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FOREWORD

This is the eighth 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 speed publication, figures have generally been draughted by the authors.

This edition of Geological Fieldwork has a revised format with two sections. Project and Applied Geology includes reports of metallic and coal field investigations, reports of District Geologists, and property examination 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 funded by grants of the Ministry.

The cover photograph depicts a fly camp in the Monashee Mountains.

Output of this publication was coordinated by W.J. McMillan and production editing and layout by the Publications Section and D. Bulinckx of Project Geology. R. Hoenson of the Geological Branch draughting office assisted with layout.

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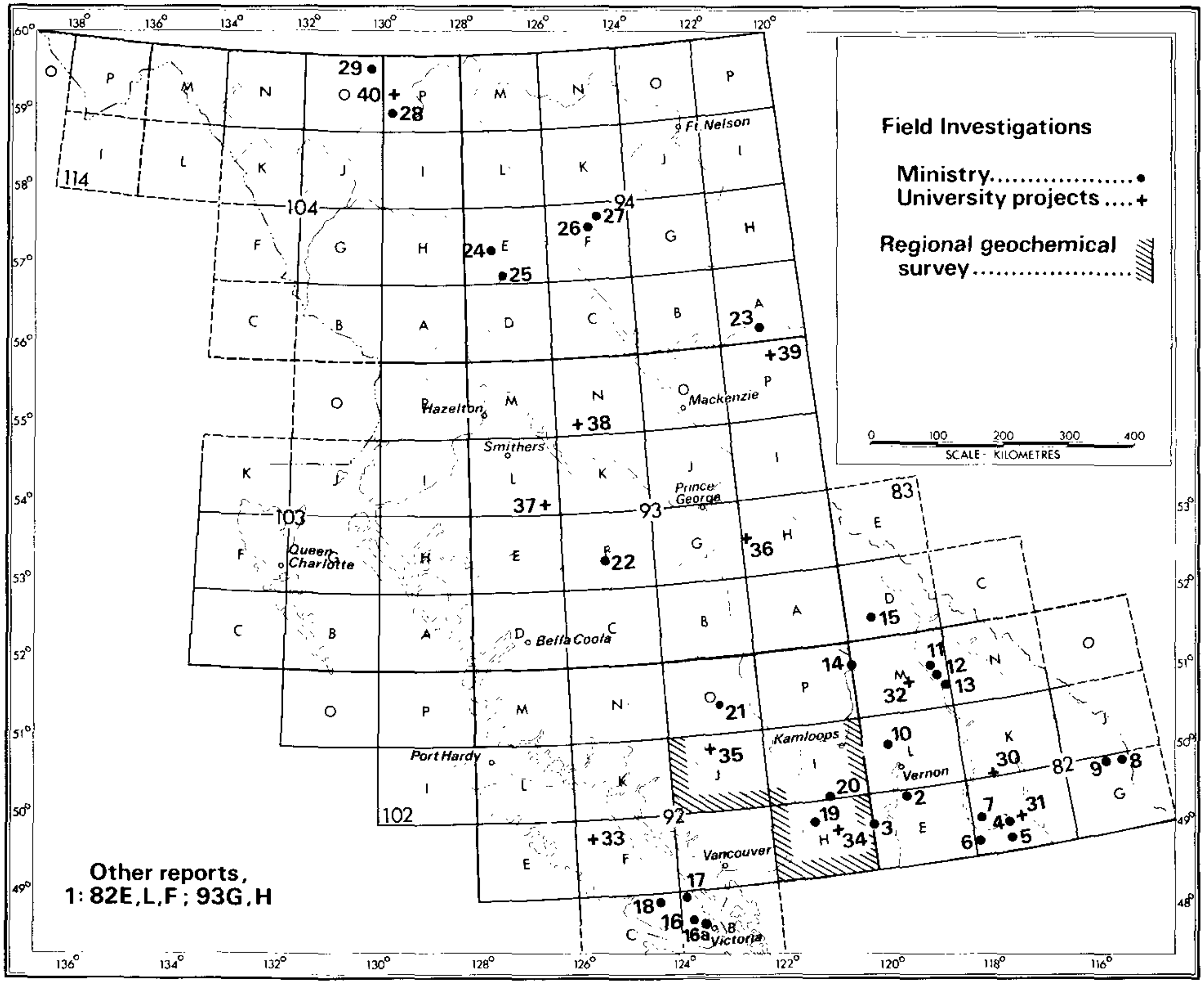

Distribution of program, Geological Fieldwork, 1981.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

PRELIMINARY INVESTIGATIONS (Continued) Page

OTHER INVESTIGATIONS

TABLE OF CONTENTS (Continued)
OTHER INVESTIGATIONS (Continued) Page

PROJECT AND APPLIED GEOLOGY

MAPPING OF SILICA OCCURRENCES IN BRITISH COLUMBIA

By Z.D. Hora

A field reconnaissance of silica occurrences with mapping and sampling was carried on during the 1981 field season. The purpose of the study is to obtain information about the industrial potential of reported occurrences in view of recent interest for raw materials to produce ferrosilicon and silicon metal. The studied occurrences were those where previous data did not provide enough information either on size or chemical composition of the silica. The following properties were examined.

WHITE ELEPHANT (82L/4E, 50° 09'-119° 33')

The silica occurrence consists of an oval-shaped quartz plug, 27 metres long and 12 metres wide, in a coarse-grained hornblende-biotite granite. Part of the plug, which is mineralized by massive pyrrhotite with a small amount of chalcopyrite and some gold values, was mined between 1921 and 1933. The mined-out area left a pit 15 metres by 9 metres that is now filled with water. The old workings extend to a depth of approximately 66 metres below the surface.

FAIRVIEW (82E/4E, 49° 12'-119° 38')

A quartz vein, with minor gold values up to 7.5 metres wide, was mined underground from 1933 to 1961 and more than 350 000 tonnes of smelter flux were shipped to Trail. In outcrop, the vein strikes 118 degrees with dip 30 to 50 degrees northeast; the quartz is exposed in an area 7.5 metres by 31 metres. The surrounding rocks consist of slightly metamorphosed sedimentary rocks, mainly dominated by quartzites and metagreywackes.

SUSIE (82E/4E, 49° 13'-119° 36')

A body of massive, milky white quartz is enclosed in a granitic intrusion and crops out as a knoll 35 metres long and 20 metres wide. Most of the outcrop seems relatively free of impurities, although limonite staining and small amounts of pyrite, galena, and pyrrhotite are present. Between 1964 and 1976 some 20 000 tonnes of silica flux with minor gold values was shipped to Trail from an underground operation.

SNOWDRIFT (82F/11W, 49° 37'-117° 29')

Massive milky white quartz forms the core of a pegmatite dyke. The quartz pod is exposed over an area of 45 metres by 60 metres and is surrounded by a large mass consisting of perthitic undergrowths of feldspar and quartz. In 1971 a small quarry, 10 metres by 20 metres, produced 500 tonnes of silica which was used locally as a stucco dash.

LOUMARK (82E/15E, 49° 58'-118° 40')

Outcrops scattered 50 metres of strike length expose an 8-metre-wide vein of white opaque quartz at least 8 metres wide with northwest strike that cuts through a body of Nelson granite. The quartz is relatively free of impurities although limited areas have disseminated pyrite.

RICE (82F/9E, 49° 34'-116° 04')

A group of outcrops over an area of 15 metres by 30 metres expose a body of hydrothermal quartz that is highly contaminated by limonite malachite stains. Small crystals of pyrite are a common accessory component in unweathered quartz; low gold values are also reported. Foliated fine-grained brown-green pyritic metasediments comprise the surrounding rocks. Some 1 400 tonnes was mined and shipped to Trail in 1973.

QUARTZ (93G/8W, 53° 22'-122° 26')

A massive white quartz vein is exposed in a zone more than 205 metres in length and 21 metres in width. It strikes 140 degrees and, to the northwest, splits into two branches. The country rock consists of slightly foliated, fine-grained, dark green-black metasedimentary rocks.

CARIBOO GOLD QUARTZ (93H/4E, 53° 04'-121° 31')

The B.C. vein is a massive, mostly barren white quartz vein. It is exposed in scattered outcrops along 250 metres of strike length and is up to 10 metres in width. The vein consists of parallel bands of massive quartz with many small fragments of phyllite wallrock between individual bands.

Several sedimentary siliceous units were also examined:

(1) Monashee quartzites in the Revelstoke area were found to be highly contaminated by muscovite, and to a lesser degree, biotite and other dark minerals.
(2) South of Salmo near the abandoned Jersey mine, the Quartzite Range Formation contains a 75-metre-wide ridge of massive quartzite with only traces of muscovite.

(3) In the Barkerville area the Yanks Peak quartzite is locally pure white with no macroscopically visible impurities. However, many exposures exhibit rusty spots replacing mafic minerals. Secondary quartz and carbonate veinlets are common.

(4) Rocky Mountain Formation sandstones in the Flathead area are highly calcareous beds, locally contaminated by micas and feldspar fragments.

ACKNOWLEDGMENTS

Fieldwork was carried out by Margaret Hanna (party chief) and Jaquie Rublee (assistant) under the supervision of Z.D. Hora.

Analysis of data information collected during the summer is in progress.

NOTES ON THE PENTICTON GROUP
A PROGRESS REPORT ON A NEW STRATIGRAPHIC SUBDIVISION OF THE TERTIARY
SOUTH-CENTRAL BRITISH COLUMBIA

(82E/L)

By B.N. Church

The name Penticton Group has been proposed for Eocene volcanic and sedimentary rocks of the Okanagan-Boundary region. The areas of recent study required to delineate these rocks are shown on Figure 1.

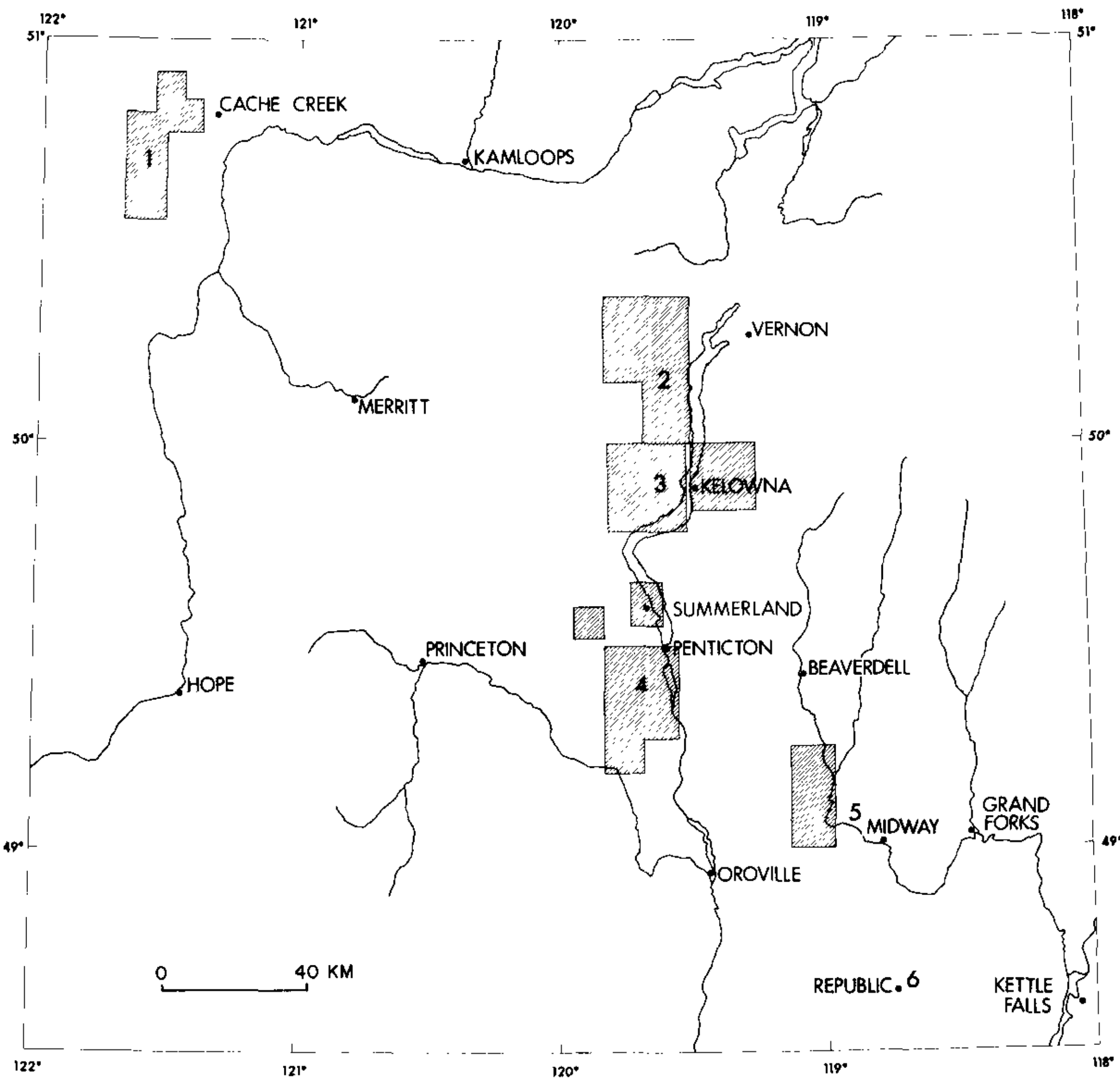

Figure 1. Index map of areas of detailed study.

The principal resources of the Penticton Group are coal, precious metal deposits, uranium, and geothermal energy.

The Group consists of six well-defined formations having an aggregate thickness of about 2 500 metres in the type area near Penticton (No. 4, Figure 2). At the base are polymictic conglomerates and breccias referred to as the Springbrook Formation and coeval beds of the Kettle River Formation consisting of granite boulder conglomerate, rhyolite breccia, and tuffaceous sedimentary rocks. Above this is the Marron Formation composed mainly of thick andesite, trachyte, and phonolitic lava flows, succeeded upward by dacitic and some andesitic domes of the Marama Formation. This is followed by volcanic breccias and lacustrine and fluvial sedimentary rocks of the White Lake Formation and, uppermost, the Skaha Formation consisting of a landslide complex and fanglomerate beds. The Group rests unconformably on pre-Tertiary granitoids, metamorphosed Mesozoic sedimentary and volcanic rocks, and older schists and gneisses.

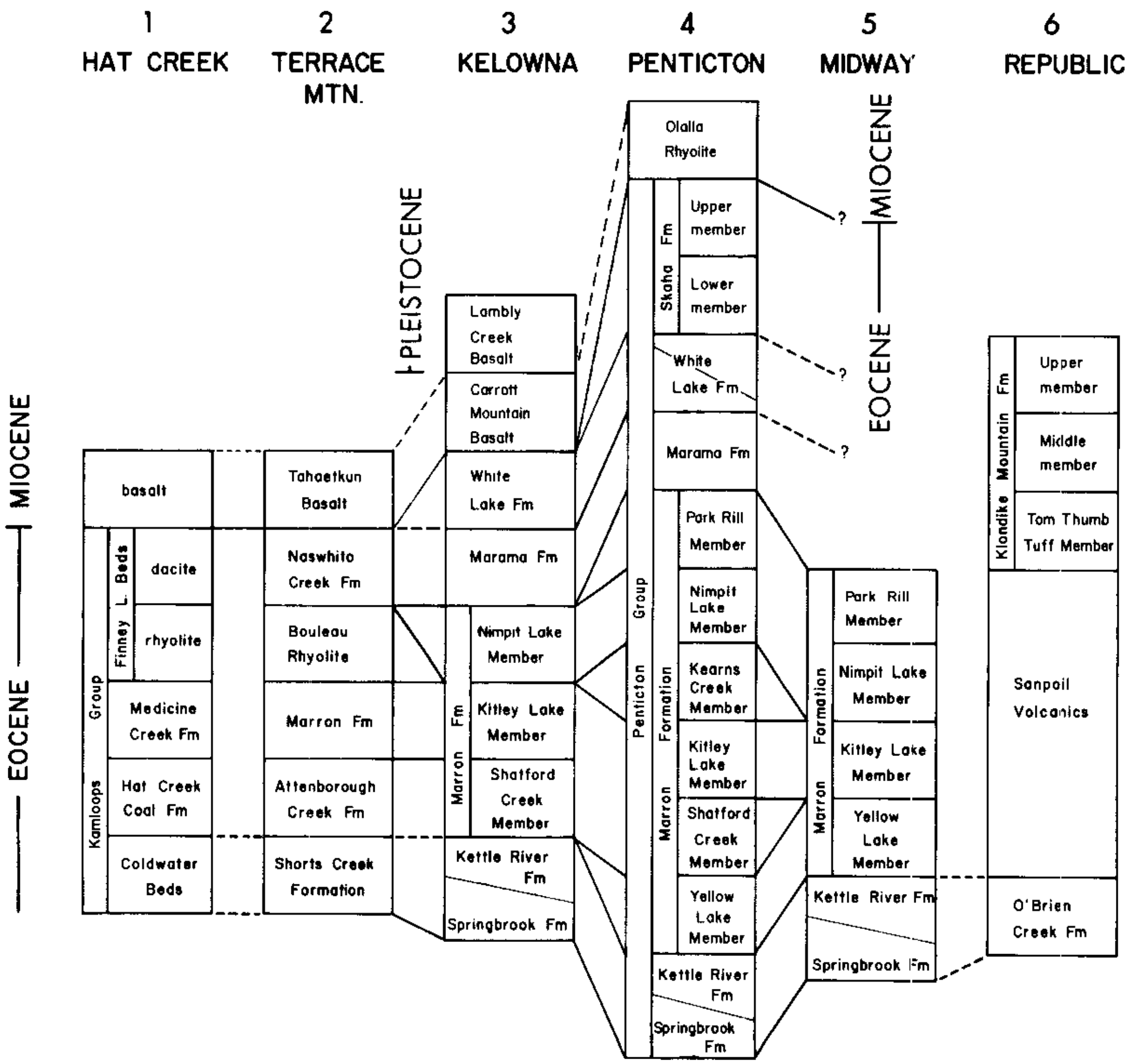

Figure 2. Correlation chart of major Tertiary units.

The age range for the Group, as determined by potassium-argon radiometric methods, is 48.4 Ma (whole rock) to 53.1 Ma (biotite) ±1.8 Ma. Preliminary tests performed on the principal lava members indicate normal magnetic polarity. Overlying the Group are isolated patches of Miocene rhyolite (Olalla rhyolite, 13 Ma) 'plateau basalt', and younger 'valley basalt.'

In the Kelowna area 'plateau basalt' occurs on Carrot Mountain (11.8 Ma) and Daves Creek (14.9 Ma). The Lambly Creek basalt (0.762 Ma) is the only so-called 'valley basalt' of the region.

North and west of the type area (see Nos. 1, 2, and 3, Figures 1 and 2) the constitutent formations interfinger and are replaced by units of the Kamloops Group (Ewing, 1981). At Terrace Mountain near Vernon the names Naswhito Creek Formation, Bouleau Rhyolite, Attenborough Creek Formation, and Shorts Creek Formation are applied to Eocene volcanic and sedimentary units that only partly correlate with the Penticton Group (Figure 2). Further west at Hat Creek few comparisons can be made other than to say that the Coldwater Beds partly resemble the basal Tertiary sedimentary rocks in the Okanagan area. Recent studies suggest that some part of these basal successions may be Cretaceous (K. Shannon, pers. comm.).

To the southeast near Midway in the Boundary area the Eocene section is incomplete but strikingly similar to the type assemblage (Monger, 1968).

In northern Washington State near the Republic area the O'Brien Creek Formation and Klondike Mountain Formation, at the base and top of the Eocene section respectively, are correlated in part with the Kettle River Formation and Skaha Formation of the Penticton Group (Pearson and Obradovich, 1977). However, the dacite-rich Sanpoil volcanics which underlie part of the Republic graben are lithologically unlike the Marron Formation and represent a significant uncorrelated unit.

A check with Dr. T.E. Bolton in the special projects section of the Geological Survey of Canada on the pre-occupation of stratigraphic names has cleared the following list for formal use in south-central British Columbia:

Area	Name	Age
Hat Creek	Finney Lake Beds	(Eocene)
	Medicine Creek Formation	(Eocene)
	Hat Creek Formation	(Eocene)
Terrace Mountain	Naswhito Creek Formation	(Eocene)
	Bouleau Rhyolite	(Eocene)
	Attenborough Creek Formation	(Eocene)
	Shorts Creek Formation	(Eocene)
Penticton	Penticton Group	(Eocene)
Kelowna	Lambly Creek Basalt	(Pleistocene)

It is considered that name Hat Creek Coal Formation (Eocene) is sufficiently different from Hat Creek beds (Oligocene) of Wyoming and Hat Creek Basalt (Recent) of northern California.

Structural control of the various outliers of the Penticton Group relates to some east-west-trending synclines and to a pattern of north-south gravity faults and pronounced conjugate shears of northeast and northwest orientation. These folds and fractures are viewed as essential elements in a north-south directed stress scheme thought to be responsible for the many graben-like structures and overall basin and range-like fabric of the region.

The Hat Creek basin is a typical graben. In this example the central zone of the valley has been downdropped on a series of north-south tension faults trending subparallel to the direction of regional maximum stress, the walls of this graben having been offset by northwest and northeast-trending conjugate shears.

Vertical movement on the graben faults is commonly in the range of hundreds of metres. As viewed on Shorts Creek near Vernon, the Tertiary beds have been downfaulted in excess of 700 metres against older limestone and granite; at Hat Creek the vertical displacement is locally in excess of 1 000 metres. As a net result of this movement, commonly the base of these continental beds is displaced well below mean sea level elevation.

Lateral movement on the shear faults is not readily documented although it is suspected that the southern Okanagan and Boundary areas may have resided on a northeast-trending geothermal lineament similar to the present Reno, Nevada-Billings, Montana volcanic-geothermal belt (Grim, 1977). This could explain the marked similarity of the stratigraphy and petrography of the Eocene volcanic rocks of the Okanagan and Boundary areas. This might also partly account for the resetting to Eocene of radiometric dates of crystalline basement rocks in the region (Ross, 1974).

The hypothetical repositioning of Penticton Group rocks in the south Okanagan and Boundary areas to juxtaposition on a northeast-trending geothermal belt would require a southeast-northwest translation of about 80 kilometres. Extending the hypothetical geothermal belt and lithological correlations to the Highwood area of central Montana (similarities noted by Church, 1973, p. 75), a translation in the order of several hundred kilometres would be required. It is noted that lateral translations of this magnitude have been recorded in the Northern Cordillera (Norris, 1981, G.A.C. abstract, p. 29).

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THE RIDDLE CREEK URANIUM-THORIUM PROSPECT

(82E/12W)

By B.N. Church

The Riddle Creek uranium-thorium prospect, 15 kilometres west of Summerland, was discovered in 1977 and acquired the same year by British Newfoundland Exploration Ltd. Work on the property to date includes line-cutting, mapping, soil geochemistry, and several short drill holes.

The present report is based on recent geological and scintillometer surveys and a lithogeochemical study sponsored by the Ministry.

GEOLOGICAL SETTING

A large radioactive anomaly coincides with an Eocene volcanic centre near the headwaters of Riddle Creek (Figure 1). The principal radioactive rocks include trachytes and mafic phonolites of the Marron Formation and consanguineous igneous intrusions of the Coryell-type.

LOW-RADIOACTIVE COUNTRY ROCKS

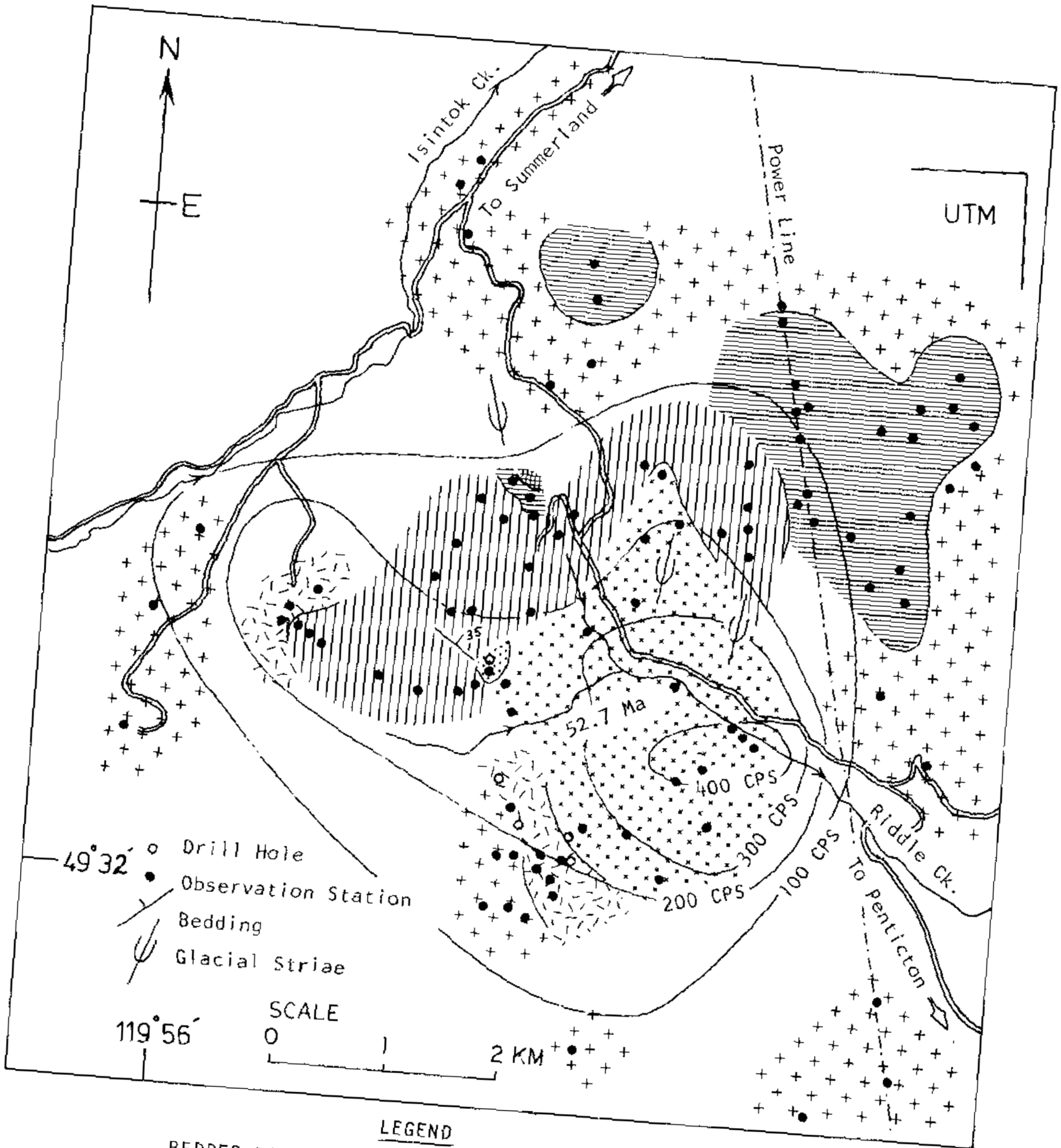
At the base of the Tertiary section and north of the zone of anomalous radioactivity, poorly exposed polymictic boulder conglomerate beds are tentatively assigned to the Springbrook Formation. These rocks appear to be unconformably underlain by granitic phases of the Okanagan Batholith (Jurassic-Cretaceous) and overlain by unnamed andesites. The andesites form a significant formation in the northeast part of the area where lava and breccia are 250 metres thick. Alkaline andesite dominates (No. 1, Table 1) and is characterized by scattered microphenocrysts of plagioclase and hornblende usually less than 1 millimetre in diameter.

