	10.099	490.	2317.	631.	0.028	1.	0.	380.	317.	480.	1.190	1650.
2902-4	0.399	0.120	54.	1.994	8646.	59.	9225.	0.570	6.	0.	5.	40.	2.	0.066	20.
3104-2	14.119	4.111	1644.	12.840	597.	1662.	126.	0.049	5.	0.	450.	306.	200.	0.980	1200.
2903-1	1.925	0.654	174.	3.084	8490.	248.	8865.	0.546	0.	0.	95.	97.	2.	0.700	50.
3010-1	1.229	0.562	133.	9.440	3244.	137.	1420.	0.241	8.	0.	280.	255.	10.	1.260	100.
3000-1	0.269	0.185	108.	3.446	16830.	29.	109895.	0.773	0.	0.	280.	233.	6.	0.102	90.
3000-3	6.253	2.093	254.	12.871	1188.	483.	516.	0.185	18.	0.	1450.	353.	25.	1.270	155.
2904-1	0.253	0.532	56.	3.276	6357.	28.	46467.	1.117	5.	0.	270.	324.	2.	1.060	65
2904-2	2.298	0.494	215.	4.196	5369.	251.	28208.	0.872	8.	0.	600.	487.	2.	0.124	60.
2955-3	2.429	0.116	296.	5.003	2147.	264.	1422.	0.167	6.	0.	620.	349.	30.	0.780	95.
2955-2	2.341	1.867	193.	6.197	1359.	285.	930.	0.201	13.	0.	560.	309.	25.	1.240	135.
2955-1	1.422	2.083	187.	7.047	1552.	142.	2030.	0.076	5.	0.	1100.	279.	6.	0.970	85.
3016-4	0.289	0.665	44.	3.058	8251.	40.	60733.	0.460	3.	0.	900.	45.	10.	1.340	80.
2910-8	0.442	0.610	65.	8.146	823.	61.	247.	0.061	6.	0.	1250.	244.	2.	1.340	90.
2905-3	0.284	0.304	77.	3.041	9390.	10.	37580.	0.434	2.	0.	150.	95.	2.	0.850	40.
2910-6	1.692	2.959	991.	16.882	3233.	224.	10832.	0.410	3.	0.	1800.	304.	2.	0.920	1350.
2910-7	0.722	2.209	975.	14.492	2138.	101.	870.	0.347	8.	0.	950.	384.	2.	1.040	1400.
2905-2	2.875	3.997	376.	9.511	2040.	399.	7110.	0.300	6.	0.	1400.	347.	2.	1.040	125.
2906-5	3.439	4.610	512.	9.908	398.	482.	152.	0.057	8.	0.	4200.	410.	50.	1.400	315.
2906-4	3.248	2.701	2367.	16.732	779.	435.	1184.	0.140	4.	0.	16000.	323.	25.	1.360	355.
2905-1	35.521	4.629	983.	13.625	1788.	442.	8616.	0.227	0.	0.	9000.	350.	2.	0.760	110.
2906-2	13.124	2.271	1035.	16.545	821.	1710.	3138.	0.075	3.	0.	2450.	325.	70.	0.320	330.
2906-3	0.442	0.378	215.	13.873	1049.	54.	4857.	0.145	5.	0.	1000.	226.	2.	0.970	90.
2911-6	4.967	0.709	2047.	1.348	238.	652.	128.	0.026	0.	0.	9100.	284.	40.	1.130	350.
2910-4	0.186	0.161	96.	6.097	2006.	12.	4402.	0.303	5.	5.	1450.	44.	2.	1.200	55.
2915-1	4.499	2.997	758.	6.505	1365.	552.	7593.	0.812	6.	0.	2300.	388.	2.	0.112	90.
2910-5	1.358	3.539	491.	14.758	439.	181.	1680.	0.079	0.	0.	5300.	235.	6.	0.860	160.
2910-2	9.452	3.581	530.	12.400	7588.	1368.	24143.	0.540	4.	0.	4200.	253.	40.	0.224	75.
2911-4	2.570	5.583	221.	10.115	4237.	396.	5623.	0.423	4.	0.	690.	360.	10.	1.150	190.
2918-1	3.033	6.324	716.	8.431	858.	379.	1180.	0.088	0.	0.	1500.	325.	30.	1.330	210.
2910-1	15.165	5.313	750.	6.949	852.	2065.	5283.	0.194	8.	0.	3850.	310.	270.	0.296	165.
2914-1	0.603	2.997	196.	12.609	2799.	97.	3126.	0.105	10.	0.	2000.	294.	2.	1.340	525.
2912-17	3.525	0.195	419.	6.059	2113.	449.	617.	0.375	2.	0.	2200.	83.	6.	0.236	60.
2912-18	0.207	0.232	89.	8.391	3920.	23.	4133.	0.285	6.	0.	1000.	65.	2.	1.330	85.
2911-2	10.249	6.903	1876.	6.658	667.	1603.	162.	0.089	18.	0.	3100.	306.	220.	1.160	460.
2911-1	12.728	3.648	2504.	14.120	799.	1736.	1111.	0.092	10.	0.	16500.	151.	70.	1.390	110.
2912-16	2.498	0.829	243.	7.019	6511.	322.	3511.	0.364	0.	0.	800.	109.	2.	1.330	65.
2912-15	0.487	0.142	164.	3.368	1108.	73.	675.	0.147	4.	11.	110.	34.	2.	1.230	40.
2912-14	9.728	3.524	734.	15.313	655.	1453.	477.	0.070	3.	0.	2100.	284.	18.	1.090	290.
2912-13	0.134	0.020	40.	0.937	534.	39.	15698.	0.235	0.	0.	30.	0.	2.	0.011	15.
2912-12	2.859	0.295	701.	8.719	1666.	368.	190.	0.178	9.	0.	3000.	30.	2.	1.340	80.
2912-11	12.947	5.054	1862.	7.798	1781.	1814.	2504.	0.248	5.	0.	3000.	321.	10.	1.130	120.
2912-9	10.274	2.998	1023.	10.764	2597.	1696.	7496.	0.220	5.	0.	7000.	212.	10.	1.030	90.
2912-10	14.804	0.362	1664.	7.556	1096.	2157.	813.	0.090	13.	0.	2100.	59.	110.	0.220	75.
2916-9	0.343	0.308	201.	2.556	1661.	41.	4504.	0.192	2.	0.	360.	14.	2.	0.160	25.
2916-8	0.532	0.258	85.	3.350	1642.	72.	481.	0.246	4.	0.	90.	7.	4.	0.098	30.
2912-8	1.684	4.938	975.	9.263	196.	264.	916.	0.035	3.	0.	3600.	293.	2.	1.050	490.
2916-7	9.825	3.517	1525	9.645	1268.	1509	4864	0.161	19	0	1700	122.	40.	0.084	125
2912-6	1.592	0.775	538.	5.042	933.	188.	1754.	0.104	1.	4.	7100.	32.	2.	0.490	40.
2912-5	2.317	0.891	390.	8.946	1338.	288.	1792.	0.194	13.	12.	3800.	51.	2.	1.350	95.
2912-4	17.334	2.840	1369.	7.319	2730.	2457.	6633.	0.244	15.	0.	3500.	112.	30.	0.188	75.

TABLE 2. Means and Standard Deviations Determined Graphically[1] for Partitioned Element Populations in Granodiorite-Hosted Vein Vein Material[2] in the Lass Vein System, Beaverdell Mine Area, South-Central British Columbia

Element	Population A[3]				Populations[3] B, B'			
	%	b	b+s	b-s	%	b	b+s	b-s
Zn %	55	3.76	9.12	1.40	45	0.38	1.40	0.11
Cd ppm	55	457	1288	178	45	43	234	10
Cu ppm	70	513	1202	195	30	76	126	45
Sb ppm	10	1318	2138	794	90	79	162	38
Pb %	38	3.00	4.30	2.09	37	0.54	1.02	0.29
					25	0.12	0.35	0.05
Fe %	60	8.99	13.49	5.94	40	3.72	6.84	2.20
Ag ppm	67	427	457	269	18	105	174	68
					15	34	135	8
Au ppb	90	646	2239	191	10	15	51	4
As %	72	1.20	1.70	0.86	28	0.13	0.24	0.07
Mn ppm	30	5012	10233	2570	70	1202	2291	617
Mg %	70	0.25	0.45	0.14	30	0.08	0.12	0.05
Hg ppb					100	20	124	3
Ca ppm					100	1143	14962	87
Co ppm [4]					100	1.75	9.90	0.31

1. Partitioned into populations on logarithmic probability plots, using the procedures of Sinclair (1976).
2. There are 209 samples in this group.
3. b is antilog of mean of logtransformed data; b+s is antilog of mean plus one standard deviation of logtransformed data; b-s is antilog of mean minus one standard deviation of logtransformed data.
4. 24% of the Co values were below the analytical detection limit.

TABLE 3. Correlation Matrix for Granodiorite-Hosted Vein Material from the Lass Vein System, Beaverdell Mine Area, South-Central British Columbia

-CORRELATION MATRIX

	ZN	CD	CU	SB	PB	FE	AG	AU	AS	HG	MN
ZN	1.0000										
CD	0.8086	1.0000									
CU	0.7463	0.6175	1.0000								
SB	0.4972	0.4023	0.6023	1.0000							
PB	0.7567	0.6310	0.7267	0.6228	1.0000						
FE	0.6195	0.5170	0.5879	0.6875	0.7283	1.0000					
AG	-0.0504	0.0106	0.0178	0.0271	0.0602	0.1464	1.0000				
AU	0.0299	0.0300	0.0592	-0.0479	0.0314	0.0230	-0.0259	1.0000			
AS	0.0221	0.0333	0.0690	0.0083	0.1299	0.0729	0.2899	-0.0057	1.0000		
HG	0.0547	0.0389	0.0007	0.0507	-0.0071	-0.0003	-0.1975	-0.0040	-0.0882	1.0000	
MN	-0.0120	0.0368	-0.1959	-0.1614	-0.0176	-0.0426	-0.0174	-0.0552	0.0819	0.1077	1.0000
CA	0.0472	0.0174	0.0094	-0.1356	0.0591	-0.0616	-0.0052	0.0124	0.0507	0.0429	0.4275
MG	-0.1026	-0.0692	-0.2099	-0.3254	-0.0782	-0.1123	-0.0472	-0.0560	0.0613	0.0794	0.7663
CO	-0.0196	-0.0090	-0.0094	-0.1760	-0.0330	0.0121	-0.0157	-0.0441	0.0519	-0.0360	0.1513
TH	0.0506	0.0283	0.0893	0.1393	0.0004	0.0545	0.0329	0.0695	-0.0785	0.1206	-0.3288

-CORRELATION MATRIX

	CA	MG	CO	TH
CA	1.0000			
MG	0.5183	1.0000		
CO	0.0054	0.3052	1.0000	
TH	-0.2336	-0.3527	-0.2295	1.0000

N=209

Values are significant at the 1% level, if greater than 0.176 and significant at the 0.1% level if greater than 0.223; all data are logtransformed except for TH (thickness).

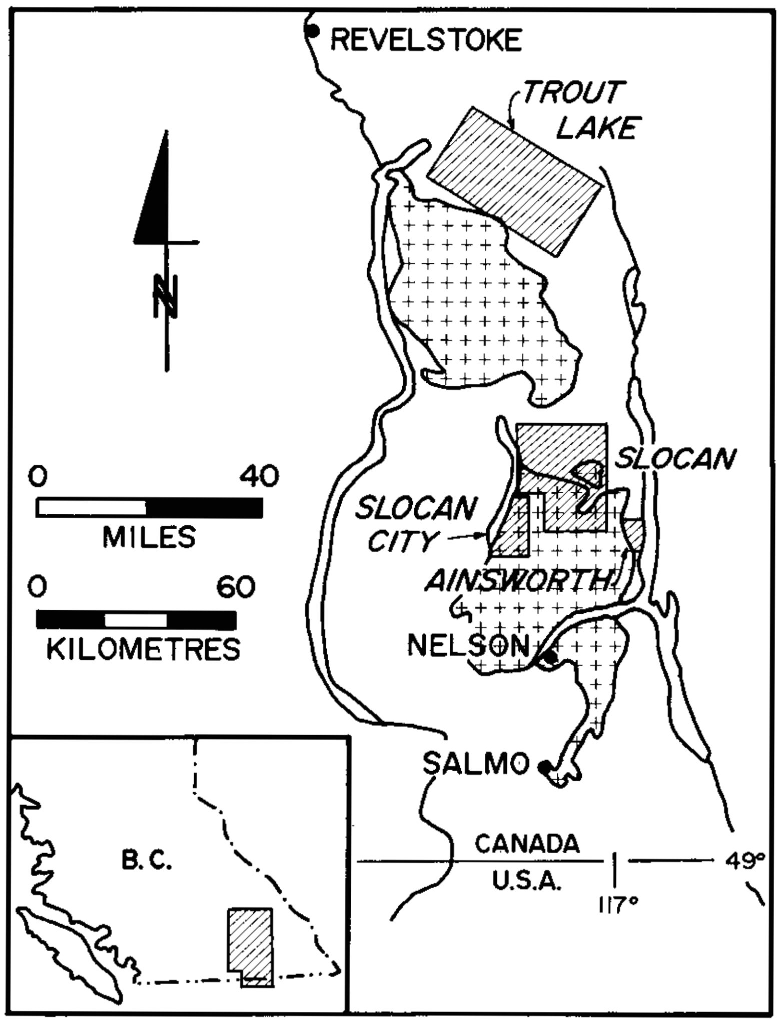


Figure 87. Generalized locations of Ainsworth, Slocan City, Slocan, and Trout Lake mining camps, southeastern British Columbia.

SPATIAL DENSITY OF SILVER-LEAD-ZINC-GOLD VEIN DEPOSITS IN FOUR MINING CAMPS IN SOUTHEASTERN BRITISH COLUMBIA (82F)

By L. B. Goldsmith and A. J. Sinclair
Department of Geological Sciences, University of British Columbia

INTRODUCTION

Spatial density appears to have several practical applications important in resource assessment, *viz*.:

(1) defining limits to mining camps,

(2) providing a systematic basis for comparing mining camps in terms of average deposit density or average metal concentration, and

(3) recognition of systematic variations in spatial density of mineral occurrences within individual mining camps.

Here we examine the potential uses of spatial density applied to clusters of vein deposits.

Sinclair (1979) suggested that contoured spatial density maps of location data (centroids) of mineral deposits might provide a consistent if empirical means of defining boundaries to certain types of mining camps or mineralized centres. In particular, he recommended that a moving average method be used as a basis for contouring 'number of veins per square kilometre' and that the 0.5 density contour be used to define the empirical limits to the Ainsworth vein camp in southeastern British Columbia. The method appears applicable to two-dimensional problems and, of course, suffers the limitation that the 0.5 spatial density contour does not exist as a real entity. Exact locations of some deposits are not always readily attainable from available literature but this problem is restricted largely to small deposits actively explored and/or exploited during the nineteenth century. Uncertain locations in general do not appear to represent problems in contouring spatial density because the uncertainty is generally small relative to the scale of a mining camp.

This study extends the early work by Sinclair (1979) to include four vein camps, Ainsworth, Slocan, Slocan City, and Lardeau (Trout Lake), in southeastern British Columbia (Fig. 87) in an attempt to generalize the approach in relation to vein camps. The data base for three of the mining camps is an updated version of a computer-based producer file established by Orr and Sinclair (1971). Data for the Lardeau (Trout Lake) camp are an edited version of a file established originally by P. B. Read (Read, 1976; Goldsmith, *et al*., in preparation). The former file (Slocan, Slocan City, and Ainsworth) contains information only for

TABLE 1

AREA MEASUREMENT STATISTICS, AINSWORTH MINING CAMP

Window Size	0.5 DEPOSIT/CELL					1.0 DEPOSIT/CELL				
	Number of Deposits	Miles^2 (4 measurements)		Av Miles^2	Av km^2	Number of Deposits	Miles^2 (4 measurements)		Av Miles^2	Av km^2
25% OVERLAP										
4km x 4km	81	77.70	78.00	77.86	201.67	81	63.66	63.84	63.83	165.31
		77.88	77.88				63.96	63.84		
2km x 2km	80	63.54	36.36	36.35	94.13	80	28.26	27.96	28.08	72.73
		36.18	36.30				28.08	28.02		
1km x 1km	72	13.68	13.00	13.74	35.58	71	10.80	10.80	10.80	27.97
		13.68	13.80				10.80	10.80		
50% OVERLAP										
	0.5 DEPOSIT/CELL					1.0 DEPOSIT/CELL				
4km x 4km	81	68.10	68.28	68.15	176.50	81	56.22	56.22	56.18	145.49
		67.98	68.22				56.28	55.98		
2km x 2km	75	30.36	30.24	30.30	78.48	75	23.28	23.22	23.24	60.18
		30.24	30.36				23.40	23.04		
1km x 1km	72	13.20	13.26	13.19	34.15	71	10.68	10.74	10.76	27.86
		13.14	13.14				10.62	10.98		
75% OVERLAP										
	0.5 DEPOSIT/CELL					1.0 DEPOSIT/CELL				
4km x 4km	81	82.20	81.78	81.95	212.24	80	66.60	67.32	67.10	173.78
		81.84	81.96				67.26	67.20		
2km x 2km	74	24.60	24.54	24.59	63.68	72	19.56	19.08	19.31	50.00
		24.60	24.60				19.56	19.08		
1km x 1km	71	11.70	11.76	11.75	30.42	71	9.48	9.42	9.44	24.44
		11.70	11.82				9.48	9.36		

TABLE 2

AREA MEASUREMENT STATISTICS, SLOCAN MINING CAMP

Window Size	0.5 DEPOSIT/CELL					1.0 DEPOSIT/CELL				
	Number of Deposits	Miles^2 (4 measurements)		Av Miles^2	Av km^2	Number of Deposits	Miles^2 (4 measurements)		Av Miles^2	Av km^2
25% OVERLAP										
4km x 4km	176	160.50	160.98	160.53	415.77	176	140.46	140.04	140.36	363.51
		160.32	160.32				140.40	140.52		
2km x 2km	176	108.00	107.46	107.67	278.86	169	73.14	73.20	73.11	189.35
		107.64	107.58				73.08	73.02		
1km x 1km	121	28.65	28.47	28.58	74.02	116	20.37	20.43	20.40	52.84
		28.53	28.65				20.37	20.43		
50% OVERLAP										
	0.5 DEPOSIT/CELL					1.0 DEPOSIT/CELL				
4km x 4km	176	157.08	156.78	156.59	405.56	175	137.40	137.76	137.75	356.76
		156.24	156.24				137.40	138.42		
2km x 2km	176	102.12	102.36	102.03	264.26	172	72.18	72.06	72.11	186.75
		102.18	101.46				72.12	72.06		
1km x 1km	124	30.60	30.42	30.51	79.02	121	19.50	19.50	19.46	50.39
		30.60	30.42				19.50	19.32		
75% OVERLAP										
	0.5 DEPOSIT/CELL					1.0 DEPOSIT/CELL				
4km x 4km	176	158.10	158.16	158.02	409.28	175	139.26	138.54	138.75	359.36
		157.74	158.10				139.02	138.18		
2km x 2km	171	90.42	90.00	90.00	233.1	165	54.78	54.66	54.74	141.76
		89.94	89.64				54.66	54.89		
1km x 1km	101	20.10	20.10	20.19	52.79	99	15.18	15.48	15.33	39.77
		20.10	20.46				15.18	15.48		

deposits with a recorded production of at least one short ton of ore. The file for Trout Lake camp contains locations of all publicly recorded deposits irrespective of whether or not they have produced ore.

METHODOLOGY

Consider the problem of depicting spatial density of mineral occurrences to be two-dimensional. An interpolation technique is required to provide spatial density estimates on a regular grid superimposed upon a district containing numerous irregularly located occurrences and/or deposits. The spatial density values for each cell of the grid then can be contoured by simple linear interpolation, either by hand or machine. One procedure used here is to move a (square) window over the field of interest in a regular, periodic fashion, count the number of deposits in the window at each position, and assign each count to the centre of the square for which the count was obtained.

Three parameters can be varied in this procedure: (1) the window shape, (2) the window area, and (3) the proportion of overlap (if any) of adjoining counting cells.

The level of variability in spatial density data that results from these sources must be quantified if spatial density is to be used in a meaningful fashion.

MEASUREMENT OF SPATIAL DENSITY VARIABILITY

We have attempted to evaluate several sources of variability in obtaining spatial density estimates for vein mining camps. In particular, we have examined the effects of:

(1) varying size of counting window, that is, 1 by 1 kilometre, 2 by 2 kilometres, and 4 by 4 kilometres,

(2) defining camp area by two different spatial density contours, that is, 0.5 deposit per cell and 1.0 deposit per cell, and

(3) testing actual reproducibility of camp area estimates by planimeter.

Data from our tests for three mining camps are summarized in Tables 1, 2, and 3 from which several conclusions seem evident. The most obvious feature of the tabulated data is that planimetric measurements in camp areas vary much less than 1 per cent of the area; these errors are negligible.

Estimated camp areas increase dramatically as the size of the counting cell increases, regardless of extent of overlap. This results largely from an ever-increasing zone of no deposits that is included within the camp boundaries as the cell size increases. This effect can be minimized

TABLE 3

AREA MEASUREMENT STATISTICS, SLOCAN CITY MINING CAMP

Window Size	0.5 DEPOSIT/CELL Number of Deposits	Miles² (4 measurements)		Av Miles²	Av km²	1.0 DEPOSIT/CELL Number of Deposits	Miles² (4 measurements)		Av Miles²	Av km²
25% OVERLAP										
4km x 4km	60	111.90	111.30	111.60	289.04	58	82.20	81.95	82.165	212.81
		111.30	111.90				82.32	82.20		
2km x 2km	57	46.62	46.68	45.68	120.90	55	39.00	39.18	39.05	101.13
		46.74	46.68				39.00	39.00		
1km x 1km	57	19.50	19.56	19.55	50.62	37	6.84	6.84	6.84	17.72
		19.50	19.62				6.84	6.84		
50% OVERLAP		0.5 DEPOSIT/CELL				1.0 DEPOSIT/CELL				
4km x 4km	59	89.52	89.52	89.48	231.74	59	77.94	77.70	77.78	201.44
		88.45	89.40				77.88	77.58		
2km x 2km	57	44.44	45.18	45.07	116.74	55	37.56	37.20	37.43	96.93
		45.06	45.12				37.50	37.44		
1km x 1km	57	20.34	20.16	20.28	52.53	50	10.17	10.18	10.17	27.38
		20.16	20.46				10.17	10.16		
75% OVERLAP		0.5 DEPOSIT/CELL				1.0 DEPOSIT/CELL				
4km x 4km	59	61.74	62.10	62.07	160.76	57	50.94	51.00	51.02	132.13
		62.10	62.34				51.18	50.94		
2km x 2km	57	42.78	43.00	42.87	111.02	55	35.50	34.32	34.43	89.16
		42.90	42.78				34.38	34.50		
1km x 1km	57	17.16	17.40	17.28	44.75	43	7.26	7.26	7.26	18.90
		17.16	17.40				7.26	7.26		

by using a 1.0 rather than a 0.5 deposit-per-cell contour. Nevertheless, window size is a large source of variability in mining camp areas by the method we outline. To counteract this problem we define a mining camp somewhat subjectively on the basis of the smallest window size that results in a high proportion (more than 90 per cent) of known occurrences being contained within a reference contour (for example, 0.5 deposit per cell).

Extent of overlap of adjoining counting windows does not appear to be an important source of variability for smallest cell sizes that produce a cohesive rather than a disaggregated outline. For example, for Slocan camp the 2 by 2-kilometre window produces areas of 121, 117, and 111 square kilometres for overlaps of 25, 50, and 75 per cent respectively.

Our subjective evaluation of these data and the many maps that we viewed (one for each line of information in each table) have led us to conclude that areas of mining camps can be defined usefully and reproducibly, if empirically and subjectively, as follows:

(1) use a 0.5 deposit per cell as the margin contour to define the outer extremity of a mining camp,

(2) use 50 per cent overlap of square counting cells, and

(3) cell size must be selected by trial and error to be that smallest size which retains the large majority of deposits of a subjectively recognized mining camp within the marginal contour.

EXAMPLES OF SPATIAL DENSITY MAPS

Two extreme cases of the application of spatial density procedures applied to mineral deposit location data are: to define boundaries of clusters of vein deposits, and to examine patterns of spatial density contours of mineral deposits within a mining camp.

OUTLINING MINING CAMPS

In a large region containing several mining camps we might wish to develop a reproducible procedure by which we can define boundaries to mining camps and determine an estimate of their individual geographic limits. Such information would be useful for purposes of quantifying the distribution of mineral occurrences in a camp in terms of average spatial density. Similarly the amount of various metals concentrated into veins per unit area in a mining camp could be examined and displayed.

The foregoing objectives require that we know the total number of deposits in a camp and the geographic limits of the camp. Of course a newly found deposit in an old camp or one outside the existing camp limits will bias the parameter we are estimating. As long as we recognize these sources of errors, they need not represent serious problems, and, in fact, are likely minimal in many old, thoroughly explored camps.

Figure 88 is a moving average spatial density contour map for an area including the northern end of the Nelson batholith. A window of 2 by 2 kilometres was used with 50 per cent overlap in the two principal grid directions. Note that in such a case a single deposit will occur in four cells whose centres are in a square with sides half the cell dimension. The 0.5 deposit per 4-square-kilometre contour around an isolated deposit is therefore the same size as the basic counting cell. In a few cases where deposit locations are exactly on the boundary of a counting cell, isolated deposits are surrounded by a rectangular contour with area less than the basic cell area. After some experimentation the artificial contour 0.5 deposit per 4-square-kilometres was selected arbitrarily as setting the outer limit of vein concentrations defining mining camps in the area.

Once an acceptable limit is defined for a mining camp we can calculate average spatial density and average known metal endowment. Our present study is concerned primarily with spatial density of mineral deposits, although the methodology can be extended easily to the presentation of metal endowment using known metal production. Average spatial densities are summarized in Table 4 for Slocan, Slocan City, and Ainsworth mining camps. It is important to realize that the figures quoted in Table 4 are derived only from those deposits lying within the 0.5 deposit per 4-square-kilometre contour.

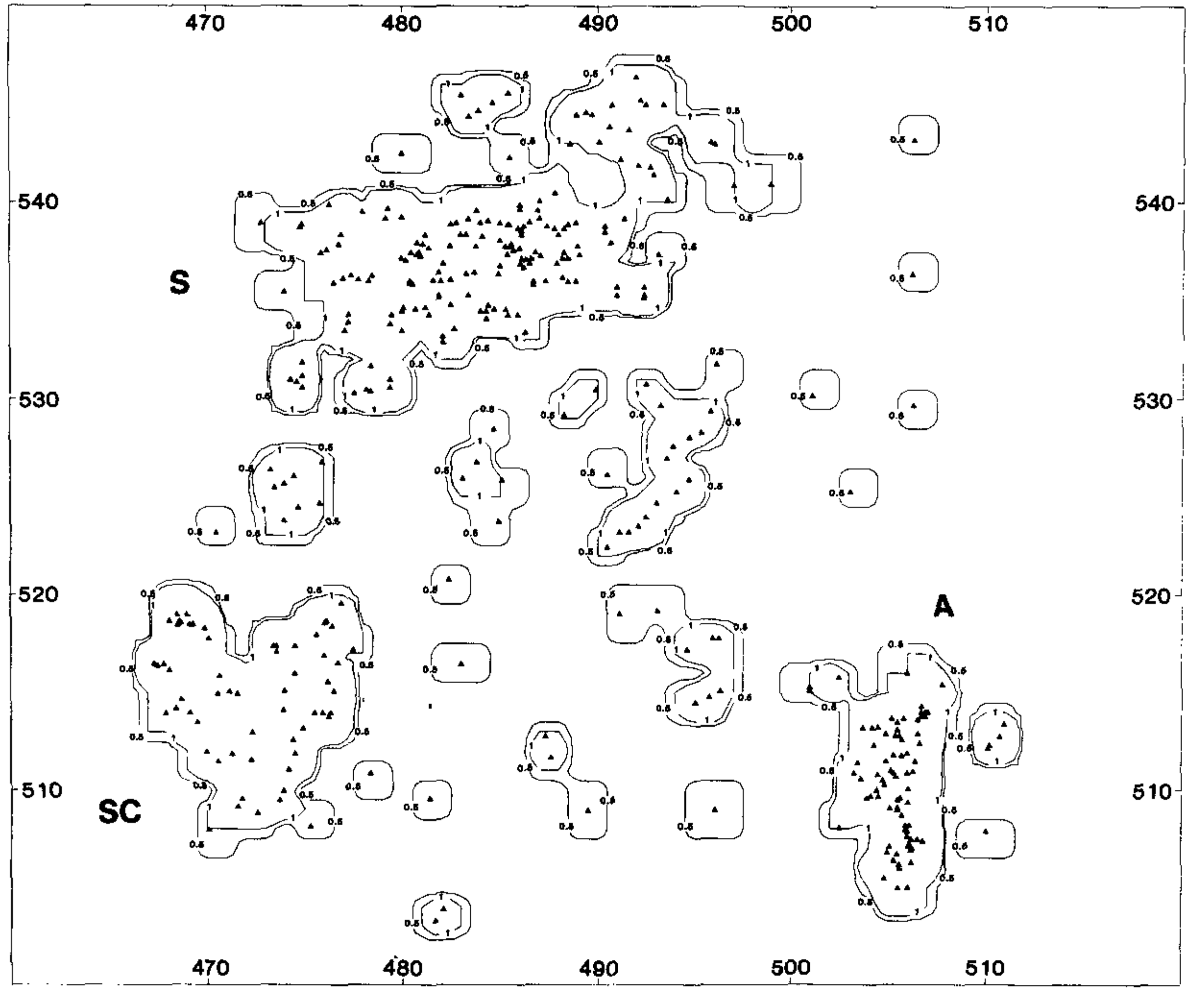


Figure 88. Machine-contoured spatial density contours for vein deposits (number of veins per 4 square kilometres) in and near the northern end of the Nelson batholith. High spatial densities centre on Ainsworth (A), Slocan (S), and Slocan City (SC) mining camps. Contours obtained for a square counting window with 50 per cent overlap of adjacent cells. Individual vein deposits are shown as closed triangles. Marginal numbers are UTM coordinates in kilometres.

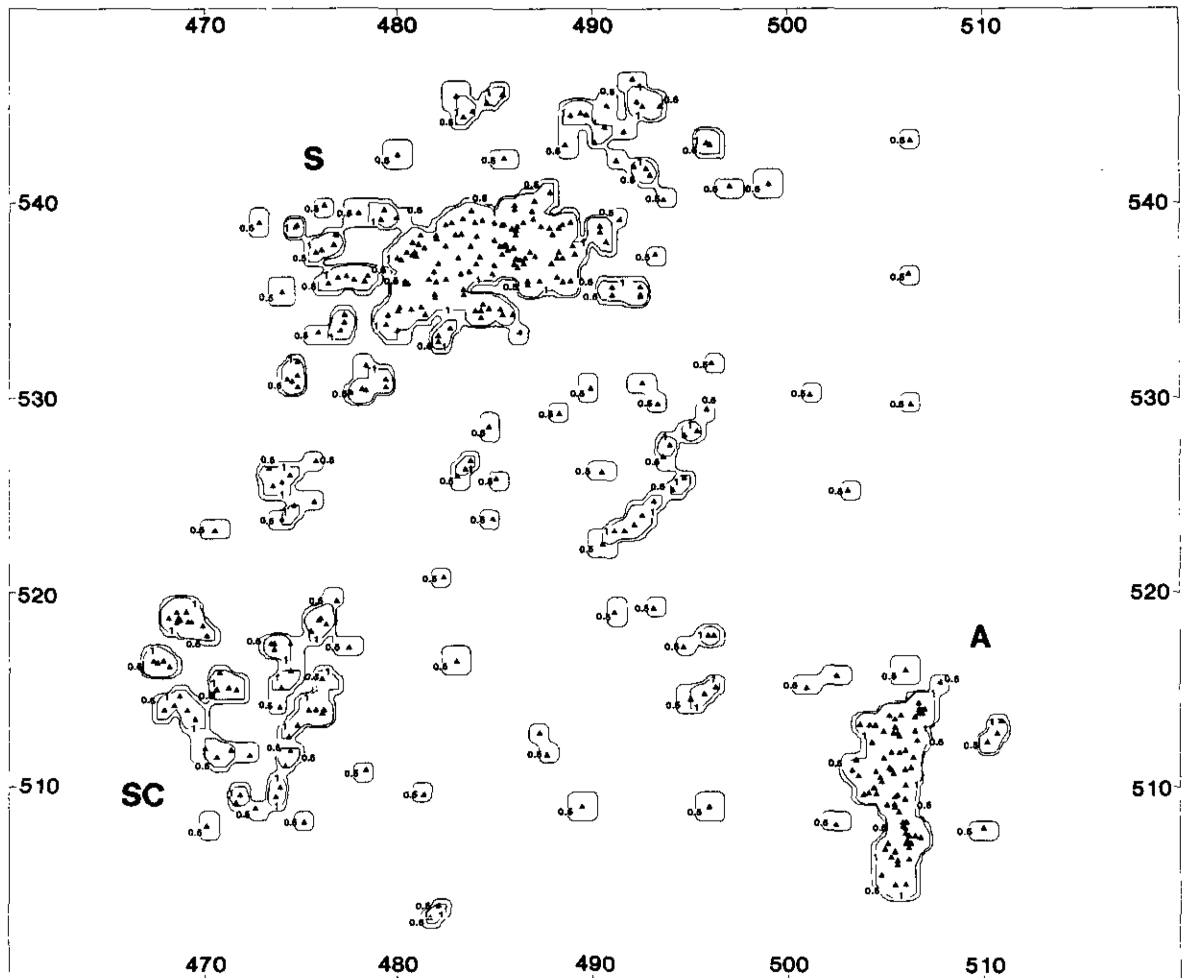


Figure 89. Machine-contoured spatial density contours for vein deposits (number of veins per 1 square kilometre) in and near the northern end of the Nelson batholith. Clusters of high spatial densities centre on Ainsworth (A), Slocan (S), and Slocan City (SC) mining camps. Contours obtained for a square counting window with 50 per cent overlap of adjacent cells. Individual vein deposits are shown as closed triangles. Marginal numbers are UTM coordinates in kilometres.

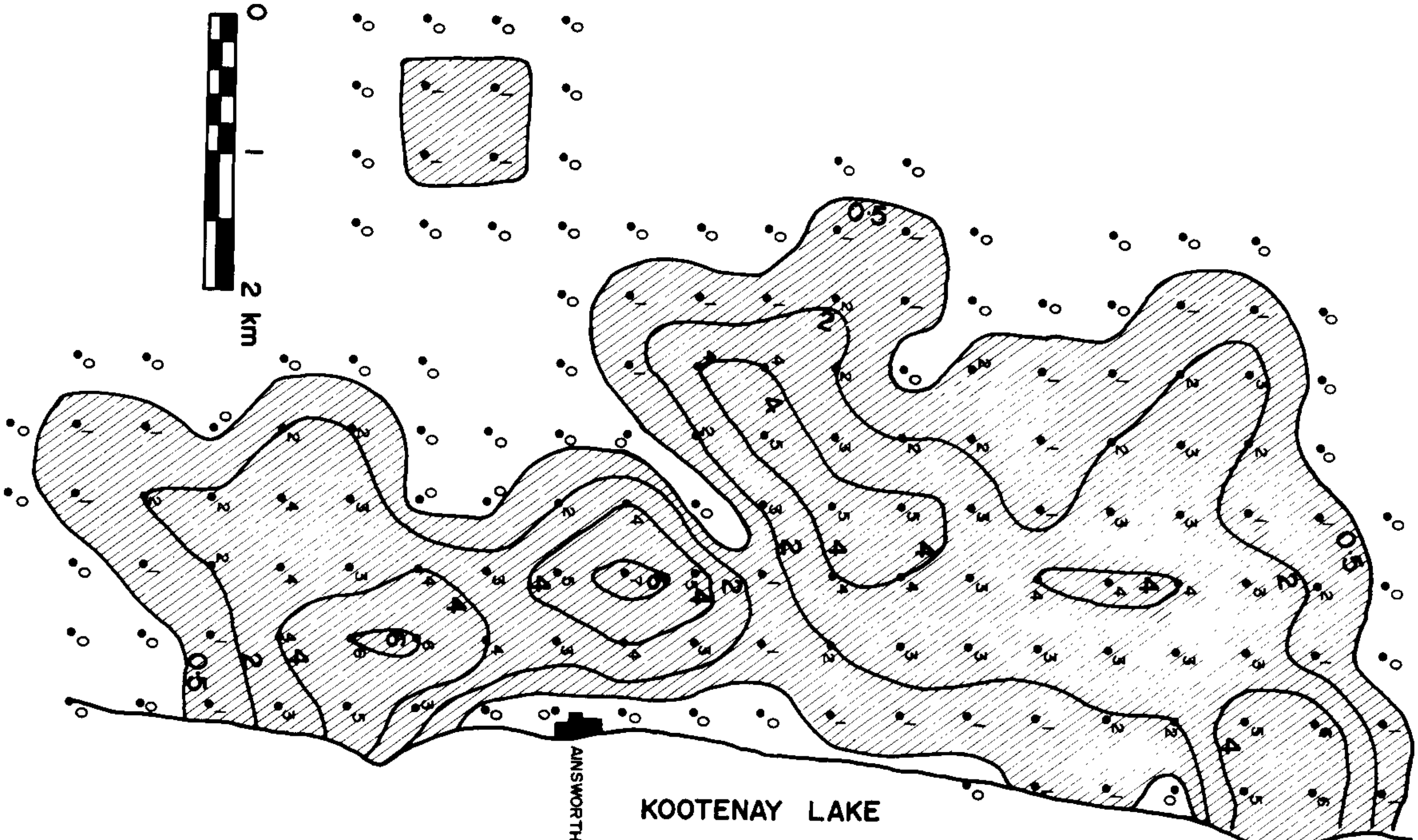


Figure 90. Hand-contoured spatial density map, Ainsworth camp. Counting cell used is 1 by 1 kilometre with 50 per cent overlap. Contours are number of past producers per 1 square kilometre. Modified from Sinclair (1979).

The data of Table 4 are based on the same counting criteria for the entire area. Such a procedure is probably desirable for reasons or practicability. However, different counting criteria may be optimal for different camps. Our experience has shown that counting cell size is particularly critical (*see* Tables 1, 2, and 3) to camp area estimates. A subjective evaluation of the Ainsworth camp, a tightly clustered group of veins in a relatively small area, suggests that a 1 by 1-kilometre counting cell is more appropriate than the 2 by 2-kilometre counting cell used for Figure 88. Spatial contours using a 1 by 1-kilometre counting cell for the equivalent area of Figure 88 are shown on Figure 89. This latter plot also demonstrates how disaggregated a camp appears if too small a counting cell is used as in the case of Slocan and Slocan City camps.

TABLE 4. AVERAGE SPATIAL DENSITIES FOR SOME SOUTHEASTERN BRITISH COLUMBIA MINING CAMPS (BASED ON 2 x 2 km COUNTING CELLS WITH 50 PER CENT OVERLAP)

Camp	Area (km^2)	No. of Deposits	Deposits per km^2
Ainsworth	78.5	71	1.0
Slocan	264.3	172	0.7
Slocan City	116.7	59	0.5

SYSTEMATIC VARIATIONS IN SPATIAL DENSITIES

Spatial density maps of mining camps also are important as a means of examining systematic patterns to deposit clustering within individual mining camps. For such a purpose we are faced with the same problem as in defining camp boundaries, that of selecting an appropriate contouring cell (window) size. If a cell is too small, many irregularities in the contours and 'holes' may obscure general trends. A practical means of selecting an appropriate contouring approach for examining variations in spatial density in a camp is to use a square cell with sides approximately the inverse of the deposit densities of Table 4. Thus, Ainsworth camp can be examined with a 1 by 1-kilometre counting window, Slocan City camp with a 2 by 2-kilometre counting window, and Slocan City midway between the two. Four separate mining camps are described in detail.

AINSWORTH CAMP

Spatial densities for Ainsworth camp (Sinclair, 1979) are shown on Figure 90. Here it is apparent that the camp is well defined as a cohesive unit with only a single nearby outlier, yet local concentrations are apparent within the camp. It is apparent that a single contouring grid will serve both purposes, that is, define general camp limits and average spatial densities, as well as showing local structure to the spatial densities. Average spatial densities calculated in this case for a square contouring grid cell of 1 by 1 kilometre provide an average density of 0.48 deposits per-square-kilometre. This compares with an average density of 1.05 deposits per-square-kilometre grid determined in an earlier section, and provides an indication of the variability of mean spatial density estimates relative to size of contouring grid. As expected, the smaller the grid, the smaller the 'camp area' and, if number of deposits remains constant, the higher will be the average spatial density.

In this particular case it appears that choosing the smallest contouring cell that provides a cohesive camp outline is the optimal empirical approach. Such a procedure, although subjective, provides potential for reproducibility by different operators.

It is interesting to speculate about the importance of the five highs shown in the detailed spatial density contours for Ainsworth camp. A plot of the five largest deposits in the camp shows that all are within the four southernmost spatial density highs. Even without further information one might speculate that the northernmost high, that consists only of small deposits, is an area that warrants investigation. The writers' interpretation for the camp is that 'bedded' veins represent syngenetic deposition in Cambrian time and that some of these bodies were partly mobilized during and/or after emplacement of the Nelson batholith to form numerous small 'transverse' veins. This model is consistent with observed distribution patterns of small (mostly transverse) deposits, relative to large (mostly bedded) deposits. It provides some geological basis for conducting further exploration in the northern spatial density high.

SLOCAN CITY CAMP

Visual examination of the distribution of deposits in Slocan City camp shows that the distribution is asymmetric with a small area of relatively high density and a much larger area mainly to the east, of much lower density (Fig. 88). A grid serving for one part may not serve for the other. However, a grid size controlled by the less dense area will serve, generally at least, for the denser areas. The contoured results of Figure 88 for Slocan City camp based on a 2 by 2-kilometre contouring grid cell cannot be improved significantly by the use of a smaller cell size. High spatial densities form a horseshoe-shaped zone with low values both in the core and surrounding the 'horseshoe.' Considering the 'structural' nature of the camp and known zonal patterns, the 'horseshoe' probably reflects a fundamental attribute of the camp. For example, near-circular fracture patterns on this scale (approximately 4 kilometres diameter) might be produced during emplacement of an underlying hypabyssal intrusion. If such is the case, the 'opening' in the horseshoe may represent an area of exploration interest because a circular pattern could be expected.

SLOCAN CAMP

In Slocan camp it is advantageous to examine spatial densities at two different scales of contouring grids. A large contouring grid cell defines a simple density high along a north-northwest direction and allows for clear definition of the camp. However, the camp contains a very large number of deposits and the possibility of determining some detailed structure to spatial densities exists. An example shown on Figure 91 is based on a counting window cell size of 1 by 1 kilometre and shows clearly separate groups or clusters of past producers. As in other examples, a considerable subjectivity exists in attempting to interpret the spatial density patterns.

TROUT LAKE CAMP

Trout Lake camp represents somewhat different data than do the other three camps considered to this point. Only a small portion of the 180 deposits reported in the camp have produced. Instead of contouring spatial densities of past producers, we have contoured spatial densities of all recorded veins and compared the positions of 45 known producers with the resulting pattern. The results, based on a contouring grid cell of 2 by 2 kilometres, are shown on Figure 92. Clearly, several separate major clusters of deposits are evident. Within each of these clusters are well-defined highs. Plotted positions of producers lie within the high contours. As with the Ainsworth camp, an explanation is not obvious, particularly since here we do not appear to have the possibility of two separate genetic models. Furthermore, there is the possibility that intense exploration in the immediate vicinity of a large deposit will give rise to more small discoveries. In other words, the association of past producers with areas of high spatial densities is self-generating. This latter explanation may be true in part, but it does not appear to provide a total explanation in old camps that have been thoroughly explored over a period of 70 or 80 years.

Spatial density contours clearly define three separate clusters of camps within the Trout Lake area. These separate clusters represent a quantification of previously recognized mineral belts.

Because of the very narrow widths of the mineral belts relative to their lengths, it is not possible to see any structure in the spatial density contours apart from the association of past producers with spatial density highs.

DISCUSSION

Spatial densities of mineral deposits offer problems relating to basic data and interpretation. One problem is illustrated by a major lode along which several different deposits are known -- at what point does an ore shoot along a lode become a separate entity for contouring purposes?

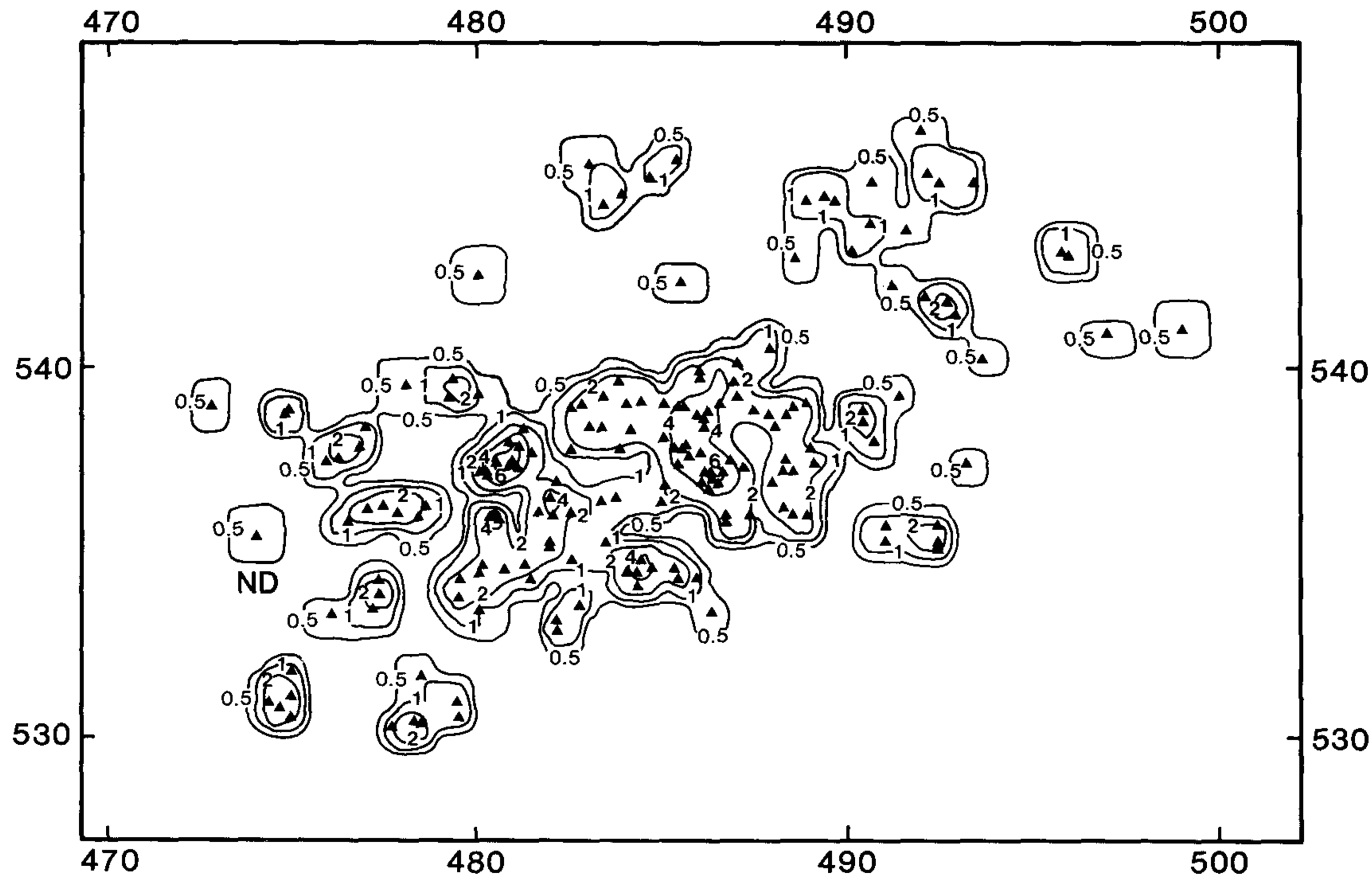


Figure 91. Redraughted machine-contoured map of spatial densities of mineral occurrences in Slocan mining camp based on 1 square kilometre counting cell with 50 per cent overlap of adjacent cells. Filled triangles are deposit locations; marginal figures are UTM coordinates in kilometres. Contour values are number of deposits per square kilometre. ND on the western part of the diagram is centred on New Denver.

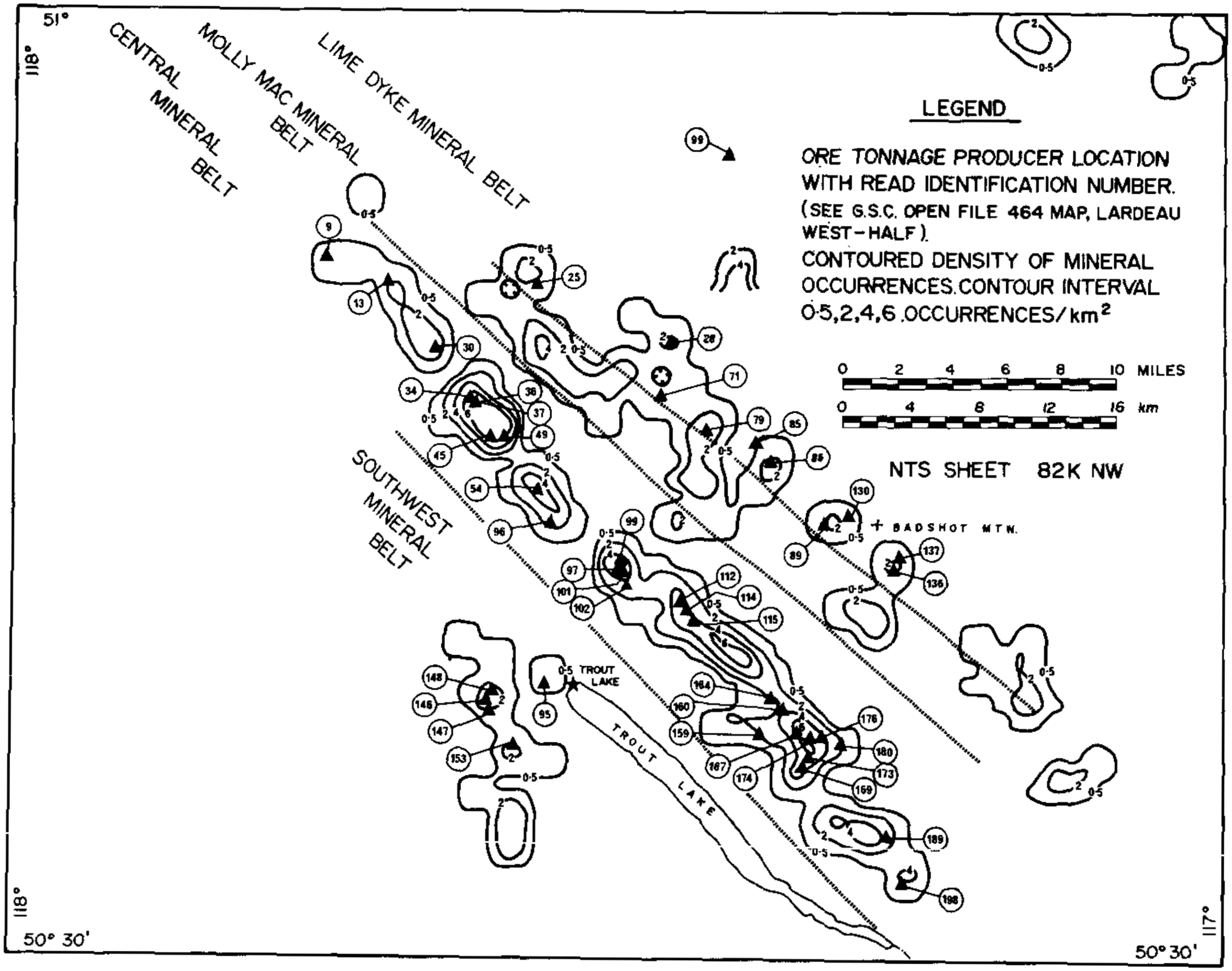


Figure 92. Manually produced spatial density contours (number of occurrences per 2 by 2-kilometre cell) for vein deposits in the Trout Lake area. Contours obtained with square counting window and 50 per cent cell overlap. Filled triangles are known vein occurrences in the camp. Numbers in circles refer to past producers for which geological and production information is tabulated by Read (1976).