Scintillometer readings on these rocks and other basal and basement units range from 40 to 80 counts per second.

RADIOACTIVE ROCKS

Rocks that show anomalous radioactivity are principally mafic phonolites and trachyte lavas and breccias (Nos. 2 and 4, Table 1). These overlie the andesites and onlap parts of the Okanagan Batholith. They are dated 52.7±1.8 Ma (K/Ar on biotite) and correlate with the Yellow Lake Member of the Marron Formation near Penticton.

Mafic phonolites, which form the base of the Yellow Lake Member, are exposed on the ridges north and northeast of Riddle Creek where interlayered lava flows and lahar deposits attain a thickness of about 75 metres. Petrographic examination shows conspicuous rhomb-shaped anorthoclase phenocrysts to 2 centimetres in length and smaller subhedral



LEGEND

BEDDED ROCKS

MARRON FORMATION (Eocene)

- Trachyte lava and breccia
- Ash flow and conglomerate beds
- Mafic phonolite lava, breccia
- Andesite lava and breccia

SPRINGBROOK FORMATION ?

- Polymictic conglomerate

IGNEOUS INTRUSIONS

CORYELL INTRUSIONS (Eocene)

- Syenite and monzonite

BASEMENT ROCKS

- Mostly granitiod bodies

Figure 1. Geology of the Riddle Creek radioactive volcanic centre.

Table of Chemical Analyses

	1	2	3	4	5	6
Oxides recalculated to 100						
SiO_2	57.89	57.37	63.87	61.39	57.58	66.51
TiO_2	0.96	0.93	0.64	0.84	0.87	0.49
Al_2O_3	16.38	19.16	17.92	17.05	16.21	17.01
Fe_2O_3	4.43	3.01	3.14	3.43	3.83	2.58
FeO	1.03	1.77	0.73	1.07	2.48	0.24
MnO	0.08	0.09	0.11	0.09	0.12	0.14
MgO	4.33	2.40	1.10	1.99	3.73	0.28
CaO	6.90	4.05	0.64	3.34	5.22	0.84
Na_2O	4.12	5.83	4.71	5.47	4.71	6.05
K_2O	3.88	5.39	7.14	5.33	5.25	5.86
	100.00	100.00	100.00	100.00	100.00	100.00
Oxides and elements as determined						
$+H_2O$	0.56	2.02	0.90	0.20	1.14	0.70
$-H_2O$	0.58	0.35	0.75	0.18	0.41	0.70
CO_2	0.25	0.25	<0.11	0.25	0.25	0.25
S	0.02	<0.01	<0.005	0.01	0.02	0.01
P_2O_5	0.82	0.46	0.25	0.32	0.68	<0.15
BaO	0.21	0.30	0.10	0.20	0.23	0.013
SrO	0.30	0.42	0.07	0.21	0.31	0.02
Molecular Norm						
Quartz	2.0	-	5.7	1.3	-	6.6
Orthoclase	22.7	31.1	41.8	31.0	30.6	34.0
Albite	36.7	38.8	41.8	48.3	41.8	53.0
Nepheline	-	7.3	-	-	-	-
Anorthite	14.6	10.0	3.1	6.1	7.5	1.9
Wollastonite	7.7	3.9	-	4.1	7.2	0.9
Enstatite	11.8	-	3.0	5.4	0.6	0.8
Ferrosilite	-	-	-	-	-	-
Forsterite	-	4.9	-	-	7.2	-
Fayalite	-	-	-	-	-	-
Ilmenite	1.3	1.3	0.9	1.2	1.2	0.7
Magnetite	0.4	2.1	0.4	0.7	3.9	-
Hematite	2.8	0.6	1.9	1.9	-	2.1
Corundum	-	-	1.4	-	-	-

Key to Analyses

1. Alkaline andesite, basal volcanic assemblage
2. Mafic phonolite lava (rhomb porphyry), Yellow Lake Member, Marron Formation
3. Trachyte ash flow, Yellow Lake Member, Marron Formation (Skaha Creek area)
4. Trachyte lava (rectangular porphyry), Yellow Lake Member, Marron Formation
5. Coryell-type monzodiorite intrusion
6. Trachyte dyke, on north fork of Riddle Creek

and euhedral phenocrysts of green diopsidic augite, biotite, apatite, and magnetite set in a devitrified glassy or fine-grained feldspathic matrix. Scintillometer readings are in the range 140 to 180 counts per second.

The most radioactive rocks are thick trachyte lava flows that comprise the upper part of the Yellow Lake Member in this area. This unit is estimated to be between 150 to 200 metres in thickness. It underlies the ridges and slopes immediately northeast and south of the confluence of the forks of Riddle Creek. The trachyte contains large rectangular or platy mixed feldspar phenocrysts of anorthoclase, sanidine, and plagioclase; otherwise it is petrographically similar to the mafic phonolite (rhomb porphyry) suite. Scintillometer measurements are in the range 300 to 420 counts per second.

Coryell plutonic rocks crop out on the hillsides north and south of the westerly source of Riddle Creek. These are high level miarolitic syenomonzonite and monzodiorite phases (No. 5, Table 1) that are mineralogically akin, and feeders to, the overlying Yellow Lake volcanic pile into which the Coryell pluton has evidently stoped. The rock is composed of about 80 per cent alkali feldspar, mostly orthoclase with rhomb-shaped anorthoclase cores, and 20 per cent smaller phenocrysts and interstitial grains of amphibole and pyroxene with poikilitic inclusions of biotite, magnetite, apatite, and sphene. The average scintillometer reading is 250 counts per second.

SCINTILLOMETER SURVEY

In the course of routine geological investigation of the Riddle Creek area, rock outcrops were tested in a manner outlined by McDermott (1977) using a portable gamma ray scintillometer (GeoMetrics/Exploranium Model GRS-101). Quantitative control was obtained for uranium from neutron activation of 24 samples, courtesy of D.R. Boyle of the Geological Survey of Canada, and for thorium from spectrometer analysis performed by the Analytical Division of the Ministry. The relationship between counts per second and uranium/thorium composition can be reduced to two equations:

$$U = \text{c.p.s.}\ (0.072) - 0.538$$
$$Th = \text{c.p.s.}\ (0.231) + 6.913$$

Accordingly, the following averages are calculated for uranium and thorium levels for the main rock types, based on c.p.s. values at 93 stations:

Rock Unit	U ppm	Th ppm
Trachyte (Yellow Lake Member)	27	94
Mafic phonolite (Yellow Lake Member)	11	45
Coryell Intrusions	18	66
Andesite Unit (unnamed)	5	23
Springbrock Formation	4	22
Okanagan Batholith	4	22

Scintillometer results (Figure 1) were contoured using the method outlined in Geological Fieldwork, 1980, Paper 1981-1, page 27. A bull's-eye arrangement of contours lies immediately south of the main course of

Riddle Creek in an area underlain by trachyte lavas and a volcanic centre. Thoroughly altered rocks are exposed below the trachyte on Riddle Creek and more distally on the slopes to the west. Pervasive hydrothermal alteration of the trachyte and vent (?) breccia has produced cream and white kaolinized rocks of variable radioactive response.

THE PROSPECT

A diamond-drill program consisting of approximately 270 metres in seven holes was completed in 1978. Six holes were sited south of Riddle Creek near the west boundary of the trachyte and one hole sited north of the creek. The purpose of the drilling was to test bedrock near geochemical soil anomalies and projected structural traps for uranium-bearing solutions.

North of Riddle Creek, drill hole No. 7 was directed at a northeast-dipping section of strata +30 metres thick of coarse clastic sedimentary rocks that is overlain by partly welded ash flow breccia at the base of the trachyte unit. (This stratigraphic-structural target is strikingly similar to the occurrence of radioactive trachyte ash and breccia in clastic sedimentary beds in the vicinity of Farleigh Lake and Skaha Creek, 15 to 20 kilometres to the southeast (No. 3, Table 1 - unit 1b on Preliminary Map 35). Although no significant uranium was found, the drilling proved good porosity of the beds below the ash flow and thus potential for further exploration.

Most of the drilling in the area of soil anomalies south of Riddle Creek intersected Coryell intrusive rocks. However, hole No. 1 near the west boundary of the trachyte cut altered rocks showing vestiges of conglomerate and breccia similar to the rocks at site No. 7.

A few prominent radioactive high spots were not tested by the drilling. The most important of these is an easterly trending felsic dyke about 4 metres wide exposed 450 metres north of the confluence of the forks of Riddle Creek. This is thought to be a feeder to the trachyte lavas of the Marron Formation (No. 6, Table 1). Scintillometer readings here averaging 1500 c.p.s. correspond to rock analyses showing 121 ppm U and 342 ppm Th. Radiographs of slabbed samples show that radioactive elements are concentrated on manganese pitch and dendritic growths on numerous small cracks. A similar dyke with scintillometer readings in the range of 600 to 900 c.p.s. was found at the contact between Coryell plutonic rocks and mafic phonolite lavas in the northwest part of the map-area between Isintok Creek and the western headwaters of Riddle Creek.

DISCUSSION

The Riddle Creek Tertiary outlier lies near the western extremity of a belt of Eocene alkaline volcanic rocks that are characterized by anomalous uranium and thorium contents (Church and Johnson, 1978). It is suggested that these rocks are the source of the relatively high uranium levels in streams of the Okanagan-Boundary area found by the 1976 URP survey. The possibilities of secondary uranium deposition and enrichment in this setting are numerous, including dykes, permeable sedimentary rocks and alteration zones associated with volcanic vents (Culbert and Leighton, 1978).

High radioactive response near the headwaters of Riddle Creek coincides with what appears to be a trachyte volcanic centre (Figure 1). In 1978, a program of short diamond-drill holes was conducted peripheral to this centre and yielded low uranium values. For future study the volcanic centre and associated ash flow deposits offer the best target.

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THE USE OF PERSONAL COMPUTERS AND OPEN FILE GEOCHEMICAL DATA TO FIND NEW EXPLORATION TARGETS

By George G. Addie

ABSTRACT

In Geological Fieldwork, 1980, Paper 1981-1, a program was presented for calculating moving averages using a Wang 2200A computer (Church, et al., 1981). The same program slightly modified has been used with a TRS-80 Level II computer.

PROGRAM MODIFICATION

The individual values are multiplied by a factor of 1/Log R where 'R' is the radius from the sample value to the centre of the computer window. This has the effect of reducing the anomaly size.

NELSON-YMIR-SALMO - Ag

An interesting anomaly is found to the south of Salmo and mostly west of the Salmo River, an area relatively unexplored. The geology indicates Nelson granite in contact with sediments. Magnetic anomalies are associated with this granite. This is an excellent area for skarn and vein deposits.

GRAND FORKS - Cu

This approach certainly would have found 'Phoenix Copper' if used prior to discovery.

GRAND FORKS - Mo

A very subtle molybdenite anomaly exists to the east of Phoenix Copper. Is a porphyry environment present?

GRAND FORKS - Ag

A low level silver anomaly exists to the south of Phoenix Copper. Is this the centre of a porphyry model?

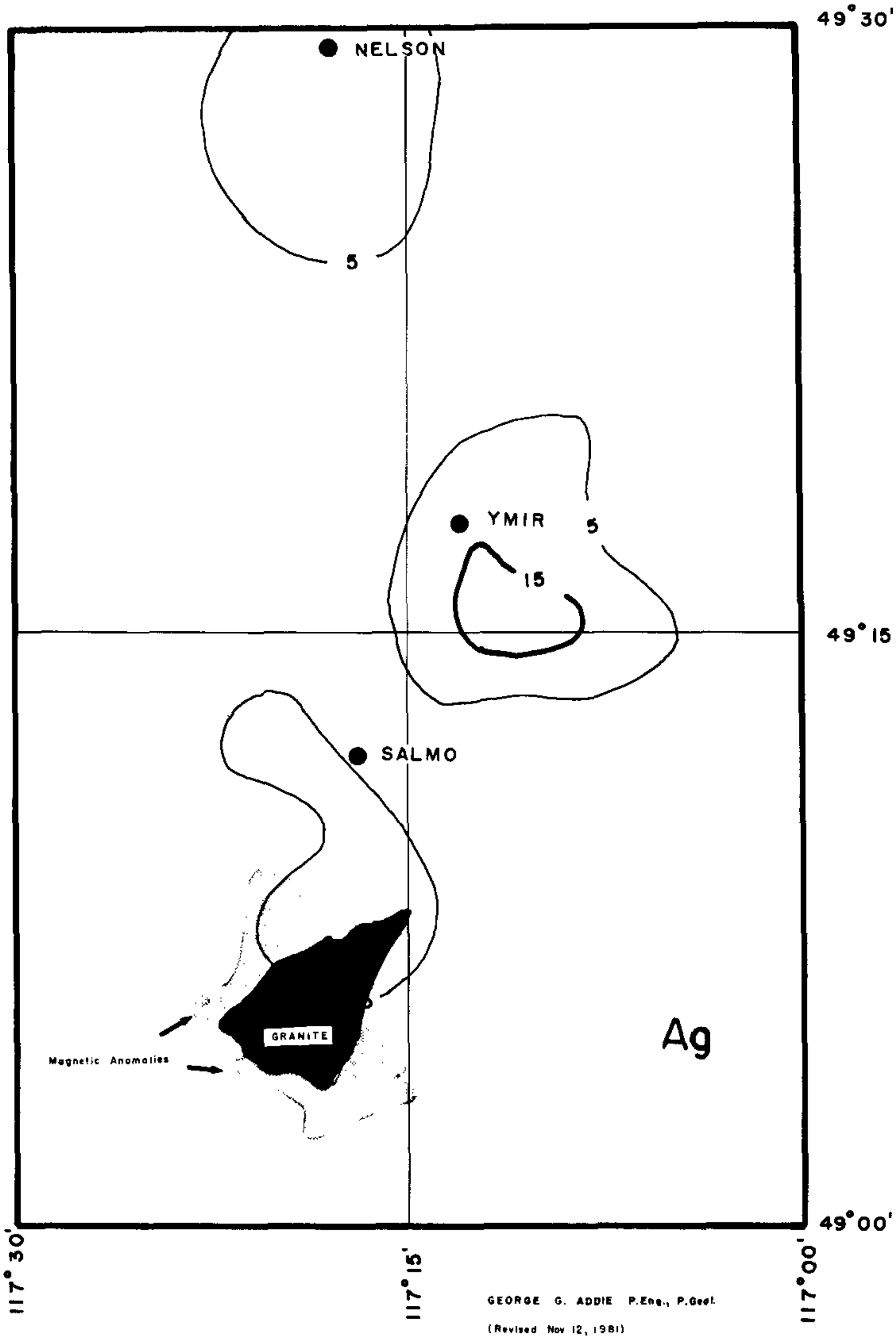

Figure 1. Moving average contour map of silver values in stream silts from Nelson-Ymir-Salmo mining camp.

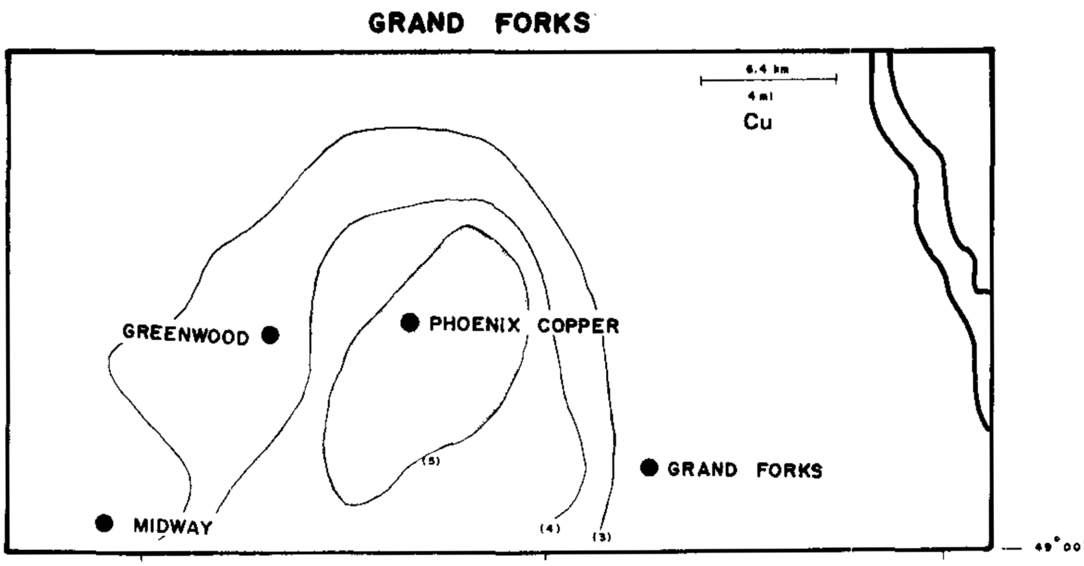

Figure 2. Contour plot using moving average method of copper in stream silts from Grand Forks area.

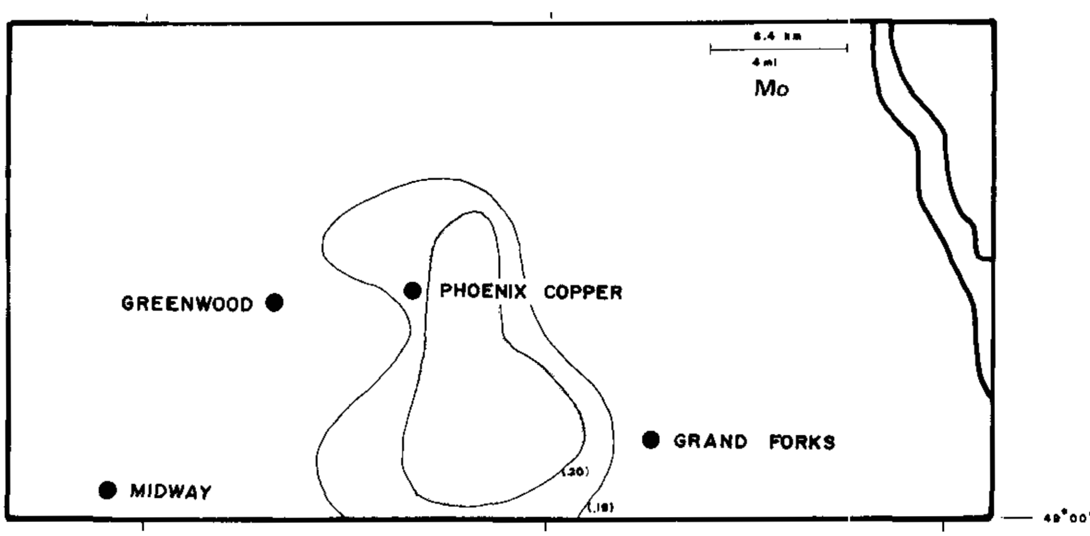

Figure 3. Contour plot of molybdenum in stream silts in Grand Forks area using moving average method.

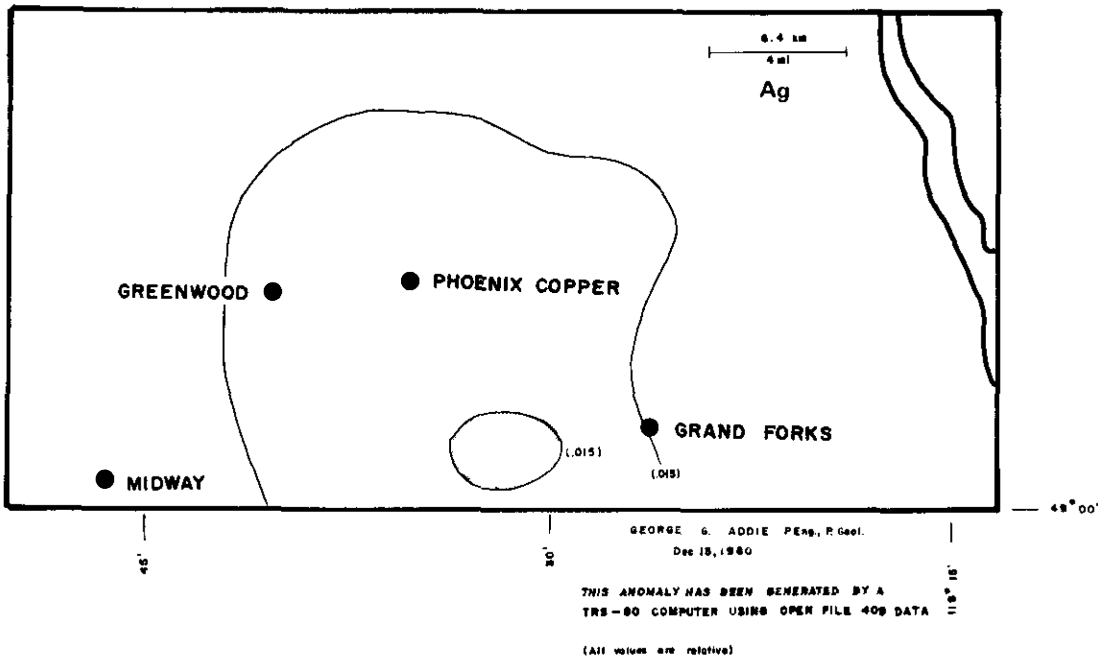

Figure 4. Contour plot of gold in stream silts in Grand Forks area using moving average method.

CONCLUSION

The use of the computer can identify low level anomalies that are not obvious from data plots only. It is on this basis that new target areas can be found in old mining camps.

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Regional Stream Sediment and Water Geochemical Reconnaissance Data, British Columbia, 1976, Geol. Surv., Canada, Open File 409.

TABLE 1. TRS-80 Level II Computer Program

GRAND FORKS
FEB 23, 1981 BY GEORGE G. ADDIE, P. ENG., P. GEOL.

```
  5 LPRINT "GRAND FORKS"
  6 LPRINT "FEB 23, 1981 BY GEORGE G. ADDIE, P.ENG., P.GEOL."
 1Ø LPRINTCHR*(29)" "
 2Ø CLS
 4Ø T=Ø:S=Ø:P=Ø:C=Ø:E=Ø:F=Ø:H=Ø:J=Ø:L=Ø:M=Ø:N=Ø:
    D=Ø:X=Ø:W=Ø:Y=Ø
 5Ø INPUT "COORDINATES OF CENTER OF FIRST CIRCLE";A,B
 6Ø INPUT "EASTING AND NORTHING INTERVALS";G,K
 7Ø Z=A:Q=B
 8Ø LPRINT TAB(Ø)"E";TAB(8)"N";
 9Ø LPRINT TAB(15)"ZN";TAB(25)"CU";TAB(35)"PB";
1ØØ LPRINT TAB(45)"AG";TAB(55)"U";TAB(6Ø)"MO"
11Ø FOR I=ITO 8:READ A(I):NEXT I
12Ø IF A(2)=-1 THEN 18Ø
13Ø IF SQR((A(1)-Z)[2+((A(2)-Q)]2))>1ØØ THEN 11Ø
131 R=SQR((A(1)-Z)[2+((A(2)-Q)]2))
132 IF R<=1 THEN R=1.1
135 U=1/LOG(R)
14Ø S=S+1:T=T+LOG(A(3)*U)
15Ø C=C+LOG(A(4)*U)
16Ø D=D+LOG(A(5)*U)
17Ø E=E+LOG(A(6)*U)
171 L=L+LOG(A(7)*U)
172 W=W+LOG(A(8)*U)
175 GOTO 11Ø
18Ø IF S=Ø THEN 28Ø
19Ø Y=EXP(T/S)
2ØØ F=EXP(C/S)
21Ø H=EXP(D/S)
22Ø J=EXP(E/S)
23Ø M=EXP(L/S)
255 X=EXP(W/S)
26Ø LPRINT TAB(Ø)Z;TAB(6)Q;TAB(11)Y;TAB(19)F;TAB(27)H;
27Ø LPRINT TAB(35)J;TAB(43)X;TAB(55)M
28Ø Z=Z-5Ø:S=Ø:T=Ø:C=Ø:D=Ø:E=Ø:L=Ø:W=Ø:Y=Ø:F=Ø:H=Ø:
    J=Ø:M=Ø:X=Ø
29Ø IF (A-Z)>G THEN 31Ø
3ØØ RESTORE:GOTO 11Ø
31Ø L=Ø:W=Ø:S=Ø:T=Ø:C=Ø:D=Ø:E=Ø:L=Ø:W=Ø:Q=Q-5Ø:P=P+1:
    Y=Ø:F=Ø:H=Ø:J=Ø:M=Ø:X=Ø
32Ø IF INT(P/2)=P/2 THEN 34Ø
33Ø Z=(Z+G+5Ø):GOTO 35Ø
34Ø Z=A
35Ø IF (B-Q)<K THEN 3ØØ
36Ø LPRINT "THE END":END
5ØØ DATA 376Ø,452Ø,35,14,5,.1,1,1Ø.7
```

THE NELSON-YMIR-SALMO MINING CAMP
A NEW LOOK AT ZONING BASED ON PRODUCTION RECORDS

By George G. Addie

INTRODUCTION

When logarithmetic values of mineral production were plotted it was found that various mines formed distinct groupings of 'populations.' Individual mines from each group can then be studied for criteria which would lead to discovery of similar deposits elsewhere in the area.

In this study log Au is plotted against log Ag for production from camps: (1) Sheep Creek, (2) Ymir, (3) Keystone Mountain, and (4) Hall Forty-nine Creek.

The mines studied are all past producers and occur in the Nelson-Ymir-Salmo area. 'Location of Mines in the Nelson-Ymir-Salmo Area' includes gold mines as well as the zinc-lead deposits of the 'Kootenay Arc.'

The mines of the Sheep Creek Camp (Figure 1) seem to fall into three natural groups based on the production figures. The same 'phases' have been used for Ymir (Figure 2), Keystone Mountain (Figure 3), and finally Hall and Forty-nine Creek (Figure 4).

Mines related to the three phases of mineralization found from the above graphs are located on the individual maps designated 'Phase 1,' 'Phase 2,' and 'Phase 3' (Figures 5, 6, and 7).

TARGET AREAS

It is proposed that mines in the same 'phase' are somehow related. When they are close together a dashed line has been used to show their possible relationships. It is on these theoretical lines or projections that I would recommend prospecting.