We have ignored this question by accepting individual mining properties as individual deposits. Conversely, two separate veins from a single property may have their production data combined in which case spatial density contours will produce an overly smoothed pattern.

Newly found deposits affect spatial density contours derived from a data base of known deposits. Of course, spatial densities become underestimates if new deposits are found within the borders of a camp. It is possible that new deposits will be found outside the margins of a camp and add to the area of a camp. In this latter case it is unlikely that average spatial densities will change greatly. Overall, spatial densities are biased on the low side of reality. In long established camps that have undergone exploration for many decades, such as are studied here, this bias is likely to be slight in terms of mineral occurrences but could be substantial, at least locally, to metal distribution contours.

Average metal endowments of several mining camps can be compared. For example, average silver endowment in Slocan City camp, based on known production and the camp limits shown on Figure 88, is about 1 325 000 grams silver per square kilometre. The comparable figure for Ainsworth camp, based on the camp limits of Figure 90, is about 2 457 000 grams per square kilometre.

The use of metal spatial density contours appears a practical means of generalizing resource (metal) productivity in mining camps where production and/or resources are not concentrated in a few deposits. Even where many deposits exist, metal productivity can change dramatically over short distances and logarithmic values for contours are desirable. Most deposits were found over a few years in the early history of the camps considered here. Modern exploration concepts and methods applied to these camps have not yet resulted in a marked improvement (increase) in the number of finds, as might be expected if existing spatial densities are highly biased. This is an interesting conclusion to emerge from an evaluation of spatial density maps, and some indication of the importance of rates of discovery becomes apparent, as does the need to evaluate recent or new discoveries in the light of their positions relative to known spatial densities.

CONCLUSIONS

(1) Average spatial densities of deposit location and metal endowment data, although biased, represent useful means of comparing vein camps.

(2) In some cases spatial densities have internal patterns that may provide some insight to specific small areas warranting additional exploration or in providing an additional framework for conceptual models of mineralization.

(3) In many cases the large, valuable deposits in a vein camp occur in clusters with many small deposits. It appears that these associations may arise through complicated genetic histories, such as early formed deposits being mobilized to produce younger deposits. In other cases the clustering of large deposits with many smaller ones may be purely a question of clusters of structures, all mineralized at more or less the same time.

(4) The suggestion that spatial densities are highly biased seems unreasonable in the camps examined here. The implication of this statement is that relatively few veins remain to be found within the camps themselves.

ACKNOWLEDGMENTS

This work has developed intermittently over several years with the financial assistance of the Geological Survey of Canada, the B.C. Ministry of Energy, Mines and Petroleum Resources, and the Science Council of British Columbia. The technical assistance of Asger Bentzen in producing large numbers of contoured spatial density maps is appreciated.

REFERENCES

Goldsmith, L. B., Sinclair, A. J., and Read, P. B. (in preparation): An Evaluation of Average Grades and Production Tonnages, Trout Lake Mining Area, Southern British Columbia.

Orr, J.F.W. and Sinclair, A. J. (1971): A Computer-Processable File for Mineral Deposits in the Slocan and Slocan City Areas of British Columbia, *Western Miner*, Vol. 44, pp. 22-34.

Read, P. B. (1976): Lardeau West-Half, *Geol. Surv., Canada*, Open File Rept. 464.

Sinclair, A. J. (1979): Preliminary Evaluation of Summary Production Statistics and Location Data for Vein Deposits, Slocan, Ainsworth and Slocan City Camps, Southern British Columbia, *in* Current Research, Pt. B, *Geol. Surv., Canada*, Paper 79-1B, pp. 173-178.

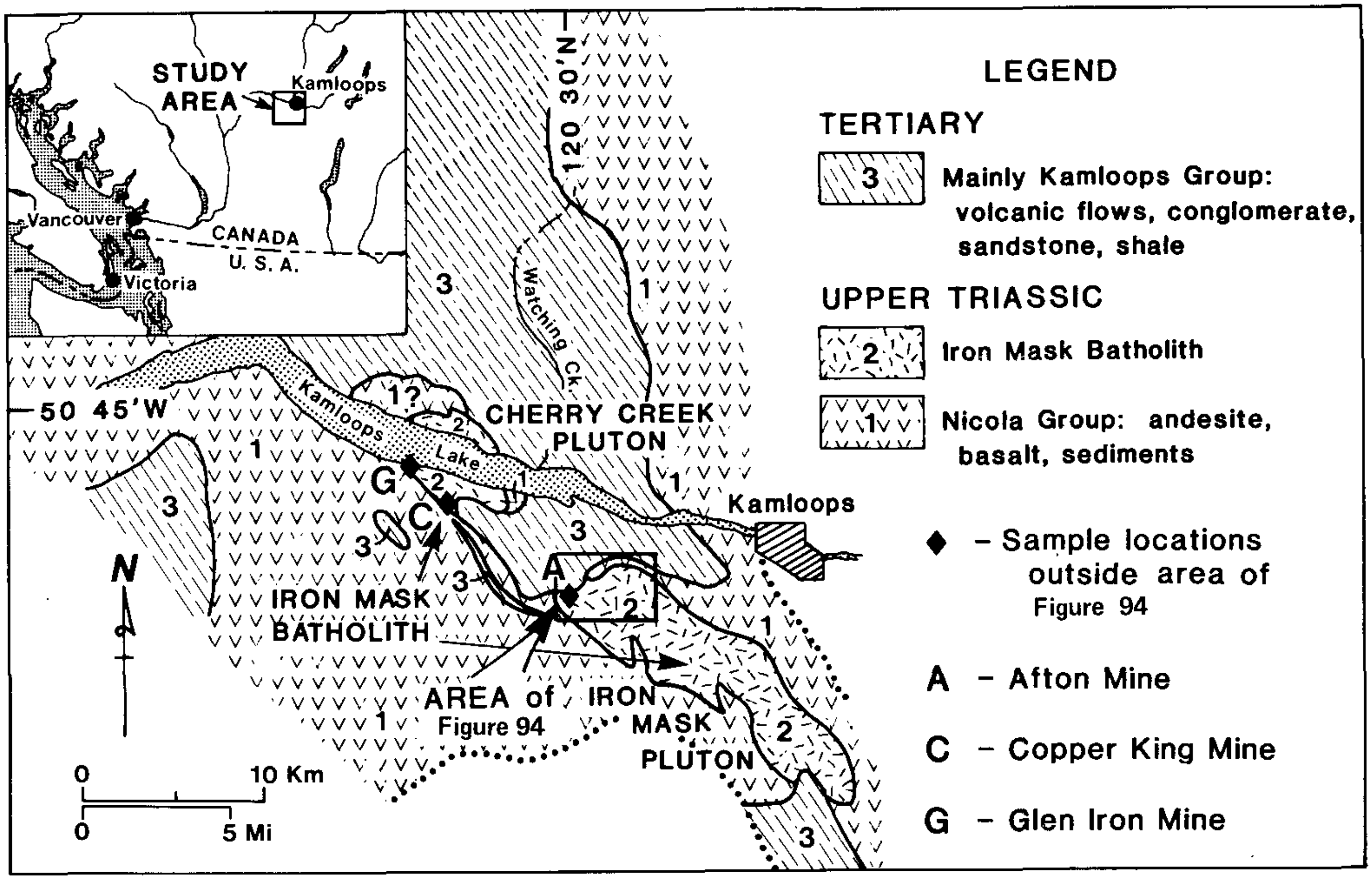


Figure 93. General location of and regional geology around the Iron Mask batholith (after Cockfield, 1948; Northcote, 1977a; Ewing, 1979).

GENESIS OF MAGMATIC MAGNETITE-APATITE LODES, IRON MASK BATHOLITH, SOUTH-CENTRAL BRITISH COLUMBIA (92I)

By R. M. Cann
3, 313 Highland Way, Port Moody

and

C. I. Godwin
Department of Geological Sciences, The University of British Columbia

INTRODUCTION

A worldwide association is known to exist between tabular to lenticular bodies of magnetite-apatite and alkalic rocks occuring in a volcanic or subvolcanic environment. Major examples include: (1) Park's (1972) brief descriptions of the occurrences of magnetite-apatite bodies in Chile, Peru, Mexico, California, Philippine Islands, and Australia; (2) Geijer's (1931, 1960) descriptions of the famous apatite iron ores of Kiruna, Sweden; (3) Kisvarsanyi and Proctor's (1967) work on iron deposits in southwest Missouri; and (4) Kolker's (1982) review of iron-titanium oxide and apatite localities in Virginia, New York, Quebec, Norway, and Sweden.

Magnetite-apatite bodies associated with Precambrian alkalic rocks in Canada have been noted in the Great Bear batholith, Northwest Territories (Badham and Morton, 1976). In British Columbia similar lodes occur in Mesozoic rocks at Galore Creek porphyry copper deposit, northwestern British Columbia (Davis, 1962), and in the Copper Mountain intrusion near the Ingerbelle porphyry copper deposit in south-central British Columbia. This study is concerned with magnetite-apatite lodes in the Iron Mask batholith.

GEOLOGICAL SETTING

The Iron Mask batholith lies in a northerly trending belt of Upper Triassic volcanic rocks known as the Nicola Group (Fig. 93), which range in composition from basalt to trachyte-dacite (Northcote, 1975; Cockfield, 1948; Preto, 1977). Argillite, limestone, and conglomerate have also been noted within the group in other areas (Cockfield, 1948; McMillan, 1978; Schau, 1970). To the north the batholith is overlain by Early Tertiary volcanic and sedimentary rocks.

Two major plutons form the Iron Mask batholith (Fig. 93). The larger one, the Iron Mask pluton, consists of a number of successively emplaced, differentiated units, whereas the smaller, more northerly Cherry Creek pluton consists of only the youngest unit. Figure 94 shows the northwest

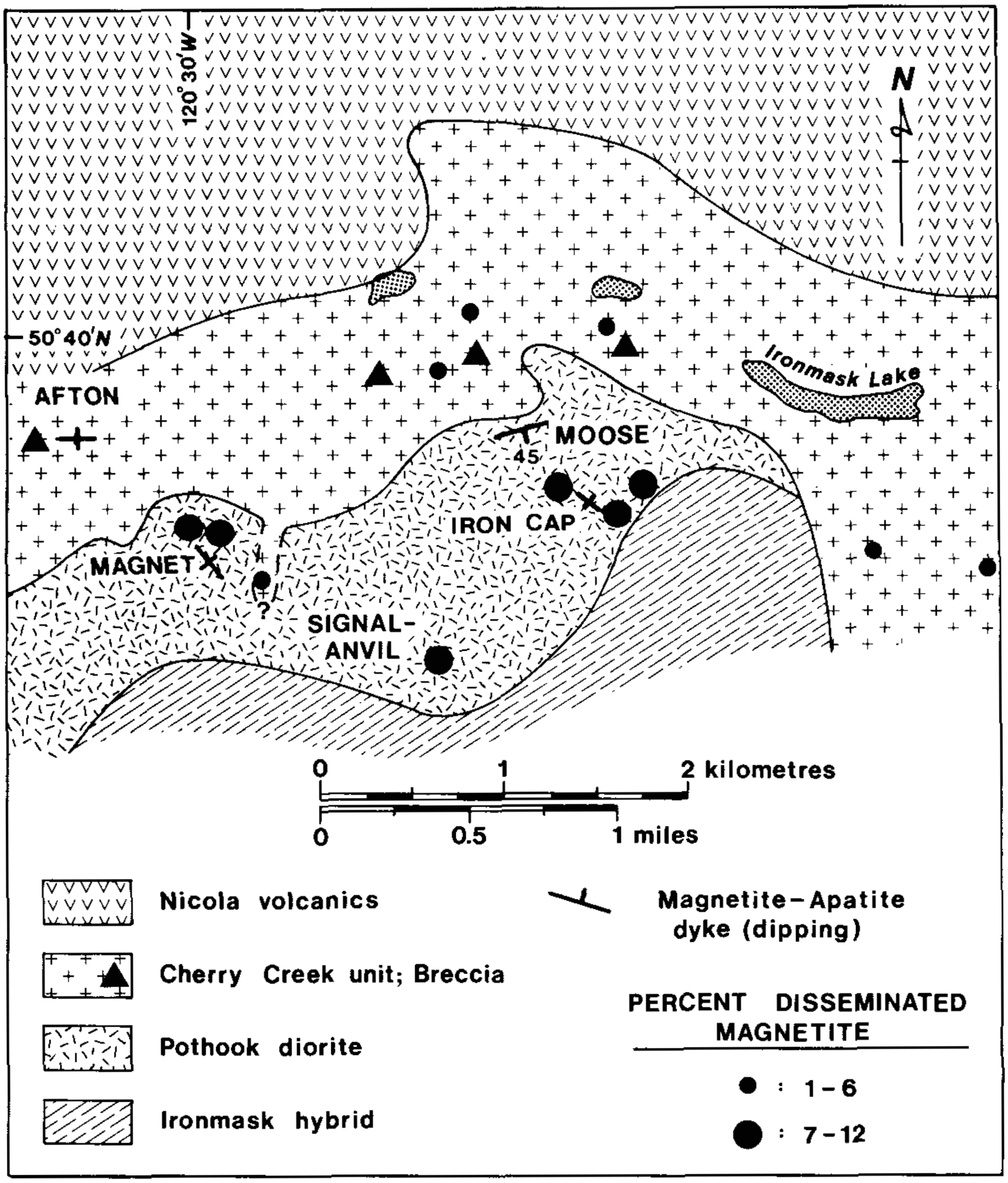


Figure 94. Simplified geology (after Northcote, 1977a) showing abundance of disseminated magnetite and distribution of magnetite-apatite dykes in Pothook (diorite) and Cherry Creek units. Data on magnetite are from this study and Mathews (1941).

end of the Iron Mask pluton, where relationships among several of the major rock units and magnetite-apatite lodes can be observed. These units are described below, with emphasis on associated magnetite mineralization. Subdivision of the units in the Iron Mask pluton follows descriptions by Northcote (1975, 1977a, 1977b).

Picrite occurs as small, fault-bounded, lenticular bodies (too small to show on Figs. 93 and 94) of serpentinized basaltic rock. Picrite is commonly associated with copper prospects (Carr, 1956; Carr and Reed, 1976). Chromium-rich magnetite occurs as fine anhedral grains in the matrix and as grains along fractures in serpentinized olivine. Volume content of magnetite is generally high, but varies from trace amounts to 15 per cent.

Iron Mask hybrid unit is agmatitic, consisting of angular and rounded mafic fragments in a dioritic matrix. Magnetite and copper sulphides are common in this unit. Only one sample of the unit, containing about 10 volume per cent magnetite, was taken for minor element analysis of magnetite.

Pothook diorite unit, gradational in composition between Iron Mask hybrid and Cherry Creek 'syenite', is medium to coarse grained, locally displays cumulate textures, and is mafic rich. Magnetite content averages about 10 per cent and occurs as interstitial grains. Most known magnetite-apatite lodes and also a number of small copper showings which are commonly associated with breccia occur within the unit (Fig. 94).

Sugarloaf unit (Preto, 1968), not known within the area of Figure 94, is a diorite containing hornblende and feldspar phenocrysts and only trace magnetite. Copper mineralization is common in this unit.

Cherry Creek 'syenite' (Preto, 1968) is a porphyritic unit ranging in composition from diorite to syenite. A monzonite composition is the most abundant. Subhedral magnetite grains, about 5 per cent by volume, occur either interstial to, or within, mafic minerals. Irregular bodies of intrusion breccia are common along the northern margin of the Iron Mask pluton and host porphyry-type copper mineralization. The Afton copper deposit (Fig. 94; Carr and Reed, 1976) is the most important porphyry deposit in the Iron Mask batholith and is located only 1.25 kilometres northwest of the largest magnetite-apatite lodes, which are known as the Magnet showings (Fig. 94).

Magnetite abundance in the previously mentioned units are shown schematically on Figure 94. A discordant decrease in magnetite abundance between the Pothook diorite and the Cherry Creek 'syenite' is evident in the diagram and from data in Table 1. A corresponding increase in apatite between Pothook and Cherry Creek units (Table 1) has also been noted by Mathews (1941).

TABLE 1

Volume Percent Disseminated Magnetite, Apatite and Apatite/Apatite+Magnetite for Dioritic and Syenitic Rocks, Iron Mask Batholith, B.C.

ARITHMETIC AVERAGE

Rock Type	%Disseminated Magnetite[1]	%Accessory Apatite[1]	%Apatite x 100 / %Apatite+%Magnetite
Diorite (Pothook)	6.5	trace[2]	12
Syenite Cherry Creek	3.5	0.8	20

1: Number of samples analyzed: magnetite in diorite-6; magnetite in diorite-2; apatite in syenite-3. Apatite data are from Mathews, 1941.

2: Trace was arbitrarily assigned 0.1%.

MAGNETITE DEPOSITS ASSOCIATED WITH THE BATHOLITH

FORM AND DISTRIBUTION

Most magnetite lodes (Cann, 1978) occur as steeply dipping tabular bodies with sharply defined walls that vary in width from less than 1 centimetre to 3 metres at the Magnet showing (Fig. 94) and 6 metres at the Glen Iron mine. Although lodes are generally steeply dipping, some dip as little as 40 degrees south (for example, Moose showing, Fig. 94). The lodes tend to split at irregular intervals and end abruptly. No single lode has been followed for more than 200 metres, in part because of limited outcrop.

Magnetite lodes are concentrated at the northwest end of the batholith. Along the northwestern margin of the Iron Mask pluton and at the Glen Iron mine, most lodes trend easterly; however, those at the Magnet and Iron Cap trend northwesterly. They are interpreted to be dykes.

MINERALOGY AND TEXTURES

The Magnet showing was studied in the most detail because exposures are excellent. Lodes at the Magnet showing consist predominantly of massive magnetite that contains white or pale pink euhedral apatite crystals up to 3 centimetres long, and prismatic amphibole crystals up to 6 centimetres long. Amphibole and apatite crystals frequently occur in layers adjacent to the walls of the lodes. Long axes are perpendicular to the walls of the lodes; textures are spinifex-like and might result from quenching at the margin of the dyke. Polished sections of massive magnetite show an euhedral or subhedral granular texture, with individual grains ranging from 0.1 to 0.5 millimetre in diameter. Trains of spinel inclusions less than 30 microns in diameter parallel some grain boundaries. When etched with bromic acid, one sample displayed an extremely fine crystallo-graphic exsolution texture of ilmenite in magnetite.

Adjacent to the main dykes, numerous subparallel dykelets are often abundant enough to form a crisscrossing network; most are less than 5 centimetres wide. Some dykes of intermediate width (10 to 15 centimetres) are breccias containing numerous angular to subrounded inclusions of host rock. Dykelets are commonly enclosed by a 1 to 2-millimetre-wide pink albitized envelope, and occasionally contain narrow epidote cores.

At the Magnet showing pyrite and chalcopyrite occur in veins along fractures in magnetite-apatite dykes, indicating that sulphide mineralization is post-magnetite. In general, magnetite-apatite bodies at Afton are sulphide poor, probably because they contain few fractures. Late-stage veins of drusy calcite crosscut magnetite and sulphide mineralization.

MINOR AND MAJOR ELEMENTS IN MAGNETITE FROM IRON MASK BATHOLITH

Characterizations of magnetite from the Iron Mask batholith have been done on overall composition based on major and minor oxides as determined by electron microprobe and in terms of minor element content alone as determined by atomic absorption. For comparative purposes magnetite samples have been grouped by form (disseminated or massive) and host rock (syenite, diorite, picrite). Syenite as used in this study is equivalent to the Cherry Creek unit, which includes syenite, monzonite, and diorite. Diorite is equivalent to the Pothook and Iron Mask hybrid units (Fig. 94). Samples were grouped on the basis of petrographic analysis, mapping by Northcote (1977a, 1977b), and examination of samples by Northcote (personal communication, 1977).

ANALYTICAL METHODS

Liberation of magnetite was achieved by passing all samples of massive and disseminated magnetite through a jaw and cone crusher, followed by pulverization between ceramic plates until the sample passed through a 100-mesh nylon sieve. Massive magnetite with little gangue was readily concentrated using a repeated cycle of underwater magnetic separation and grinding by hand with ceramic mortar and pestle until the desired purity of greater than 95 volume per cent magnetite was obtained. Magnetite disseminated in intrusive rocks and massive magnetite with abundant gangue required initial rough separation with an Eriez Wet Drum Magnetic Separator and density separation in bromoform before using the method described previously.

Quantitative analysis of magnetite for cobalt, chromium, copper, manganese, magnesium, nickel, lead, titanium, vanadium, and zinc was done by atomic absorption spectrophotometry. A Varion-Techtron AA-4 unit was used for chromium, copper, magnesium, manganese, vanadium, and zinc analysis, and a Perkin-Elmer model 303 unit with background correction (Fletcher, 1970) was used to determine cobalt, nickel, and lead.

TABLE 2

Summary of Electron Microprobe Analyses[1] of

Magnetite from the Iron Mask Batholith, B.C.

Host Rock (Character)	Parameter[2]	SiO_2	TiO_2	Al_2O_3	Cr_2O_3	V_2O_3	FeO	MnO	MgO	CaO	Sum	FeO[3]	Fe_2O_3[3]	Total
Cherry Creek Syenite (Disseminated)	n	4	4	4	4	4	4	4	4	4	4	4	4	4
	$\bar{x}$	0.11	1.20	0.20	0.06	1.54	88.50	0.13	0.12	0.65	92.56	31.51	63.35	98.92
	s	0.06	1.55	0.27	0.04	0.18	2.01	0.16	0.17	1.27		2.96	3.34	
Pothook Diorite (Disseminated)	n	2	2	2	2	2	2	2	2	2	2	2	2	2
	$\bar{x}$	0.09	0.97	1.38	0.03	1.49	88.86	0.36	0.10	0.04	93.32	32.82	62.30	99.53
	s	0.01	1.05	0.82	0.02	0.16	4.04	0.31	0.03	0.04		0.35	4.89	
Cherry Creek plus Pothook Syenite plus Diorite (Disseminated)	n	6	6	6	6	6	6	6	6	6	6	6	6	6
	$\bar{x}$	0.10	1.12	0.59	0.05	1.52	88.62	0.24	0.11	0.45	92.80	31.94	63.00	99.12
	s	0.04	1.30	0.74	0.04	0.15	2.39	0.21	0.14	1.03		2.32	3.44	
Picrite (Disseminated)	n	1	1	1	1	1	1	1	1	1	1	1	1	1
	$\bar{x}$	0.04	1.81	7.49	7.02	0.26	67.05	0.29	3.85	0.04	92.87	25.51	46.18	87.52
Cherry Creek Syenite[4] (Massive)	n	1	1	1	1	1	1	1	1	1	1	1	1	1
	$\bar{x}$	0.25	0.98	0.35	0.03	1.71	89.77	0.23	0.42	0.00	93.73	32.27	63.90	100.14
Pothook Diorite (Massive)	n	3	3	3	3	3	3	3	3	3	3	3	3	3
	$\bar{x}$	0.43	0.06	0.42	0.01	1.02	89.62	0.11	0.33	0.03	92.09	31.13	65.00	98.60
	s	0.22	0.03	0.15	0.01	0.06	2.15	0.06	0.30	0.06		0.77	1.61	

1: Analyses done on an ARL-SEMQ instrument at the Department of Geological Sciences, The University of British Columbia.

2: n = number of samples; $\bar{x}$ = arithmetic mean; s = standard deviation.

3: Recalculated analyses (after Carmichael, 1967).

4: Massive magnetite fragment in Cherry Creek syenite.

Titanium was determined at a commercial facility, Min-En Laboratories, North Vancouver. Sample digestion and analytical methods were similar to those of Nakagawa (1975), except that in this study calcium was not removed from solutions prior to analysis.

Microprobe analyses were done on an ARL-SEMQ instrument (Cann, 1979). Background, deadtime, absorption, atomic number, and fluorescence corrections were applied using a computer program developed by Rucklidge and Gasparrini (1969).

COMPOSITION OF MAGNETITE SAMPLES FROM IRON MASK BATHOLITH

Compositions of 13 disseminated and massive magnetite samples were determined using the electron microprobe. Results of the analyses are displayed in Table 2 and plotted on Figure 95. A minimum of three magnetite grains per sample were analysed. For purposes of determining average compositions, only analyses with totals exceeding 97 per cent were considered. Molecular per cent ulvospinel was calculated based on the measured titanium content.