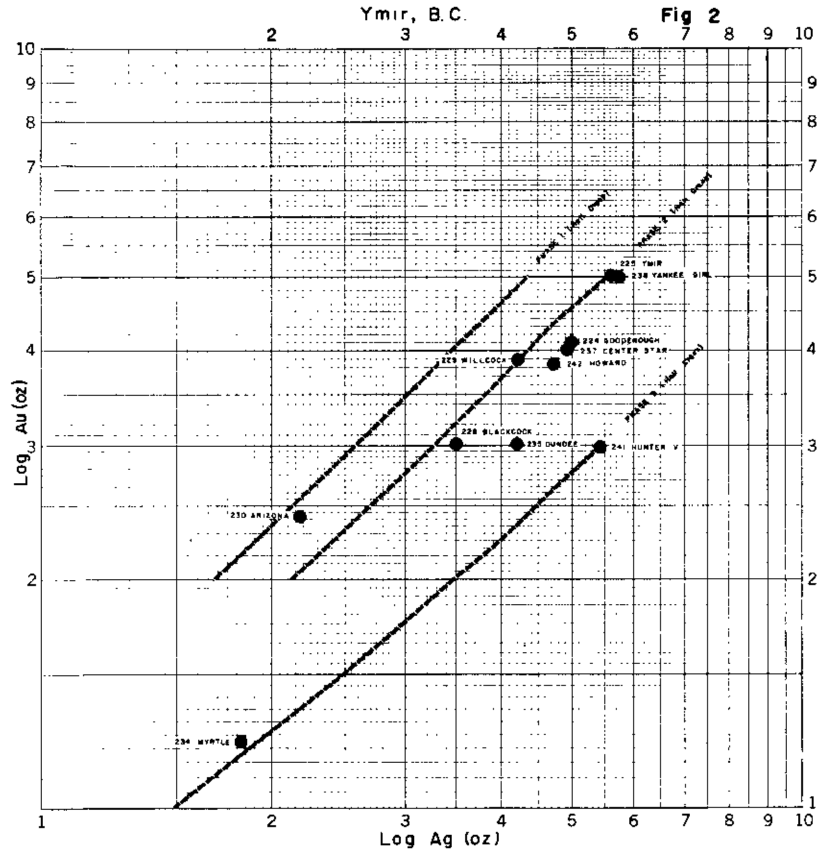


Figure 2. Plot of the log Au against log Ag for the Ymir mining camp.

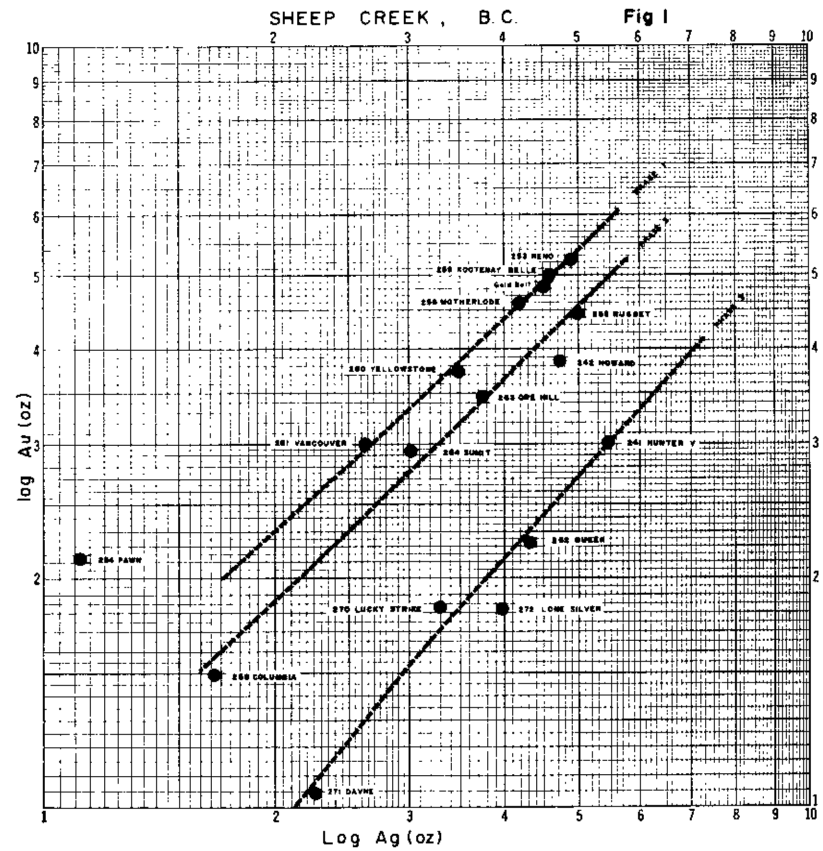


Figure 1. Plot of log Au against log Ag for mines of the Sheep Creek camp.

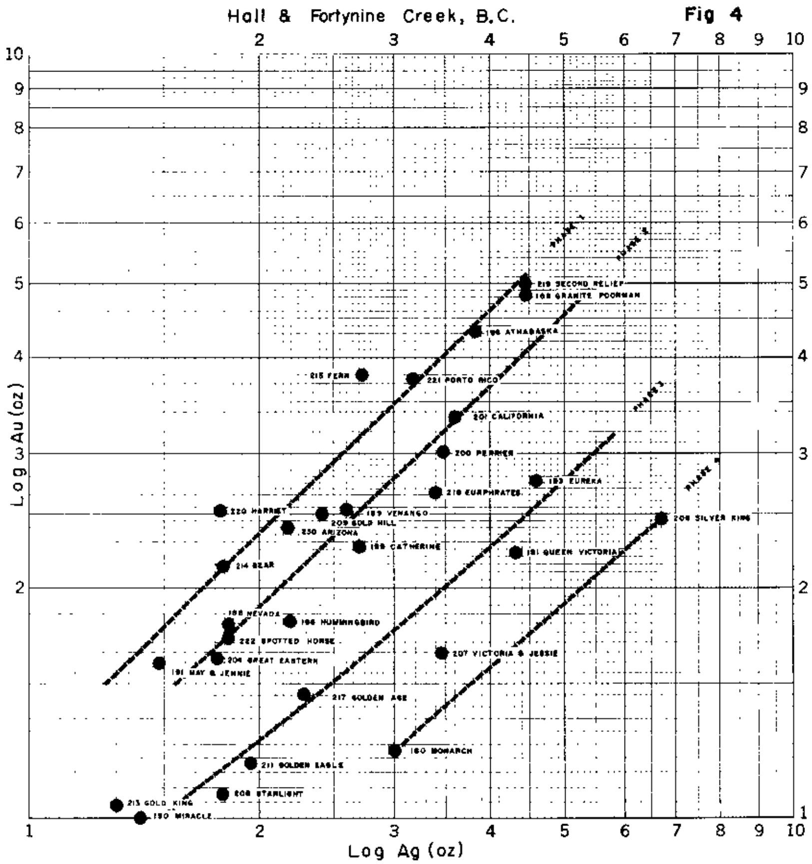


Figure 4. Plot of log Au against log Ag for mines in the Hall and Forty-nine Mile Creek areas.

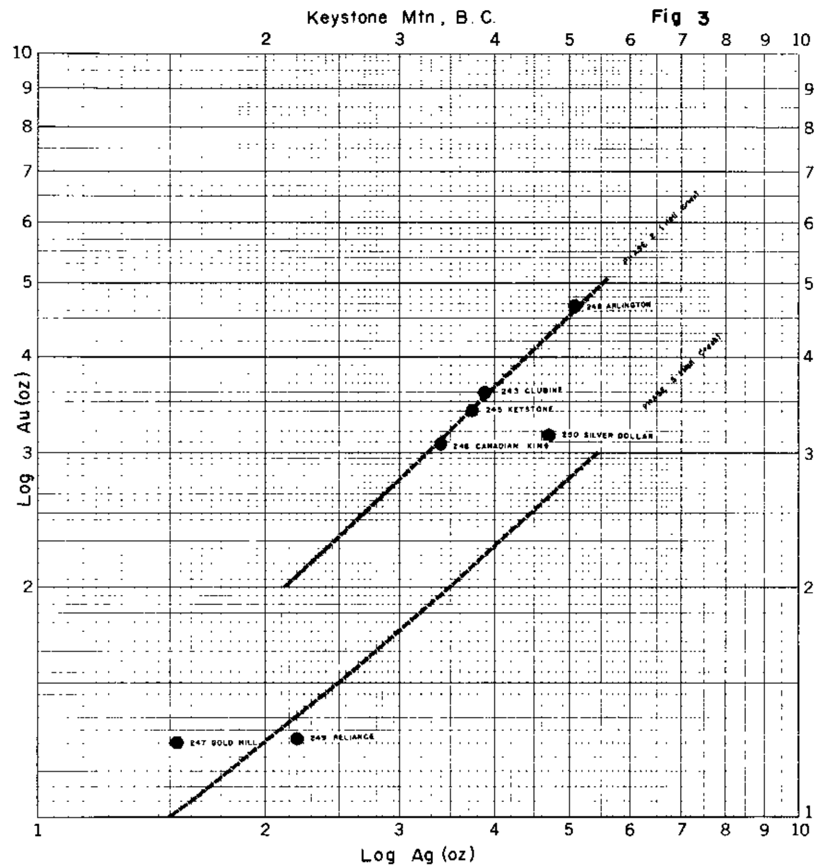


Figure 3. Plot of log Au against log Ag for mines in the Keystone Mountain area.

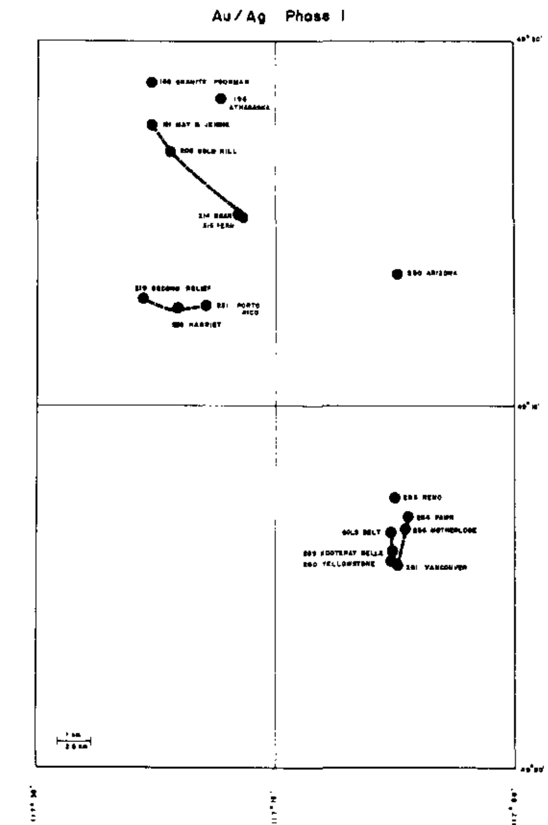


Figure 5. Locatin of phase 1 deposits In Nelson-Ymir-Salmo mining camp.

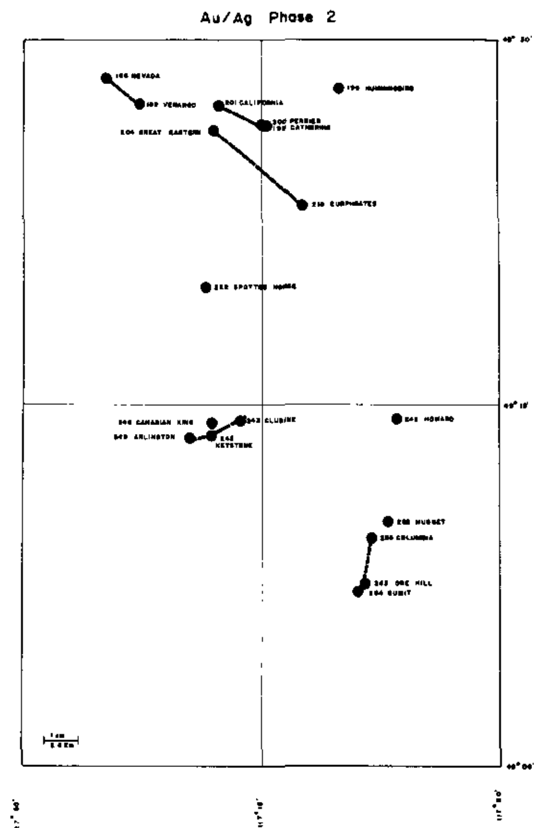


Figure 6. Location of phase 2 deposits In Nelson-Ymir-Salmo mining camp.

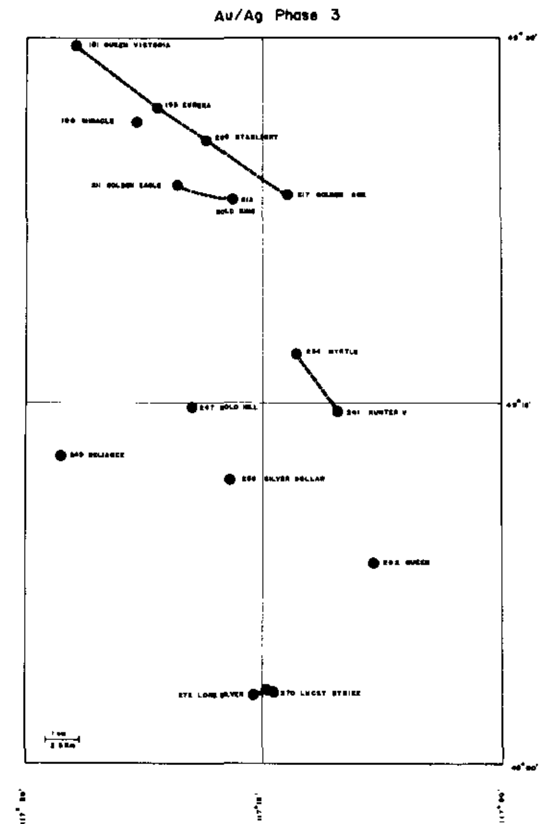
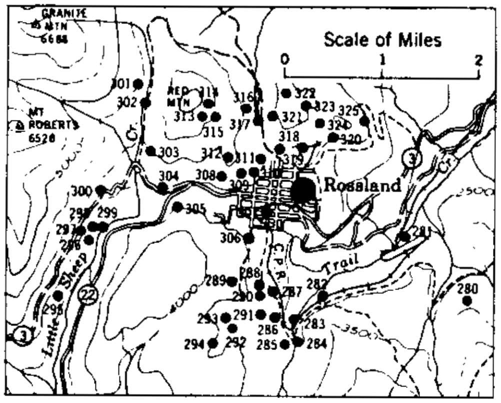
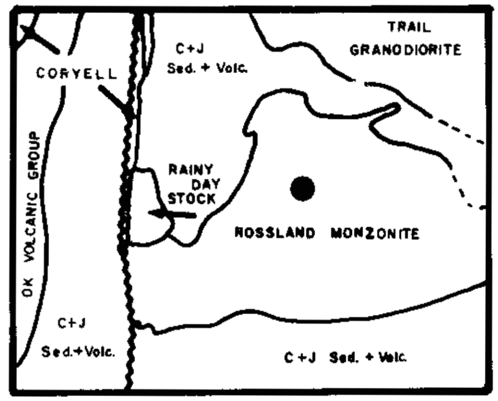


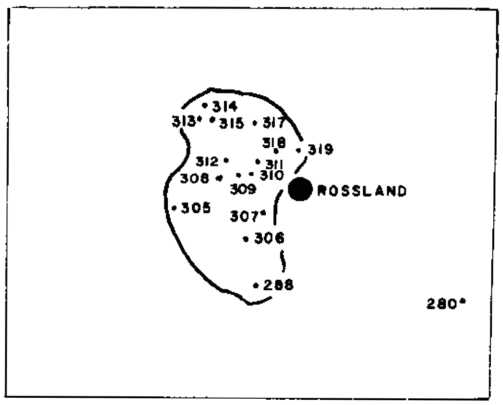
Figure 7. Location of phase 3 deposits In Nelson-Ymir-Salmo mining camp.



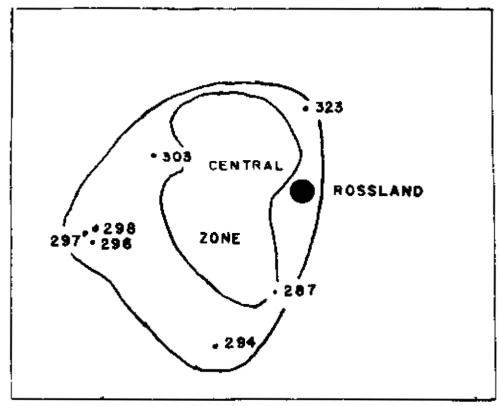
INDEX from Map 1091A Memoir 308 by H.W Little



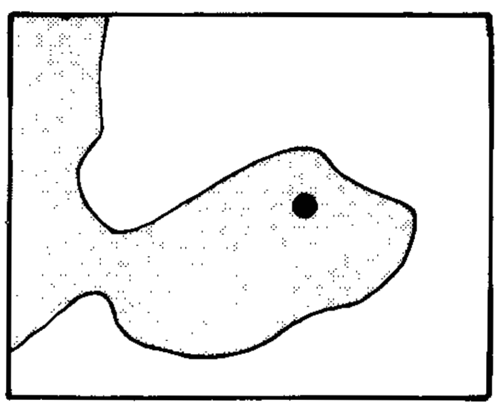
GEOLOGY after FYLES, 1973



PHASE I Mines – Central Zone



PHASE 2 & 3 Mines



Aeromagnetic Map 8483 G at 58,000 gammas

Figure 1. Index of location of former mines of the Rossland mining camp; first phase - location of mines on Phase 1 line from graph 2; second and third phase - location of these phases from graph 2; geology of the Rossland mining camp after Fyles, et al., 1973; aeromagentic map 84836 of the Rossland mining camp at 58,000 gammas.

A NEW LOOK AT THE ROSSLAND AND BOUNDARY MINING CAMPS USING LOG Cu (lb.)/Log (Au + Ag)(oz.) FROM PRODUCTION DATA

By George G. Addie

INTRODUCTION

Up to 1967 gold production from the Rossland Camp ranked second and that from the Boundary Camp, fourth, of all the mining camps in British Columbia (Grove, 1971, p. 94). In the Rossland Mining Camp (this paper) three 'phases' of mineralization are indicated while the Boundary Camp has one (Addie 1975). At Rossland the distribution of the mines by 'phase' indicated a concentric distribution more or less centred on the Rossland monzonite. Similar zoning was identified by Thorpe (1967). He points out (p. 11) 'the Rossland District, then produced a very rare type of gold ore.' This paper proposes that the Boundary Camp has similar ore.

The Rossland monzonite also has a coincident magnetic anomaly (Figure 1) which seems to be connected to a large magnetic anomaly to the west that is associated with the contact zone of the Coryell Batholith. The Rossland monzonite has also been intruded by the Coryell, which may contribute to the magnetic anomaly. The Rossland monzonite may have acted as a buttress against which the Carboniferous and Jurassic volcanic and sedimentary rocks were broken to give the vein structures. Thrusting in the area may be related to emplacement of the Trail granodiorite (49.5 - 50.5±1.5 Ma) and/or the Rainy Day Stock (48.7±1.5 Ma). Fyles (1973) suggests that the mineralization is related to one of the plutonic masses, probably the Trail Batholith. All authors (Brock, 1906; Drysdale, 1923; Little, 1963; Fyles, 1973) agree that the mineralization is Tertiary. The only question is the source of the mineralization. This author proposes that the Coryell intrusions should be examined more closely. It is clear from the literature that Coryell pulaskite dykes were emplaced both before, and after, the mineralization. This is important because we now have a direct link to the Coryell Batholith, at least for timing, as a potential cause, if not the source, of the economic mineralization. The presence of weak molybdenite mineralizaation suggests the Coryell as a possible source of the Rossland molybdenite deposits.

In the Boundary Camp, the Phoenix Copper ore zone is cut off by a pulaskite dyke (Coryell). The dyke intruded along a fault plane which has had repeated movement, before and after some of the mineralization (Addie, 1964). Recent geochemical data from Geological Survey of Canada Open File 409 indicates a molybdenite anomaly adjacent to the Phoenix Copper area (Addie, 1981). Tertiary diorite (McNaughton, 1936) is just to the north of the Phoenix Copper pit and contains a showing of mineralization similar to the mine, that is, the precious metal/copper

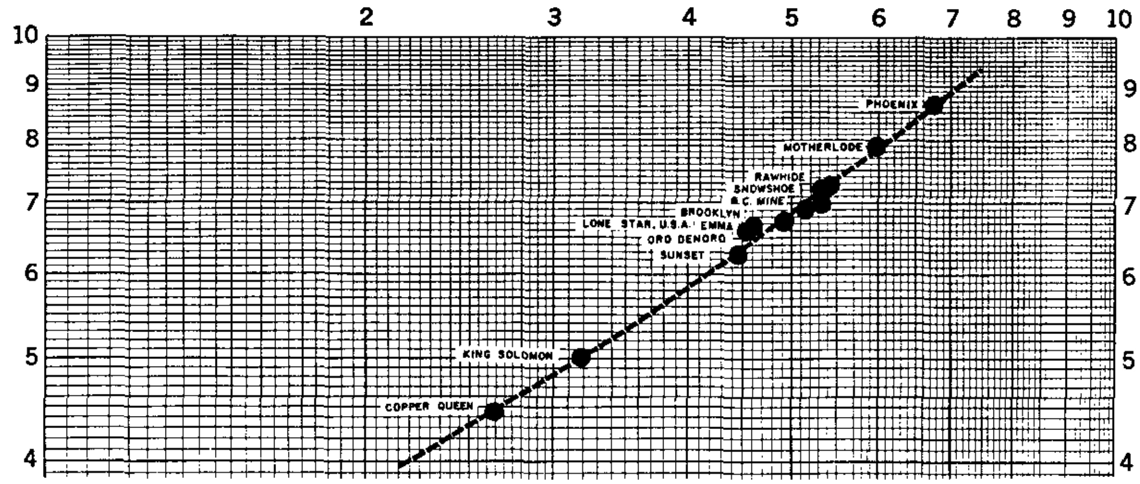


Figure 2. Boundary district, log Cu (lb.) versus Log (Au + Ag) (oz.).

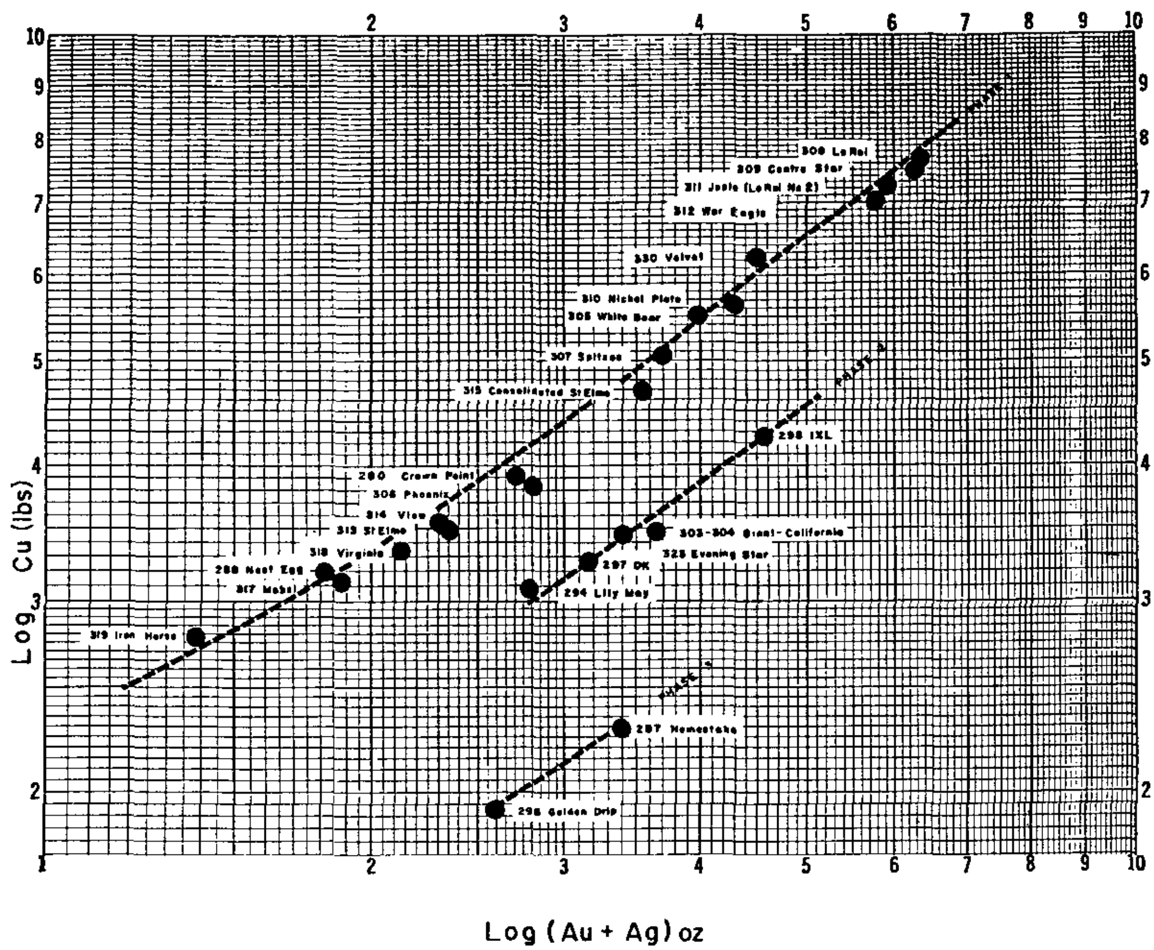


Figure 3. Rossland, Log Cu (lb.) versus Log (Au + Ag) (oz.).

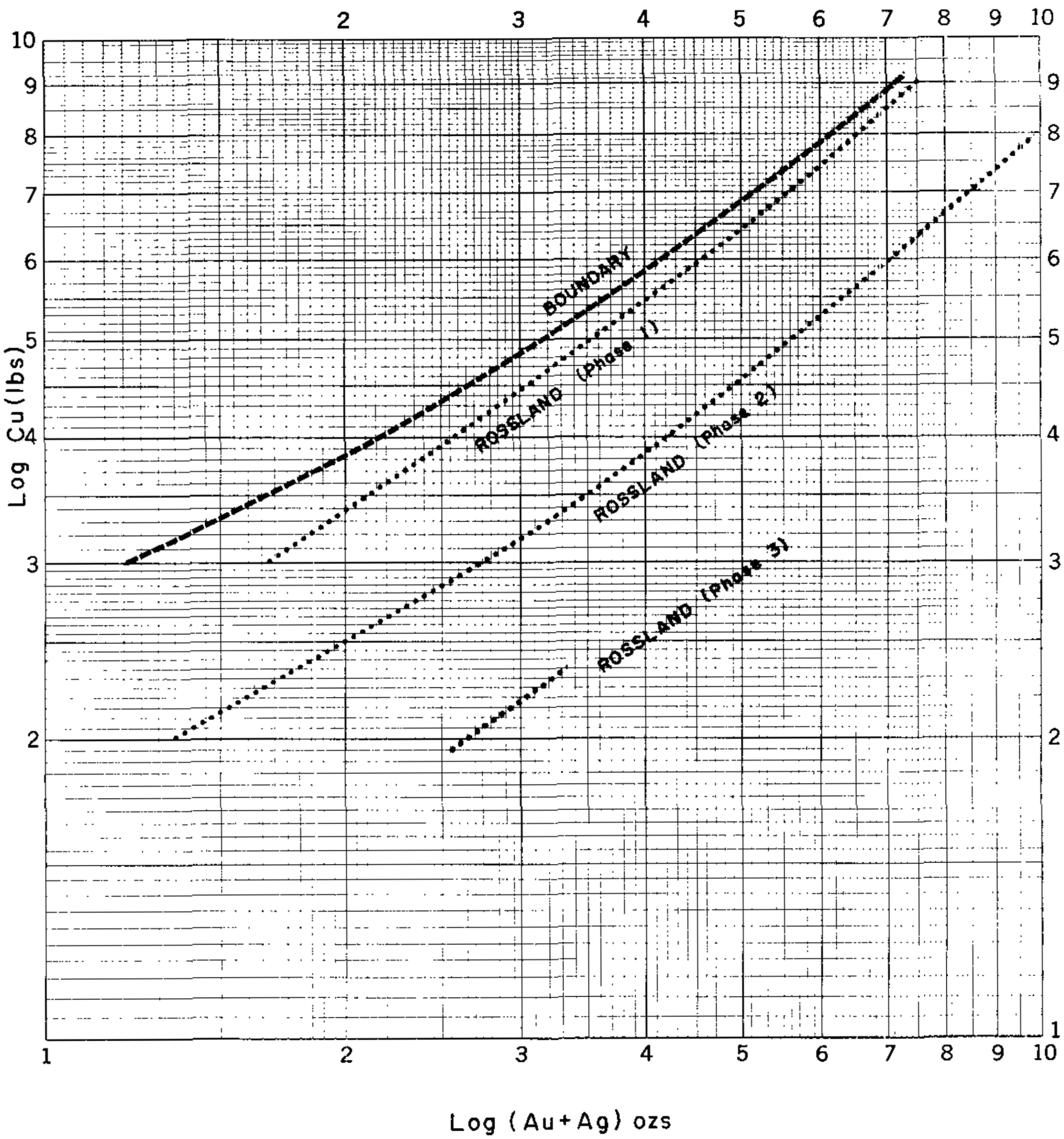


Figure 4. Comparison of Boundary and Rossland, log Cu (lb.) versus log (Au + Ag) (oz.).

ratios are identical (Addie, 1964). These Teritary intrusions (see also Church, 1970) therefore deserve a closer scrutiny for other skarn deposits, porphyry deposits, or another mining camp similar to Rossland.