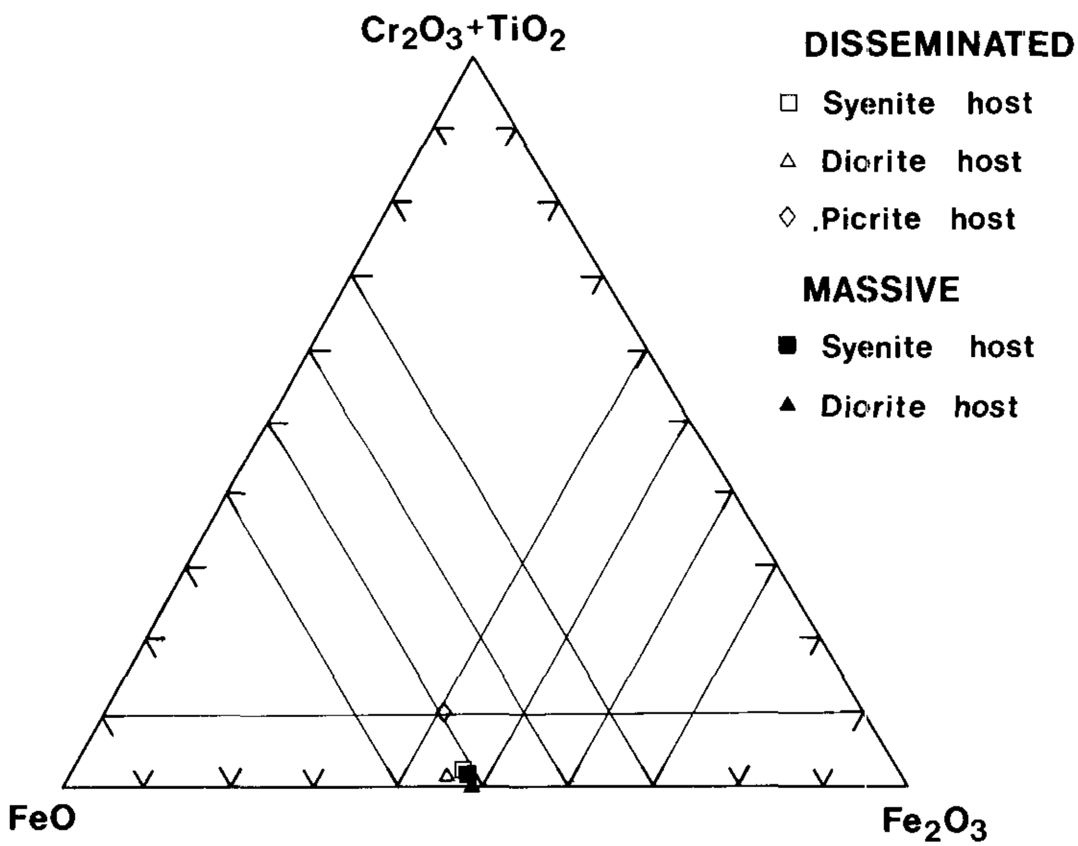


Figure 95. Composition of magnetite from Iron Mask batholith in terms of molecular per cent $FeO-Fe_2O_3-TiO_2+Cr_2O_3$.

TABLE 3

Average of Six Electron Microprobe[1] Analyses of Apatite from the Glen Iron Magnetite Lode Iron Mask Batholith, B.C.

Element or Oxide	Weight %	S[2]
F^-	2.19[3]	0.39
MgO	0.04	0.004
P_2O_5	40.83	0.36
Cl	0.83[3]	0.35
CaO	55.47	1.41
MnO	0.10	0.01
FeO	0.13	0.009
TOTAL	99.59	

1: Analyses done on an ARL-SEMQ instrument at the Department of Geological Sciences, The University of British Columbia.

2: S is the standard deviation based on six analyses.

3: Analyses are qualitative due to inadequate microprobe standard.

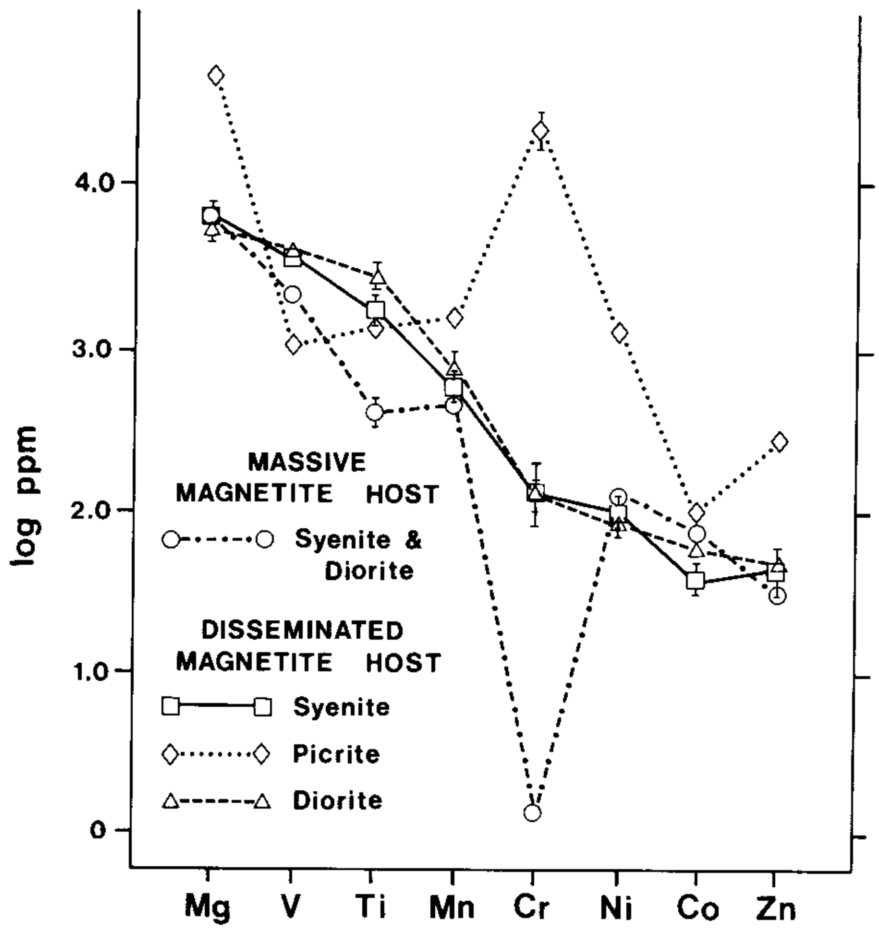


Figure 96. Mean minor element content of massive and disseminated magnetite in syenite, diorite, and picrite, Iron Mask batholith. Error bars show the standard error of the mean. Data are from Table 2.

Inspection of Figure 95 shows that chromium-rich magnetite from picrite has a composition which is distinct from disseminated and massive magnetite in syenite and diorite. The composition of this chromium-rich magnetite is similar to compositions reported for magnetites from basaltic rocks (Table Hg-20 *in* Haggerty, 1976).

Lode magnetite and disseminated magnetite from syenite and diorite plot in a compact cluster. There is no statistical difference (at 99 per cent confidence limits) between the means and standard deviation of oxides in disseminated magnetite from syenite or from diorite. Comparison of oxides in diorite-hosted massive magnetite to those in diorite and syenite-hosted disseminated magnetite shows a significant difference only in the mean V_2O_2 content and the standard deviations of SiO_2, TiO_2, and CaO. The almost identical composition of lode and disseminated magnetite from syenite and diorite suggests close genetic associations.

COMPOSITION OF APATITE IN MAGNETITE LODES

The apatite analysis in Table 3 is the average of six electron microprobe analyses of three crystals of apatite in massive magnetite from the Glen Iron mine (Fig. 93). Composition of apatite is uniform between crystals. Additional analytical traverses from centre to edge of an individual crystal showed no zoning. Glen Iron apatite is fluorine rich, which is also typical of apatite in the magmatic Kiruna iron ores (Frietsch, 1978).

MINOR ELEMENTS IN MAGNETITE

Mean minor element abundances in disseminated magnetite from syenite, diorite, syenite plus diorite, and picrite, and minor element abundances in magnetite from syenite and diorite-hosted magnetite-apatite lodes are summarized in Table 4. All variables reported have lognormal density distributions; consequently, geometric means and corresponding standard deviations are reported. Zero values were assumed to be 0.1 for purposes of log transformations. Copper and lead are not included, due to poor analytical or sampling precision as revealed by a nested analysis of variance (Griffiths, 1967).

Element abundances in massive magnetite and in syenite, diorite, and picrite-hosted disseminated magnetite are shown schematically on Figure 96. Several points are well displayed by the diagram, namely:

(1) minor element abundances are very similar in diorite and syenite-hosted disseminated magnetite,

(2) minor element abundances in disseminated magnetite in picrite are markedly different from those in all other magnetites, and

TABLE 4

Summary of Data (PPM) for Minor Elements in Disseminated Magnetite

(numbers are antilogarithms of log-transformed data)

Property	Host Rock (Character)	Parameter[1]	Co	Cr	Mg	Mn	Ni	Ti[2]	Y	Zn
	Cherry Creek Syenite (disseminated)	n	8	8	8	8	8	7	8	8
		Xg	40	132	6800	600	106	1850	3740	42
		Xg+S	65	543	11200	1100	192	3760	5210	101
		Xg-S	25	32	4100	400	58	910	2690	18
	Pothook Diorite (disseminated)	n	7	7	7	7	7	5	7	7
		Xg	60	124	5800	800	81	3020	4020	46
		Xg+S	68	252	9700	1400	107	5160	4740	77
		Xg-S	53	61	3500	500	62	1770	3400	27
	Cherry Creek plus Pothook Syenite plus Diorite (disseminated)	n	15	15	15	15	15	12	15	15
		Xg	49	128	6300	700	94	2270	3870	44
		Xg+S	73	387	10400	1200	151	4420	5020	89
		Xg-S	32	42	3800	400	58	1170	2990	22
	Picrite (disseminated)	n	6	6	6	6	6	6	6	6
		Xg	100	248000	55300	1700	1340	1545	1100	290
		Xg+S	133	493000	76200	2500	2140	2930	1400	360
		Xg-S	75	125000	40200	1200	840	815	860	230
Magnet, Iron Cap	Pothook Diorite (massive)	n	33	33	33	33	33	33	33	33
		Xg	76	1	6400	400	135	450	3050	27
		Xg+S	104	12	8900	700	164	920	3440	38
		Xg-S	56	0	4600	300	111	220	2710	19
Afton, Glen Iron	Cherry Creek Syenite (massive)	n	5	5	5	5	5	5	5	5
		Xg	93	1	6500	800	129	312	2010	88
		Xg+S	187	7	11100	2000	220	787	3210	324
		Xg-S	47	0	3800	300	75	124	1260	24
Magnet, Iron Cap, Afton, Glen Iron	Diorite and Syenite (massive)	n	38	38	38	38	38	38	38	38
		Xg	78	1	6400	500	134	427	2990	32
		Xg+S	114	11	9100	800	173	900	3670	62
		Xg-S	54	0	4500	300	104	202	2290	16

[1]: n = number of analyses; Xg = geometric mean; s = standard deviation.

(3) minor elements in massive magnetite show a similar distribution to those in syenite and diorite-hosted disseminated magnetite, except for strong depletion of chromium and titanium, and weak depletion of vanadium in massive magnetite.

Statistical comparison of means and variances at 99 per cent confidence limits confirms the previously described observations and also shows that in six out of eight elements, abundances in massive magnetite are significantly closer to those in disseminated magnetite from syenite than to those in disseminated magnetite from diorite (Cann, 1979).

COMPARISON OF MINOR ELEMENTS IN MAGNETITE LODES IN IRON MASK BATHOLITH WITH MINOR ELEMENTS IN MAGNETITE DEPOSITS IN OTHER AREAS

Variances and means of elements in Iron Mask magnetite-apatite deposits have been statistically compared to those of Missouri and Swedish deposits and show that at the 99 per cent confidence level statistical distribution of most minor elements in magnetite of the Iron Mask lodes are similar (Fig. 97) to those for magnetite from three deposits in Missouri (Kisvarsanyi and Proctor, 1967) and four deposits in Kiruna, Sweden (Parák, 1975, pp. 199-202). This statistical similarity for most elements is readily apparent on Figure 97, and reinforces the interpretation that Iron Mask magnetite-apatite lodes have an intrusive-magmatic origin, like the Kiruna and Missouri deposits.

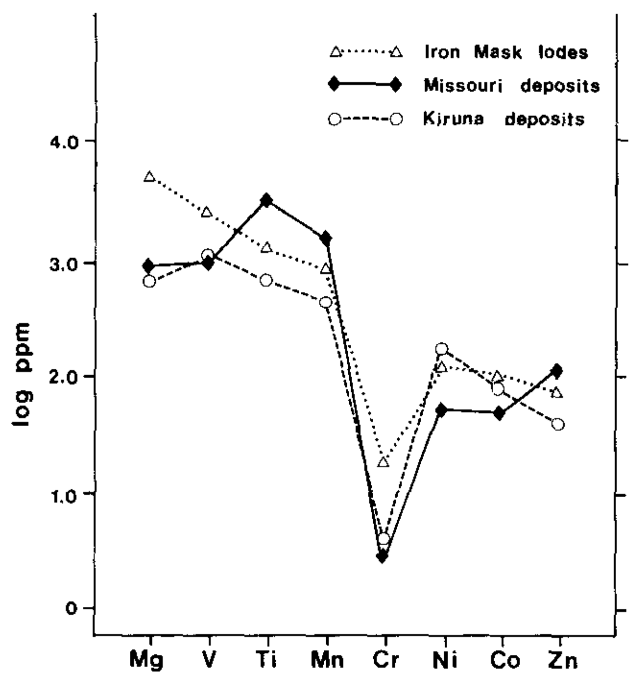


Figure 97. Arithmetic means of minor element abundances in magnetite from Iron Mask lodes, and magmatic magnetite-apatite deposits from Missouri, U.S.A. and Kiruna, Sweden. See text for references to data.

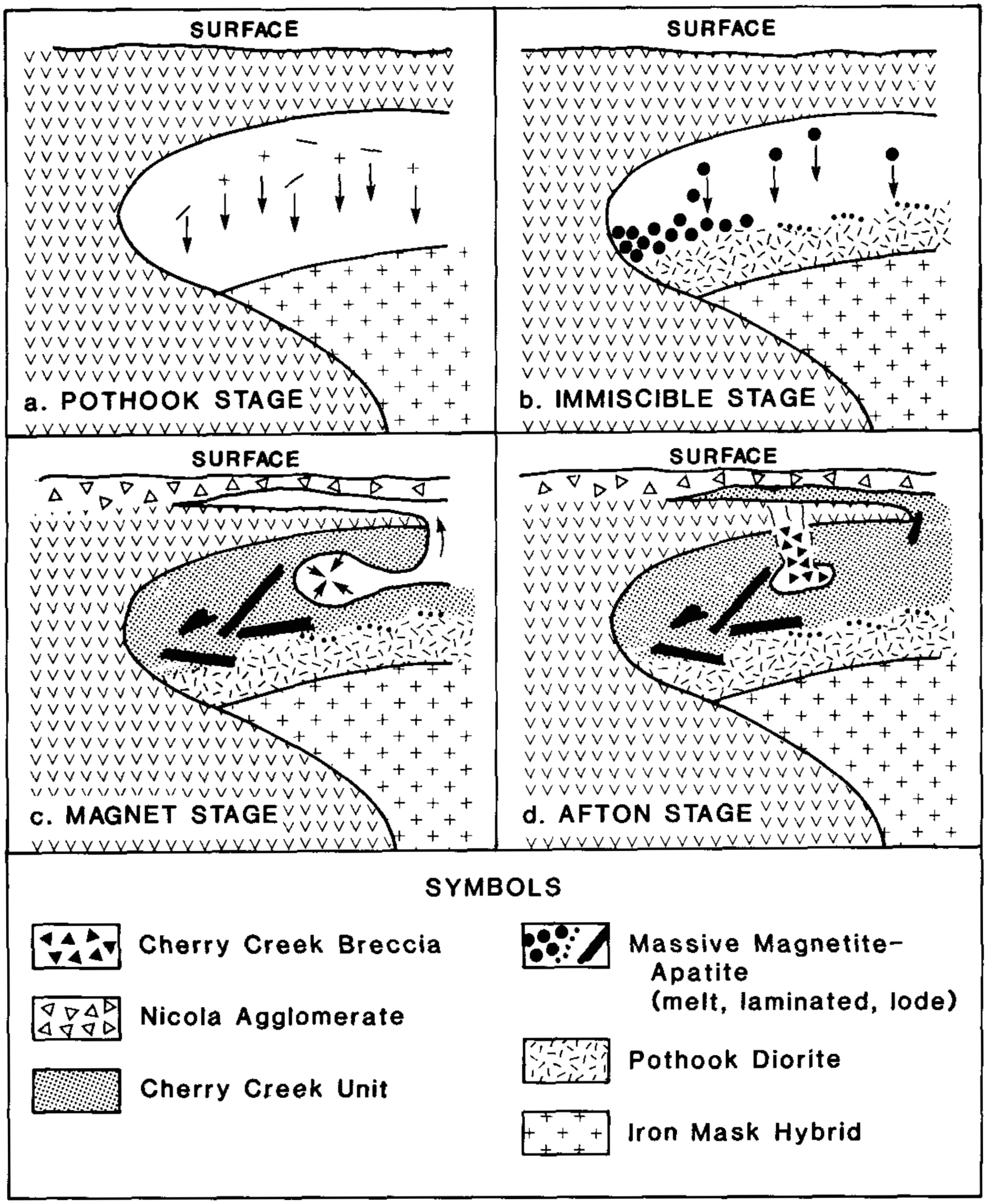


Figure 98. Diagrammatic cross-sections (looking east) illustrating genesis of magnetite-apatite lodes in the northwest end of Iron Mask pluton (see Fig. 94). Reference should be made to the text for descriptions of the stages illustrated.

For statistical comparison with Iron Mask magnetite deposits, minor element data for five metasomatic magnetite deposits and one hydrothermal magnetite deposit in the U.S.S.R. (Borisenko, *et al.*, 1969) were compiled. These data suggested that metasomatic deposits have one-hundredth to one-thousandth the nickel and chromium contents of magmatic magnetite-apatite deposits and that hydrothermal magnetite deposits have significantly less cobalt and chromium than magmatic magnetite deposits.

DISCUSSION

Major and minor element data on magnetite and petrologic analysis lead to several important conclusions regarding the genesis of magnetite lodes in the Iron Mask batholith. A metasomatic origin can probably be discounted on the basis of the chromium and nickel contents, sharp contacts, and the tabular nature of the lodes. Origin as hydrothermal veins can be discounted on the basis of higher chromium content than other hydrothermal vein deposits. Nevertheless, to make the existence of a 'magnetite-apatite' melt feasible at geologically acceptable temperatures, a high volatile content is probably necessary. Park (1972) and Geijer (1967) pointed out the apparently high volatile content of magnetite-apatite dykes. Fluorine-rich apatite in Iron Mask dykes suggests that fluorine is a significant volatile component.

CONCLUSIONS

A model for the origin of magnetite-apatite lodes is presented on Figure 98. It is based on our trace element in magnetite data and on experimental evidence for magnetite-apatite lodes.

The sequence of events is pictured as follows:

(1) POTHOOK STAGE. Crystal settling of plagioclase and pyroxene to form Pothook diorite. With continued differentiation the residual magma becomes increasingly rich in iron as suggested by interstitial magnetite in Pothook diorite (Table 1).

(2) IMMISCIBLE STAGE. Near the point where the residual magma becomes alkalic in character, the magma enters an immiscibility field that is expanded by high volatile components (Philpotts, 1967) and the 'oxide-apatite' melt separates from the silicate magma. The heavy 'oxide-apatite' droplets settle to the bottom of the magma chamber and coalesce to form layers and pools in Pothook diorite at the margins of the magma chamber (*see* Ramdohr, 1969, p. 8).

(3) MAGNET STAGE. Residual alkalic magma, now depleted in iron (Fig. 94; Table 1), continues crystallizing as Cherry Creek 'syenite.' Extrusion of Nicola agglomerate containing Cherry Creek fragments (Northcote, 1977a) occurs and emphasizes the near surface and

cogenetic nature of the intrusion and Nicola volcanic rocks. Injection of magnetite-apatite melt into fractures formed in the now consolidated surrounding intrusion occurs synchronously with eruptions of alkalic magma to the surface. Such activity might in part result from increasing volatile pressures.

(4) AFTON STAGE. Increasing volatile pressure at the end of magmatic differentiation exceeds external load pressure and tensile strength of the surrounding rocks (Norton and Cathles, 1973) resulting in explosive emplacement of Cherry Creek breccias. Orthomagmatic hydrothermal fluids follow the breccia and result in copper mineralization at Afton and elsewhere in the Cherry Creek unit. Copper mineralization crosscuts the earlier magnetite lodes.

Comparison of cross-section D (Afton stage, Fig. 98) to the simplified geological plan of the northwestern end of the batholith (Fig. 94) shows remarkable similarities despite the differences in perspective. The deficiency of magnetite in Cherry Creek syenite compared to Pothook diorite (Fig. 94; Table 1) is well explained by fractionation of the immiscible iron oxides from the alkalic magma that crystallizes to form the Cherry Creek unit. The model also explains the close spatial association of the lodes with Cherry Creek unit as well as their common occurrence within or near the iron-rich Pothook diorite.

An important implication from the model, regarding the relationship between magnetite-apatite and copper mineralization at Afton, is that the same magma phase was parent to both the magnetite and copper mineralization. Magnetite lodes were formed before a sulphide-rich hydrothermal system became important. Elsewhere in the batholith magnetite occurs as fragments in a Cherry Creek phase indicating magnetite emplacement was not the last magmatic event to take place (Cann, 1979).

Picrites appear to be more primitive and genetically distinct from alkalic and dioritic rocks in the batholith. Thus copper mineralization that is spatially and possibly genetically related to picrite, such as the Iron Mask mine, might not be related directly to Afton-type mineralization. This conclusion has direct implications to mineral exploration because it suggests that different geological models apply to different types of copper occurrences in the Iron Mask batholith.

Our model for iron and copper mineralization suggests that copper mineralization is produced by late-stage magmatic fluids that resulted in formation of Cherry Creek breccias. A magmatic origin for copper mineralization is supported by Hoiles (1978), who found that the $\delta^{34}S$ values of sulphides from the Afton deposit are comparable to other deposits of magmatic hydrothermal origin because they are close to 0 per mil with a small standard deviation. Alkaline-type porphyry deposits, such as Afton, are known to be significant only in the North American Cordillera in the region from Alaska to Idaho (Hollister, 1978). Possibly the unique alteration and mineralogy of alkalic porphyries result from strong differentiation, whereas mineralization in calc-alkalic porphyries is due to collapsing hydrothermal systems that involved both meteoric and magmatic waters (Taylor, 1974; Whitney, 1975).

ACKNOWLEDGMENTS

The writers thank the British Columbia Ministry of Energy, Mines and Petroleum Resources and Natural Science and Engineering Research Council for supporting this study with grants. A. Waskett-Myers assisted in atomic absorption analyses and J. Knight and L. Pigage helped with microprobe analyses. A. J. Sinclair guided the statistical interpretations and critically read the manuscript.

REFERENCES

Badham, J.P.N. and Morton, R. D. (1976): Magnetite-Apatite Intrusions and Calc-Alkaline Magmatism, Camsell River, Northwest Territories, *Cdn. Jour. Earth Sci.*, Vol. 13, No. 2, pp. 348-354.

Barr, D. A., Fox, P. E., Northcote, K. E., and Preto, V. A. (1976): The Alkaline Suite Porphyry Deposits -- A Summary, *in* Porphyry Deposits of the Canadian Cordillera, A. Sutherland Brown, editor, *C.I.M.*, Special Vol. 15, pp. 359-367.

Borisenko, L. F., Lebedeva, S. I., and Serbodova, L. I. (1969): Titanium Magnetite and Magnetite of Iron Ore Deposits of Different Genesis, *Internat. Geol. Rev.*, Vol. II, No. 12, pp. 1408-1418.

Cann, R. M. (1978): Genesis of Magnetite Deposits in the Iron Mask Batholith, *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1977, Paper 1978-1, pp. 86-88.

.... (1979): Geochemistry of Magnetite and the Genesis of Magnetite-Apatite Lodes in the Iron Mask Batholith, British Columbia, unpub. M.Sc. thesis, *University of British Columbia*, 196 pp.

Carmichael, J.S.E. (1967): The Iron-Titanium Oxides of Salic Volcanic Rocks and their Associated Ferromagnesian Silicates, *Contr. Min. Petrol.*, Vol. 14, pp. 36-64.

Carr, J. M. (1956): Deposits Associated with the Eastern Part of the Iron Mask Batholith near Kamloops, *B.C. Ministry of Energy, Mines & Pet. Res.*, Ann. Rept., 1956, pp. 47-54.

Carr, J. M. and Reed, A. J. (1976): Afton: A Supergene Copper Deposit, *in* Porphyry Deposits of the Canadian Cordillera, A. Sutherland Brown, editor, *C.I.M.*, Special Vol. 15, pp. 376-387.

Cockfield, W. E. (1948): Geology and Mineral Deposits of Nicola Map-Area, British Columbia, *Geol. Surv., Canada*, Mem. 249.

Davis, R.E.G. (1962): A Magnetite Breccia, Galore Creek, Stikine River Area, British Columbia, unpub. B.A.Sc. thesis, *University of British Columbia*.

Ewing, T. (1979): Geology of the Kamloops Group, *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1978, Paper 1979-1, pp. 119-123.

Fletcher, K. (1970): Some Applications of Background Correction to Trace Metal Analysis of Geochemical Samples by Atomic Absorption Spectrophotometry, *Econ. Geol.*, Vol. 65, pp. 588-591.

Frietsch, R. (1978): On the Magmatic Origin of Iron Ores of the Kiruna Type, *Sveriges Geol. Unders.*, Ser. C, No. 624, 32 pp.

Frutos, J. J. and Oyarzun, J. M. (1975): Tectonic and Geochemical Evidence Concerning the Genesis of El Laco Magnetite Lava Flow Deposits, Chile, *Econ. Geol.*, Vol. 70, pp. 988-990.

Geijer, P. (1931): The Iron Ores of the Kiruna Type, *Sveriges Geol. Unders.*, Ser. C, No. 367, 39 pp.

.... (1960): The Kiruna Iron Ores, *in* Archean Geology of Vastervotten and Norrbotten, Northern Sweden, *Geol. Surv., Sweden*, Guide to IGC Excursions A32 and C2b, pp. 34-48.

.... (1967): Internal Features of the Apatite-Bearing Magnetite Ores, *Sveriges Geol. Unders.*, Ser. C, No. 624, 32 pp.

Griffiths, J. C. (1967): Scientific Method in the Analysis of Sediments, *McGraw-Hill*, 508 pp.

Haggerty, S. E. (1970): The Laco Magnetite Lava Flow, Chile, *Geoph. Lab.*, Ann Rept., 1968-1969, pp. 329, 330.

.... (1976): Opaque Mineral Oxides in Terrestrial Igneous Rocks, *in* Oxide Minerals, D. Rumble III, editor, *Min. Soc. Am.*, Short Course Notes, Vol. 3, pp. 101-300.

Hoiles, H. K. (1978): Nature and Genesis of the Afton Copper Deposit, Kamloops, British Columbia, unpub. M.Sc. thesis, *University of Alberta*.

Hollister, V. F. (1978): Geology of the Porphyry Copper Deposits of the Western Hemisphere, *A.I.M.M.E.*, 219 pp.

Kisvarsanyi, G. and Proctor, P. D. (1967): Trace Element Content of Magnetites and Hematites, Southeast Missouri Iron Metallogenic Province, U.S.A., *Econ. Geol.*, Vol. 62, pp. 449-471.

Kolker, A. (1982): Mineralogy and Geochemistry of Iron-Titanium Oxide and Apatite (Nelsonite) Deposits and Evaluation of the Liquid Immiscibility Hypothesis, *Econ. Geol.*, Vol. 77, pp. 1146-1158.

Llaumett, C. (1967): Los Depósitos de Fierro de El Laco, Provincia de Antofagasta, Chile, *Cía. Minera*, unpub. rept.

Mathews, W. H. (1941): Geology of the Iron Mask Batholith, unpub. M.A.Sc. thesis, *University of British Columbia*, 42 pp.

McMillan, W. J. (1978): Nicola Project, *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1977, Paper 1978-1, pp. 26-30.

Montgomery, J. H. (1967): Petrology, Structure, and Origin of the Copper Mountain Intrusions near Princeton, British Columbia, unpub. Ph.D. thesis, *University of British Columbia*, 172 pp.

Nakagawa, H. M. (1975): Atomic Absorption Determination of Silver, Bismuth, Cadmium, Cobalt, Copper, Nickel, Lead, and Zinc in Calcium and Iron-Rich Geological Materials, *in* New and Refined Methods of Trace Analysis Useful in Geochemical Exploration, F. N. Hall, editor, *U.S.G.S.*, Bull. 1408, pp. 85-96.

Northcote, K. E. (1975): Geology of Northwest Half of Iron Mask Batholith, *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1974, Paper 1975-1, pp. 22-26.

.... (1977a): Iron Mask Batholith, *B.C. Ministry of Energy, Mines & Pet. Res.*, Prelim. Map 26.

.... (1977b): Geology of Southeast Half of Iron Mask Batholith, *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1976, Paper 1977-1, pp. 41-46.

Norton, D. L. and Cathles, L. M. (1973): Breccia Pipes-Products of Exsolved Vapor from Magmas, *Econ. Geol.*, Vol. 68, pp. 540-546.

Parák, T. (1975): The Origin of the Kiruna Iron Ores, *Sveriges Geol. Unders.*, Ser. C, No. 709, 209 pp.

Park, C. F. (1972): The Iron Ore Deposits of the Pacific Basin, *Econ. Geol.*, Vol. 67, pp. 339-349.

Philpotts, A. R. (1967): Origin of Certain Iron-Titanium Oxide and Apatite Rocks, *Econ. Geol.*, Vol. 62, pp. 303-315.

Preto, V. A. (1968): Geology of the Eastern Part of the Iron Mask Batholith, *B.C. Ministry of Energy, Mines & Pet. Res.*, Ann. Rept., 1967, pp. 137-147.

.... (1972a): Report on Afton, Pothook, *B.C. Ministry of Energy, Mines & Pet. Res.*, GEM, pp. 209-220.

.... (1972b): Geology of Copper Mountain, *B.C. Ministry of Energy, Mines & Pet. Res.*, Bull. 59, 87 pp.

.... (1977): The Nicola Group: Mesozoic Volcanism Related to Rifting in Southern British Columbia, *in* Volcanic Regimes in Canada, W. R. Baragar, L. C. Coleman, and J. M. Hall, editors, *Geol. Assoc. Can.*, Special Paper 16, pp. 39-57.

Ramdohr, P. (1969): The Ore Minerals and their Intergrowths, *Pergamon Press*, 1174 pp.

Ringwood, A. E. (1955): The Principles Governing Trace Element Behaviour During Magmatic Crystallization, Part II: The Role of Complex Formation, *Geochim. et Cosmochim. Acta*, Vol. 7, pp. 242-254.

Rucklidge, J. C. and Gasparrini, C. (1969): EMPADR VII: Specifications of a Computer Program for Processing Electron Microprobe Data, *University of Toronto*.

Ruiz, C. (1965): Geologia y Yacimientos Metaliferos de Chile, Santiago, *Inst. Inv. Geologicas*, 305 pp.

Schau, M. (1970): Statigraphy and Structure of the Type Area of the Upper Triassic Nicola Group of South-Central British Columbia, *in* Structure of the Southern Canadian Cordillera, J. O. Wheeler, editor, *Geol. Assoc. Can.*, Special Paper 6, pp. 123-135.

Taylor Jr., H. P. (1974): The Application of Oxygen and Hydrogen Isotope Studies to Problems of Hydrothermal Alteration and Ore Deposition, *Econ. Geol.*, Vol. 69, pp. 843-883.

Whitney, J. A. (1975): Vapor Generation in a Quartz Monzonite Magma: A Synthetic Model with Application to Porphyry Copper Deposits, *Econ. Geol.*, Vol. 70, pp. 346-359.

Young, G. A. and Uglow, W. L. (1926): The Iron Ores of Canada, *Geol. Surv., Canada,* Econ. Geol. Ser., No. 3, pp. 109-128.

A COMPUTER-BASED PROCEDURE FOR QUANTIFYING GEOLOGICAL DATA FOR RESOURCE ASSESSMENT

By A. J. Sinclair and A. Bentzen
Department of Geological Sciences, The University of British Columbia

INTRODUCTION

A computer-based procedure is described for quantifying geological data as a prelude to resource assessment. The method involves: (1) digitizing geological data, and (2) a series of programs to make quantitative estimates of areas and distances with geological significance. Procedures described are general in nature but in our immediate case are being applied to the Guichon Creek batholith (including the Highland Valley porphyry copper area) as a basis for resource assessment.

A common method of coding geological information for inclusion in quantitative resource assessment and exploration modelling is to superimpose a square grid on a geological map and record characteristics pertaining to each cell of the grid (*see* Agterberg, 1981). Such a procedure has been used by Kelly and Sheriff (1969) in their efforts to outline 20 mile by 20 mile cells in British Columbia, having a high mineral potential. At a different scale Sinclair and Woodsworth (1970) coded geological information from the Terrace area relative to a grid with a cell size of 2 miles by 2 miles. In a direct application to porphyry copper evaluation, Godwin and Sinclair (1979) developed a file of geological, geochemical, and geophysical data for the Casino porphyry copper-molybdenum deposit, Yukon Territory, relative to 400 foot by 400 foot cells of an exploration grid on the property. All the foregoing studies and many other comparable investigations have been directed toward a quantitative approach to resource evaluation in which some measure of value of a cell is related to geological and other variables coded for that cell. Types of geological variables recorded are generally found in the following categories:

(1) percentage of a cell underlain by a particular rock type,
(2) distance from cell centre to a specific geological feature,
(3) spatial density values, for example, fracture density,
(4) lengths of contacts, fractures, etc., in a cell, and
(5) (projected) absolute areas of nearest specific rock units, etc.

Two problems in a manual approach to coding of geological information for cells of a grid are: (1) it is tedious and time-consuming, and (2) manual methods are prone to mechanical errors, many of which are not readily identifiable in normal editing procedures. To overcome these problems we have developed a computer-based approach for the estimation of geological and other variables for cells of a grid. This work is a prelude to a quantitative resource assessment of the Guichon Creek batholith and early results of this study will provide examples of our procedure.

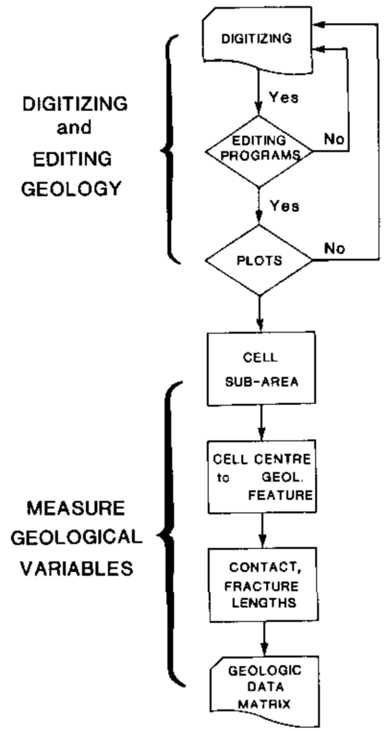


Figure 99. Flow chart illustrating the general computer-based system for generating a file of quantitative geological measurements as a prelude to resource assessment.

PROCEDURE

Our general system, as outlined in the flow chart on Figure 99, includes two main elements:

(1) digitizing and editing of map information, and
(2) development of a series of subroutines to make measurements relative to an arbitrary grid and digitized data.

The principal advantages of the methodology are its consistency and the ease with which a variety of editing procedures can be employed. An important feature is that new combinations of variables can be obtained rapidly if information is digitized, whereas normal methods would require an additional tedious effort of measurement. Perhaps most important is the fact that sensitivity of cell size on resource assessment is more feasible with a computer-based as opposed to a manual approach.

DIGITIZING GEOLOGICAL INFORMATION

The digitizing procedure is illustrated with reference to the Guichon Creek batholith resource assessment study. All phases and varieties of batholithic rocks were digitized using Preliminary Map 30 (B.C. Ministry of Energy, Mines and Petroleum Resources, McMillan, 1978) which contains the most detailed and up-to-date geological information available on the scale of the entire batholith. The digitizing procedure was to outline each separate area of a given phase by a closed polygonal outline with as many points as necessary to honour the level of detail of the base map. Very small areas of younger or older rock were ignored.

Editing of digitized data involves a variety of procedures including: (1) separating digitized polygons with end-of-polygon flags, (2) collecting polygons representing the same geological unit into a single file, (3) closing the polygons, (4) reversing polygons if necessary so that all are digitized in consistent fashion (for example, counterclockwise), and (5) deletion of incorrect points in a polygon. The digitized polygons were then placed in a number of separate files, one for each geological unit and machine-drawn maps were prepared for each unit as a final editing step (Fig. 100). These maps were produced to the same scale as the base map and were compared visually (using a lighttable) with the base map.

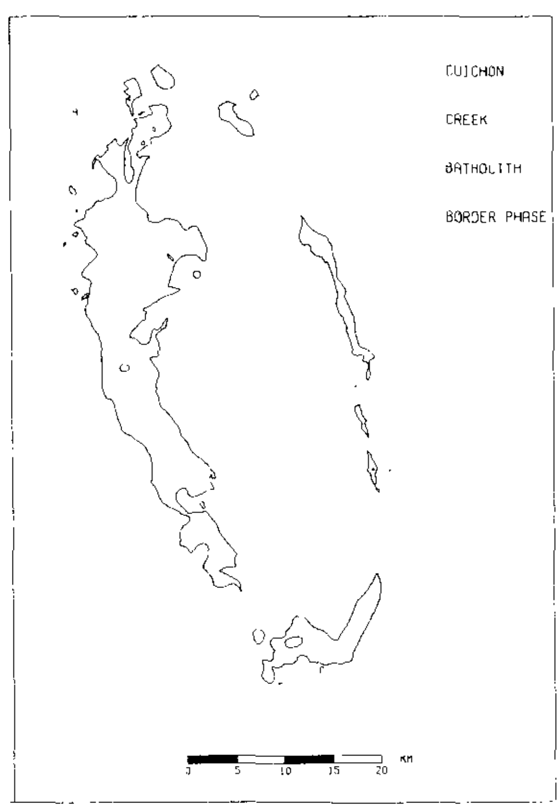


Figure 100. Computer-controlled plot of digitized areas underlain by the Border phase of the Guichon Creek batholith, central British Columbia. An 'A' near the northwestern corner of the map is centred on Ashcroft and a 'C,' just below the southernmost exposure, is centred on Craigmont pit. Data digitized from McMillan (1978).

MEASUREMENT OF GEOLOGICAL VARIABLES

Our computerized approach to resource assessment in which geological variables are referenced to systematic grid cells, depends on a series of computer programs designed to measure geological variables (Fig. 99). Some of the procedures are described briefly to illustrate the nature of variables that can be measured and to give some indication of the potential wide range of applications of our computerized approach.

(1) Within cell area measurements. A grid of stipulated cell size is superimposed on a 'map' of single rock category and the proportion of each cell underlain by the rock type is calculated. The procedure used for one geological unit is to move systematically along each polygon recognizing the intersections with grid cell boundaries. The part of a cell area within a polygon is then determined. After all polygons have been treated in this manner, a set of cells remains for which no area estimates have been made. They are checked systematically and if the cell centre is within a polygon, an area of 100 per cent is assigned; otherwise an area of zero is assigned. If there are islands of other rock types within a polygon, the area occupied by these is subtracted automatically. The result is a file of the per cent of area of each cell underlain by a specific rock type. Repetition of the process for other rock units results in a quantitative file of geological 'areas' per cell.

(2) Length of contacts (dyke, fracture, etc.) in a cell. Variables of this type are very straightforward to calculate from digitized contacts. Each polygon is examined and its intersection with grid cell boundaries used to define a segment of a polygon in which point-to-point distances will be summed to provide a length.

(3) Distance from cell centre to a specific geological feature. This process involves checking whether a cell centre is within or outside the limits of a particular geological feature. If the centre is not enclosed in polygons of a particular geological feature, then the shortest distance from the cell centre to the nearest part of the nearest polygon is determined.

Programs to accomplish the foregoing types of measurement include the majority of variable types outlined in the introduction. Other useful types of quantitative measurements can be added as desired. We are presently generating a quantitative data base for the Guichon Creek batholith using a cell size of 2.59 square kilometres (1 square mile). This up-to-date geological data base will be merged with our existing file for geophysical and geochemical data based on the same grid size, and will provide the fundamental information for a resource assessment in the Guichon Creek batholith.

CONCLUSIONS

A computer-based approach to the quantitative measure of geological variables as a base for resource assessment has been established. The procedure involves two major components: (1) digitizing of geological features, and (2) a variety of programs designed to extract quantitative measurements of geological variables relative to cells of a reference grid. A variety of editing procedures are built into the system.

We are presently applying the procedures to an assessment of resources in the Guichon Creek batholith (including the long established porphyry copper area of the Highland Valley). Of course, the procedures and software are general in nature and potentially have much wider application not restricted to geological variables.

ACKNOWLEDGMENTS

This study is funded by the Science Council of British Columbia and is part of the MINDEP project of computer-oriented, mineral deposit studies done in cooperation with the Mineral Resources Division of the British Columbia Ministry of Energy, Mines and Petroleum Resources. Some assistance in computer programming was obtained from Mr. Tai Chen of International Geosystems Corporation, Vancouver, for which we are grateful.

REFERENCES

Agterberg, F. P. (1981): Cell Value Distribution Models in Spatial Patterns Analysis, *in* Future Trends in Geomathematics, R. G. Craig and M. L. Labovitz, editors, *Pion Ltd.*, London, England, pp. 5-28.

Godwin, C. I. and Sinclair, A. J. (1979): Application of Multiple Regression Analysis to Drill-Target Selection, Casino Porphyry Copper-Molybdenum Deposit, Yukon Territory, Canada, *Trans. Inst. Min. Met.*, Sec. B, pp. B93-B106.

Kelly, A. M. and Sheriff, W. J. (1969): A Statistical Examination of the Metallic Resources of British Columbia, *in* Proceedings of a Symposium on Decision-Making in Mineralization Exploration II, A. M. Kelly and A. J. Sinclair, editors, Extension Dept., *University of British Columbia*, February 6, 7, 1969, pp. 221-243.

McMillan, W. J. (1978): Geology of the Guichon Creek Batholith and Highland Valley Porphyry Copper District, British Columbia, *B.C. Ministry of Energy, Mines & Pet. Res.*, Prelim. Map 30.

Sinclair, A. J. and Woodsworth, G. J. (1970): Multiple Regression as a Method of Estimating Exploration Potential in an Area near Terrace, British Columbia, *Econ. Geol.*, Vol. 65, pp. 998-1003.

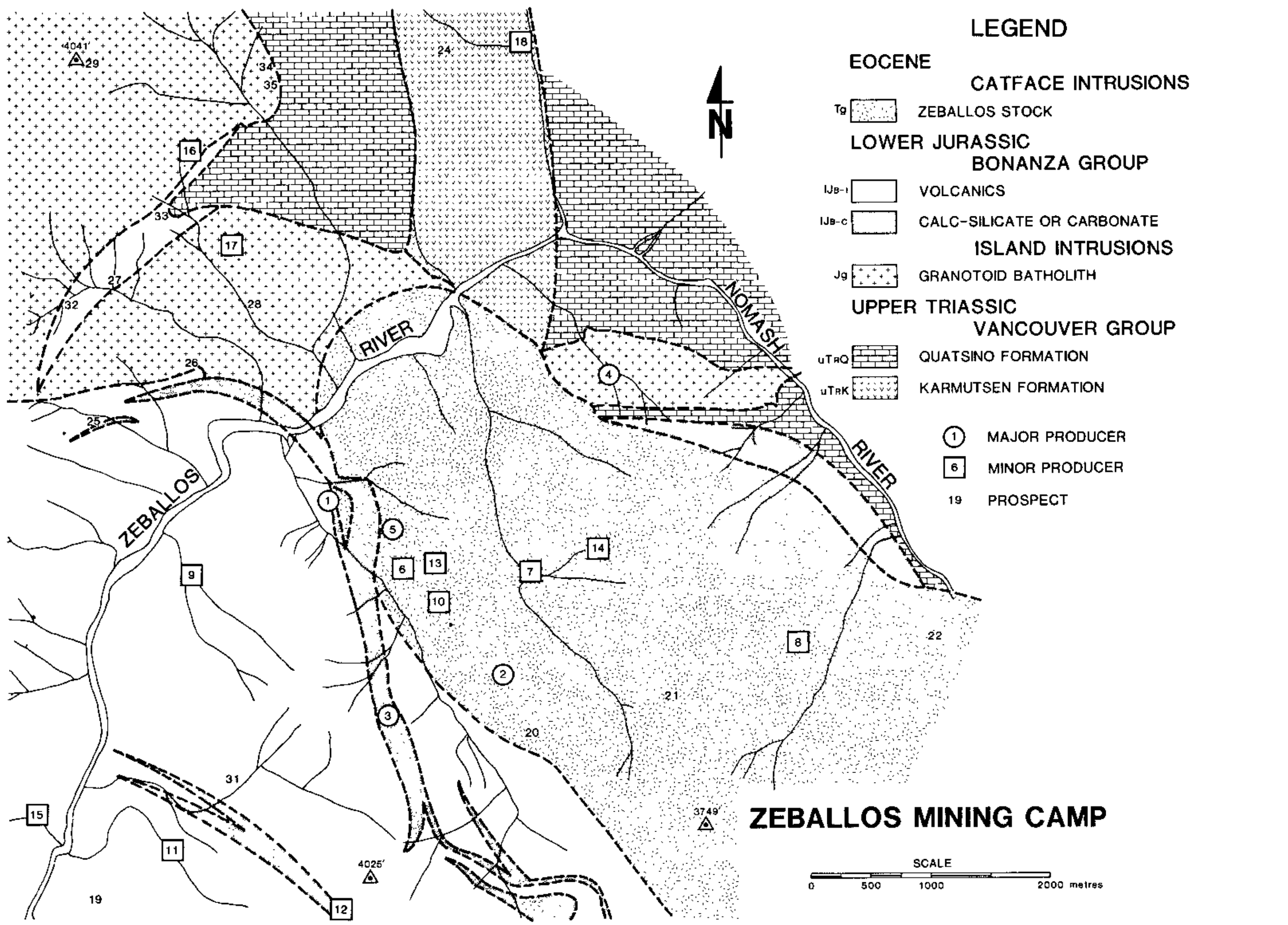


Figure 101. General geology and location of recorded mineral occurrences and past producers, Zeballos mining camp (after Stevenson, 1950).

RESOURCE ASSESSMENT OF GOLD-QUARTZ VEINS, ZEBALLOS MINING CAMP VANCOUVER ISLAND - A PRELIMINARY REPORT (92L)

By A. J. Sinclair and M. C. Hansen
Department of Geological Sciences, The University of British Columbia

INTRODUCTION

Production data and various geological measurements have been compiled and tabulated for gold-quartz veins of the Zeballos mining camp, Vancouver Island, British Columbia. A preliminary qualitative evaluation of some of these data indicate that: (1) mined tonnage is an acceptable relative value estimator, (2) on average, large deposits are lower grade than small deposits, (3) gold and silver are highly correlated, (4) gold grade is related systematically to bulk sulphide content as indicated by average combined lead plus copper, and (5) an important systematic relation exists between gold content of a deposit and distance from the contact of the Zeballos stock. A quantitative evaluation of these data is in progress.

Zeballos mining camp is on the west coast of Vancouver Island about 320 kilometres northwest of Victoria, British Columbia. Access is via an all-weather road between the settlements of Zeballos (5 kilometres south of the mining camp) and Nimpkish. The surrounding countryside is mountainous and rugged with elevations from near sea level to about 1 300 metres; it experiences mild winters and high rainfall.

The first gold-quartz vein staked in the area was the Tagore in 1924 although limited quantities of placer gold had been mined previously. Lode production began in 1934 and reached a peak in 1937 to 1943. By 1948 most production had ceased. Two deposits, Privateer and Spud Valley, have produced 473 082 of the 651 797 tonnes of ore mined in the camp.

Recorded metal production to date totals 9 465 244 grams of gold and 4 119 118 grams of silver, as well as minor amounts of copper and lead from a total of 651 797 metric tonnes of ore mined. This tonnage includes the substantial dilution resulting from mining veins commonly about 10 to 30 centimetres wide. Average mined grades for the camps are 15 grams gold per tonne and 6.5 grams silver per tonne although vein material contained as much as 30 to 150 grams gold per tonne.

Our evaluation of Zeballos camp is oriented toward a quantitative resource assessment following the approach of Sinclair (1979), Goldsmith, *et al.* (in preparation), and Orr and Sinclair (1971). The study is divided into two parts: (1) development of a quantitative data file, and

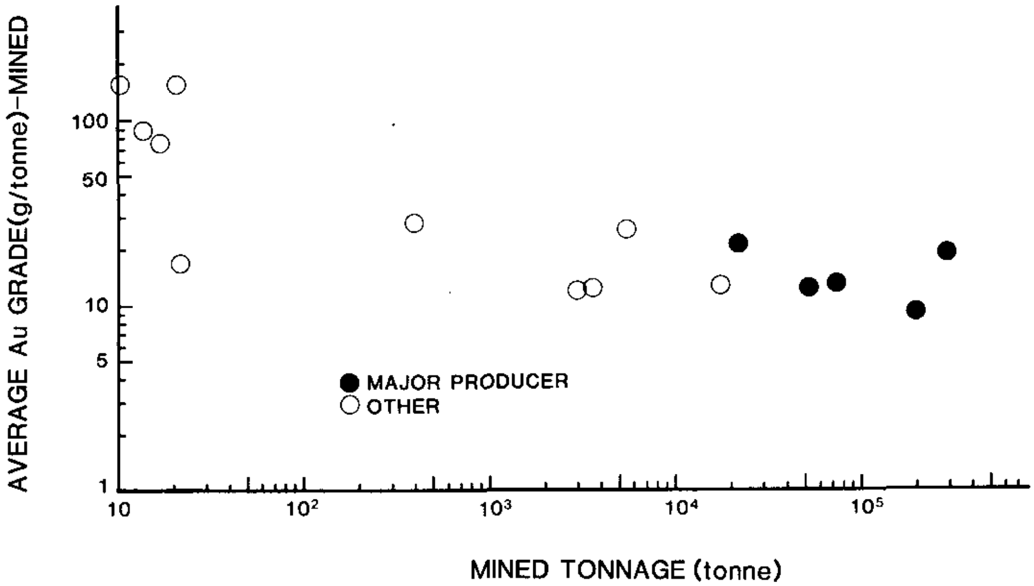


Figure 102. Average gold grade per tonne mined (grams per tonne) versus mined tonnes, Zeballos mining camp. Three deposits with tonnages of 2, 1, and 1 and corresponding gold grades of 70, 156, and 156 grams per tonne are not included in the plot.

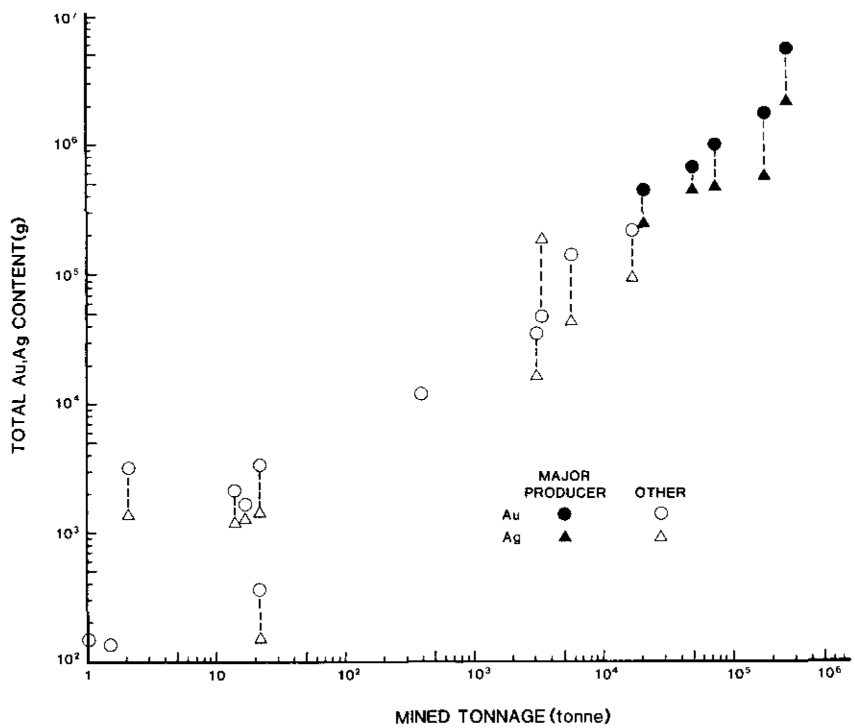


Figure 103. Plot of precious metal contents versus mined tonnes, Zeballos mining camp. Gold contents are shown with circles and silver contents by triangles.

(2) evaluation of quantitative data. This report describes the detailed data file and presents some of our initial results stemming from a preliminary evaluation of the file.