SOURCE OF DATA

Production data are from 'Index 3 to Publications of the Department of Mines.' Note that 20 of the mines shown on Figure 1 are not used in our study because no copper production was reported.

CONCLUSION

The copper/gold plus silver mineralization at Rossland seems to be identical to that at the Boundary Camp except that more phases are involved. Geologically and from argon age dating it is clear that the mineralization at Rossland is Tertiary (Fyles, 1973). This paper proposes that the Boundary area be examined in this light and that the Coryell intrusions, especially the edges, be examined for new mining camps. As at Rossland, these may be identified from the aeromagnetic maps.

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Thorpe, R.I. and Little, H.W. (1973): The Age of Sulfide Mineralization at Rossland, British Columbia, Econ. Geol., Vol. 68, pp. 1337-1339.

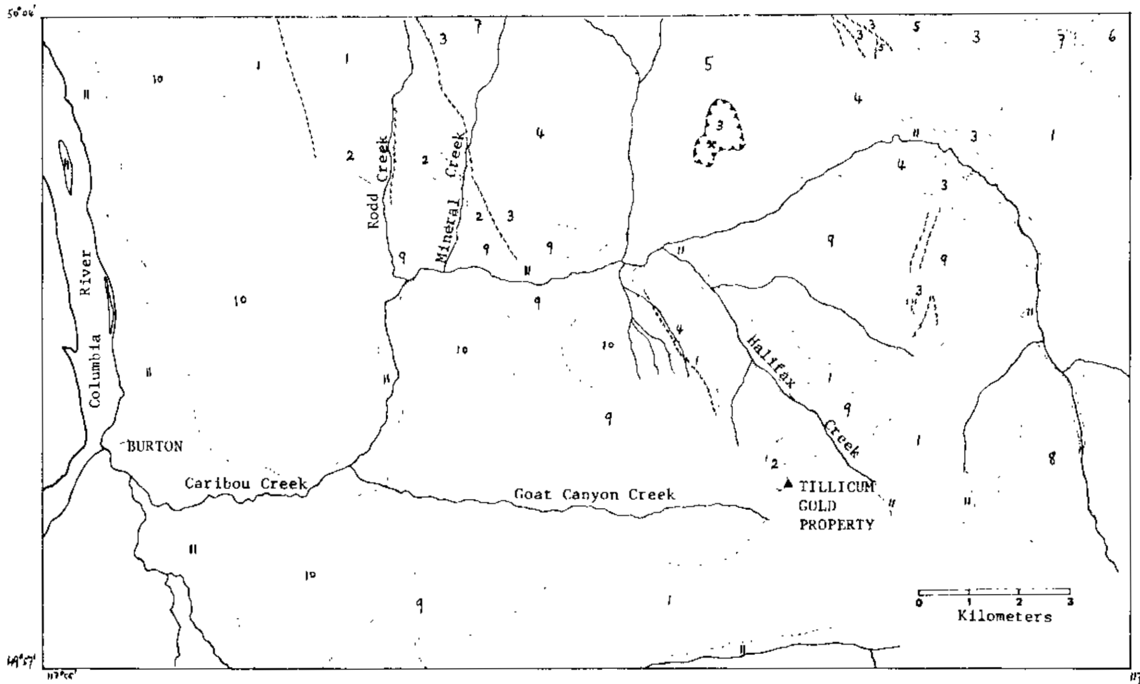

Figure 1. Geological setting of the Tillicum gold property (▲); after Hyndman (1968, Geol. Surv., Canada, Map 1234A).

LEGEND

Quaternary

11 Glacial, lacustrine and fluviatile gravel, sand, silt and clay

Cretaceous and/or Jurassic

10 Lower Caribou Creek stock: quartz monzonite, granodiorite, quartz diorite and granite

8 | 9 9. Goat Canyon-Halifax Creek stock: quartz monzonite, minor quartz diorite and granodiorite
8. Snowslide Creek stock: quartz monzonite, quartz diorite and granodiorite

7 Ruby Range stock: quartz diorite, diorite, quartz monzonite, monzonite and syenodiorite

6 East Caribou stock: quartz monzonite and quartz diorite

Jurassic

Rossland Group

5 Andesite and basalt flows and tuffs

Lower Jurassic (?) and Triassic

Slocan Group

4 Andesite to dacite, tuffs and flows

3 Undivided argillite, shale to siltstone, tuff and pelitic to silty phyllite and slate

Triassic

Kaslo Group

2 Amphibole-metavolcanic rocks

(?) Pennsylvanian to Triassic

Milford (?) Group

1 Pelitic schist and calc-silicate metasedimentary rocks

Thrust fault

Fault

Geological contact

TILLICUM MOUNTAIN GOLD PROSPECT

(82F/13)

By Y.T. John Kwong and George G. Addie

INTRODUCTION

The Tillicum Mountain gold property with latitude 49 degrees 59.2 minutes north and longtitude 117 degrees 42.7 minutes west is located 13 kilometres east of Burton in the Arrow Lakes region of the Kootenay District, south-central British Columbia. The general geologic setting of the property is shown on Figure 1. It is being developed under the joint venture between Welcome North Mines Ltd. and Esperanza Explorations Ltd. To the end of August 1981, trenching has revealed several high-grade gold occurrences within the property including the 16-metre-long Money pit, from which a 21.3-ton bulk sample yielded 3.887 ounces per ton gold, 2.30 ounces per ton silver, and 1.9 per cent zinc. Moreover, according to a recent report in the George Cross News Letter (No. 167, September 1, 1981), geochemical surveys have outlined two northwest-trending belts with anomalous gold values in soils varying from 100 to 3250 ppb over a strike length of 500 metres (see Figure 2).

GEOLOGY

Figure 2 presents a simplified geological map of the Tillicum gold property. In detail, the contact between the rocks of the Milford Group and the Kaslo Group is apparently marked by a band of argillite that is generally less than 5 metres in width. The argillite band, considered to be the youngest member of the Milford Group exposed in the area, consists of layers of different lithology. These include dark grey, relatively fissile argillite, whitish, highly siliceous cherty rock, and interbeds or rather massive, tuffaceous-looking rocks with streaks of sulphides. For clarity, these rocks are not shown on Figure 2. Similarly, small patches and dykes of garnet-bearing pegmatite, presumably derived from partial melting during the peak of regional metamorphism, and aplite and lamprophyre dykes are omitted from the figure.

With the exception of those occurring in and adjacent to the Money pit, rocks of the Milford Group near the contact zone with Kaslo Group rocks are silica-rich and resemble altered rhyolite in places. However, binocular microscope examination of collected specimens and thin sections indicate that these rocks are fine-grained muscovite-garnet schists with comparatively coarser grained quartzite lenses and interbeds. Relative proportions of quartz, muscovite, chlorite, K-feldspar, and plagioclase vary. Garnet is generally less than 5 per cent by volume. Opaque minerals rarely exceed 2 per cent. Schistosity in these rocks is generally marked by subaligned muscovite and chlorite. At least part of the latter mineral appears to be an alteration product of biotite.

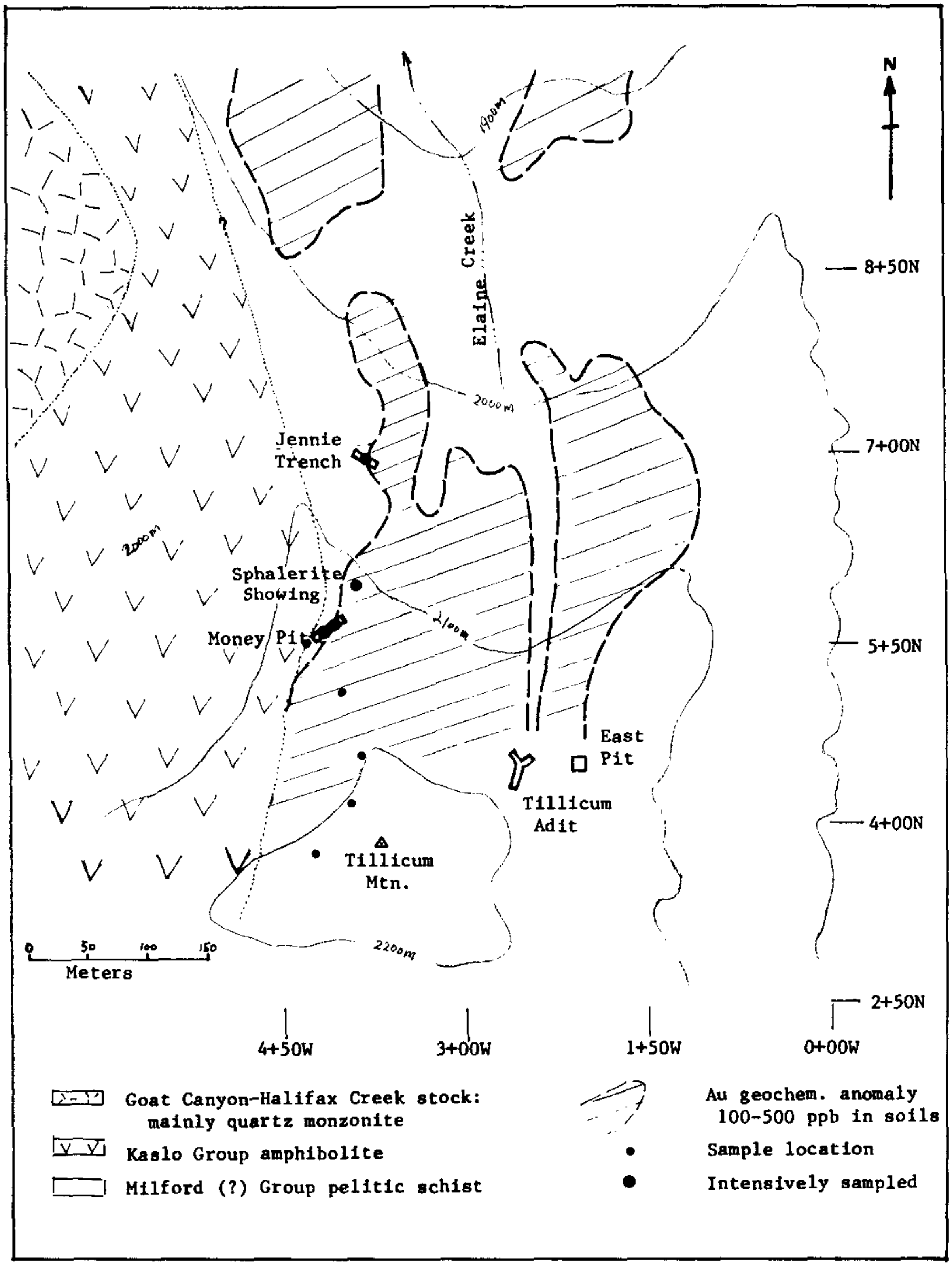

Figure 2. Local geology of the Tillicum gold property (partly after Crawford, pers. comm.). Soil geochemistry data are from George Cross News Letter, No. 167, September 1, 1981).

Metamorphosed, porphyritic, and locally amygdaloidal hornblende andesite and hornblende crystal tuff (?) are among the most common rock types of the Kaslo Group adjacent to the Milford contact. Intrusive rocks of the Goat Canyon-Halifax Creek stock to the northwest have not been examined in detail.

Figure 3 shows the geology in the vicinity of the Money pit and the location of samples collected for detailed petrographic and X-ray studies. Biotite-garnet-amphibole schists occurring around the perimeter of the Money pit are generally compact, fine-grained rocks. Common mineral constituents include K-feldspar, plagioclase, tremolite, biotite, and chlorite with lesser amounts of garnet (or its alteration product), quartz, opaque minerals, and rare calcite. Like the muscovite-garnet schists found away from the pit, schistosity in these rocks are defined by subaligned biotite and its alteration product, chlorite. Tremolite crystals are aligned either subparallel to the schistosity or at a small angle to it. Occasionally, tremolite also occurs with K-feldspar in patches and bands of varying dimensions. The proportion of these patches increases toward the Money pit and schistosity in the rock unit is locally destroyed. In four out of six thin sections cut from these rocks, garnet has been replaced by clusters of biotite and, less commonly, chlorite. Thus, a second episode of alteration featuring the stable appearance of tremolite, chlorite and possibly some K-feldspar and biotite was superimposed on regional metamorphism in which quartz-feldspar-mica-garnet±amphibole were stable. Prehnite and zoisite are locally associated with chlorite. Besides sulphides, a few samples also carry small amounts of amorphous carbon. Fold structures on a microscope scale occur in specimens from sampling stripes I and L.

Calc-silicate rocks in the Money pit consist, in order of decreasing abundance, of clinopyroxene (diopsidic augite ?), amphibole (tremolite-actinolite), quartz, K-feldspar, calcite, plagioclase, opaque minerals, and chlorite. Amphibole occurs either as fine-grained clusters or as elongated single crystals that cut across and include remnant fragments of clinopyroxene. Quartz, calcite, the feldspars, and opaque minerals commonly occupy interstitial spaces between the clinopyroxene and amphibole grains. All of these interstitial minerals appear to be in equilibrium with amphibole but most have a reaction contact with clinopyroxene. Less commonly, quartz occurs as scattered granular lenses or coarse fragments in locally brecciated clinopyroxene-dominated rocks.

These fragments and lenses are especially obvious in the southeastern corner of the pit where abundant sulphide minerals occur. Geological contacts of the calc-silicate rocks with the biotite-garnet-amphibole rock are sharp but the calc-silicates pinch out abruptly in a short distance. Consequently the limit of the calc-silicate unit depicted in the figure is very approximate.

Argillite adjacent to the Money pit are very similar to argillite bands described above except for the ubiquitous presence of tremolite. In most cases, the amphibole occurs in K-feldspar-rich bands that cut foliation defined by aligned mica and/or chlorite at a small angle. In a bulk sample, however, plagioclase is more abundant than K-feldspar.

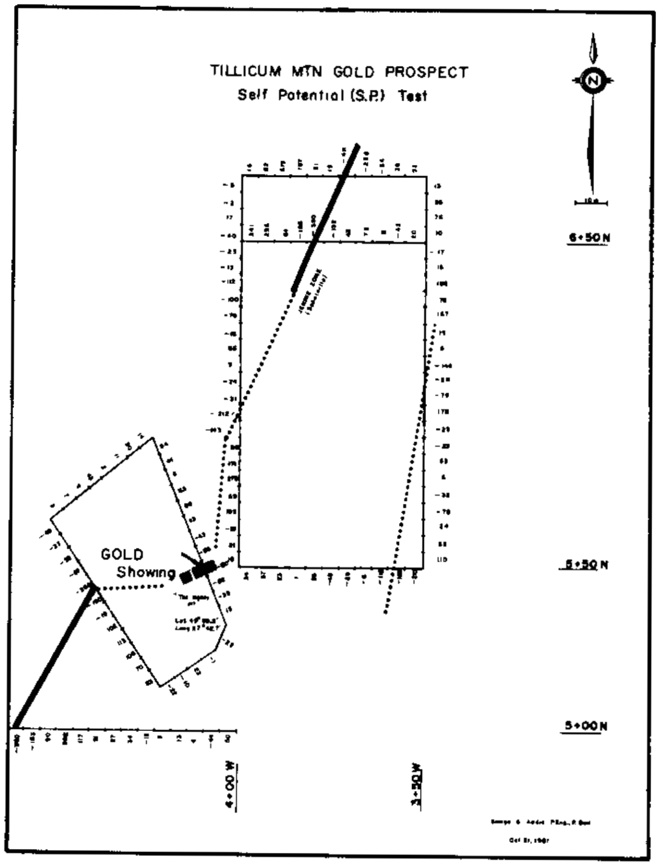

Figure 3. Lithology and location of samples at the Money pit and its immediate vicinities. The plan of the pit was kindly provided by Welcome North Mines.

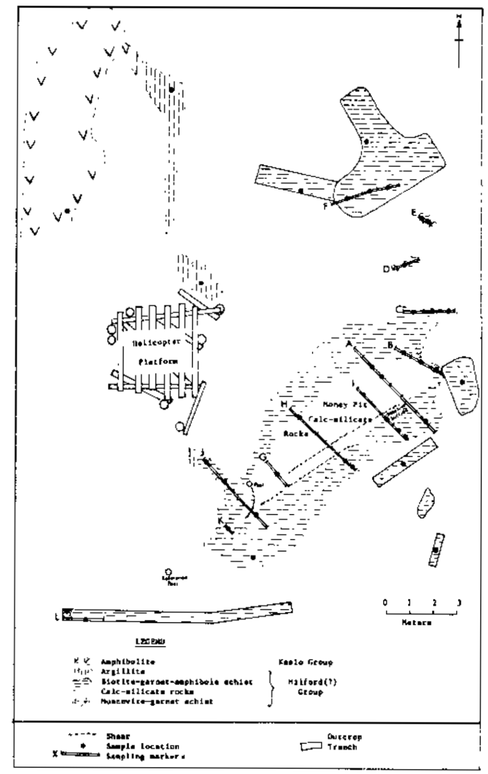

Figure 4. Self-potential test, Tillicum gold property.

Amphibolite west of the argillite unit was probably a porphyritic andesite prior to metamorphism. Subaligned hornblende phenocrysts, which define the foliation, are replaced by clusters of tremolite, biotite, and chlorite. Less abundant plagioclase phenocrysts and fine-grained clinopyroxene in the matrix, however, remain intact. Deformed lenses of quartz aggregates frequently enclose a carbonate core; they may have been amygdules originally.

MINERALIZATION AND ALTERATION

Native gold and sulphide minerals occur in the Money pit. Sulphides include sphalerite, pyrrhotite, galena, pyrite and rarely arsenopyrite, chalcopyrite, and marcasite. Polished sections indicate that native gold, sphalerite, pyrrhotite, and galena were precipitated in equilibrium. Sphalerite commonly includes discontinuous trains of exsolved blebs of chalcopyrite and pyrrhotite along cleavages indicating that it was originally deposited at a relatively high temperature. Many large pyrrhotite grains are replaced by marcasite and possibly some pyrite. Weathering products occurring in the Money pit have been confirmed by X-ray diffractometry to include colourless gypsum, white hydrozincite, and hemimorphite, black and dark brown goethite, reddish clayey hematite, and yellowish brown limonite.

As the intensity of mineralization decreases away from the Money pit, the sulphide mineralogy also changes. Whereas small amounts of sphalerite and locally galena are present in rocks of the Milford Group throughout the property, little or no pyrrhotite persists beyond the occurrence of biotite-garnet-amphibole schists. In the place of pyrrhotite, pyrite and locally arsenopyrite become the predominant sulphide minerals in the muscovite-garnet schists. Most of these sulphides are conformable with the schistosity, and hence with the original bedding because the two are parallel. Some sulphides, particularly sphalerite and galena, also occur along fractures at an angle to the schistosity or in association with silicate bands and patches at variable angles to the schistosity. Hydrous iron oxides are the predominant weathering products observed but locally, for example at the Jennie trench, arsenopyrite alters to abundant greenish yellow scorodite ($FeAsO_4 \cdot 2H_2O$). In the sphalerite showing lying northeast of the Money pit (see Figure 2 for location), an alteration mineral assemblage similar to that observed at the Money pit is present. However, neither visible gold nor extensive calc-silicate rocks were noted.

SP SURVEY

SP loops by both long and short wire methods got anomalous results at both the Money pit and the Jennie trench (Figure 4).

DISCUSSION

Pennsylvanian to Triassic sediments of the Milford Group deposited in the vicinity of Tillicum Mountain were probably made up of pelite with highly siliceous interbeds and localized pockets and lenses of impure carbonate which were precursors of a Money pit. These sediments might or might not contain small amounts of syngenetic sulphides. Undergoing progressive metamorphism up to the lower almandine-amphibolite facies, the carbonate was gradually converted into a clinopyroxene-dominating rock. The conversion process required a continual supply of silica from the neighboring rocks which accounts for the paucity of quartz in the biotite-garnet-amphibole rocks in comparison with the muscovite-garnet schist. A net transfer of FeO toward the nucleating calc-silicate zone was also likely so that diopsidic augite rather than diopside was stabilized and that biotite instead of muscovite preferentially occurred in the vicinity. The conversion of carbonate to a calc-silicate assemblage also involved a significant decrease in total volume that might induce incipient porosity and permeability in the resultant rock in the form of microfractures and pore space. Such inherited defects would be accentuated by structural deformation during or subsequent to regional metamorphism resulting in the formation of a highly permeable zone. In this way the Money pit was chemically and structurally prepared as a suitable site for the introduction of ore which probably took place during the intrusion of the Goat Canyon-Halifax Creek stock. Besides deposition of the ore minerals, the intrusive event also initiated an episode of recrystallization in the host rocks. Details of chemical changes and reactions involved in the formation and modification of the rocks in the Money pit and its vicinity will be dealt with in a later paper. It should be pointed out here that the ore reserve generated in the model would depend on the size of the original carbonate pocket, and consequently the extent of occurrences of deformed calc-silicate rocks.

Regarding the ultimate source of the ore elements, three alternatives are possible and each carries its own implications on further exploration targets in the region. First, the metals were derived from the intrusive stock and transferred to the Money pit by enriched magmatic hydrothermal fluid. In this case, the entire contact zone of the stock with the country rocks would be of interest. Besides Au-Zn-Pb, other types of mineralizatin like Cu-Mo would also be expected to occur closer to the stock. Second, Au+Zn$\pm$Pb was scavenged from the Kaslo Group amphibolite by hydrothermal fluid emanating from the stock. Under such a situation, the area around Mineral Creek (northwest of the centre of Figure 1) where a similar lithologic assemblage crops out should be investigated for similar deposits. Third, the mineralization at the Money pit represents a concentration of remobilized ore elements from the Milford Group rocks themselves. In view of the overall poor permeability of the fine-grained schists, which would readily hinder the formation of an extensive convection system, this alternative seems unlikely. Nevertheless, if it were true, then permeable zones in the Milford Group rocks occurring close to the intrusive stock should be examined for possible mineralization.

ACKNOWLEDGMENTS

The property was first visited by George Addie on August 22, 1980, with Mr. and Mrs. Arnold Gustafson (Prospectors Assistance Program).

Thanks are extended to Mr. John Brock, Mr. John Guild, and Dr. Jim Crawford of Welcome North Mines Ltd. for their cooperation and hospitality. Matt Holtz helped conduct the SP survey. Lloyd Addie acted as an assistant.

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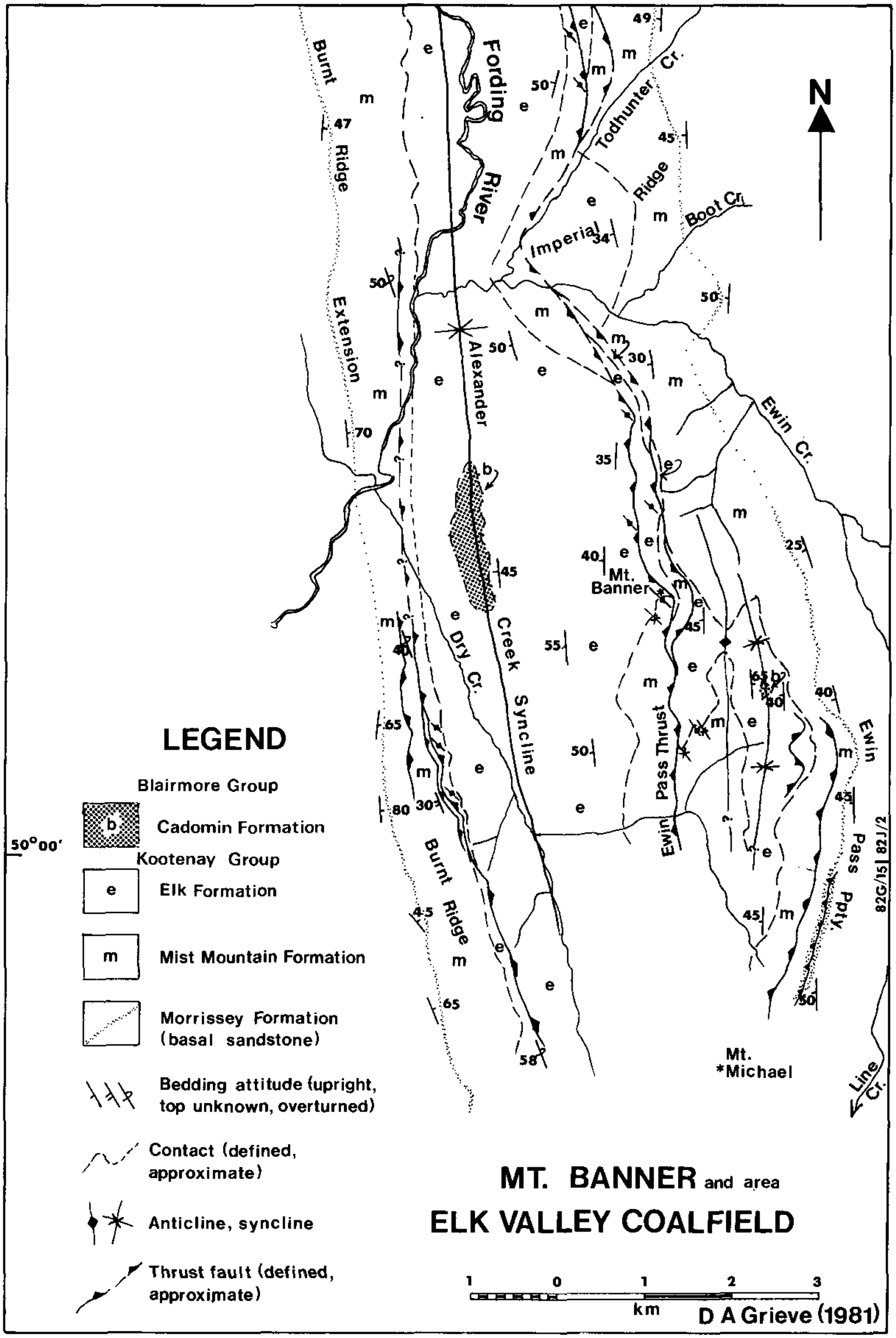

Figure 1. Geology of the Mount Banner area, Elk Valley Coalfield.

MOUNT BANNER AREA
ELK VALLEY COALFIELD

(82G/15, J/2)

By D.A. Grieve

INTRODUCTION

The Mount Banner area is south of Ewin Creek in the southern portion of the Elk Valley coalfield (Figure 1), and adjoins the area investigated in 1980 (Grieve, 1981). Geological mapping was carried out to provide new data concerning structure, stratigraphy, and coal resources of the coalfield.

Coal rights in the study area are held in part by B.C. Coal and in part by Crows Nest Resources, and both companies are actively engaged in exploration. Proximity to developing mines at Line Creek (Crows Nest Resources) and at Greenhills (B.C. Coal), both are approximately 10 kilometres away, suggests that the study area is strategically located for future mine expansion.

Mount Banner is 10 kilometres east of Elkford, and is accessible from both the Fording mine road and the Line Creek minesite. Elevations within the area range from 1 500 to 2 600 metres.

FIELD WORK

Data was plotted directly on British Columbia government air photographs and transferred to 1:10 000-scale orthophotos. Stratigraphic sections of the coal-bearing Mist Mountain Formation were measured using 'pogo stick,' chain, and compass. Coal outcrops, roadcuts, and trenches were grab-sampled for petrographic rank determinations. Channel samples were collected in certain areas to provide representative material for maceral analyses.

Results of petrographic studies will be published at a later date.

STRATIGRAPHY

Sedimentary rocks of the Jurassic-Cretaceous Kootenay Group comprise the Elk Valley coalfield. 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, medium-grained sandstone unit.

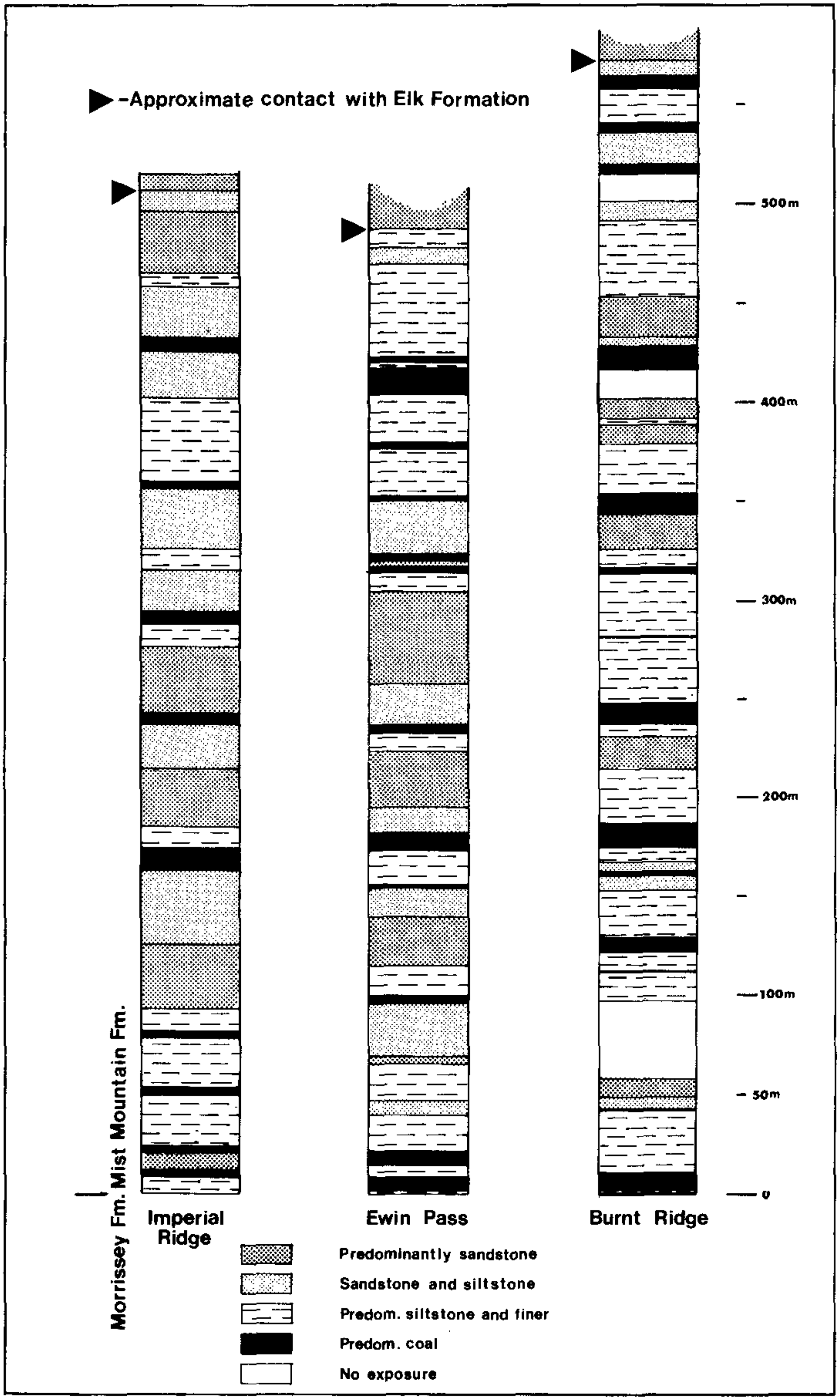

Figure 2. Generalized stratigraphic columns of the Mist Mountain Formation at Imperial Ridge, Ewin Pass, and Burnt Ridge. Coal seams thicker than 1 metre are not indicated.

The overlying Mist Mountain Formation consists of interbedded sandstone, siltstone, mudstone, coal, and minor amounts of conglomerate. It is on the order of 500 metres thick in the study area (Figure 2).

In this area the overlying Elk Formation includes an estimated 250 to 300 metres of strata which resemble those of the Mist Mountain Formation. However, coal seams in the Elk rarely exceed 1.5 metres in thickness. Other characteristics of the Elk Formation are described elsewhere in this paper.

The contact between Mist Mountain and Elk Formations is not readily identified in the study area. Generally the contact is placed either at the lowest occurrence of Elk coal, or at a locally mappable, resistant sandstone unit which appears to separate strata that are characteristic of the two formations. Because lateral transitions within the coarse clastics of the Kootenay Group are rapid, some inconsistencies occur.

Kootenay Group is overlain at two locations in the study area by conglomerate of the Cadomin Formation of the Blairmore Group (Figure 1).

STRUCTURE

The north-south-trending Alexander Creek syncline is the dominant structure in the Elk Valley coalfield. In the Mount Banner area it is asymmetric with a steep west limb (Figure 1). Parallel smaller scale folds with similar geometry occur on the east limb and have the effect of bringing Mist Mountain Formation to the surface in the small drainage basin west of the Ewin Pass property (Figure 1).

Thrust faults are also important structural features in the Mount Banner area. The Ewin Pass (or Fording) thrust crops out on the east limb of the Alexander Creek syncline throughout the south half of the Elk Valley coalfield (Pearson and Grieve, 1980; Grieve, 1981). It is a west-dipping fault with at least one major splay in the Mount Banner area (Figure 1). Steeply northwest-plunging dragfolds (Figure 1) occur on both the hanging and foot walls. Its major effects were to emplace Mist Mountain over Elk Formation, especially south of Mount Banner peak and on Mount Michael, and to create an apparently excessive thickness of Mist Mountain Formation on the south side of Ewin Creek (Figure 1).

Several other thrust zones of lesser lateral continuity and small to negligible stratigraphic displacement occur on the east limb; three are noted on Figure 1.

The Burnt Ridge property, which is on the west limb, also contains a significant zone of faulting (Figure 1). Movement on this zone produced northwest-southeast-trending dragfolds, and a persistent zone of overturned, west-dipping strata.

Assuming that these overturned strata are in the footwall of an east-dipping fault, there are two possible explanations for their orientation:

(i) gravity movement toward the core of the syncline, perhaps along an earlier thrust surface; or (ii) early formation of the Ewin Pass thrust, with subsequent folding around the axis of the syncline. The second alternative implies that the fault on Burnt Ridge is part of the Ewin Pass thrust, and that the easterly dip and apparent normal movement were produced by the folding. This alternative is also consistent with the relatively large degree of stratigraphic displacement on the Ewin Pass thrust considering the proximity of the synclinal axis. This suggests that movement was initiated some distance further to the west. It may also be significant that dragfolds associated with the fault have a northwest-southeast trend, compared with the nearly north-south trend of the Alexander Creek syncline and associated minor folds.

Further work is required to test these two hypotheses.

ACKNOWLEDGMENTS

It is a pleasure to record my appreciation of field assistance provided by Mr. Gerry Pellegrin.

Discussions with Crows Nest Resources' staff, especially Dr. Barry Ryan, along with logistical support, were invaluable to the study.

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STRATIGRAPHY OF THE ELK FORMATION IN SOUTHEASTERN BRITISH COLUMBIA

(82 G, J)

By D.A. Grieve
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and
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The Elk Formation is the uppermost formation of the Jurassic-Cretaceous Kootenay Group (Gibson, 1979). It conformably overlies the Mist Mountain Formation, the host formation for economic coal seams in the southeastern British Columbia coalfields. It is overlain, generally unconformably, by the Cadomin Formation of the Blairmore Group.

Changes in the lithology and stratigraphy of the Elk Formation caused by rapid lateral facies changes in the Elk Formation away from and particularly east of the type section on Coal Creek render it less distinct from the underlying Mist Mountain Formation. A consistent definition of the Elk Formation and identification of a precise contact with the Mist Mountain Formation become increasingly difficult away from the type section. These problems prompted the authors to undertake a detailed analysis of the Elk Formation in the southern Fernie Basin area in an attempt to formulate a more consistent definition of the formation and to describe its variations. We attempt to identify the problems and to provide some practical guidelines for recognition of the Elk Formation.

FIELDWORK

Two weeks have been devoted to the study so far. Stratigraphic sections have been measured at Coal Creek (type section, Newmarch, 1953), Morrissey Ridge (reference section, Gibson, 1979), Flathead Ridge, and the Lodgepole property (McLatchie Ridge), all within the Fernie Basin.

In addition, drill-core from the Lillyburt property in the Flathead coalfield was logged.

Sections were measured using 'pogo stick' and chain.

STRATIGRAPHY

Elk Formation in the study area is an eastward-thinning unit of non-marine clastic sedimentary rocks including sandstone, siltstone, mudstone, local conglomerate, and coal. Clastic units are similar in terms of composition and sedimentary structures to those in the underlying Mist Mountain Formation.

Several lithological criteria aid in identifying the Elk Formation in southeastern British Columbia. These are: the abundance and distribution of coarse clastic material; the distinctive nature of Elk coal; the presence of needle siltstone; the relative scarcity of coal seams; and the absence of coal seams greater than about 1.5 metres in thickness.

A thin-bedded, dark grey to black, well-indurated, carbonaceous siltstone is a distinctive feature of the Elk Formation. It weathers a distinctive light grey colour, and where it is exposed to weathering the bedding surface is irregular and hummocky. This unit is informally called 'needle siltstone' because it contains fragments of needle coal (Gibson, 1977, p. 782).

Coal in the Elk Formation is of two main types. The more common is bright and vitrain-rich and occurs in thin lenticular beds that are generally less than 0.5 metre and nearly always less than 1.5 metres in thickness. It is indistinguishable in outcrop from some coal seams of the Mist Mountain Formation. The other coal type is a brittle and resistant cannel coal containing alginite, referred to by the authors as 'Elk coal.' A conspicuous variety of Elk coal, needle coal, consists of algal needles which resemble pine needles. Elk coal comprises thin, usually less than 0.3 metre, lenticular, discontinuous beds. These commonly directly overlie needle siltstone.

The contact between the Elk and Mist Mountain Formations is gradational. The prominent basal, cliff-forming sequence of conglomerate and sandstone units in the Coal Creek area (Newmarch, 1953) is a local phenomenon. Elsewhere, selection of a basal contact often involves a compromise, or an arbitrary placement. In these instances, the contact is not traceable for mapping purposes.

A more detailed discussion of the results of this ongoing study will be published at a later date.

ACKNOWLEDGMENTS

This study was initially suggested and planned by D.E. Pearson, formerly with the British Columbia Ministry of Energy, Mines and Petroleum Resources.

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A COPPER-SILVER OCCURRENCE IN THE FALKLAND AREA (82L/12E)

By G.P.E. White

A copper-silver showing on the Top claims owned by Don Campbell and under option during 1981 to Craigmont Explorations Limited is located at 50 degrees 31 minutes latitude, 119 degrees 36 minutes longitude, 1 190 metres elevation, approximately 3 kilometres northwest of Falkland.

Finely disseminated chalcopyrite, bornite, chalcocite, and possibly digenite are found in a coarse volcanic breccia. Fragments are predominately porphyritic green and buff lava, chert, micrite, and rhyolite, generally in a finer clastic crystal fragment-bearing green matrix. The porphyritic green phase is the most common rock type and, in mineralized areas, it has been altered predominately to calcite with 20 per cent albite and some chlorite, quartz, and K-feldspar. Phenocrysts are altered to vermiculite-hydrobiotite with small amounts of chlorite, calcite, and amphibole. Away from the mineralized area, the volcanic breccia consists of sericitic to kaolinitic altered porphyry and clasts of altered microlitic volcanic flows. In this unit, relatively fresh augite phenocrysts are present. Apatite is often present in the chert and veinlets of quartz, K-feldspar, and calcite are occasionally present.

This 'augite porphyry' breccia is interbanded with some rhyolite and light-coloured flow rocks; some of the rhyolites are flow banded.

South of the mineralized area, 1.5-metre green porphyry blocks are set in a fragmental green porphyry matrix. Occasional clasts are mineralized with copper and there are infrequent, well-rounded, 5-centimetre-diameter milled rock fragments.

To the north of the mineralized showing outcrops in a narrow stream valley show 'augite porphyry' and altered basalt breccia in faulted contact with a coarse conglomerate and interbedded calcite-cemented arkosic sandstone. The conglomerate and sandstone are cut by basaltic dykes. Above is basalt clast sandstone that grades upward into sandstone with plant fossils. It is suggested that the fault juxtaposes Triassic and Tertiary rocks.

The mineralization is proximal to a Triassic diatreme. The present topography is related to Tertiary vent systems and may in part represent coincident areas of crustal weakness which also served as volcanic centres during Triassic time.

Using this concept, Mount Martin to the northwest was investigated but so far only one outcrop of relatively unaltered augite porphyry has been found on the north side. However, it is interesting to note that outcrops below 1 200 metres south and east of Mount Martin in Paxton Valley, along St. Laurent Creek, on Mail Creek, and on Bolean Creek are Permian-Pennsylvanian, not Tertiary. This interpretation is based on lithology, paleogeography, and fossil evidence. Cherty limestones contain productid brachiopods and schwagerinid fusulinids, possibly Parafusulina (Monger, pers. comm.). Monger suggested that these rocks are late Early to Middle Permian in age and may correlate with the Harper Ranch Group.

Prospector Don Campbell on the Ministry's Grant Program worked in this area off and on for several years before making this find. Thanks are extended to John Kwong who identified minerals, and Bill McMillan and Vic Preto for their interest and suggestions. M. Hanna made the initial suggestion that the fossils were Permian-Pennsylvanian and this was confirmed by J. Monger of the Geological Survey of Canada.

THE STIRLING MOLYBDENITE SHOWING

(82M/8W)

By G.P.E. White

The Stirling property (MDI No. 082M/087), owned by CJC Explorations Ltd. of Revelstoke, was optioned by Newmont from July 1980 until July 1981. The property is located approximately 54 kilometres north of Revelstoke at latitude 51 degrees 23 minutes, longitude 118 degrees 25 minutes. Most of the showings are easily accessible from the old or new Mica Dam Highway.

Molybdenite occurs in concordant pegmatite-like sills in Lardeau Group metasediments. The sills consist of quartz, albite, pyrite, pyrrhotite, with carbonate, fuchsite, galena, occasional sphalerite, and rare allanite. Sericitic impure quartzite, quartz-chlorite-muscovite schist, graphite schist, crystalline limestone, and chlorite-muscovite-magnetite schist have a general strike of 015 degrees with a 30-degree northwest dip.

During the 1980-1981 season Newmont collected 252 rock, 28 soil, and 10 trench samples for alteration studies and geochemical assaying, did 23 kilometres of magnetometer surveying, and drilled 45 overburden and 10 BQ diamond-drill holes, the latter totalling 1 320.8 metres.

One of the better intersections in diamond-drill hole 81-8 comprised 2 metres of 4.67 per cent MoS_2. In diamond-drill hole 81-2 there was 0.39 per cent MoS_2 over 2.4 metres.

The above information for the most part was taken from reports by Denis Bohme of December 29, 1980 and July 10, 1981, personal communication with Denis Bohme June 17, 1981, and a report by D.M. Hausen of Newmont dated June 2, 1981.

John Kwong of the Analytical Laboratory identified the allanite.

A NEW ZINC OCCURRENCE IN THE REVELSTOKE AREA

(82M/8W)

By G.P.E. White

While searching for scheelite north of Revelstoke the Cameron-Jenkins-Campbell prospectors discovered zinc with secondary hydrozincite at an elevation of 835 metres, north of Mars Creek, latitude 50 degrees 21 minutes, longitude 118 degrees 22 minutes.

Sphalerite and pyrite in a manganese-dioxide-stained metamorphosed siliceous sediment occur in 1-metre bands with an exposed strike length of 10 metres. The host rocks are sericite-chlorite schist, sericite-quartz-albite schist, biotite-chlorite schist, and minor amounts of sericitic quartzite. The regional attitude is 170 degrees, 25 degrees east. Due to the incompetent nature of the schists many crenulations and minor folds are present.

Analysis by our Analytical Laboratory of a grab sample gave a 2.23 per cent zinc, 0.15 per cent lead, and 0.01 per cent cadmium; the cadmium was by spectrographic analysis.

THE THANKSGIVING TUNGSTEN SHOWING

(82M/1E)

By G.P.E. White

Scheelite was discovered on the Thanksgiving property in the fall of 1980 by the Cameron-Jenkins-Campbell prospecting group of Revelstoke. The showing is located about 25 kilometres north of Revelstoke, latitude 51 degrees 12 minutes, longitude 118 degrees 12 minutes, along the new Mica Dam Highway at an elevation of 670 metres.

Skarn near the crest of an antiform consists of scheelite, calcite, quartz, K-feldspar, plagioclase, diopside, clinozoisite, vesuvianite, garnet, hornblende, sphene, pyrite, pyrrhotite, and chlorite. The zone is reported to be stratabound and about 3 metres in thickness. Mineral content varies both vertically and laterally and, in one thin section examined, the rock has a cherty matrix. The host rocks are sericitic quartzites and biotite-quartz-plagioclase schists, with local fissile, micaceous partings. Foliation has a general east-west strike and a 30-degree north dip. A major low angle north-south fault that crosses the property is marked by graphitic shearing. In the easternmost trenched area tight crenulated folds with axial planes normal to the major fold axis occur in a calcareous unit.

Quartz feldspar porphyry with a grey biotite-rich matrix, muscovite-quartz-feldspar pegmatite, and quartz veining occur in close proximity to scheelite on the property but not with the skarn assemblage. No tungsten was detected in a semiquantitative spectrographic analysis of the pegmatite.

Conversations with Roy Wares representing Northair Mines were held at various times during the field season.

CLEARWATER AREA

(82M/12W; 92P/8E, 9E)

By Paul Schiarizza
Department of Geology, University of Calgary

INTRODUCTION

Geological mapping of the Fennell and Eagle Bay Formations between Clearwater and Chu Chua Mountain was initiated in 1980 (Schiarizza, 1981) and completed during the 1981 field season. Little new ground was covered this season; the main effort was devoted to refining and filling in details of the area covered previously. Extensive sampling of cherty sediments within the Fennell Formation was carried out in an effort to find microfossils. Results from this sampling are not yet available. Structural interpretations advanced after the first seasons' fieldwork were generally confirmed by this year's work. An early stage syncline was outlined with the Lower Fennell Formation between Clearwater and Granite Mountain. Improved understanding of the internal stratigraphy and structure of the Eagle Bay Formation confirms that the bulk of this formation is in discordant fault with adjacent Fennell rocks.

STRATIGRAPHY

EAGLE BAY FORMATION (UNITS 1 TO 4)

Considerable time was spent mapping within the Eagle Bay Formation. The work allowed significant refinement and regrouping of Eagle Bay stratigraphy compared to that advanced by the writer previously.

The structurally highest unit within the formation (unit 4; units 3 and 4 of Schiarizza, 1981) consists mostly of rusty weathering, greenish grey feldspathic chlorite-sericite schists. An attempt to map darker green, more chloritic schists as a separate unit (Schiarizza, 1981) proved untenable, although rocks in the lower part of the unit do seem to be generally more chloritic. Igneous textures are clearly displayed in weakly schistose specimens from this unit and discrete feldspar grains evident throughout the unit appear to be relict igneous grains. Fragmental rocks occur in the lower parts of the unit, but are rare. A light grey relatively pure quartzite (4a) was traceable for a little over 1 kilometre just south of Foghorn Mountain. However, the bulk of this unit is monotonously uniform. It may have been derived from a series of flows, or may represent an intrusive body.

Structurally beneath unit 4 is a unit dominated by schists of felsic to intermediate volcanic origin (unit 3). The unit is best exposed along lower McDougal and Foghorn Creeks. Along McDougal Creek these rocks are mainly light silvery grey quartz-sericite schists. Substantial chlorite is present in places, and chloritoid porphyroblasts were observed at a number of localities. 'Eyes' of clear quartz are often evident. Thin sections show that these are embayed quartz phenocrysts. Sedimentary interlayers of dark grey phyllite found throughout this section range up to a few tens of metres in thickness. These same rock types also comprise the succession along Foghorn Creek. There, however, the unit is more varied and includes not only medium green chlorite schist and light grey platy sericitic quartzite but also trachytic rock which hosts mineralization at the Rexspar uranium deposit (Preto, 1978). Fragmental rocks that probably represent volcanic breccia are also present, particularly near the Rexspar deposit. Immediately north of the Baldy Batholith at Granite Mountain, outcrops of fine to medium-grained biotite-quartz gneiss with interlayered amphibolite and pelitic hornfels (3a) may be the contact metamorphosed equivalent of unit 3.

Unit 2 consists of medium green chlorite schist with interbedded grey phyllite and limestone. It structurally underlies unit 3 along upper Foghorn Creek. Scattered outcrops of chloritic schist immediately south of Birch Island may also belong to this unit.

Black phyllite with interbedded siltstone, sandstone, and grit (unit 1) crops out adjacent to the Fennell Formation immediately south of Clearwater. This unit is truncated on the south by a transverse northeast-trending fault. It does not crop out again until the Fennell/Eagle Bay contact emerges south of the Baldy Batholith. There, it forms a substantial unit which continues southward adjacent to and east of the Fennell Formation, and extends across the Barriere River to Johnson Creek (unit 6a of Preto, 1981). Mississippian conodonts were extracted from two lenses of limestone within this unit in the Barriere Lakes area (Okulitch and Cameron, 1976; Preto, et al., 1980). South of Clearwater, unit 1 structurally overlies rocks of the immediately adjacent, east-dipping Fennell Formation, and itself appears to be structurally overlain by felsic schists of unit 3. The nature of these contacts will be discussed in the section on Structural Geology.

FENNELL FORMATION (UNITS 5 AND 6)

The Fennell Formation has been divided into an upper unit consisting almost entirely of massive and pillowed greenstone; and a lower, more heterogeneous unit dominated by greenstone and cherty sediments. Fennell greenstones have suffered varying degrees of low-grade metamorphism and alteration, but appear to be dominantly of basaltic composition. M.J. Orchard has identified conodonts extracted from Fennell Formation cherts in the Barriere Lakes area. They range in age from Late Mississippian or Early Pennsylvanian to Permo-Triassic (V.A. Preto, pers. comm., April, 1981). Chert samples from the Clearwater area are presently being analysed for microfossils.

LOWER FENNELL (UNIT 5)

A wide variety of rock types comprise the Lower Fennell Formation. Individual units are generally discontinuous and often intercalated on a scale that is too fine to be represented at the mapping scale. Greenstone (5a) predominates. It ranges from aphanitic to very coarse grained and includes both intrusive and extrusive phases. Because of metamorphism, the two are generally indistinguishable; consequently they have not been separated on the accompanying map (Figure 1). Recognizable extrusive varieties are generally aphanitic to fine grained; these may be pillowed, but most are massive. Obviously intrusive dioritic to gabbroic units generally occur as concordant sill-like bodies, although irregular discordant masses are also present.

Chert to cherty mudstone (5b) is the dominant sedimentary rock type present. It is generally well bedded; beds range up to 15 centimetres thick and are separated by thinner argillaceous partings or interbeds. As with all units within the Lower Fennell, chert horizons tend to lens out and be discontinuous; however, in places individual chert units are persistent and provide the best local marker units within the succession.

Two substantial concordant layers, and a number of smaller bodies of light grey, massive to weakly foliated quartz-feldspar porphyry (5c) occur in unit 5. These appear to be mainly of extrusive origin; some were eroded and occur as clasts in overlying conglomerate.

Conglomerate (5d) forms discontinuous lenses throughout the Lower Fennell, but is most common in a belt that extends from the vicinity of Axel Lake north-northwestward to Blackpool. Clasts appear to have been derived entirely from surrounding Fennell units; they are dominantly chert, greenstone, and argillite.

Bodies of sandstone, argillite, and phyllite (5e) are most common in the lower part of unit 5. In places, they are well bedded and sandstone layers alternate with finer grained argillite or phyllite; more commonly, bedding is disrupted, giving the rock a lensey to conglomeratic appearance.

Limestone (5f) is a minor component of the Lower Fennell. It is present as small, discontinous lenses in the lower part of the formation adjacent to the Eagle Bay contact.

UPPER FENNELL (UNIT 6)

The Upper Fennell consists mainly of aphanitic to fine-grained greenstone. Pillows are commonly present, and the greenstone appears to be largely of extrusive origin. Small discontinuous pods of chert are present in places, and two somewhat larger bodies of bedded chert (6a) were traceable for short distances.