GEOLOGY OF ZEBALLOS CAMP

General geology of the area in and around Zeballos camp is shown on Figure 101. The area is underlain by an essentially monoclinal sequence of Mesozoic volcanic and sedimentary rocks cut by Jurassic and Tertiary intrusions. The Lower Jurassic Bonanza Group is a typical island arc sequence of largely basaltic to rhyolitic volcanic rocks. This unit is underlain conformably by limestones of the Quatsino Formation and tholeiitic basalts of the Upper Triassic Karmutsen Group. All these rocks are cut by Jurassic plutons of the Island intrusions, mainly dioritic and granodioritic in composition. The Zeballos stock, with its spatially related gold-quartz veins, is a quartz dioritic phase of the Catface intrusions of Eocene age.

A QUANTITATIVE DATA BASE

We have established a quantitative data base relating to mineral deposits and occurrences in Zeballos camp by reference to two sources of information: a report and map by Stevenson (1950), and the MINFILE computer file of mineral deposits in British Columbia. In addition to numerical data relating to grades and tonnage mined and/or milled, we have made a number of other measurements of a geological nature from Stevenson's (1950) map, as well as coding mineralogical information. These data are summarized in Tables 1 to 5, where deposits are listed in order of decreasing tonnage mined. The tables are self-explanatory but some comments on the nature and quality of data are warranted.

Mined tonnage refers to ore brought to surface and subject to hand sorting prior to milling. Quoted grade values refer to mined tonnage.

The two most productive vein orientations are shown for each deposit; each orientation may represent several veins. In general, an effort was made to record mean directions of undulatory surfaces.

Vein width recorded in Table 3 applies to the most productive segment of a vein; thus, is a subjective variable of uncertain value. The term 'sheeted zone' refers to '... joints spaced 2 to 8 inches apart and (which) contain either gouge or quartz-sulphide stringers an eighth of an inch to an inch wide' (Stevenson, 1950). Tensional features include gash veins and comb quartz. Associated replacement/alteration category refers to features observed in a vein or adjacent wallrock such as silicification or oxidation. In general, such data are sparse in available literature.

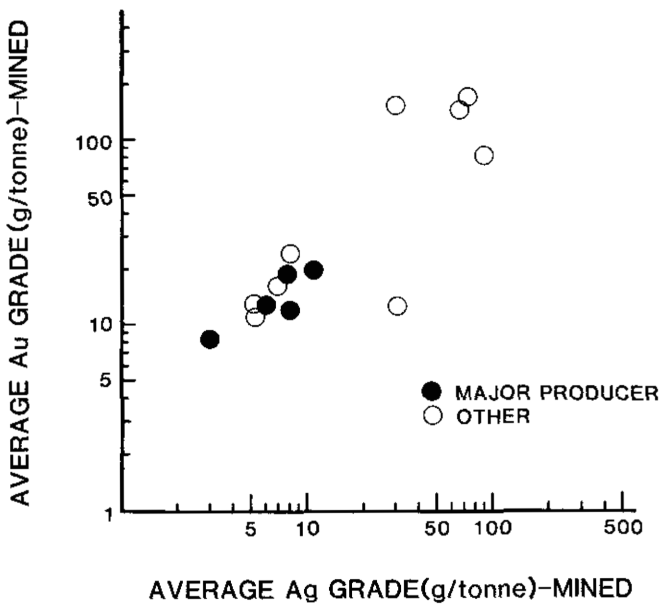


Figure 104. Average gold grade (grams per tonne) versus average silver grade (grams per tonne) for gold-quartz veins, Zeballos mining camp.

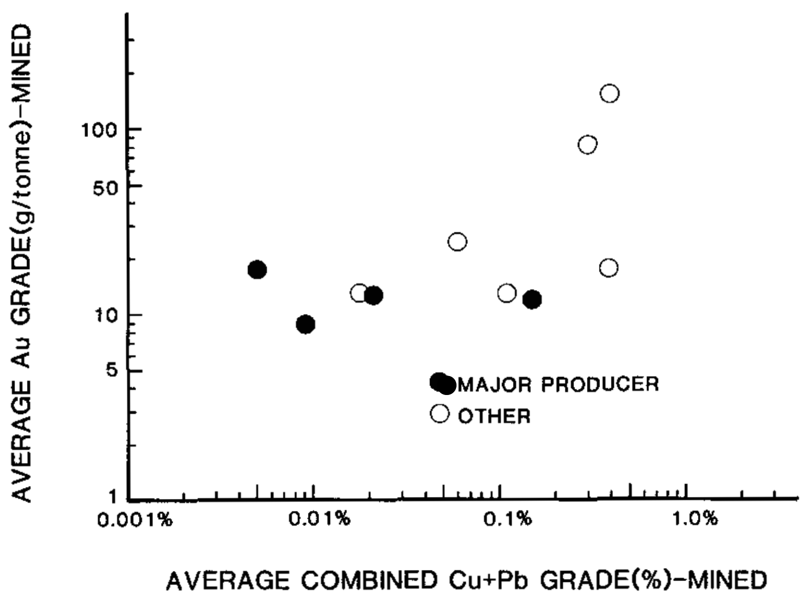


Figure 105. Average gold grade (grams per tonne) versus combined lead plus copper (per cent) for gold-quartz veins, Zeballos mining camp. Deposit 17 (Cordova) is included in this plot.

Distances of various deposits from the contact of the Zeballos stock were measured from Stevenson's (1950) geological map of the camp (*see* Fig. 101). In a few cases the contact had to be extended across drift-covered areas in order to obtain distance measurements.

PRELIMINARY EVALUATION OF ZEBALLOS DATA BASE

There are many blanks in Tables 1 to 5, particularly as regards to grade and tonnage information. Complete production statistics exist for only nine of 18 deposits with recorded production. Consequently, it will be difficult, if not impossible, to apply some of the techniques of evaluation recommended by Sinclair (1979) for vein camps.

Instead, we have chosen to examine various plots as a basis for a subjective preliminary evaluation of the data. Some of these graphs appear to establish important relations concerning deposit location or attributes. Figure 102 is a graph of average gold grades versus mined tonnages. A size of about 2 000 tonnes clearly divides the deposits into two size categories with different mean grade characteristics. The high tonnage category has a lower grand average grade and less dispersion of average grades than the low tonnage category. Some of this difference may be the result of selective mining and/or hand sorting.

Precious metal contents (gold and silver) are plotted versus production (mined tonnage) on Figure 103. This graph demonstrates that where production has been reported, both gold and silver metal contents increase systematically with an increase in size; consequently, production tonnage is an acceptable single measure of relative value of vein deposits in the Zeballos camp (*see* Sinclair, 1979).

Figure 104 is a plot of average gold grade versus average silver grade and demonstrates: (1) the consistently lower grade in silver compared with gold, and (2) the positive correlation between log gold and log silver. This correlation may be partly artificial; as indicated earlier, some of the high grades for small deposits may be the result of selective upgrading of ore. This possibility is suggested by the two clusters of points on Figure 104; such patterns represent dubious correlations. Even if this explanation is correct, it appears that a reasonable correlation exists between gold and silver as demonstrated by the five major producers in the camp.

Average gold grade of tonnes mined is plotted against copper plus lead on Figure 105 where there is a suggestion of a regular relation between the two. In general, precious metal grade is higher if copper plus lead is also high. The relation does not appear to be linear on the log-log plot suggesting that the effect is not due solely to hand sorting of ore.

Figure 106 is a plot of deposit relative value (total grams of gold per deposit) versus distance from the contact of the Zeballos stock. The graph shows a remarkably consistent pattern both in the Zeballos stock and in the country rock. The five principal producers are localized within 500 metres of the contact and smaller producers are more removed from the contact in a surprisingly regular pattern. These trends can be approximated by the following linear equation:

Within Stock: $\log(\text{Total gold}) = -0.0029D + 6.778$
Within Wallrock: $\log(\text{Total gold}) = 0.0025D + 6.778$

where gold is in grams, D is a positive distance into the stock or a negative distance into the wallrock measured in metres. These equations provide a means of contouring expected gold content of deposits remaining to be discovered. As such they outline a zone about the contact of the Zeballos stock that has high potential for relatively large new gold-quartz veins. The expected target in this zone can be estimated from Figure 102 to have a potential of 25 000 to 250 000 tonnes of ore grading about 10 to 20 grams gold per tonne. A median deposit would contain about 75 000 tonnes grading 12 grams gold per tonne. The gross value of gold in this median deposit, assuming a price of Canadian dollars 450 per ounce, is about $12 000 000.

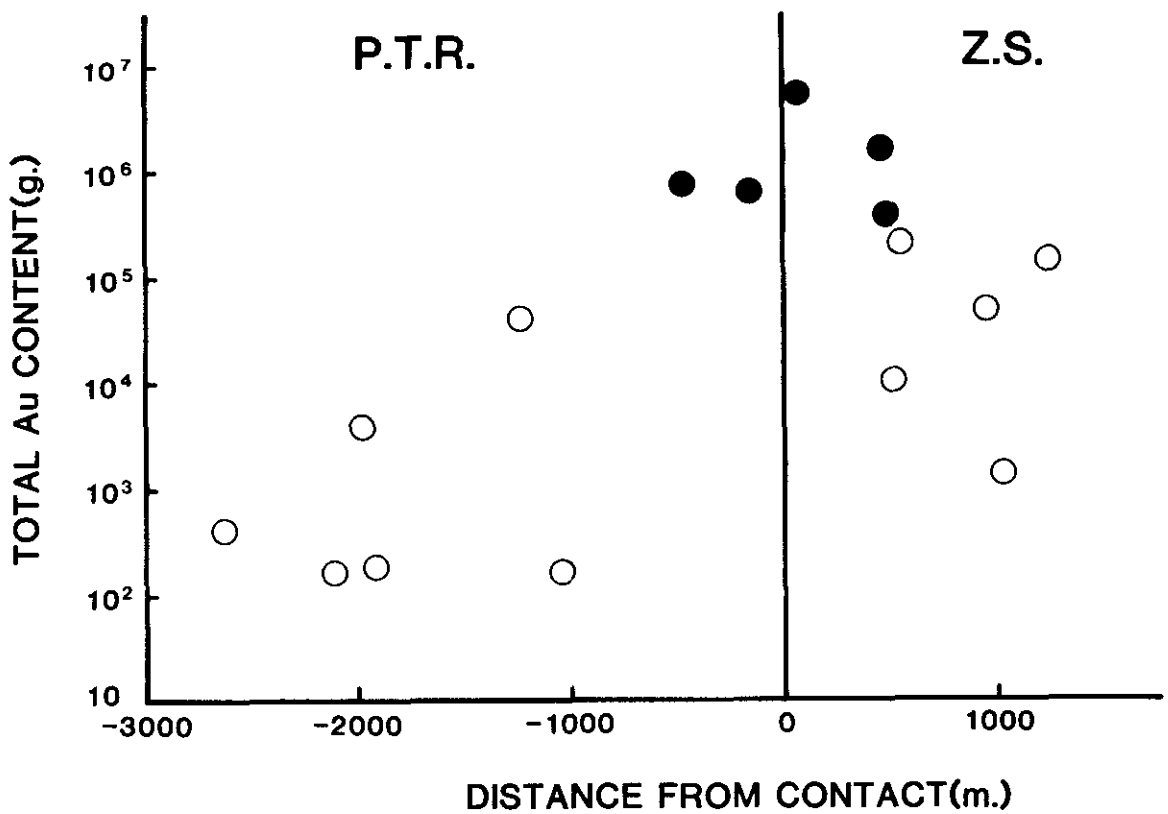


Figure 106. Total gold content (grams) versus distance of gold-quartz veins from contact of Zeballos stock (Z.S.) with pre-Tertiary rocks (P.T.R.). Positive distances are within the stock; negative distances are within country rock. Deposits greater than 2000 mined tonnes are closed circles, smaller deposits are are open circles.

TABLE 1

LISTING OF MINERAL DEPOSIT DATA FILE FOR
ZEBALLOS MINING CAMP - GENERAL INFORMATION

DEPOSIT NUMBER	DEPOSIT NAME	LOCATION UTMN	UTME	MINFILE REF.	YEARS OF PRODUCTION (19__)	ELEVATION (FEET)	(METRES)
1	PRIVATEER	43400	56600	092L/008	34-53,75	750	229
2	SPUD VALLEY	42400	58000	092L/012	36,39-42,51	2000	610
3	MOUNT ZEBALLOS	42000	57000	092L/012	39-42,44	2000	610
4	CENTRAL ZEBALLOS	44800	58700	092L/018	38-42,46,47	1500	457
5	PRIDENT	43500	56900	092L/009	41-43,47,48	1500	457
6	C.D.	43300	58100	092L/015	38-41	1400	427
7	HOMEWARD	42700	60400	092L/019	41,42	2000	610
8	VAN ISLE	43100	55400	092L/038	40	600	183
9	WHITE STAR	43200	57100	092L/010	35-42,52,57	1500	457
10	ZEBALLOS PACIFIC	42900	57500	092L/011	34	1500	457
11	GOLDEN PORTAL	40900	55200	092L/005	40	750	229
12	BEANO	40600	56300	092E/002	48,49	2500	762
13	I.X.L.	43400	57300			2000	610
14	RIMY	43300	58700	092L/016	38	2500	762
15	TAGORE	41100	54300	092L/006	30,32,39	400	122
16	BARNACLE	46700	55300	092L/029		2400	732
17	CORDOVA	45800	55500	092L/027	39	2000	610
18	KING MIDAS	47700	58000	092L/020	40	500	152
19	ANSWER	40400	54600	092E/023		350	107
20	BRITANNIA	41900	58300	092L/013		1900	579
21	BIG STAR	42300	59300	092L/017		2500	762
22	MONITOR	42600	57300			1500	457
23	NORTH FORK EXPL.	48800	57800	092L/021		750	229
24	GOLD SPRING	47600	57300			1750	533
25	BODEN	44300	54400	092L/022		1200	366
26	MAQUINNA	44800	55300	092L/023		600	183
27	OMEGA	45500	54600	092L/024		1400	427
28	PANDORA	45300	55700	092L/026		850	259
29	LUCKY STRIKE	47300	54500	092L/030		3750	1143
30	FRIEND	39200	57800	092E/003		2500	762
31	PROSPERITY	41400	55500	092L/007		1000	305
32	PEERLESS	45300	54200	092L/025		1900	579
33	F.L./RIDGE	46200	55000	092L/028		2600	793
34	CHURCHILL	47400	55800	092L/031		2250	686
35	CAVALIER	47100	55800	092L/032		2500	762

NOTE: 1. DEPOSITS 1 TO 5 REFERRED TO AS MAJOR PRODUCERS.
DEPOSITS 6 TO 18 REFERRED TO AS MINOR PRODUCERS.
DEPOSITS 19 TO 35 REFERRED TO AS PROSPECTS.
2. BLANKS INDICATE NO AVAILABLE DATA, OR NON-APPLICABLE VARIABLE/ATTRIBUTE.
3. DEPOSITS 1 TO 30 & 34 ARE GOLD-QUARTZ VEIN PAST PRODUCERS OR PROSPECTS. THE CHURCHILL PROPERTY ALSO COVERS MAGNETITE REPLACEMENT MINERALIZATION. THE BEANO PROPERTY ALSO COVERS SKARN-TYPE MINERALIZATION. THE PROSPERITY PROPERTY SHOWS NO SIGN OF MINERALIZATION AT ALL, BUT IS INCLUDED FOR THE SAKE OF COMPLETENESS. DEPOSITS 33 & 34 ARE MAGNETITE REPLACEMENT DEPOSITS, AGAIN INCLUDED FOR SAKE OF COMPLETENESS.

TABLE 2

LISTING OF MINERAL DEPOSIT DATA FILE FOR
ZEBALLOS MINING CAMP - PRODUCTION DATA

DEP NO	PRODUCTION (TONNES) MINED	MILLED	TOTAL METAL CONTENT (GRAMS) Au	Ag	(KILOGRAMS) Cu	Pb	GRADE (Gr,Kg/TONNE MINED) Au	Ag	Cu	Pb
1	282328	146798	5301289	2160196	4063	10093	18.7	7.7	.01	.04
2	190754	95876	1682859	575219	9195	8093	8.8	3.0	.05	.04
3	74268	51540	946589	444399	2408	12726	12.7	6.0	.03	.17
4	52596	37789	636773	432238	7370	71140	12.1	8.2	.14	1.35
5	21585		433440	239812			20.1	11.1		
6	5645	405	143074	44322	470	2982	25.3	7.9	.08	.53
7	3586	1375	46374	108705	318	347	12.9	30.3	.09	.10
8	3044		35929	16470			11.8	5.4		
9	1293		220987	92531	1563	17144	171.0	71.6	1.21	13.25
10	393		11174				28.0			
11	22		373	156	44	39	17.0	7.1	2.00	1.77
12	21		3297	1400	33		157.0	66.7	1.57	
13	20									
14	17		1369	1586			80.5	93.3		
15	14		1245	2022	23	20	89.0	144.4	1.64	1.43
16	2		140					70.0		
17	1		156	31	0	4	156.0	31.0		4.00
18	1		156	31	10		156.0	31.0	10.00	
19										
20										
21										
22										
23										
24										
25										
26										
27										
28										
29										
30										
31										
32										
33										
34										
35										

TABLE 3

LISTING OF MINERAL DEPOSITS DATA FILE FOR
ZEBALLOS MINING CAMP - GEOLOGICAL FEATURES OF HOST ROCK

DEP NO	HOST ROCK TYPE Tg	Jg	(I) lJB	(C) lJB	uTrQ	muTrK	HOST ROCK STRIKE	DIP	D/DRN	DYKES	DIST(M)/BRG FROM NOSE OF Z.STOCK DIST	BRG
1	3	0	3	2	0	0	010	60	270	5	1700	185
2	3	0	1	0	0	0				1	3400	160
3	0	0	3	2	0	0	160	90		2	3400	175
4	3	0	0	0	3	3				3	2270	110
5	3	0	2	0	0	0				2	1890	170
6	3	0	0	0	0	0				2	2650	150
7	3	0	0	0	0	0				2	4730	125
8	0	0	3	0	0	0	135	80	045	2	2650	210
9	3	0	0	0	0	0				2	2270	170
10	3	0	0	0	0	0				5	2650	165
11	0	0	3	0	0	0				3	4910	200
12	0	0	3	3	0	0	360	80	090	2	5100	185
13	3	0	0	0	0	0				5	2270	165
14	3	0	0	0	0	0				2	2840	135
15	0	0	3	2	0	0	080	80	000	3	4910	212
16	0	2	3	0	0	0				5	1890	315
17	0	3	0	0	0	0				2	1130	295
18	0	0	0	0	3	5				2	2650	035
19	0	0	3	0	0	0				2	5480	205
20	3	0	1	0	0	0				5	1130	160
21	3	0	0	0	0	0				1	4160	140
22	3	0	0	0	0	0				5	5670	120
23	0	0	0	0	0	3				5		
24	0	0	0	0	0	3	145	60	225	3	2270	020
25	0	0	3	0	0	0				5	2460	245
26	0	3	3	0	0	0	060	75	360	5	1520	250
27	0	2	3	0	0	0	050	80	135		1510	275
28	0	3	0	0	0	0					950	270
29	0	0	0	0	0	0				3	3030	310
30	0	0	3	3	0	0	135	50	225	2		
31	0	0	3	2	0	0	135	90		0	4350	196
32	0	0	3	0	0	0				2	2650	270
33	0	0	3	0	3	0				3		
34	0	3	0	0	3	0	150	45	045	3	2080	340
35	0	3	0	0	3	0				5		

HOST ROCK TYPE;Tg - TERTIARY CATFACE INTRUSIONS (ZEBALLOS STOCK); Jg - ISLAND INTRUSIONS; lJB - BONANZA GROUP(I-IGNEOUS, C-CALC-SILICATE OR CARBONATE); uTrQ & muTrK - QUATSINO FORMATION & KARMUTSEN FORMATION OF THE VANCOUVER GROUP. 0 - ABSENT; 1 - PRESENT; 2 - MINOR; 3 - MAJOR; 5 - PRESENT TO AN UNKNOWN EXTENT

DYKES,PRESENCE OF DYKES OF VARYING COMPOSITION; 0 - ABSENT; 1 - PRESENT 2 - MINOR; 3 - MAJOR; 5 - PRESENT TO AN UNKNOWN EXTENT

DIST FROM NOSE;BEARING & DISTANCE FROM NOSE OF INTRUSION TO DEPOSIT

TABLE 4

LISTING OF MINERAL DEPOSITS DATA FILE FOR
ZEBALLOS MINING CAMP - GEOLOGICAL FEATURES OF VEINS

DEP NO	MAJOR VEIN/S STRIKE	DIP	D/DRN	2NDARY VEIN/S STRIKE	DIP	D/DRN	NO MINZ VEINS	AV VEIN WIDTH(CM) MIN	MAX	ASSOC ZONES	AV SHEAR WIDTH(CM) MIN	MAX
1	080	65	315	065	80	180	5	15	30	1	30	90
2	055	80	315	070	85	315	3	15	20	1	10	60
3	045	70	135	045	90		2	5	8	1	5	60
4	090	75	180				1	20	25	1	8	45
5	040	80	135	180	80	225	3	2	12	1	30	90
6	045	80	135	060	60	315	7	8	12	1	10	45
7	090	85	360	090	90		5	0	30	1	25	75
8	045	75	315	032	80	315	2	3	30	1	3	30
9	040	75	135	040	80	135	2	1	15	1	3	90
10	035	90		057	80	315	7	1	20	1	5	75
11	160	70	045				1	0	15	1	4	20
12	000	90								4		
13	040	75	135				1	1	10	1	3	90
14	095	80	180	080	90		2	3	8	1	3	25
15	045	90					1	0	35	2		
16	000	90		000	65	135	4	5	10	1	5	60
17	063	80	135				1	0	25	1	5	45
18	176	90		000	90		5	0	8	1	10	20
19	057	75	315	090	90		3	2	5	1	3	5
20	050	90		060	80	315	4	1	3	1	10	60
21	090	90		090	90		10	0	5	1	150	1500
22												
23	010	75	045				1	3	12	1	15	25
24	175	60	135	030	70	135	2	3	20	1	15	20
25	090	72	360				1	5	15	1	15	60
26	090	80	360				1	5	15	1	45	75
27	052	80	135				1	5	10	1	10	30
28	058	90					1	0	10	1	15	180
29	047	90		050	90		2	4	8	1	5	15
30	160	70	135	050	90		3	5	10	1	15	60
31												
32	065	90					1	5	5	3		
33										4		
34	155	60	225				1	0	30	1	50	75
35										4		

ASSOCIATED ZONES; 1 - VEINS INTIMATELY ASSOCIATED WITH SHEAR ZONES; 2 - VEINS ASSOCIATED WITH DILATANT ZONES; 3 - MINERALIZATION ASSOCIATED WITH CONTACT ZONE; 4 - ASSOCIATED REPLACEMENT (SKARN) ZONE

TABLE 5

LISTING OF MINERAL DEPOSITS DATA FILE FOR
ZEBALLOS MINING CAMP - VEIN MINERALOGY AND CHARACTER

DEP NO	ASSOCIATED VEIN MINERALS									SH'TD ZONES	VEIN FORM	TENL FEAT	REPL	DIST(M) TO CONTACT
	Pyr	Sp	Aspy	Py	Cpy	Gn	Qtz	Cc	Ank					
1	1	2	1	3	1	2	3	2	3	3	2	3	2	+ 57
2	0	2	0	2	0	2	3	0	0	2	2	3	0	+ 473
3	0	0	3	3	0	0	3	2	2	0	2	3	3	- 473
4	5	0	0	5	3	3	3	0	0	2.	2	2	3	- 151
5	0	3	0	3	0	2	3	0	0	0	1	3	0	+ 473
6	0	2	2	3	2	2	3	0	0	0	2	2	0	+1229
7	0	2	3	3	0	2	3	0	0	0	1	2	0	+ 964
8	2	3	2	3	0	3	3	2	0	2	4	5	0	-1229
9	0	2	2	2	2	3	3	0	0	0	1	3	0	+ 529
10	0	2	2	2	0	2	3	0	0	2	2	2	0	+ 491
11	3	3	0	2	1	2	3	2	0	0	2		0	-2646
12	3	0	0	0	0	0	3	3	0	0		0	3	-1985
13	2	0	2	0	0	0	3	0	0	0	1	5	0	+ 548
14	0	1	2	2	0	1	3	0	0	0	2	2	0	+1040
15	3	3	0	2	1	2	3	2	0	0	2	5	5	-3175
16	2	0	0	0	2	0	0	3	0	0	3		0	-1890
17	0	0	2	2	0	0	3	0	0	0	1	5	0	-1115
18	0	2	2	2	2	1	3	0	0	0	2		3	-2174
19	0	0	0	2	0	0	3	3	0	0	1	2	0	-3400
20	0	0	0	2	0	0	3	2	0	0	1	2	0	+ 113
21	0	1	2	3	0	1	3	2	0	0	2	3	0	+1130
22	0	0	0	3	0	0	3	0	0	0	1	0	0	+ 435
23	2	3	3	0	2	0	3	0	0	0	1		0	
24	0	1	0	3	2	1	3	0	0	0	2	5	0	-1985
25	5	1	1	1	0	0	2	2	0	0	2		0	-1814
26	1	1	2	1	1	1	3	0	0	0	1	5	0	- 983
27	0	1	1	2	1	1	3	2	0	0	1	5	0	-1852
28	0	0	0	1	0	0	3	0	0	0	2		0	- 718
29	1			2			2				1		0	-2948
30	1	1	1	1	1	0	3	2	0	0	1	5	0	
31	0	0	0	0	0	0	0	0	0	0		0	0	-2022
32	0	1	0	0	1	0	3	3	0	0	1		0	-2211
33													3	
34	0	2	3	2	0	2	3	0	0	0	2	3	0	
35													3	

ASSOCIATED VEIN MINERALS ; MINERALS WHICH ARE PRESENT ALONG WITH Au AND Ag; 0 - ABSENT; 1 - MINOR; 2 - MODERATE; 3 - MAJOR; 5 - PRESENT TO UNKNOWN EXTENT.