Although it was not exposed, the contact between the Lower and Upper Fennell appears to be stratigraphic rather than tectonic. Traverses across the contact zone along Joseph Creek and on the slopes west of the Baldy Batholith show a gradual transition, marked by decrease in the

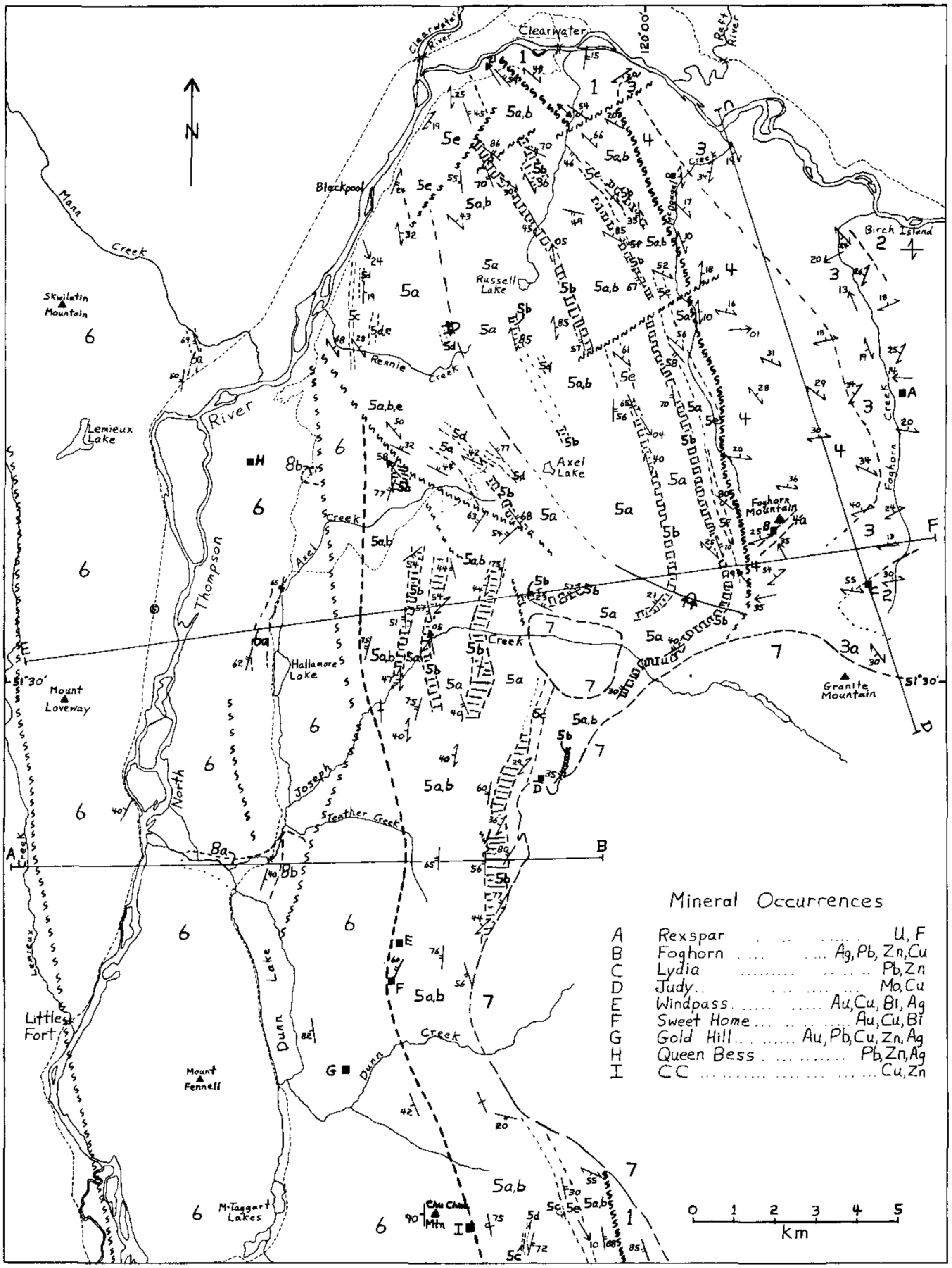

Figure 1. Generalized geological map of the Clearwater-Chu Chua area.

LEGEND

EOCENE AND LATER (?)

8 (b) Skull Hill Formation: vesicular andesite

(a) Chu Chua Formation: conglomerate, sandstone, shale

CRETACEOUS

7 Biotite quartz monzonite of Baldy Batholith and Joseph Creek stock

UPPER PALEOZOIC

FENNELL FORMATION

6 Upper Fennell Formation: pillowed and massive greenstone, minor chert

6a: bedded chert

5 Lower Fennell Formation

(f) limestone

(e) sandstone, argillite, phyllite

(d) conglomerate

(c) quartz feldspar porphyry

(b) bedded chert

(a) greenstone

Eagle Bay Formation

4 Rusty weathering, greenish grey, feldspathic chlorite-sericite schist

4a: quartzite

3 Quartz-sericite schist with interbedded dark grey phyllite; minor chlorite schist, platy sericitic quartzite, and trachyte

3a: biotite-quartz gneiss, amphibolite, pelitic hornfels

2 Chlorite schist, minor grey phyllite and limestone

1 Black phyllite with interbedded siltstone, sandstone, and grit

Symbols

Bedding: tops known, overturned; tops not known ....

Schistosity: inclined; horizontal ....

Early mesoscopic fold axis ....

Late mesoscopic fold axis ....

Inferred fault ....

Early synclinal axial trace, overturned ....

Geological contact ....

Mineral occurrence .... ■

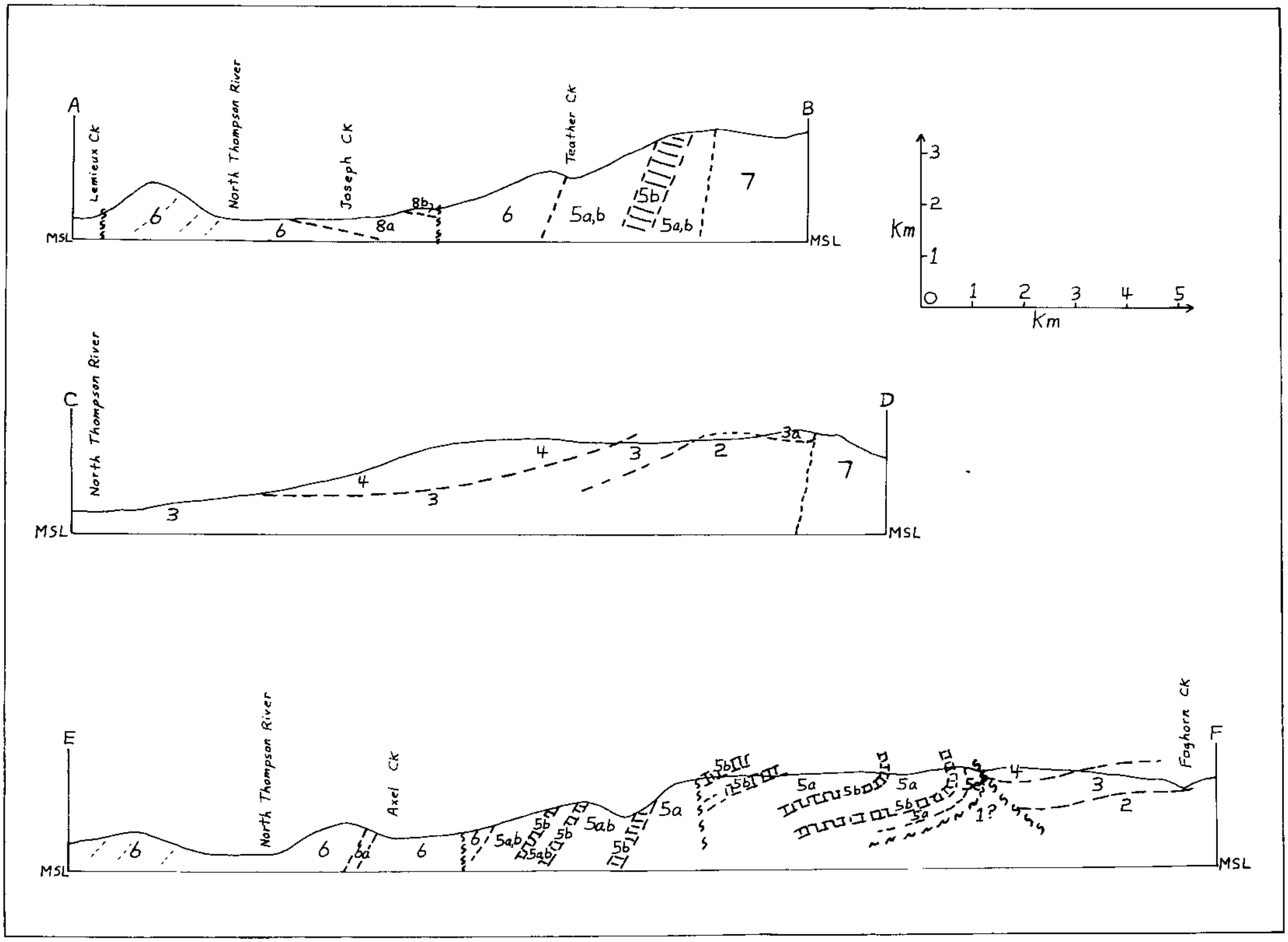

Figure 2. Vertical cross-sections to accompany Figure 1.

thickness and number of chert horizons until the succession consists almost entirely of greenstone.

UNIT 7

The Middle Cretaceous (Wanless, et al., 1966) Baldy Batholith occupies the southeast corner of the map-area where it cuts the Fennell/Eagle Bay contact. A small body of similar rock outcrops in the Joseph Creek valley just northwest of the batholith. Coarse-grained biotite quartz monzonite comprises much of the batholith. It is commonly porphyritic, with K-feldspar phenocrysts up to a few centimetres in size. The contact with adjacent country rocks is sharp, steeply inclined, and, with some exceptions, fairly regular in orientation.

UNIT 8

Conglomerate, sandstone, and shale of the Eocene (Campbell and Tipper, 1971) Chu Chua Formation (8a) and overlying vesicular andesite of the Skull Hill Formation (8b) unconformably overlie the Fennell Formation in Joseph Creek valley immediately north of Dunn Lake. A smaller exposure of Skull Hill Formation occurs 9 kilometres to the north. Bedding within the Chu Chua Formation dips consistently at moderate angles to the east, apparently due to rotation along late faults that lie east of exposures of the unit.

STRUCTURE

Three phases of folding are indicated by mesoscopic structures within the area. Early folds generally plunge to the northwest. The associated axial planar schistosity has been variably reoriented by later structures. Phase 2 folds plunge northwest or southeast, while phase 3 folds plunge at low angles east or westward. Axial surfaces of the later fold sets are relatively upright; axial planar strain slip cleavage developed locally during second phase folding, but is not pervasive throughout the map-area.

A westerly overturned phase 1 syncline in the Lower Fennell Formation dominates the macroscopic structure between Clearwater and upper Joseph Creek. This syncline is outlined by the stratigraphy immediately north of the Baldy Batholith. There it plunges shallowly toward the north-northwest and the axial surface dips gently toward the north-northeast for several kilometres, then swings and takes on a more northerly trend. The location of the axial trace is approximate because outcrops are sparse, Fennell stratigraphy is discontinuous, and massive greenstone, from which little structural data could be obtained, predominates.

West of the Baldy Batholith, in the southern half of the area, the Fennell Formation comprises a west-dipping and facing homocline. Bedding/schistosity relationships and minor fold asymmetry suggest that this homo cline is the result of a late (phase 2 ?), antiformal deflection of the western (upright) limb of the phase 1 syncline. Stratigraphic units could not be traced around this antiform, however, because there appears to be a zone of faulting between Joseph and Axel Creeks. This faulting may be related to, or post-date, the second phase of folding.

Units 2 through 4 of the Eagle Bay Formation comprise a relatively flat-lying plate which appears to be discordant with the adjacent Fennell Formation. Previously (Schiarizza, 1981) a gentle northerly plunging synform was tentatively outlined in this package. However, the zone actually appears to represent a slight upturning as it contacts the Fennell Formation. This contact may be an east-dipping thrust fault that post-dates the phase 1 syncline within the Fennell Formation.

Immediately south of Clearwater, unit 1 of the Eagle Bay Formation appears to be roughly concordant with rocks of the adjacent Fennell Formation, and to have been subjected to the same (phase 1) westerly overturned folding. Farther east, felsic schists of unit 3 appear to overlie unit 1, although the contact was not exposed. Units 1 and 3 may be separated by the same east-dipping fault which has been inferred to separate units 2 through 4 of the Eagle Bay Formation from the Fennell Formation. The position where the Fennell/Eagle Bay (unit 1) contact emerges south of the Baldy Batholith suggests that this contact was folded along with rocks of the Fennell Formation. As was the case south of Clearwater, the metasediments of unit 1 appear to be approximately conformable with adjacent Fennell units. However, an apparent thinning (truncation ?) of the Lower Fennell southward along the contact, the presence of a tectonized zone between unit 1 and the Fennell Formation immediately south of the Baldy Batholith, and the absence of feeder sills or dykes of the Fennell Formation within unit 1, suggest that this contact may be a fault. Since the contact appears to have been folded by a phase 1 fold, the fault would pre-date this folding.

In addition to those previously discussed, conspicuous faults within the area have two dominant orientations. Late faults, in places marked by brecciated zones, trend northerly and occur mainly along the western side of the map-area. These may be more common than indicated on the map and occupy a number of northerly trending valleys, including the North Thompson River valley. Outliers of the Tertiary Chu Chua and Skull Hill Formations appear to have been preserved, at least in part, as a result of movement along this system of faults. Northeast-trending faults in the northeast corner of the map-area are inferred on the basis of abrupt structural discordances and truncation of stratigraphic units. These also appear to be relatively late features, imposed after the dominant structural geometry had already been established. Intrusion of the Baldy Batholith (Middle Cretaceous) apparently post-dated most of the folding in the area. However, there is some deflection and reorientation of contacts and structures near its contact.

MINERAL DEPOSITS

The locations of the most important mineral showings in the area are indicated on the geological map (Figure 1). The most significant of these are the Rexspar (U, F) (Preto, 1978) and CC (Cu, Zn) (McMillan, 1980) deposits. Mineralization in each of these deposits appears to be syngenetic with the enclosing volcanic host rocks. In contrast, other showings in the area occur in crosscutting quartz or quartz-carbonate veins which formed late in the geological history of the area. These are often associated with local shear zones, such as at the Queen Bess (Pb, Zn, Ag) and Gold Hill (Au, Pb, Cu, Zn, Ag) properties, where Fennell greenstones are cut by steep easterly trending shear zones and altered to rusty ferrodolomite.

ACKNOWLEDGMENTS

Bruce Gaiesky provided able assistance in the field. Discussions with P.S. Simony, V.A. Preto, and W.J. McMillan have proved very helpful and are much appreciated.

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NOTES ON CARBONATITES IN CENTRAL BRITISH COLUMBIA (83D/6E)

By G.P.E. White

Carbonatites were examined at the Verity (Lempriere), Paradise Lake, Howard Creek, Mud Lake, and Gum Creek localities as well as at one new site; an extension of the Gum Creek carbonatite which lies to the west of the original locality.

Generally carbonatite is conformable to the hosting schists or, less commonly, syenite as at Howard Creek. Two or more bodies of carbonatite separated by schist bands may be present. Beforsite is sometimes interbanded with sovite and their contacts are usually well defined. Some textures resemble flow banding, but others are suggestive of carbonate phenocrysts in a carbonate matrix.

In the Verity area, coarse olivine is often associated with sovite and apatite creates banding in trenched areas; otherwise lateral and vertical mineral zoning is not obvious.

Minerals identified in carbonatite on the JTM property (Mud Lake) are calcite, dolomite, apatite, ilmenite, olivine (ferroan forsterite with secondary iddingsite and goethite), tremolite-actinolite, chlorite, antigorite, vermiculite, talc, hydromica, and pyrrhotite along with previously reported phlogopite, chondrodite, pyroxene, magnetite, and limonite.

From the Howard Creek site zircon, baddeleyite, pyrochlore, sphene, apatite, calcite, pyrite, richterite, and titanite were identified as well as traces of ilmenite and hornblende (possibly edenite).

In the Howard Creek area there is a black, hard, relatively coarse-grained rock consisting of hornblende, sphene, clinopyroxene (acmite-augite) and apatite with interstitial calcite, and minor mica, for which A. Mariano has tentatively suggested the name 'lemprierite' (Bent Aaquist, pers. comm., September 1981).

Columbite and pyrochlore are common to many of these sites and molybdenite was noted in core from the Gum Creek area.

Attempts at age dating have not been definitive or correlative to date. Potassium-argon dates by Joe Harakal of the University of British Columbia were 205±8 Ma on phlogopite from Howard Creek, and 92.5±3.2 Ma and 80.2±2.8 Ma on richterite from the Verity site. Dr. R. Armstrong of the University of British Columbia has suggested that we confine our dating with zircons. Euhedral, coarse-grained zircon is present at the Verity site and zircon has been noted in thin sections from the Howard Creek carbonatite.

John Kwong of the Analytical Laboratory in Victoria is responsible for much of the mineral identification while Lynn Sheppard carried out the heavy mineral separations. Bill McMillan suggested methods to obtain age dates and thanks are due to Mitch Mihalynuk who assisted in the field.

Bent Aaquist of Anschutz Mining Corporation gave freely of his time and discussed results of their work in the area.

LEECH RIVER AREA, VANCOUVER ISLAND

(92B/5g, 12 b-c)

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 Early Cretaceous. The formation contains numerous small quartz veins carrying trace amounts of gold, and Clapp (1917) concluded that the placer gold was derived from them.

A prospector, Marvin Richter, did not believe this and in 1980 claimed to have found nugget gold in shear zones in the Leech River Formation. He speculated that these were localized along fold limbs. There were thus stratigraphic, structural, and economic reasons for taking another look at the Leech River area. In 1981 the writer spent 7 days on a reconnaissance of a strip between the mouth of the West Leech and Sooke Rivers. It was then learned that the Greater Victoria Water District plans to build a 20-metre dam across the Leech River at the end of the new road on the north side and to drive a 4-kilometre tunnel from a point immediately above northeast to Deception Gulch, near Sooke Lake.

This area may be reached on weekends via a Pacific Logging main haul road from Sooke, or at any time from the Shawnigan Lake Road via the Sooke Lake Road and a succession of secondary roads that lead to the old Leechtown site. The former bridge over the upper Sooke River is gone, so it is necessary to ford the river immediately above its junction with the Leech River. The passable roads and main streams are shown on Figure 1. A gate across the new road on the north side of the Leech River is kept locked, and a key was borrowed from the Greater Victoria Water District. The north slope and lower part of the south slope of the Leech River valley are moderate, whereas the upper part of the south slope is bluffy. The river is slightly incised over most of its length. Martins Gulch is actually a V-shaped creek valley with a moderate gradient. Bedrock is well exposed along the beds of the Leech River and Martins Gulch, moderately so in road cuts at lower elevations, and not at all on the upper part of the north slope.

GENERAL GEOLOGY

In this area exposures of the Leech River Formation consist of interbedded black phyllite, light to dark grey siltite, and white to light grey fine-grained quartzite. The siltite constitutes about half the rock and phyllite is least abundant. Most of the beds are thin: phyllite commonly 0.5-1.0 millimetre, siltite 1-5 millimetres, and quartzite 1-3 centimetres. A few quartzite beds are metre-thick, and at one place several beds coalesced to form a unit 10 metres wide. Along the Leech River between Martins Gulch and the end of the new road, these thin-bedded rocks have been closely dragfolded; most of the limbs have been stretched and pinched off, producing a striped and roddy rock. All gradations can be seen between perfectly cylindrical rods, which resemble stretched pebbles, and flanged rods which are clearly the thickened axial parts of dragfolds. These beds have a moderate schistosity parallel to the striping and bedding. Downstream, 680 metres above the haul road bridge, the beds are not dragfolded and are cleaved to slightly schistose. Southwest and west of Macdonald Lake mesoscopic dragfolds are scattered and the beds are only locally schistose. Such folds are abundant up Martins Gulch but not sheared out; the rocks are cleaved to somewhat schistose.

No definite stratigraphic units could be distinguished. Two quartzite units exposed in the Leech River might be traceable but because exposure is largely restricted to the river, the likelihood is not promising.

Thin sheets of slightly gneissic granitic rock intrude the phyllite and siltite in a road cut on the north side of the river about 800 metres west of the haul road bridge.

STRUCTURAL GEOLOGY

Observations of the structural elements are shown on Figure 1. There is a coherent pattern west from Martins Gulch where dragfolds consistently indicate overriding (vergence) toward the south. They have one long upright limb and one short overturned limb. Viewed along the east plunging fold axis, the folds resemble a staircase with narrow treads and high risers. The easterly plunge of the folds decreases westward from 35 degrees at Martins Gulch to 20 degrees at the end of the new road. Furthermore, the bedding generally steepens southward, to near vertical at the mouth of Martins Gulch and is overturned at the west end of the area. Dips of bedding were necessarily measured on the long limbs of the dragfolds, hence the average true dip of a bed is somewhat less where dragfolds were not dismembered. In areas with sheared out folds, the average dip differs little from the true dip.

The Leech River fault was not observed; its trace has been taken from a line of change in topography seen on airphotos. If it were vertical or north-dipping the river would presumably have eroded down along it. Since the trace is part-way up the south slope the fault zone must dip south and has been partially protected from erosion by overhanging erosion-resistant Metchosin basalt. A south dip is also consistent with steepening and overturning of the Leech River beds toward the fault. The fold pattern is consistent with a large flexure in beds that have been downfaulted. The pattern of disrupted dragfolds can be understood if it is assumed that beds on the concave side of the flexure were initially

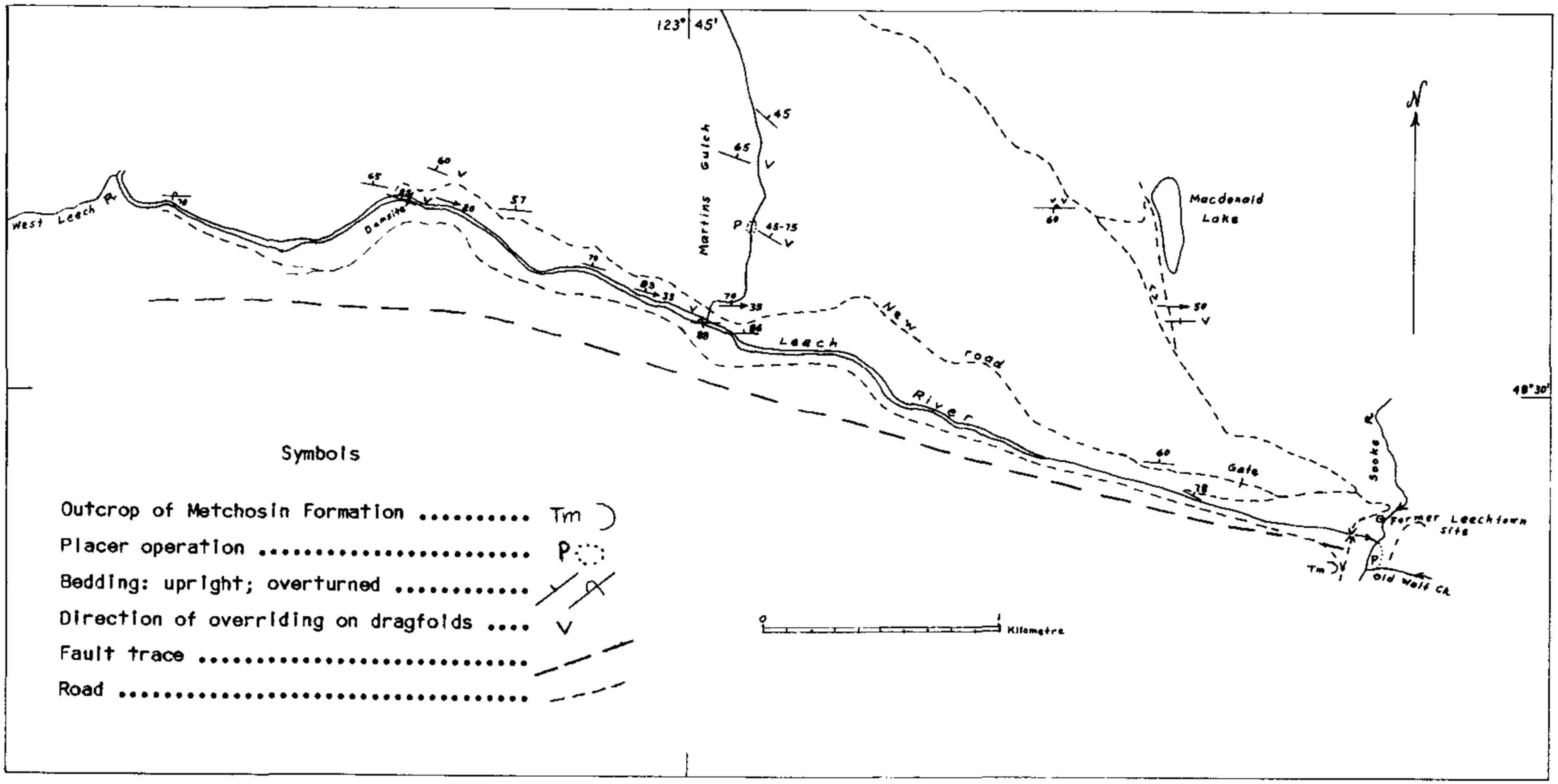

Figure 1. Leech River area.

under compression and responded by dragfolding with relative movement of the upper bed up toward the fault, and subsequently were under tension and stretched as subsidence of the package continued. Thus, on the section of the fault between points opposite the mouths of the west Leech and Martins Gulch the Metchosin Formation has been thrust over the Leech River Formation. The plunge of the dragfolds would indicate an eastward component of movement.

In the eastern part of the area the structural pattern is less clear. Near the Sooke River the fault trace approaches Leech River and the fault may be close to vertical. The vertical and overturned dips south and west of Macdonald Lake appear anomalous and may be unrelated to the faulting. The steep plunge is also difficult to account for. Farther east, near Goldstream, Clapp found that the Leech River fault dips north.

The thin Leech River beds are particularly susceptible to downhill creep. Spectacular examples occur at the end of the road along the north side of the river and at the end of the lower road on the south side. At the first, beds dipping 65 degrees north are curved through horizontal to a gentle south dip at the surface. At the second, beds overturned to 70 degrees south in the river bank are bent over to a gentle south dip (upside down) in the bluff above. Shallow cuts on hillsides cannot be expected to show true dips.

ECONOMIC GEOLOGY

The source of the placer gold remains undetermined. In 1864 the main placer accumulations were found at the mouth of Martins Gulch and at the junction of the Leech and Sooke Rivers. A weekend placer prospector told the writer he had traced gold by panning up the Leech River and Cragg Creek as far as the middle of Survey Mountain, but had found no lode gold on the mountain. The writer's assistant panned a few grains of gold from mid-channel gravel patches opposite the mouth of Martins Gulch, but could find no gold in Leech River gravels immediately above this. The gold grains were well-rounded, almond shaped, and possibly laminated; they could have formed either by deformation of individual nuggets or by pounding together of a number of small flakes. The Razzos had a small placer operation in Martins Gulch but declined to report results. These observations hint at a zone or zones of gold mineralization passing through Survey Mountain and the upper part of Martins Gulch. Several shear zones were seen about the middle of Martins Gulch but they appeared barren. A 1922 report on the Invereck talc deposit on Deception Creek notes that trace gold was found in the talc, and a 1924 report notes that colours of gold can be panned from the gouge between the talc and the enclosing Leech River beds. Quartz veins in Leech River beds are so
A significant post-Nanaimo fault is indicated by the abrupt termination of the basal conglomerate and by a large notch in the river wall. A major component of the movement had to be south side up. Not enough work has been done to indicate its westward extension, and to the east it passes under extensive glacial cover.

The Nanaimo-Sicker contact has been offset 30 metres to the left on a tight vertical fracture which angles across the river bed. A possible thrust in the Nanaimo beds has been noted above. And because the basal grit is not repeated there may be a fault along the south side of the Sicker inlier in the Chemainus River.

ECONOMIC GEOLOGY

No significant mineralization was found. Pyrite occurs in the schist belt and in the mafic volcanic rocks. The shonkinites contain sporadic grains of chalcopyrite.