SH'TD ZONES ; OCCURENCE OF SHEETED ZONES ON THE VEIN: 0 - ABSENT; 2 - MINOR; 3 - MAJOR

VEIN FORM;LOCAL FEATURES OF THE VEINS; 1 - PLANAR & APPROX PARALLEL-SIDED; 2 - VARIABLE IN WIDTH & ATTITUDE; 3 - LENTICULAR; 4 - COMBINATION OF 2 & 3.

TENL FEAT,TENSIONAL FEATURES,E.G.DIAGONAL GASH VEINS; 0 - ABSENT 2 - MINOR; 3 - MAJOR; 5 - PRESENT TO UNKNOWN EXTENT

REPL,ASSOCIATED REPLACEMENT/ALTERATION; 0 - ABSENT; 2 - MINOR ; 3 - MAJOR; 5 - PRESENT TO UNKNOWN EXTENT

DIST TO CONTACT;DISTANCE FROM DEPOSIT TO NEAREST CONTACT BETWEEN THE ZEBALLOS STOCK AND COUNTRY ROCK(+,WITHIN THE STOCK; -,WITHIN THE COUNTRY ROCK).

FUTURE WORK

We are in the process of examining the application of a variety of multivariate statistical methods of evaluation to the Zeballos data file. Among these methods are multiple regression, discriminant function analysis, cluster analysis, and characteristic analysis. These are complex methods of data evaluation that are hampered in the case of Zeballos data by the limited number of deposits for which data are relatively complete.

In addition to statistical evaluation of our quantitative data file, a detailed structural analysis appears to warrant attention to assist in defining a resource model for Zeballos camp.

CONCLUSIONS

An extensive quantitative data file has been established for gold-quartz veins in Zeballos mining camp. A preliminary evaluation of these data leads to the following conclusions:

(1) For past producers, total production in metric tonnes is an indicator of relative gross value of a deposit.

(2) Large vein deposits are lower grade on average than are small vein deposits.

(3) Gold and silver average grades appear highly correlated on a log-log plot although this relationship appears to be accentuated by extreme hand sorting of small deposits.

(4) A systematic relation exists between gold grades and combined copper plus lead content.

(5) A pronounced systematic relationship exists between relative deposit worth (approximated by total gold content) and distance from the nearest contact of the Zeballos stock. This relationship leads to a procedure for defining areas of greatest potential for gold-quartz veins in the camp.

(6) A 1 000-metre-wide zone centred on the contact of the Zeballos stock is an area of high potential for location of a deposit equivalent to the five largest producers known in the camp.

(7) A median target defined from the five producers contains 900 000 grams of gold in 75 000 tonnes of ore.

ACKNOWLEDGMENTS

This study, financed by the Science Council of British Columbia, is part of MINDEP research project of the Department of Geological Sciences, University of British Columbia, and is undertaken with the cooperation of the Mineral Resources Division, British Columbia Ministry of Energy, Mines and Petroleum Resources. Technical assistance has been provided by Asger Bentzen.

REFERENCES

Goldsmith, L. B., Sinclair, A. J., and Read, P. B. (in preparation): An Evaluation of Average Grades and Production Tonnages, Trout Lake Mining Area, Southern British Columbia.

Orr, J.F.W. and Sinclair, A. J. (1971): A Computer-Processable File for Mineral Deposits in the Slocan and Slocan City Areas of British Columbia, *Western Miner,* Vol. 44, No. 4, pp. 22-34.

Sinclair, A. J. (1979): Preliminary Evaluation of Summary Production Statistics and Location Data for Vein Deposits, Slocan, Ainsworth and Slocan City Camps, Southern British Columbia, *in* Current Research, Pt. B, *Geol. Surv., Canada,* Paper 79-1B, pp. 173-178.

Stevenson, J. S. (1950): Geology and Mineral Deposits of the Zeballos Mining Camp, *B.C. Ministry of Energy, Mines & Pet. Res.,* Bull. 27, 145 pp.

TABLE 1: GALENA-LEAD ISOTOPE ANALYSES FROM MINERAL DEPOSITS
Cariboo Area (Omineca Belt and Adjacent Intermontane Belt), South-Central British Columbia

Sample Number	Analysis	Deposit Name	Map Name	Lat. North	Long. West	Lead Isotope Ratios (Relative 1S Error as %) 206/204	207/204	208/204
NTERMONTANE BELT								
G79CD-001*	1	Cedar Creek	CD	52.55	121.47	18.757 (.09)	15.584 (.17)	38.310 (.21)
G79MR-001*	1	Mariner	MR	52.59	121.27	18.953 (.03)	15.654 (.11)	38.845 (.13)
Number of deposits (n)= 2		Arithmetic average ($\bar{x}$) =				[18.855 (.06)]	[15.619 (.14)]	[38.577 (.17)]
Number of analyses (a)= 2		Standard deviation (S) =				[0.139]	[0.050]	[0.378]
		Std. error of mean (S·n-½) =				[0.098]	[0.035]	[0.267]
MINECA BELT (CARIBOO DISTRICT)								
G79AU-001*	1	Aurum (Island Mountain)	AU	53.10	121.58	19.237 (.07)	15.759 (.14)	39.280 (.13)
G79CC-001*	1	Cunningham Creek (A-Zone)	CC	52.93	121.38	19.209 (.09)	15.759 (.19)	39.233 (.19)
G79CG-001	1	Cariboo Gold Quartz	CG	53.08	121.55	19.202 (.06)	15.703 (.16)	39.198 (.08)
30431-001	2	Cariboo Gold Quartz	CG	53.08	121.55	19.163 (.07)	15.692 (.08)	39.064 (.08)
30132-AVG*		Cariboo Gold Quartz (n=2)	CG	53.08	121.55	19.183 (.04)	15.698 (.09)	39.131 (.05)
G79CH-001*	1	Cariboo Hudson	CH	52.88	121.37	19.201 (.04)	15.752 (.12)	39.258 (.12)
30426-001	2	Pin Money	426	53.03	121.49	19.184 (.23)	15.720 (.24)	39.225 (.25)
30426-001@	2	Pin Money	426	53.03	121.49	19.195 (.15)	15.729 (.17)	39.213 (.18)
30426-002	2	Pin Money	426	53.03	121.49	19.245 (.22)	15.783 (.32)	39.417 (.28)
30426-AVG*	2	Pin Money	426	53.03	121.49	19.208 (.20)	15.744 (.24)	39.285 (.24)
30427-001	2	Mosquito Creek	427	53.10	121.57	19.046 (.20)	15.745 (.22)	39.133 (.24)
30427-002	2	Mosquito Creek	427	53.10	121.57	19.169 (.06)	15.759 (.07)	39.267 (.07)
30427-AVG*	2	Mosquito Creek	427	53.10	121.57	19.107 (.13)	15.752 (.15)	39.200 (.16)
Number of deposits (n)= 6		Arithmetic average ($\bar{x}$) =				[19.194 (.10)]	[15.744 (.16)]	[39.231 (.15)]
Number of analyses (a)= 10		Standard deviation (S) =				[0.045]	[0.023]	[0.058]
		Std. error of mean (S·n-½) =				[0.018]	[0.009]	[0.024]

1. Analyses by B.D. Ryan, Geology-Geophysics Laboratory, The University of British Columbia.
2. Analyses by A. Andrew, Geology Laboratory, The University of British Columbia.
3. The * symbol denotes those analyses used in the calculation of averages, standard deviations and standard errors.
4. The @ symbol denotes a duplicate analysis.
5. Two samples of galena, one coarse grained and one fine grained, were taken from the same hand specimen.

Table 2

Sample Data for K and Ar analyses on Whole Rock and Muscovite

Sample Number	Lat.	Long.	K%	Ar^{40*} (mol/gm)	rad. Ar%	Age (Ma)
Whole Rock						
A81 SN1	53 5'	121 33'	2.49 .07	8.114×10^{-10}	95.2	179 8
Muscovite						
A81 VN1	53 5'	121 33'	8.61 .06	21.986×10^{-10}	96.9	141 5

K was determined by Krista Scott by atomic absorption using a Techtron AA4 spectrophotometer. Ar was determined by J.E. Harakal, by isotope dilution, using an AEI MS-10 mass spectrometer and high purity ^{38}Ar spike (White et al., 1967). Errors are for two standard deviations. The constants used are:

$$\lambda^{40}K_{\varepsilon} = 0.581 \times 10^{-10} a^{-1}, \quad \lambda^{40}K_{\beta} = 4.962 \times 10^{-10} a^{-1},$$

$$^{40}K = 0.01167 \text{ atom per cent.}$$

AGE AND GENESIS OF CARIBOO GOLD MINERALIZATION DETERMINED BY ISOTOPE METHODS (93H)

By Anne Andrew, C. I. Godwin, and A. J. Sinclair
Department of Geological Sciences, The University of British Columbia

INTRODUCTION

The Cariboo area in southeastern central British Columbia (Fig. 107) is one of the oldest gold-producing regions in Canada (Sutherland Brown, 1957). Gold-bearing quartz veins occur in Hadrynian to Cambrian metasedimentary strata of the Omineca Belt. Triassic volcanic strata in the adjacent Intermontane Belt also host quartz-gold veins. Galena-lead isotope data were obtained from veins in both terranes (Fig. 107) in order to determine any genetic relationship that might exist between them. Galena was also collected and analysed from stratiform and vein type mineralization in the Mosquito Creek Gold mine near Wells (Fig. 107, No. 427), to investigate the possibility that at least some of the mineralization there might be syngenetic. K/Ar dates were obtained for muscovite from a quartz-barite vein associated with the Cariboo Gold Quartz mine, and for regionally metamorphosed phyllite.

Locations of galena and K/Ar samples are shown on Figure 107, and analyses are listed in Tables 1 and 2. Most galena samples were collected by D. Klepacki and R. Cook. Mosquito Creek and Cariboo Gold Quartz samples were collected by the author, and Pin Money samples were collected by B. Price and C. I. Godwin. Most lead isotope analyses were by B. D. Ryan. *For these analyses galena was dissolved in hydrochloric* acid and this solution was purified using anion exchange columns and electrodeposition. Samples, loaded using the silica gel-phosphoric acid technique, were analysed on a 30-centimetre, solid source mass spectrometer in the Department of Geophysics and Astronomy. Analyses of Pin Money, Cariboo Gold Quartz and Mosquito Creek samples were by A. Andrew who followed similar chemical separation and loading techniques but did the analyses on a V. G. Micromass 54R mass spectrometer in the Department of Geological Sciences. K/Ar dates were determined by J. Harakal and K. Scott (*see* Table 2).

GEOLOGY

Triassic andesitic volcanic rocks of the Intermontane Belt are juxtaposed against Proterozoic to Early Paleozoic metasedimentary strata of the Omineca Belt (Fig. 107). The boundary is thought to be a low-angle, southwesterly dipping thrust fault (Klepacki, personal communication, 1981; Rees, 1981). East of this boundary the Proterozoic to Cambrian Kaza and Cariboo Groups are made up of conglomerates, arkosic and quartzose sandstones, shales and carbonate rocks (Campbell, *et al.*, 1972;

1972). The Snowshoe Formation (Sutherland Brown, 1963) is equivalent to the Kaza Group (Campbell, *et al.*, 1972; Struik, 1981a). Kaza Group and Cariboo Group rocks are overlain unconformably by rocks of the Black Stuart Formation, which are dark argillites and chert and dolomite breccias with Lower Devonian fossils at their base (Campbell, *et al.*, 1972; Struik, 1979). Mississippian volcanic and sedimentary rocks of the Guyet Formation unconformably overlie the Black Stuart Formation. Several minor ankeritic, acidic dykes of pre-Mississippian age intrude the Cariboo Group and are known as the Proserpine dykes (Sutherland Brown, 1957).

West of the boundary, Triassic volcanic strata of the Intermontane Belt are predominantly andesitic and have been interpreted as arc-type volcanic rocks (Monger, *et al.*, 1972). Several intrusions occur within this belt, and most have Jurassic K/Ar ages of approximately 180 Ma. The Cariboo Bell and Mitchell Bay porphyry deposits also have 180 Ma K/Ar ages and are auriferous (Hodgson, *et al.*, 1976; Schink, 1974).

Quartz-gold veins that occur within the Snowshoe Formation contain galena, sphalerite, free gold, scheelite, and locally pyrrhotite or arsenopyrite. All these veins contain important values in silver. Veins that occur in the Triassic strata differ in that they lack scheelite and sphalerite; sulphide minerals are mainly galena and chalcopyrite.

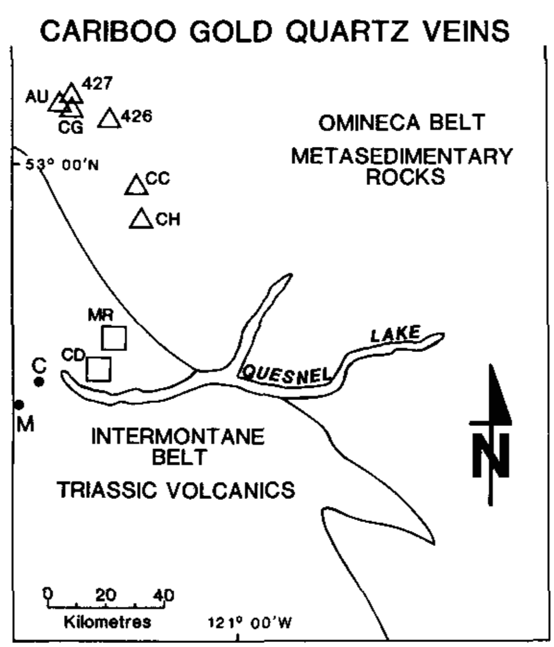


Figure 107. Locations of gold deposits from which galena-lead isotope analyses were obtained (refer to Table 1 for deposit names). K/Ar analyses were obtained from a vein and phyllite near CG. The line dividing the Omineca and Intermontane Belts is probably a generally west-dipping thrust. C is Cariboo Bell porphyry deposit, and M is Mitchell Bay porphyry deposit.

LEAD ISOTOPE DATA

Lead-lead plots of the data (Table 1) from each of the deposits (Fig. 107) are shown on Figure 108. The Omineca Belt data forms a single group (Cluster 1), which plots above but close to the 'shale curve' of Godwin and Sinclair (1982), but markedly above the average crustal curve of Stacey and Kramers (1975); both of these model curves are shown for reference on Figure 108. Data from stratiform mineralization at the Mosquito Creek mine plot within Cluster 1.

Vein leads from Triassic volcanic rocks are less radiogenic than those of the Omineca Belt, plotting below the 'shale curve' on Figure 108. Thus they are distinctly different from Cluster 1.

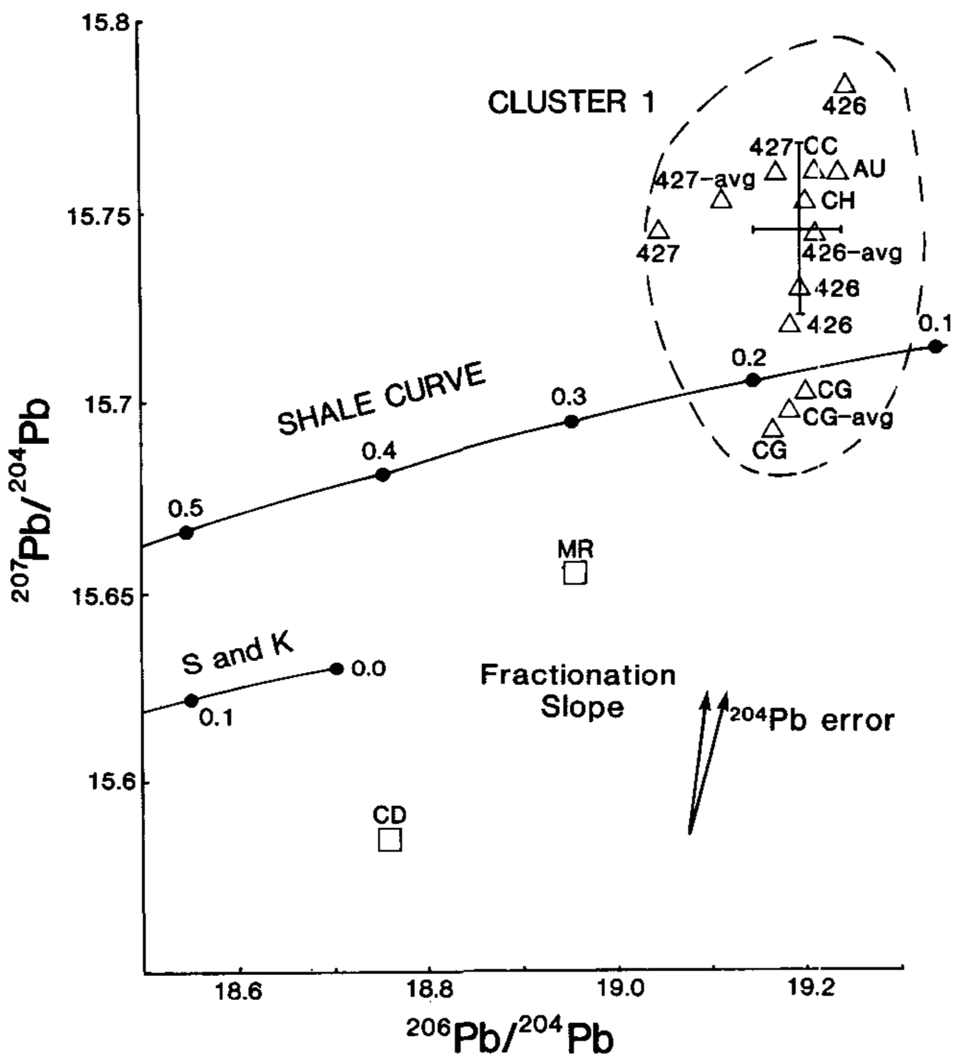


Figure 108. $^{207}Pb/^{204}Pb$ versus $^{206}Pb/^{204}Pb$ plot of galena analyses from Cariboo and adjacent Intermontane Belt gold deposits (Table 1). Symbols are the same as those of Figure 107.

DISCUSSION

Coincidence of Cluster 1 (Figs. 108 and 109) with the 'shale curve' model suggests that a model age can be given to the gold mineralization event. If the 'shale curve' model applies, it also implies that the source of the lead, and by inference gold, is upper crustal, since the 'shale curve' represents lead evolution in a sialic, upper crustal environment (Godwin and Sinclair, 1982).

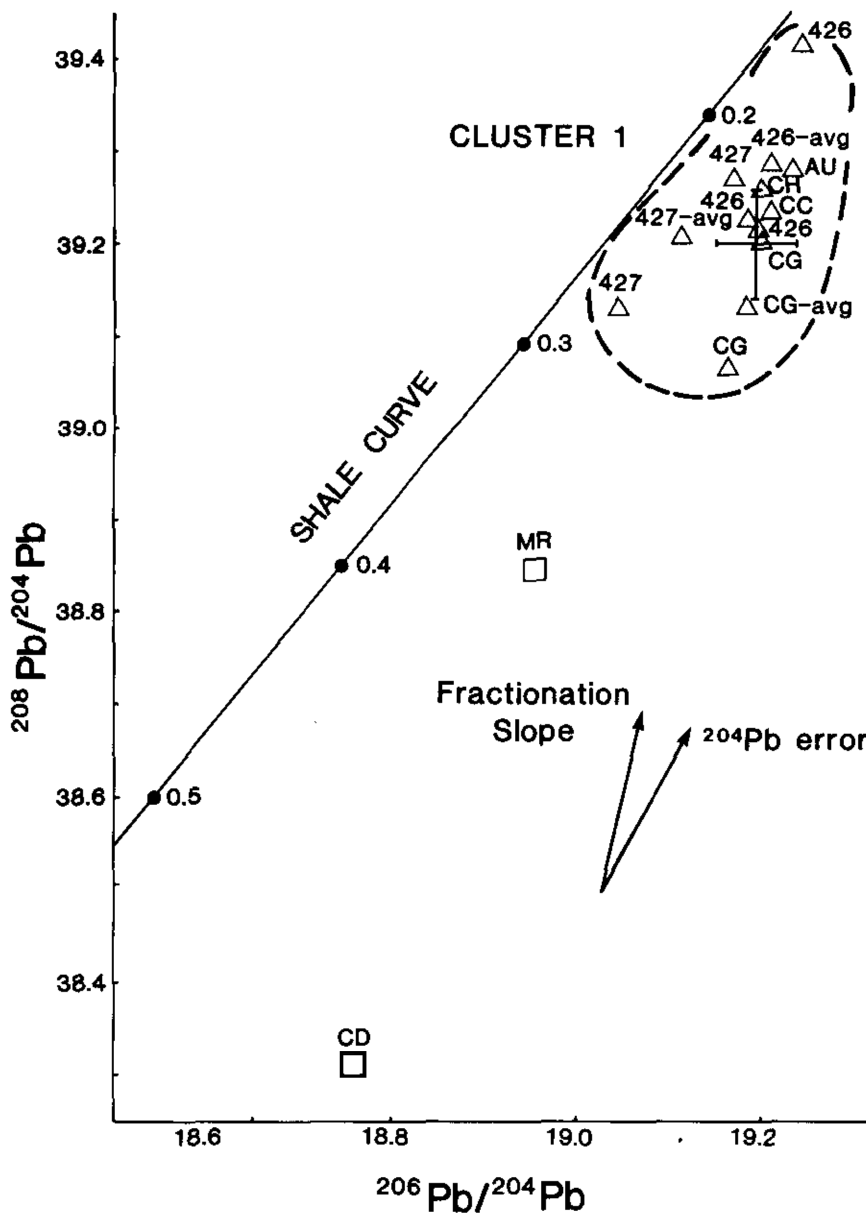


Figure 109. $^{208}Pb/^{204}Pb$ versus $^{206}Pb/^{204}Pb$ plot of galena analyses from Cariboo and adjacent Intermontane Belt gold deposits (Table 1). Symbols are the same as those of Figure 107.

Justification for using the 'shale curve' model in this part of the Omineca Belt comes from four lines of evidence:

(1) Lead data from Sullivan, which is in the southern Omineca Belt, were used in the construction of the curve.

(2) Similarities in the geology of the Barkerville-Cariboo River area with the Selwyn basin and Cassiar platform of northern British Columbia and the Yukon have been noted (Struik, 1981b). Therefore although most of the lead data used in the construction of the 'shale curve' were from the Selwyn basin, Omineca Belt lead should have similar characteristics.

(3) The provenance of sedimentary rocks in the Omineca Belt is essentially the same as for those in the Selwyn shale basin, since they are both autochthonous terranes which formed at the western margin of the North American craton. Therefore similar geochemical and isotopic characteristics are to be expected for the Selwyn basin and Omineca Belt.

(4) Stratabound carbonate-hosted deposits from the Cariboo area also have lead isotopic compositions which fall on the 'shale curve', giving ages which agree with the Cambrian age of their host rocks. These deposits (Maeford Lake and Comin Thro' Bear), clearly epigenetic as crosscutting bodies in carbonate rocks (Holbek, personal communication, 1982), are probably only slightly younger than their host rocks. Some epigenetic carbonate-hosted deposits in the Yukon can apparently be dated with the 'shale curve' model (Godwin, *et al.*, 1980). Therefore carbonate-hosted deposits also support the hypothesis that the 'shale curve' model is generally applicable to the Omineca Belt.

The calculated age for the gold mineralization event is 185 Ma according to the 'shale curve' model, but this is only accurate to approximately 50 Ma (Godwin and Sinclair, 1982). K/Ar dating of a regionally metamorphosed phyllite gives an age of 179±8 Ma (Table 2) which is interpreted as being the age of the latest metamorphism. This agrees with previous estimates for the age of metamorphism by Pigage (1977) and Wanless, *et al.* (1965). Struik (1981b) suggests that metamorphism occurred during the Middle Mesozoic Columbian orogeny. Similarity in metamorphic and mineralization ages suggest that the veins may be synmetamorphic, rather than magmatic in origin.

At least three phases of veins are present in the Cariboo Gold Quartz mine, and not all vein phases are gold-bearing (F. Beaumann, personal communication, 1981). Muscovite from one quartz-barite vein yielded a K/Ar model age of 141±5 Ma (Table 2), which is the same as ages obtained for post-tectonic granodiorite plutons southeast of the area (Pigage, 1977). Thus at least one set of veins is post-tectonic and may be related distally to plutonic activity. Although none are seen in the immediate area of the mine, plutons may be present at depth. Whether the veins are synmetamorphic or magmatic in origin does not alter the conclusion that most of the lead and gold were derived from the host rocks, either by lateral secretion during regional metamorphism (Boyle, 1979), or by hydrothermal activity related to magmatism.

Lead isotope data from stratiform mineralization at the Mosquito Creek Gold mine are indistinguishable from those of the quartz-gold veins of Cluster 1 (Figs. 108 and 109). Since the Snowshoe Formation is Paleozoic or older and the mineralization is Mesozoic, the difference between syngenetic and epigenetic lead would be readily distinguishable by lead isotope analyses. The lead from Mosquito Creek is clearly epigenetic based on lead isotopic composition.

Lead isotopic characteristics of quartz-gold veins in Triassic strata are distinctly different from those of the Omineca Belt deposits (Figs. 108 and 109), indicating a fundamental difference in the source of lead (and perhaps gold) in these tectonic belts. Markedly different mineralogy supports the hypothesis that the two vein types have lead sources which are different and unrelated. For example, lithophile tungsten in scheelite-bearing veins in the Snowshoe Formation could have been derived from the sialic host rocks; its absence from veins in the more mafic Intermontane Belt is to be expected on chemical grounds if the veins have a host rock source. Thus, the differences in the lead isotopes can be attributed to growth of lead in different uranium and thorium environments. Figure 110 shows data from this study plotted with Insular Belt data from Andrew, *et al.* (1982) to display the contrast between these three different lead provinces. Intermontane Belt lead is more like lead from the Insular Belt than lead in the Omineca Belt.