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GRAVITY SURVEY OF THE COLWOOD SECTION OF THE LEECH RIVER FAULT

By B.N. Church, D. Brasnett, and G.E.P. Eastwood

The purpose of this survey is to determine the position of the Leech River fault in an area of glacial cover between Langford Lake and Esquimalt Lagoon through the Colwood area of greater Victoria.

The approximate position of the fault is known from the early works of Clapp (1912). It crosses 60 kilometres of the southern tip of Vancouver Island, trending in an east-southeast direction from a point near the west entrance of Juan de Fuca Strait to the vicinity of Brochy Ledge in the strait immediately south of the Fairfield-James Bay area of Victoria.

The fault is a major geological boundary that marks the contact between oceanic and continental plates. The success of the gravity survey relies on the density difference between the Metchosin oceanic basalts (specific gravity ~3.0) south of the fault and the Leech River metasedimentary and volcanic rocks (specific gravity ~2.67) to the north.

The survey comprises 43 stations on three northeast-trending lines across the projected course of the fault (Figure 1). The precise route of the survey takes advantage of recently published municipal topographic bench marks (British Columbia Ministry of Environment, Map Project No. 79-087 T-C) and various well-known thoroughfares including Jacklin Road on the west, Lagoon Road on the east, and Wishart Road-Sooke Road-Old Island Highway in the centre. The gravity reference station for the survey is No. 9282-60 with a local gravity value of 980959.31, established on the window sill at the northeast corner of the main Legislative Building in Victoria.

The course and attitude of the fault is defined by inflections in the profile of observed gravity readings (Figure 2a, b, and c). The profile along Jacklin Road is most definitive owing to good spacing of the stations and probably thin glacial cover in this area. One point on the fault is indicated by a sharp inflection in readings observed near station 5. A flat profile on the north passes to a steady increase in gravity values on the south. The profile for the Wishart Road-Sooke Road section which places the fault near station 27 is similar. Control of the exact positions of the fault in this case is not as good owing to a large gap between stations 27 and 28. The Lagoon Road section is least definitive of the three lines showing only a gradual increase in gravity readings to the south. This relatively subdued profile probably results from a great thickness of relatively low specific gravity sand and gravel over the Metchosin basalts. A small notch in the profile near station 38 may mark the position of the fault.

The combined evidence from the three profiles seems to give a fairly accurate location for the Leech River fault through the Colwood area. The fault strikes 117 degrees, bisects Jacklin Road and Esquimalt Lagoon, and

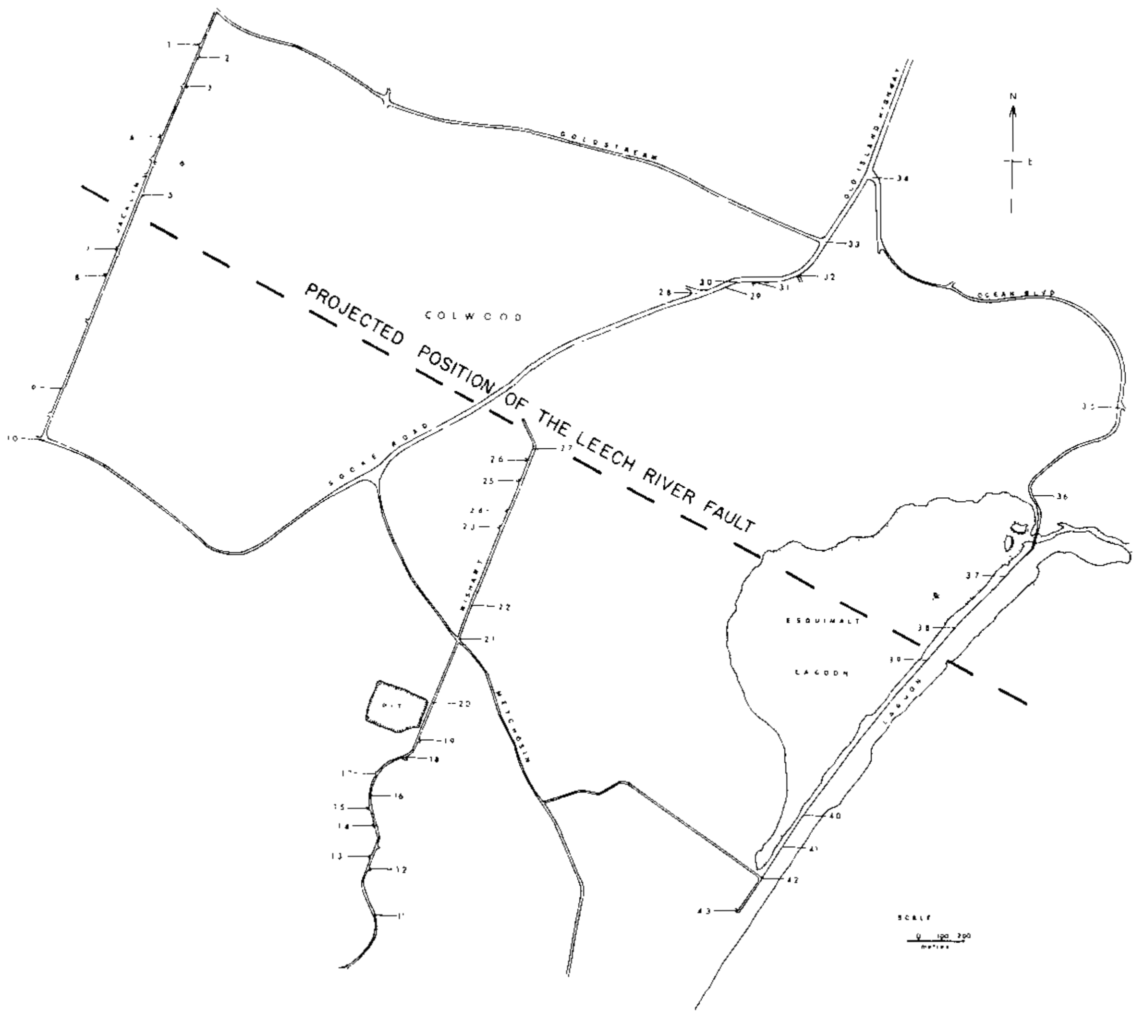

Figure 1. The projected position of the Leech River fault in the Colwood area from gravity stations on the Jacklin Road, Wishart Road-Sooke Road, and Lagoon Road sections.

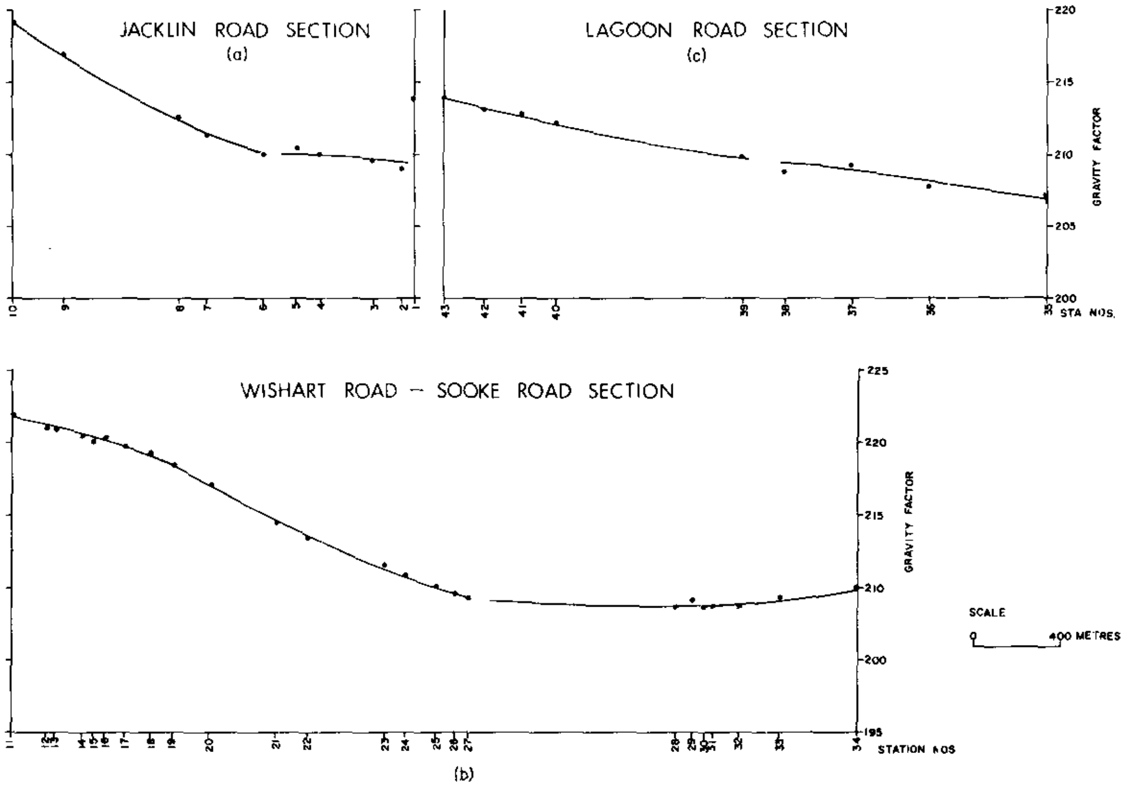

Figure 2. Relative gravity sections in the Colwood area.

passes just north of the north end of Wishart Road. The steady increase in gravity readings south of the fault suggests some decrease in thickness of sialic crust southward and suggests that the fault dips southward. There is no evidence from this study on the direction or magnitude of motion along the fault although the marked geological differences suggest that it is large. It is anticipated that additional gravity readings in the area and careful modelling of the results will provide more information about the attitude and displacement of this important fault.

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GEOLOGY OF THE WHITEHOUSE CREEK AREA

(92B/13f, g)

By G.E.P. Eastwood

INTRODUCTION

The Whitehouse Creek area (Figure 1) overlaps the Mount Richards area on the northwest and represents a continuation of the Sicker mapping project. Some of the mapping was done in 1978 and 1979 but most was done during four weeks in 1981. The principal object of the study is to relate the Sicker rocks north of the Chemainus River to the section established on Mount Richards.

Physiographically the area includes the widening valley of the Chemainus River, the north footslope of Big and Little Sicker Mountains, and the extreme southeast footslope of Mount Brenton. The valley narrows to a notch in the west part of the area. Within it the river has been incised through thick drift and, along most of the included length, deeply into

LEGEND

NANAIMO GROUP

4d	Sandstone dyke
4c	Siltstone and shale
4b	Sandstone
4a	Conglomerate and grit

INTRUSIVE ROCKS

3	Hornblende shonkinite
2	Quartz feldspar porphyry

SICKER GROUP

1d	Quartz-mica schist
1c	Siltite and fine quartzite
1b	Hornblende trachyte
1a	Mafic trachyte; chlorite schist

Symbols

Outcrop; outcrop area .... +

Geological contact ....

Bedding; schistosity ....

Orientation of sandstone dyke ....

Trend and plunge of minor fold; combined with bedding .....

Direction of overriding (vergence) on minor folds ....

Fault ....

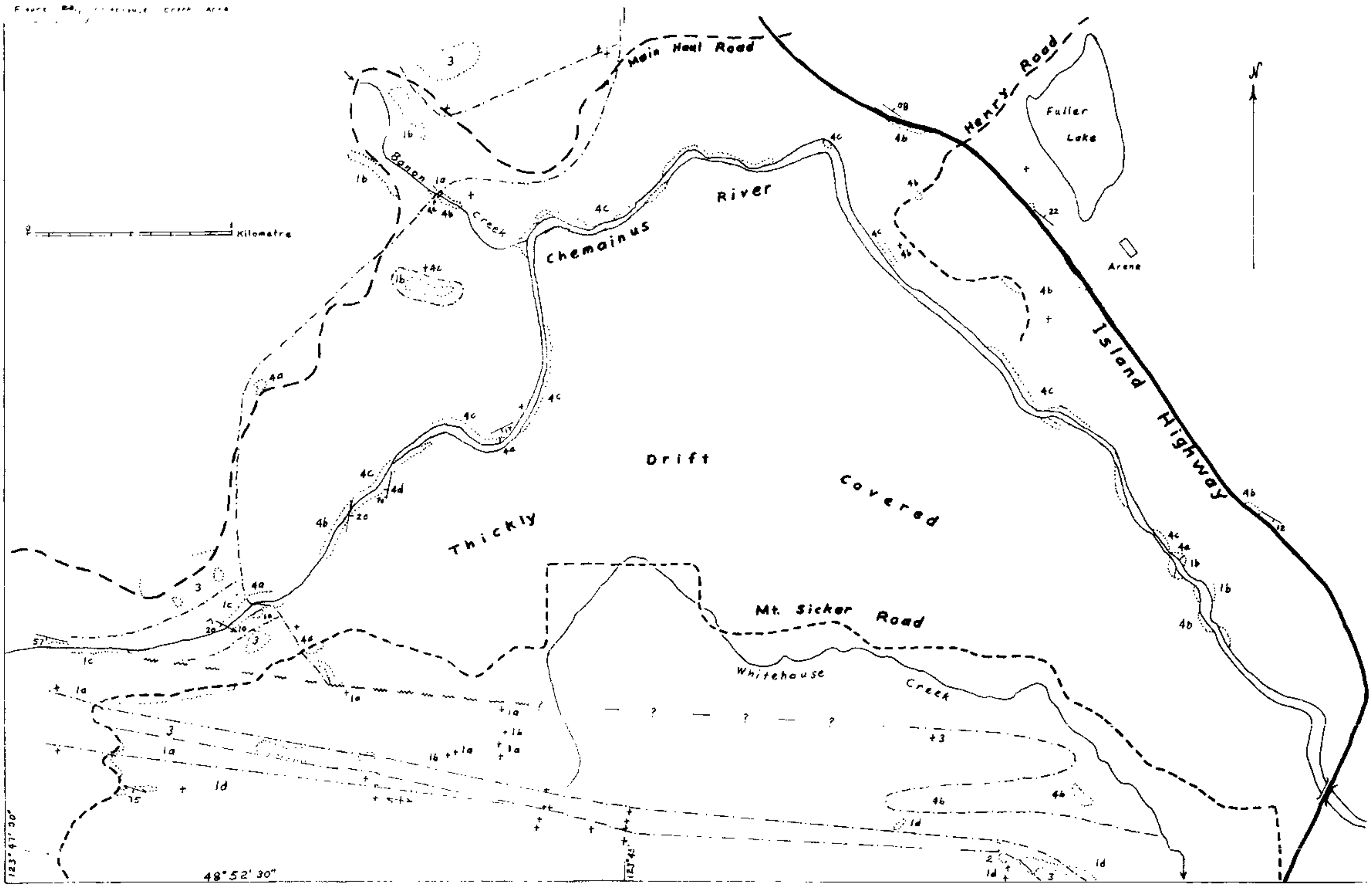

Figure 1. Whitehouse Creek area.

bedrock. In summer it is possible to walk long stretches of the river on bedrock pavement and gravel bars, crossing where necessary by rock-hopping or wading. Two canyons in the west part are inaccessible but the section between them can be reached with the aid of a rope.

Thick drift in the valley extends up the slope of Big Sicker Mountain, and outcrops are mostly confined to a few exposures in watercourses and road cuts. Most of this slope is covered by tall timber, and airphotos are virtually useless. Mapping here was done by altimeter and compass traverses using a contour map at 1:2500 obtained through the courtesy of Serem Limited.

GENERAL GEOLOGY

Volcanic and sedimentary rocks of the Paleozoic Sicker Group have been intruded by small bodies of quartz feldspar porphyry, deformed, then intruded by larger bodies of hornblende shonkinite. The thick Lower Mesozoic section seen elsewhere on Vancouver Island is missing from this area, and the older rocks are directly and unconformably overlain by clastic sedimentary rocks of the Upper Cretaceous Nanaimo Group. The Nanaimo beds form a lobe extending some distance up the ancestral Chemainus River valley.

SICKER GROUP

Trachyte characterized by medium to coarse-grained hornblende phenocrysts is the dominant Sicker rock north of the Upper Cretaceous lobe. It is similar to a band of hornblendic trachyte traced through the Mount Richards area. Outcrops are massive and erosion-resistant, forming low hills and ridges. The outcrop area south of Banon Creek is interpreted as a hill in the pre-Nanaimo surface. The inlier in the lower Chemainus River may be a similar hill or it may represent tilting on a post-Nanaimo fault. Coarse volcanic breccia occurs in the area of hornblendic trachyte in Banon Creek both near the Nanaimo contact and at the base of a transmission pylon east of the creek. It is probable that the hornblendic phase was repeated several times in the volcanic sequence, so the Banon Creek unit cannot be positioned in the sequence from the present mapping.

Mildly deformed sedimentary rocks are exposed in the Chemainus River upstream from the Nanaimo Group basal conglomerate. They consist of dark grey to black argillite, chert-like siltites, and fine-grained light grey quartzite. The siltites are more or less banded in white and shades of grey. A few tuffaceous beds are intercalated. These rocks resemble the upper, sedimentary part, of the Sicker Group in the Cowichan Lake area to the west and are probably somewhat younger than unit 1d of the Mount Richards area. Mafic volcanic rocks appear to overlie these beds in a small bluff south of the Nanaimo contact, but this section is complicated by faulting and the mafic rocks do not occur in an equivalent stratigraphic position in the river bed.

A belt of volcanic rocks occurs south of the Sicker and Nanaimo sedimentary rocks. The volcanic rocks are mostly mafic, though a few thin bands of the hornblendic phase are intercalated. The rocks are variably chloritized and slightly to completely schistose. A hornblende band appears to overlie the Sicker beds in the right bank of the river near the southwest limit of mapping, but the contact is sheared and is close to a projected fault. The position of these mafic volcanic rocks in the Sicker sequence is uncertain.

Unit 1d has been traced along Crofton and Breen Ridges, north of Mount Richards, across the flats, and along the north slope of Big Sicker Mountain to the mine road. Where least deformed, the rock is a white to light grey siltite. Most of it is schistose, and the intensity of schisting increases northward; the outcrops shown on Figure 1 are white to light brown quartz-mica schists. This schist belt is interpreted to be a diffuse fault zone. The largest single movement apparently occurred in the siltites at the contact with the mafic volcanic rocks but the total movement was distributed over a considerable thickness of rock. Bands of chlorite schist indicate that some movement took place in the volcanic rocks. An undisturbed shonkinite dyke angles across the contact, consequently the movement is pre-shonkinite.

INTRUSIVE ROCKS

A few small dykes of quartz feldspar porphyry occur in the schist belt, and are schisted along with the siltites, but none have been found to the north.

Three, or possibly four, bodies of shonkinite (mafic hornblende syenite) were found in the map-area. One extends out of the area to the north and appears to be a stock. A second appears to be a thick sheet dipping gently westward up the Chemainus River. It rests on Sicker sedimentary rocks and is overlapped by Nanaimo sedimentary rocks. A small outcrop south of Whitehouse Creek may represent a faulted segment of this sheet or perhaps a completely separate body. A relatively narrow dyke angles through the schist belt in the south part of the area and appears to be an extension of the much thicker body that underlies Crofton Ridge.

NANAIMO GROUP

The Nanaimo beds are well exposed along the walls and bed of the Chemainus River and sporadically elsewhere. The early sedimentation varied from place to place. Along the west edge of the lobe there is a thick, coarse basal conglomerate. In Banon Creek this conglomerate thins to 30 metres. In both places it is overlain by sandstone which fines upward. In the river near the highway, 4.5 metres of hard grit (granule conglomerate and poorly sorted sandstone) overlies the Sicker rocks. The sandstone and grit are overlain by a thick section of dark grey silt-stones and black shales, which in turn are overlain by fine-grained sand-stone which is exposed along the highway. South of Banon Creek siltstone appears to rest directly on the Sicker inlier. In the Chemainus River south of Banon Creek, a 5-metre grit bed has a discordant strike and rests on rumpled siltstone; it may be the basal unit thrust northwest over the younger beds.

Fossiliferous sandstone dykes cut the siltstones in two places: just above the discordant grit bed, south of Banon Creek in Chemainus River at the place marked 4d. The attitude symbol is for the largest dyke, one which is 20 to 30 centimetres thick. Others are as thin as 5 centimetres and curved. One was seen to bifurcate upward.

STRUCTURAL GEOLOGY

Pre-shonkinite and post-Nanaimo episodes of faulting occurred. In addition the Sicker sedimentary rocks (1c) have been folded and the dip of the Nanaimo beds suggests that the area has been tilted eastward. The overall dip of the Sicker beds is to the south-southwest. A syncline-anticline pair indicate overriding or vergence to the north. A shear zone on the flank of the anticline dips 32 degrees south and is probably a thrust. The timing of this folding and faulting is unclear but it is probably pre-Nanaimo.

The sense of movement in the schist belt is unclear. If the mafic volcanic rocks to the north are correlative with those on Mount Richards then at least a component of the movement was north side up. However, the mafic volcanics may be intercalated in the sediments in this area.

A significant post-Nanaimo fault is indicated by the abrupt termination of the basal conglomerate and by a large notch in the river wall. A major component of the movement had to be south side up. Not enough work has been done to indicate its westward extension, and to the east it passes under extensive glacial cover.

The Nanaimo-Sicker contact has been offset 30 metres to the left on a tight vertical fracture which angles across the river bed. A possible thrust in the Nanaimo beds has been noted above. And because the basal grit is not repeated there may be a fault along the south side of the Sicker inlier in the Chemainus River.

ECONOMIC GEOLOGY

No significant mineralization was found. Pyrite occurs in the schist belt and in the mafic volcanic rocks. The shonkinites contain sporadic grains of chalcopyrite.

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UPPER SUTTON CREEK AREA

(92C/16c)

By G.E.P. Eastwood

INTRODUCTION

This area lies south of Cowichan Lake and may be reached from either Honeymoon Bay or Caycuse by main logging roads. Local access is provided by Truck Road 3, which is badly eroded but was still passable by four-wheel-drive vehicle as far as Sutton Creek in 1981 (see Figure 1).

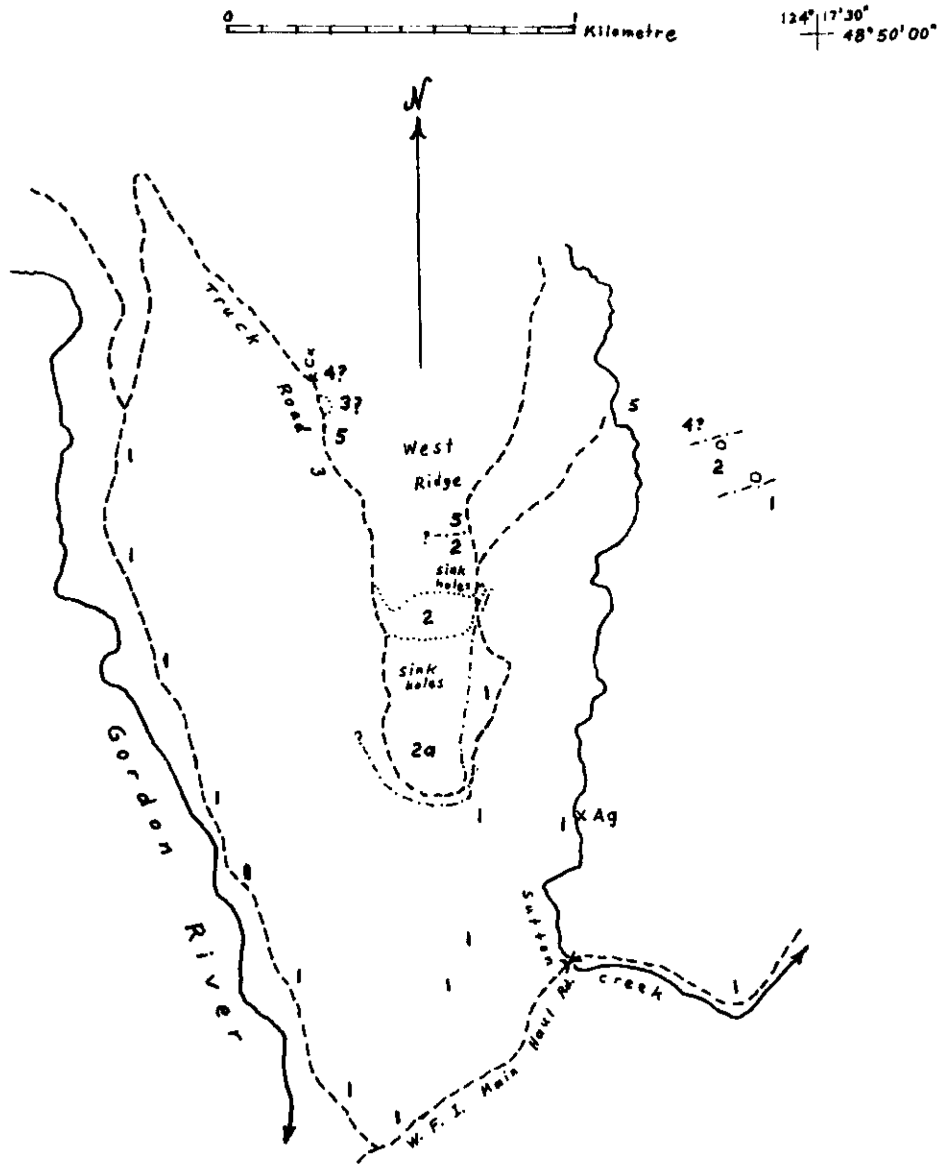
Sutton Creek flows down a steep V-shaped valley between two spur ridges onto a flat-floored valley followed by the main haul road. The west ridge is fairly flat crested. Much of the area is covered with second-growth timber, and growth is thick on the Gordon River slope.

About 1971 Western Forest Industries leased the mineral rights to a tract of land extending westward from upper Sutton Creek from the Esquimalt and Nanaimo Railway. In 1980 the company instructed its prospector, V. Allan, to assess the mineral potential. He asked for assistance with the geology, and the writer spent an aggregate of 13 days in 1981 cruising roads in and east of the area of Figure 1 and mapping on the west ridge. The company kindly provided free accommodation for the writer and his assistant.

GENERAL GEOLOGY

Most of the area between Cowichan Lake and the main haul road is underlain by Bonanza volcanic rocks, but along the section of the Gordon River road (Figure 1) the rocks are dark greenish grey or grey amygdaloidal Karmutsen Formation lavas. On the south nose of the west ridge the rock is generally much sheared and rubbly, a feature characteristic of the Bonanza, but creek exposures show that the rocks are Karmutsen.

A solid mass of blue-grey Quatsino limestone occupies part of the summit and west slope of the west ridge. It is massive, a typical feature of Quatsino limestone that has been moderately metamorphosed. A few andesite dykes occur in the limestone at the north end of the exposure. Both north and south the area is largely covered, but numerous sink holes indicate extension of the limestone. On the south part of the ridge crest small outcrops of limestone are interspersed with outcrops of massive andesite, and limestone is exposed in two road cuts. No limestone was found below the road. In the Kennedy Lake area and elsewhere on Vancouver Island the Quatsino limestone is extensively intruded by massive andesite or basalt, which is believed to represent a resurgence of Karmutsen volcanism. Intrusion into the lower part of the limestone



LEGEND

5 Areas of abundant porphyry dykes
4 Bonanza Formation
3 Parson Bay Formation
2 Quatsino Formation
2a: limestone remnants in intrusive andesite
1 Karmutsen Formation

Symbols

Area of continuous outcrop ....
Inferred formational contact ..
Mineral occurrence x

Figure 1. Upper Sutton Creek area.

on the west ridge has completely disaggregated the limestone so it now occurs as blocks in the andesite. Along the south part of the third leg of Truck Road 3 the rock is mostly amygdaloidal Karmutsen lava. Two outcrops of limestone occur on the east ridge and suggest that the limestone body strikes northeastward. Here the limestone is succeeded to the north by a reddish grey volcanic rock which is assumed to be Bonanza. Near the end of the east branch of Truck Road 3 the reddish rock passes northward to a chert-like rock such as is seen in lower Bonanza in other areas. Westward, the limestone does not reach the Gordon River road within the map-area. It must either be faulted or dip at a low angle to the north and pass under the covered area around the first switchback.