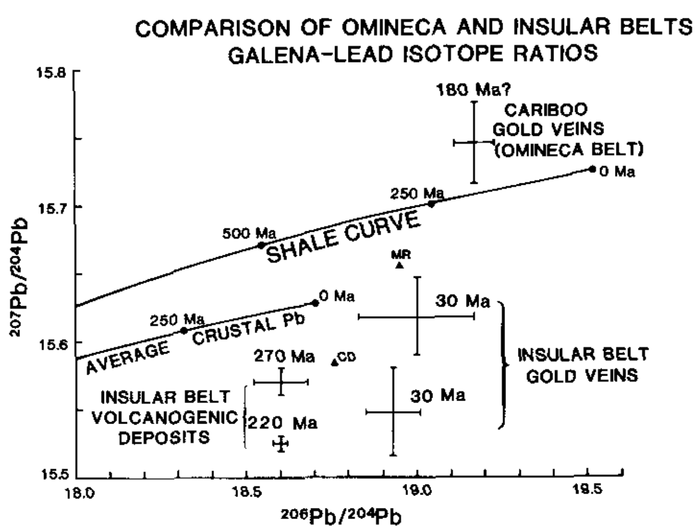


Figure 110. Comparison of Omineca, Insular, and Intermontane Belt galena-lead isotope ratios. Triangles represent Intermontane Belt deposits in Table 1. Error bars on the five clusters shown mark standard deviation of the suite for each cluster. The two growth curves shown are the 'shale' curve (Godwin and Sinclair, 1982), and the average crustal curve (Stacey and Kramers, 1975).

The age of mineralization of the veins in the Intermontane Belt is not known, but is probably Jurassic, *ca.* 180 Ma, based on the plutonic and volcanic activity related to auriferous porphyry deposits in this part of the Intermontane Belt.

CONCLUSIONS

The difference in isotopic composition of veins in Hadrynian metasedimentary rocks and in Triassic volcanic rocks precludes derivation of lead from the same source, thus ruling out the possibility that the gold in the Cariboo area was derived from the Intermontane Belt. Similarity in lead isotopic composition of stratiform galena from the Mosquito Creek deposit with galena from clearly epigenetic quartz-gold veins in the Omineca Belt suggests that syngenetic mineralization is not present.

Lead isotope and K/Ar evidence indicate that the age of mineralization of the Omineca Belt quartz-gold veins is Mesozoic. Location of Cluster 1 (Figs. 108, 109, and 110) near the 'shale curve' model suggests that the lead and gold have an upper crustal, host-rock source. The process by which metals were mobilized from their host rocks into the quartz-gold veins was probably by lateral secretion during regional metamorphism. Support for this theory comes from coincident metamorphic and mineralization ages, but the possibility that the veins are related to distant Jurassic plutons is not ruled out completely.

A host-rock source for the gold in quartz-gold veins in the Triassic arc-volcanic rocks may explain the unradiogenic nature of the lead in these veins.

ACKNOWLEDGMENTS

D. Klepacki suggested this study, and a visit to the area was arranged by V. Hollister. F. Beaumann kindly provided hospitality and acted as guide to the geology of the Cariboo Gold Quartz property. The staff at Mosquito Creek mine provided a tour of the underground workings.

We thank B. D. Ryan for his careful analyses of our samples. Financial support for this study was generously provided by Rio Tinto Canadian Exploration Limited and the British Columbia Ministry of Energy, Mines and Petroleum Resources. Figures were drafted by J. Newlands and E. Andrew. The senior author received a Graduate Student Fellowship bursary from the University of British Columbia, which is gratefully acknowledged.

REFERENCES

Andrew, A., Godwin, C. I. and Sinclair, A. J. (1982): Preliminary Examination of the Metallogeny of Gold in the Insular Belt using Lead Isotope Analyses, *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1981, Paper 1982-1, pp. 202-217.

Boyle, R. W. (1979): The geochemistry of Gold and Its Deposits, *Geol. Surv., Canada,* Bull. 280, pp. 390-428.

Campbell, R. B., Mountjoy, E. W., and Young, F. G. (1972): Geology of McBride Map-Area, British Columbia, *Geol. Surv., Canada,* Paper 72-35, 96 pp.

Godwin, C. I., Sinclair, A. J., and Ryan, B. D. (1980): Preliminary Interpretation of Lead Isotopes in Galena-Lead from British Columbia Mineral Deposits, *B.C. Ministry of Energy, Mines & Pet. Res.,* Geological Fieldwork, 1979, Paper 1980-1, pp. 171-177.

Godwin, C. I. and Sinclair, A. J. (1982): Average Lead Isotope Growth Curve for Shale-Hosted Lead-Zinc Deposits, Canadian Cordillera, *Econ. Geol.,* Vol. 77, pp. 675-690.

Hodgson, C. J., Bailes, R. J., and Verzosa, R. S. (1976): Cariboo-Bell, *in* Porphyry Deposits of the Canadian Cordillera, *C.I.M.* Special Vol. 15, pp. 388-398.

Monger, J.W.H., Souther, J. G. and Gabrielse, M. (1972): Evolution of the Canadian Cordillera: A Plate Tectonic Model, *Am. Jour. Sci.,* Vol. 272, pp. 577-602.

Pigage, L. C. (1977): Rb/Sr Dates for Granodiorite Intrusions on the Northeast Margin of the Shuswap Metamorphic Complex, Cariboo Mountains, British Columbia, *Cdn. Jour. Earth Sci.,* Vol. 14, pp. 1690-1695.

Rees, C. J. (1981): Western Margin of the Omineca Belt at Quesnel Lake, British Columbia, *in* Current Research, Pt. A, *Geol. Surv., Canada,* Paper 81-1A, pp. 223-226.

Schink, E. A. (1974): Geology of the Shiko Lake Stock, near Quesnel Lake, British Columbia, B.Sc. thesis, *University of British Columbia,* 64 pp.

Stacey, J. S. and Kramers, J. D. (1975): Approximation of Terrestrial Lead Isotope Evolution by a Two-Stage Model, *Earth Planet. Sci. Lett.,* Vol. 26, pp. 207-221.

Struik, L. C. (1979): Stratigraphy and Structure of the Barkerville-Cariboo Area, Central British Columbia, *in* Current Research, Pt. B, *Geol. Surv., Canada,* Paper 79-1B, pp. 33-38.

.... (1981a): Snowshoe Formation, Central British Columbia, *in* Current Research, Pt. A, *Geol. Surv., Canada,* Paper 81-1A, pp. 213-216.

.... (1981b): A Re-examination of the Type Area of the Devono-Mississippian Cariboo Orogeny, Central British Columbia, *Cdn. Jour. Earth Sci.,* Vol. 18, pp. 1767-1775.

Sutherland Brown, A. (1957): Geology of the Antler Creek Area, Cariboo District, British Columbia, *B.C. Ministry of Energy, Mines & Pet. Res.,* Bull. 38, 105 pp.

.... (1963): Geology of the Cariboo River, British Columbia, *B.C. Ministry of Energy, Mines & Pet. Res.,* Bull. 47, 69 pp.

Wanless, R. K., Stevens, R. D., Lachance, G. R., and Rimsaite, R.Y.H. (1965): Age Determinations and Geological Studies, Part 1 - Isotopic Ages, Rept. 5, *Geol. Surv., Canada,* Paper 64-17 (Pt. 1), 126 pp.

White, W. H., Erickson, G. P., Northcote, K. E., Dirom, G. E., and Harakal, J. E. (1967): Isotopic Dating of the Guichon Batholith, British Columbia, *Cdn. Jour. Earth Sci.,* Vol. 4, pp. 677-690.

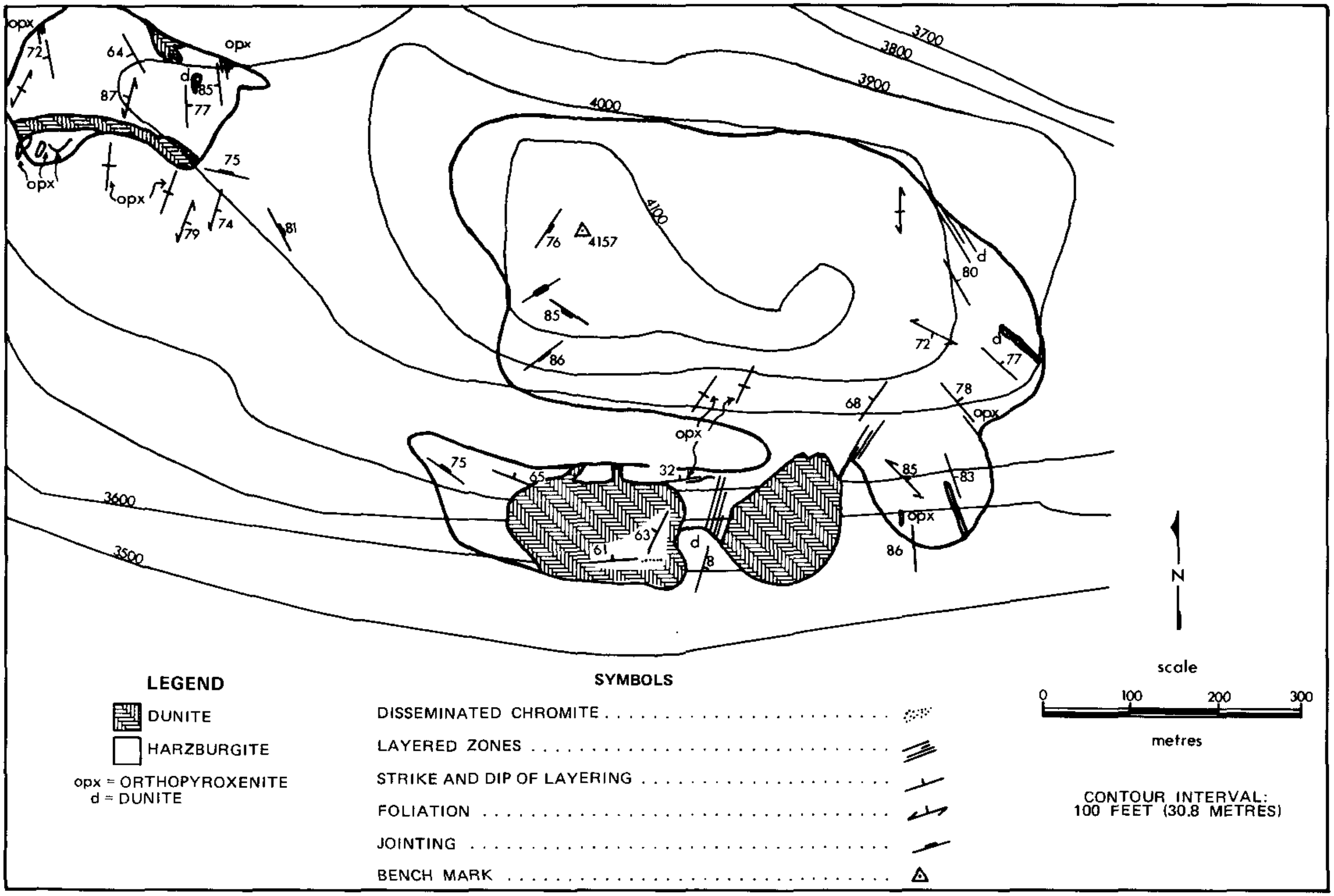


Figure 112. Geology of the upper part of Pinchi Mountain.

CHROMITE IN THE MOUNT SIDNEY WILLIAMS AREA, CENTRAL BRITISH COLUMBIA (93K)

By P. J. Whittaker
Department of Geology, Carleton University

INTRODUCTION

Fieldwork during the summer of 1982 constitutes the third and final field season involving detailed mapping of ultramafic massifs and associated chromite occurrences, primarily in central British Columbia. The past field season saw additional work done at Murray Ridge (Whittaker and Watkinson, 1981) and new mapping on part of Pinchi Mountain. Both of these bodies are in the Pinchi fault zone (Paterson, 1977) in the Fort St. James area. Most of the fieldwork was done at Mount Sidney Williams, an ultramafic massif 85 kilometres northwest of Fort St. James (Fig. 111). Mount Sidney Williams is also 44 kilometres south of the Mitchell Range ultramafic massif, mapped in 1981 (Whittaker, 1982a, 1982b). Both Mount Sidney Williams and Mitchell Range ultramafic rocks were included in regional mapping by Armstrong (1949) and Little (1947).

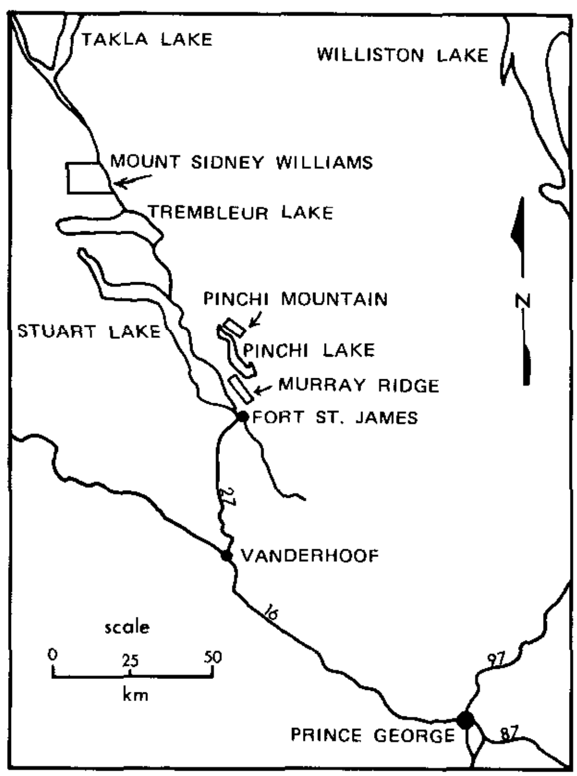


Figure 111. Location map of Pinchi Mountain, Murray Ridge, and Mount Sidney Williams.

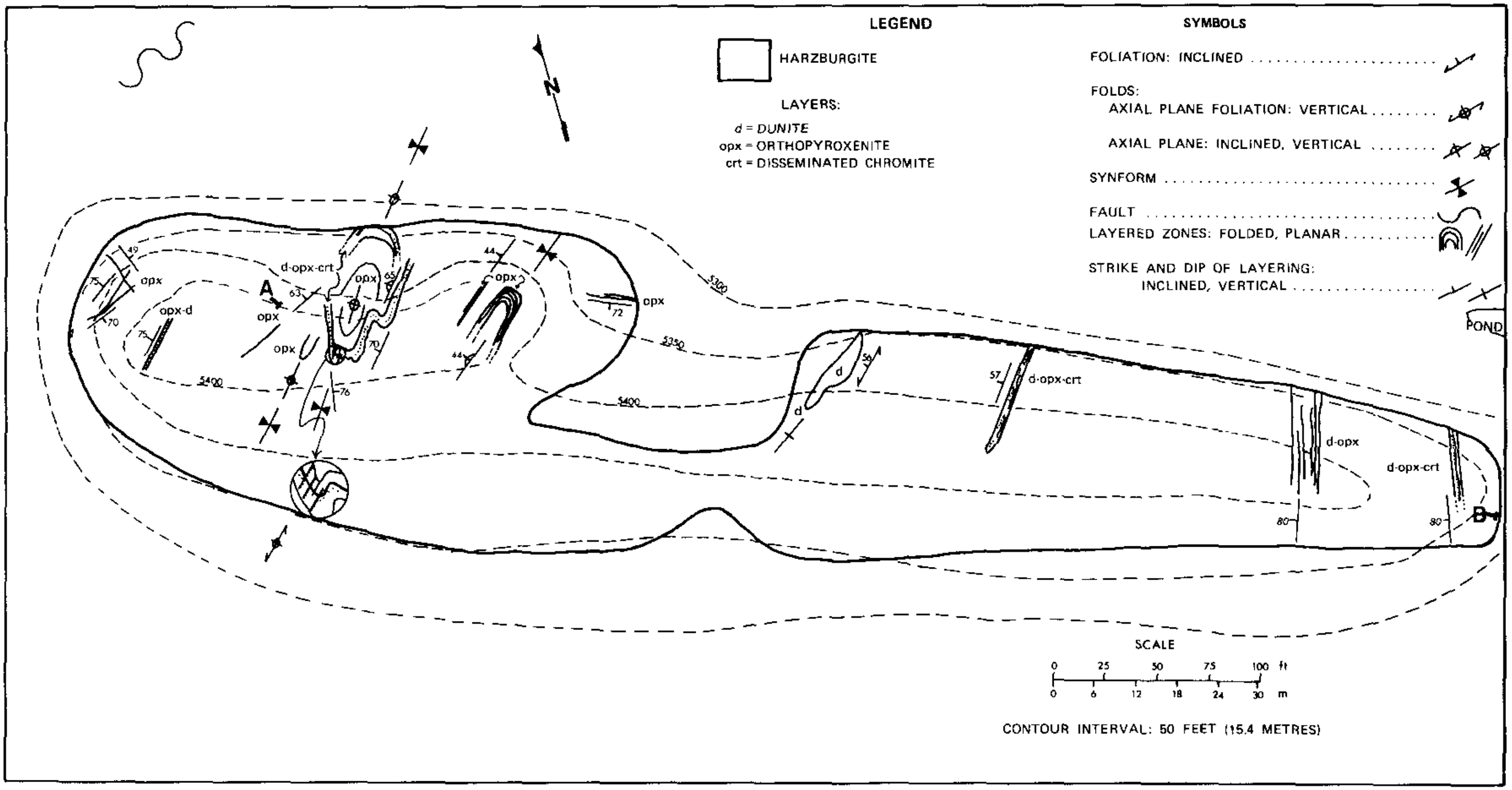


Figure 113. Deformed dunite-orthopyroxenite-chromite layers at Baptiste Spur, southeast flank of Mount Sidney Williams.

PINCHI MOUNTAIN

Pinchi Mountain is underlain predominantly by harzburgite tectonite and, to a lesser extent, by dunite. Brittle shear from movement in the Pinchi fault zone has developed an intense foliation resulting in friable platy, greyish brown weathered surfaces. Harzburgite tectonite is medium to coarse-grained, equigranular, and carries accessory chromite. Serpentinization is extreme, usually 80 per cent or more complete.

Dunite occurs as deformed layers and pods within harzburgite tectonite and is also completely serpentinized. Ductile passively folded dunite layers and irregularly shaped dunite pods suggests movement in a still-hot environment, which could be the upper mantle (Fig. 112).

Chromite was observed in an irregularly shaped dunite pod, 100 metres wide. The chromite layer has been openly folded and is about 30 centimetres long and exhibits a pinch-and-swell structure up to 3 centimetres thick. Chromite in it is medium grained, subhedral to euhedral, and forms 80 per cent of the layer. Bleached serpentine, greenish white in colour, forms the groundmass. In 50 per cent of the chromite, individual grains are rimmed by 0.5 to 1.0-millimetre-thick bleached serpentine halos.

MOUNT SIDNEY WILLIAMS

Detailed mapping on Mount Sidney Williams indicates a predominance of harzburgite tectonite with minor dunite, orthopyroxenite, and scattered chromite-chromitite layers in dunite. The West Peak area, northwest of and in fault contact with Mount Sidney Williams, consists of massive and layered norite (Little, 1947) with dunitic dykes or schlieren. This gabbro may be related to the ultramafic massif as a stratigraphically higher component of a dismembered ophiolite or it may have been emplaced along an active fault zone during obduction.

Layered zones within the Mount Sidney Williams massif were mapped and have roughly parallel orientation, north striking with vertical dip. Layering is rhythmic and is defined by alternating layers of harzburgite and dunite. In some cases one or more orthopyroxenite layers occur, usually within dunite layers. Disseminated chromite and chromitite layers, up to 2 centimetres thick, are hosted by some dunite layers. Layered zones up to 5 metres wide were mapped with harzburgite layers up to 1 metre, dunite layers up to 25 centimetres, and orthopyroxenite layers up to 4 centimetres in thickness. In most cases layered zones are planar with sharply defined contacts. One layered zone exhibited a doubly plunging synformal structure with higher order small-scale folding concentrated in the noses of the structure (Fig. 113). This passive folding suggests that ductile deformation took place in zones within the ultramafic massif.

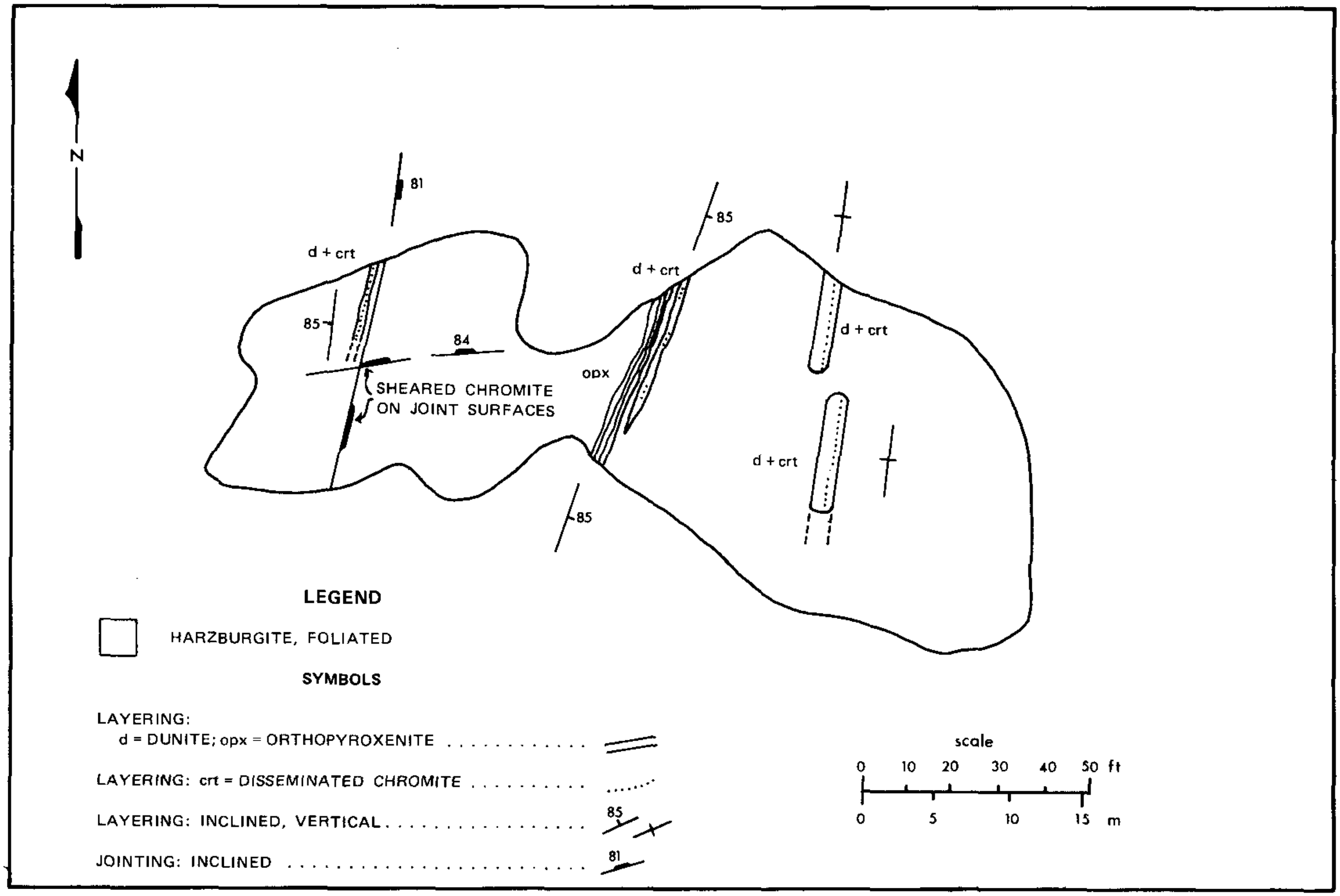


Figure 114. Planar dunite-orthopyroxenite-chromite layers 500 metres north of the summit of Mount Sidney Williams.

Several layered chromitite occurrences were mapped; some have considerable lateral extent (about 500 metres). A vertical zone consisting of several dunite layers, one of which carries a 0.5 to 2-centimetre-wide chromitite band, occurs 50 metres north of the summit of Mount Sidney Williams. This layer strikes north and is subparallel to the summit ridge. A similar zone with a chromitite layer (Fig. 114) crops out on the floor of a cirque 500 metres to the north and directly on strike with the summit chromitite occurrence.

Chromite in layered occurrences on Mount Sidney Williams often exhibit bleached greenish white reaction rims. These serpentine-chlorite rims surround medium-grained subhedral to euhedral chromite and are 0.5 to 1 millimetres thick. Preliminary microprobe analyses show the chromite to be highly altered with high aluminum, magnesium, and sometimes high iron compositions. Texturally the altered chromite exhibits skeletal to dendritic form which is made up of magnetite and low chromium chromite or ferrichromite. In some grains remnant unaltered cores of chromite occur; these are irregular in form and have serrated borders. The chromite cores are amber to reddish brown in transmitted light and have lower chrome values than chromite from podiform chromitite described from the Mitchell Range (Whittaker, 1982a, 1982b).

ACKNOWLEDGMENTS

Financial support for fieldwork was received from the British Columbia Ministry of Energy, Mines and Petroleum Resources and the Geological Survey of Canada (Grant 203/4/81) via grants to Dr. D. H. Watkinson.

REFERENCES

Armstrong, J. E. (1949): Fort St. James Map-Area, Cassiar and Coast Districts, British Columbia, *Geol. Surv., Canada,* Mem. 252, 210 pp.

Little, H. W. (1947): The Ultrabasic and Associated Rocks of the Middle River Range, British Columbia, unpub. Ph.D. thesis, *University of Toronto.*

Paterson, I. A. (1977): The Geology and Evolution of the Pinchi Fault Zone at Pinchi Lake, Central British Columbia, *Cdn. Jour. Earth Sci.,* Vol. 14, pp. 1324-1342.

Whittaker, P. J. (1982a): Chromite Occurrences in Ultramafic Rocks in the Mitchell Range, Central British Columbia, *in* Current Research, Pt. A., *Geol. Surv., Canada,* Paper 82-1A, pp. 239-245.

.... (1982b): Chromite Occurrences in Mitchell Range Ultramafic Rocks of the Stuart Lake Belt, Cache Creek Group, *B.C. Ministry of Energy, Mines & Pet. Res.,* Geological Fieldwork, 1981, Paper 1982-1, pp. 234-243.

Whittaker, P. J. and Watkinson, D. H. (1981): Chromite in Some Ultramafic Rocks of the Cache Creek Group, British Columbia, *in* Current Research, Pt. A, *Geol. Surv., Canada,* Paper 81-1A, pp. 349-355.