After a covered interval, the second leg of Truck Road 3 cuts through andesite containing bands of limestone and calcareous argillite. Some thin limestone bands are black and resemble Parson Bay Formation, but one comprises 10 metres of thinly banded light grey limestone. This section has no counterpart on the east ridge. The andesite is intruded by a 4.5-metre monzonite dyke and by many small dykes of fine-grained light grey feldspar porphyry. Shear zones cut all the rocks in several directions.

On the east ridge the Bonanza-like rocks are cut by diorite dykes up to 25 metres wide. These in turn are cut by small dykes of feldspar porphyry. At the road junction on the west ridge a similar porphyry dyke intrudes limestone and intrusive andesite, and farther north another intrudes a nondescript grey rock.

STRUCTURAL GEOLOGY

The distribution of the Quatsino limestone suggests that it dips moderately northwestward on the east ridge and gently toward the west-northwest on the west ridge. A flow contact in Karmutsen on the Gordon River road, 365 metres south of the foot of Truck Road 3, strikes east-west and dips 25 degrees north. The banded limestone strikes 050 degrees and dips 55 degrees northwest. However, the belt south of Cowichan Lake is intricately faulted and isolated attitudes may not be significant. Individual shear zones are legion, but no major faults have been demonstrated.

ECONOMIC GEOLOGY

Two mineral occurrences have been found in the map-area. At the point indicated on Truck Road 3 (Figure 1) a little chalcopyrite and arsenopyrite occur with pyrite in a rusty, altered, dense rock. At the point indicated in Sutton Creek a little wire silver occurs with pyrite in a shear zone in Karmutsen lava. However, there is much barren shearing in the area and the prospects are poor. There is also a lack of skarn development in andesite intrusions into Quatsino limestone; such alteration usually occurs where mineralizing solutions migrate through the rocks.

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CAROLIN MINE - COQUIHALLA GOLD BELT PROJECT

(92H/6, 11)

By G.E. RAY

INTRODUCTION

This project was initiated in June 1981, and has been centred around the Carolin gold mine (MDI No. 092H/NW/007), situated approximately 18 kilometres northeast of Hope. The main objectives are:

(1) Regional mapping to outline the relationship between the Coquihalla Serpentine Belt and the adjoining Ladner Group. The contact between these units is of economic interest because the Carolin mine, several former gold producers, and numerous gold occurrences lie close to it. Regional mapping during this initial season was confined to an area stretching 13 kilometres south and 5 kilometres east of the Carolin mine (Figure 1).

(2) Detailed mapping at the Carolin gold mine, with particular emphasis on interpreting the structural history of the rocks hosting the gold mineralization (Figures 2, 3, and 4; Table 1).

(3) Geochemical analysis and, where possible, microfossil identification on rock samples collected from the entire region. Mineralogical and trace element studies will be undertaken on underground ore samples taken from the Idaho Zone at Carolin mine and from other former gold mines in the area.

TABLE 1. STRUCTURAL HISTORY OF THE CAROLIN MINE AREA

F_3	Sporadically developed, minor conjugate folds associated with kink banding and crenulation cleavage.
F_2	Open to tight, disharmonic folds having sub-vertical to easterly dipping, southeast-striking axial planes and northwest to southeast, gently plunging axes. It is the dominant fold episode in the area and is associated with a widespread axial planar slaty cleavage and mineral lineation. Some disruption along fold limbs and axial planes.
F_1	Widespread structural inversion of the Ladner Group and greenstone volcanics, probably related to major recumbent folding. No associated axial plane fabric recognized.
Early to Middle Jurassic ?	Unconformable deposition of the Ladner Group sediments on a greenstone volcanic unit of unknown age.

HISTORY AND PREVIOUS WORK

By the early part of this century, numerous gold-bearing quartz veins had been discovered in rocks adjacent to the eastern edge of the Coquihalla

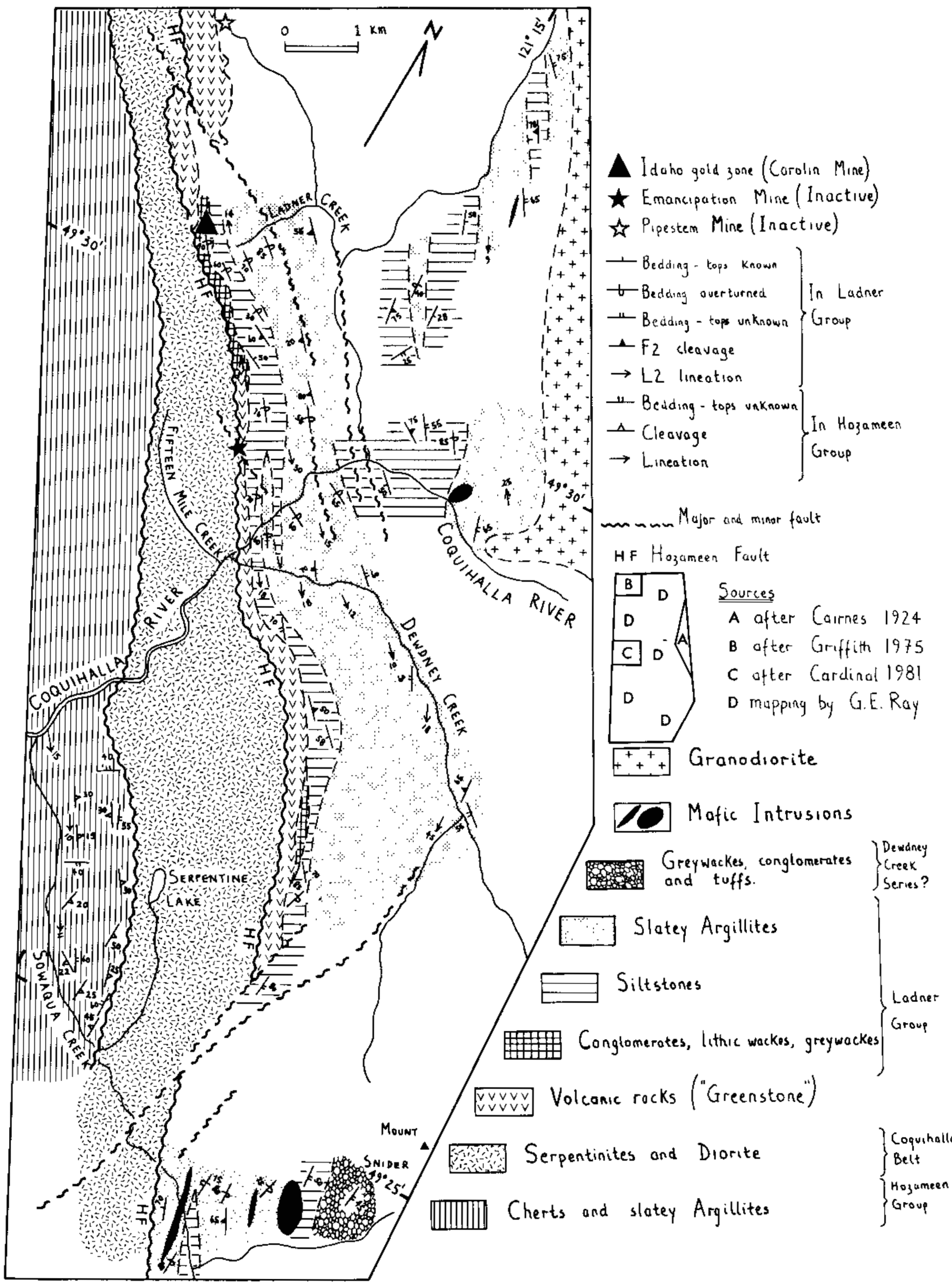

Figure 1. Regional geology of the Coquihalla River area.

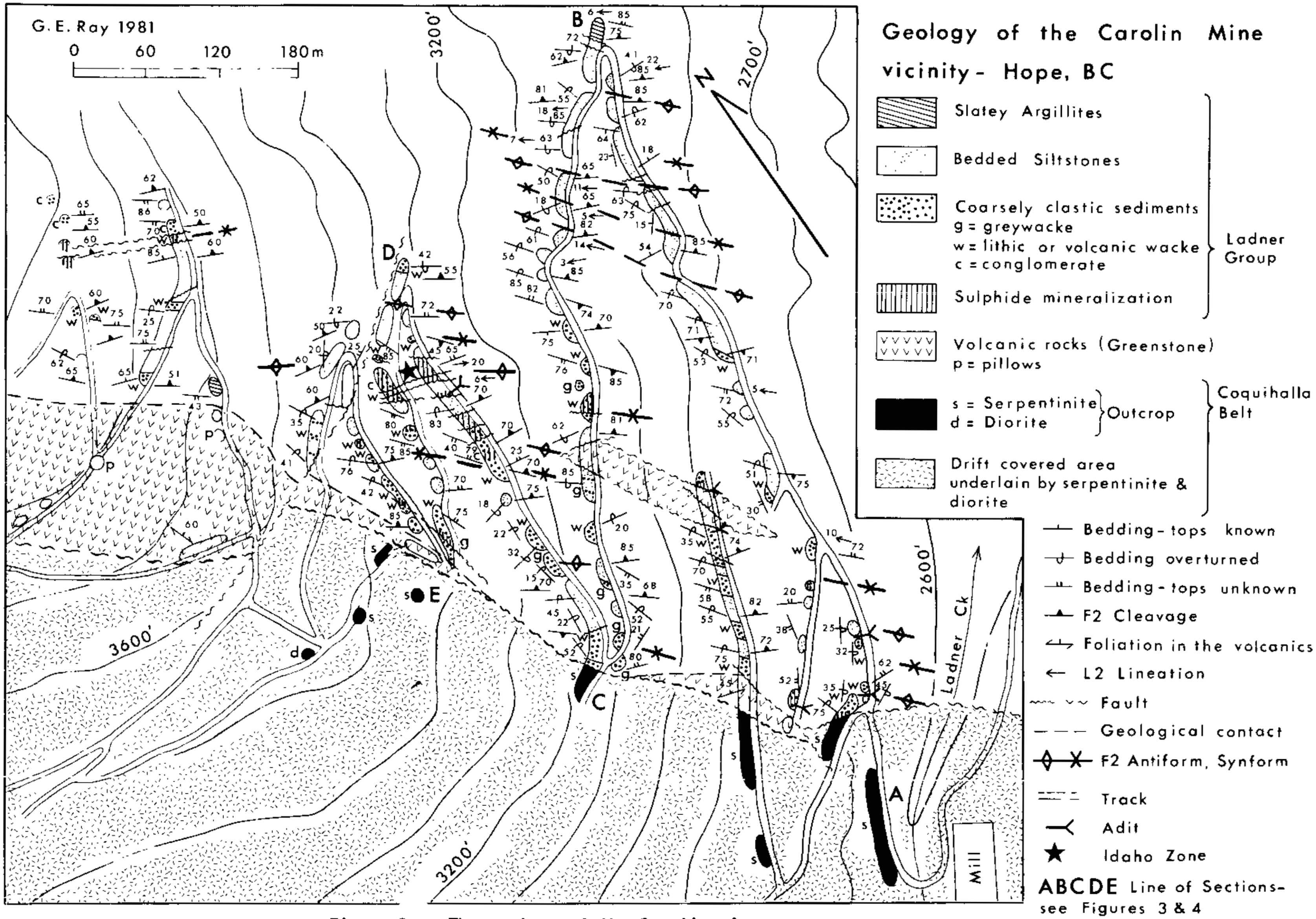

Figure 2. The geology of the Carolin mine area.

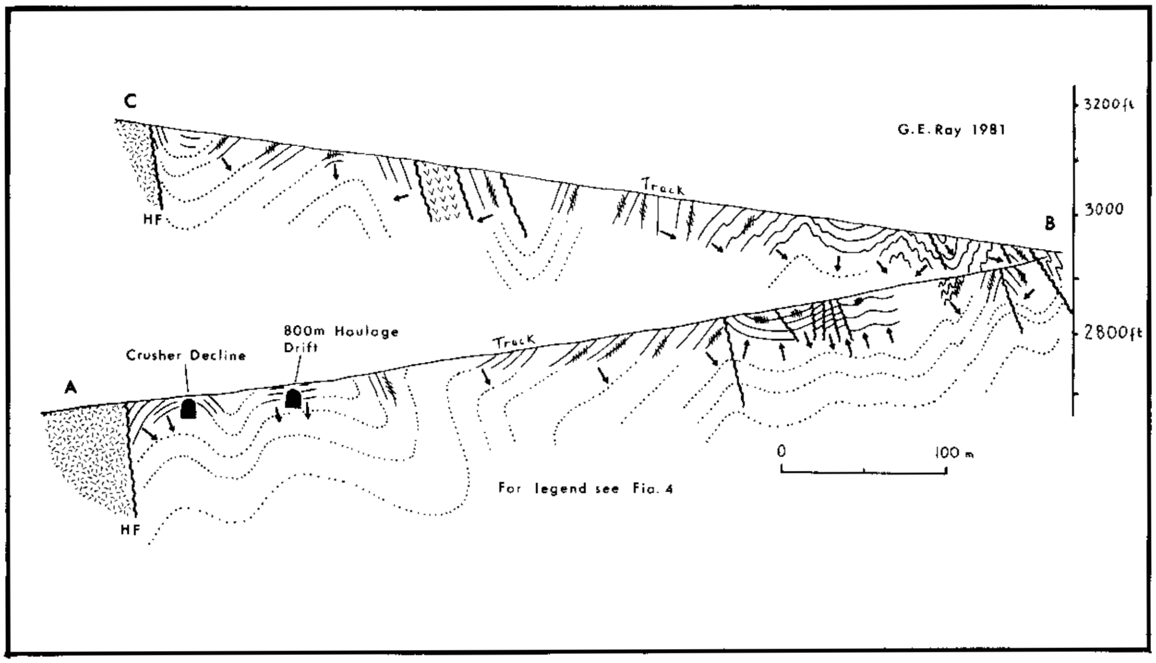

Figure 3. Geological sections AB, BC (see Figure 2) in the Carolin mine area.

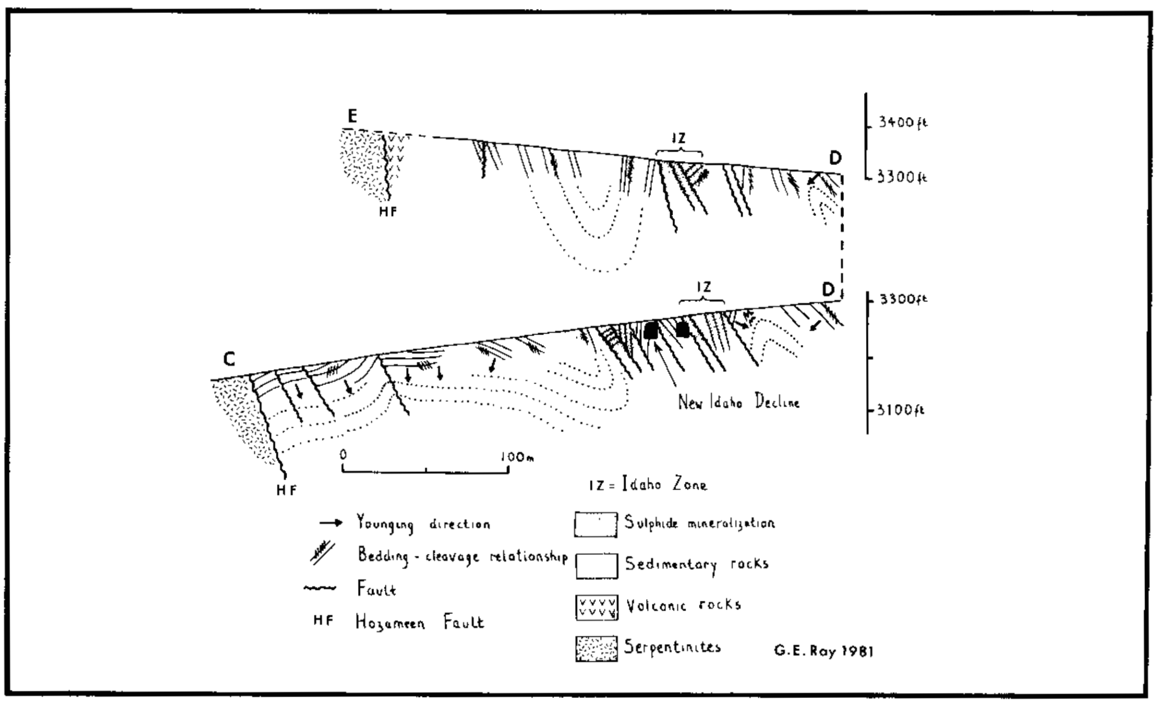

Figure 4. Geological sections CD, DE (see Figure 2) across the Idaho Zone, Carolin mine.

Serpentine Belt. These discoveries eventually led to underground production from three deposits, the Pipestem, Emancipation, and Aurum mines (Figure 1). All three properties are now closed and the mineralization and geology at these sites are described by Cairnes (1924, 1929). Mineralization at the Emancipation mine was in quartz veins cutting altered volcanic rocks whereas at Pipestem the gold-bearing veins cut sedimentary rocks of the Ladner Group. In both deposits gold is associated with silver, pyrite, and arsenopyrite, while pyrrhotite, chalcopyrite, and calcite are reported from the Emancipation property. The Emancipitation area was recently re-examined by Aquarius Resources Ltd. (Cardinal, 1981).

In 1927, the Aurum gold mine was discovered just south of the Idaho Zone. Spectacular values of free gold, hosted in a talcose shear, were found in the Hozameen fault which is a major fracture marking the eastern margin of the Coquihalla Serpentine Belt. At Aurum, gold is associated with pyrrhotite, pyrite, chalcopyrite, arsenopyrite, and possibly millerite (Cairnes, 1929).

Surface exposures of the Idaho Zone (Figure 4), the gold deposit which comprises the current Carolin mine operation, were originally described by Cairnes (1929). At that time the gold values were not economic but the increased price of gold in the early 1970's led Carolin Mines Ltd. to conduct a major exploration and development program on the property. Current outlined ore reserves are as follows:

Tonnes	Oz./tonne	Cut-off Grade
2 000 000	0.128	0.05 oz./ton Au
1 500 000	0.141	0.08 oz./ton Au

Carolin mine started production in December 1981, and the mill should handle approximately 1,500 short tons of ore per day.

Brief details on the geology of the Idaho Zone were given by Barr (1980), but most work on the deposit is in unpublished form; this includes work by Cochrane, et al. (1974), Griffiths (1975), and a mineralogical and petrographic study on the ore zone by Kayira (1975).

The regional geology, involving early major work by Cairnes (1924, 1929), was compiled by Monger (1970). Additional work relevant to the area includes that by McTaggart and Thompson (1967), Coates (1970, 1974), and Anderson (1976).

REGIONAL GEOLOGY

In the Carolin mine vicinity, the Coquihalla Serpentine Belt forms an elongate north-northwest-trending unit that separates rocks of the Ladner and Hozameen Groups to the east and west respectively (Figure 1); both margins of the belt appear to represent major long-lived tectonic fractures. In the Coquihalla River area, the belt exceeds 2 kilometres in width, but it gradually thins to the north and south until in the

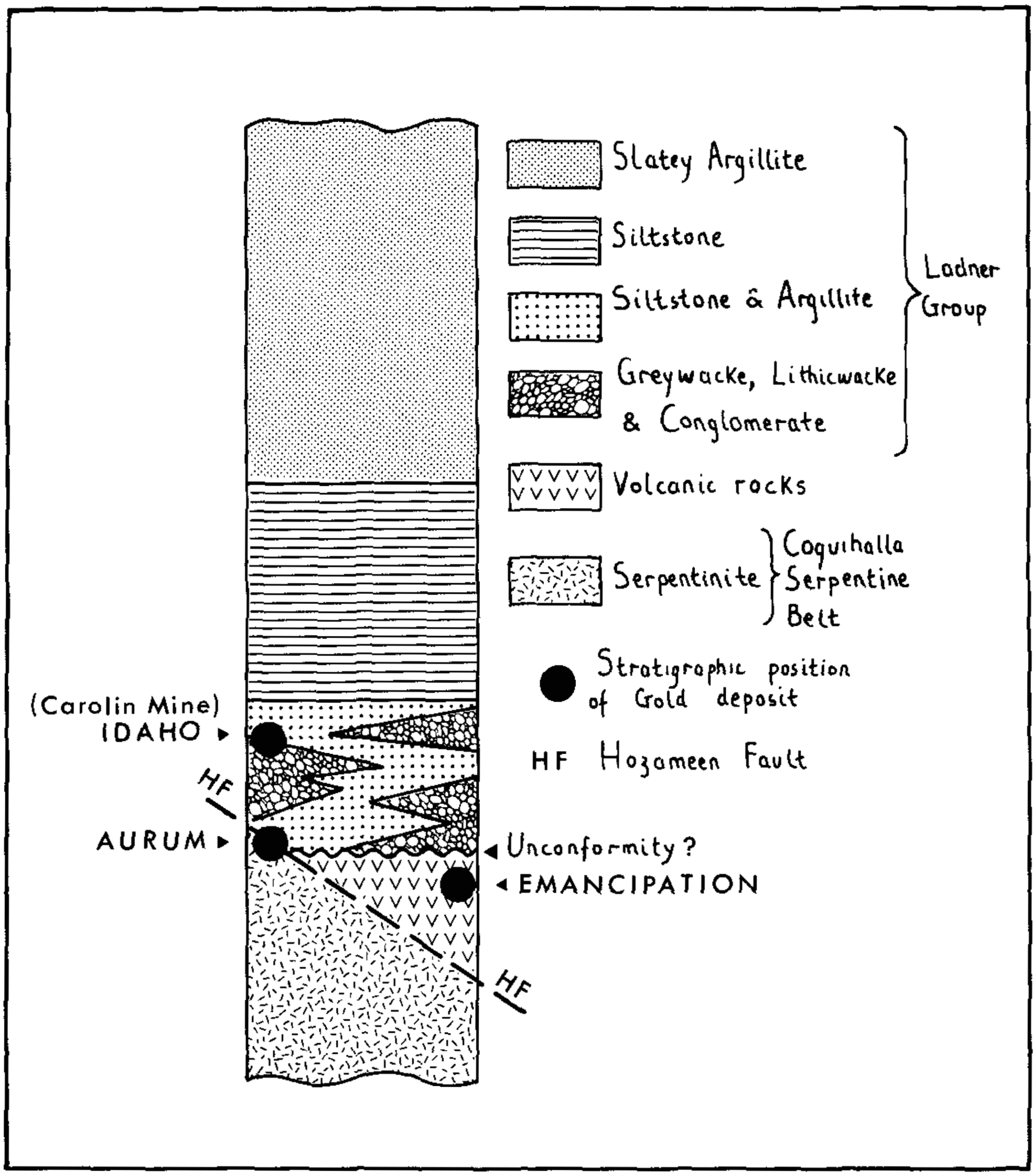

Figure 5. Schematic stratigraphic succession in the Carolin mine area (not to scale): (1) F_2 folding of the Ladner Group sedimentary rocks containing carbonaceous argillites (black); (2) late F_2 high-angle reverse faulting localized along the carbonaceous horizon (black) within the F_2 fold limb; (3) hydrothermal epigenetic emplacement of sulphide-gold mineralization (stippled) along the fault shatter zone; and (3) late normal faulting (F) causing displacement of the mineralized zone.

Boston Bar and Manning Park areas (Monger, 1970; Coates, 1974) the Hozameen and Ladner Groups are in direct fault contact. The Hozameen Fault marks the eastern boundary of the belt while the fracture along the belt's western margin (Figure 1) is currently unnamed. Near Carolin mine the belt is dominated by two major rock types: massive dark serpentinite of probable peridotite parentage (Cairnes, 1929) and medium to coarse-grained, massive and highly altered hornblende diorite. The basalts, diabases, and multiple sheeted dykes observed by Anderson (1976) were not seen in this portion of the belt.

Serpentinite is the dominant rock type and characterizes the belt, except in the Serpentine Lake vicinity (Figure 1) where diorite is abundant and forms sub-parallel sheets and lenses up to 250 metres in width. The age and genetic relationships between these two rock types are unknown because their rarely observed contacts are highly sheared.

The Hozameen Group in the map-area consists of phyllitic argillites interlayered with both massive and ribbon cherts. They have been subjected to intense deformation and lower greenschist metamorphism, and other than the ribbon layering in the cherts, no sedimentary structures have been positively identified. Some schistose argillites contain highly deformed clasts, but it is uncertain whether these represent sedimentary or tectonic features. Elsewhere, the Hozameen Group includes spillitic basalts (greenstones) and minor limestones interlayered with cherts and pelites (Daly, 1912; Cairnes, 1924; McTaggart and Thompson, 1967; Monger, 1970). Monger (1975) interprets the group as a supracrustal oceanic sequence of possibly Triassic or pre-Triassic age.

The Ladner Group (Cairnes, 1924) consists of a thick sequence of fine-grained, poorly bedded, black slaty argillites and well-bedded, grey-coloured siltstones with minor amounts of coarse clastic sedimentary rocks. Most outcrops show evidence of low grade metamorphism with the imposition of a weak to intense slaty cleavage, but in many instances the original sedimentary structures are clearly preserved. Graded bedding is commonly observed in the siltstones and coarse clastic units, while other, less common, sedimentary structures present include cross-bedding, ripple marking, scouring, flame, load cast, ball and pillow structures, and chaotic slumping. Graded bedding and scour structures indicate that most Ladner Group rocks adjacent to the Serpentine Belt, including those hosting the gold mineralization at Carolin mine, are structurally inverted (Figures 3 and 4).

A broad stratigraphic sequence is recognized in the Ladner Group consisting of a thin, lowermost unit characterized by a heterogeneous assortment of coarse clastic, partly volcanogenic, sedimentary rocks, that pass upwards into a thicker sequence of fine to medium grained well bedded siltstones. These are overlain in turn by a thick unit of very fine-grained, organic, and iron-rich argillites (Figure 5). The lower clastic unit hosts the Carolin gold mineralization; it includes discontinuous wedges of greywacke, lithic wacke, conglomerate, and possible reworked tuffs with intervening units of argillite and finely bedded volcanogenic siltstones. Pebbles of volcanic origin are common with lesser amounts of quartz, jasper, and chert; one extensive conglomerate unit contains fragments of limestone that are derived from an unknown source. Cochrane, et al. (1974) mentions possible welded tuffs and volcanic bombs in the lowermost section, while Anderson (1976) notes the presence of 'serpentine (clasts) recognizably derived from Coquihalla Belt rocks' but these observations were not verified in this study. The overall upward fining of the Ladner Group suggests a progressive temporal change from shallow to deeper water conditions. The initial rapid and chaotic deposition of near-shore clastics was superceded by early siltstones (proximal turbidites) and later argillites (distal turbidites).

The Ladner Group overlies a volcanic greenstone (Figure 5) of unknown age, whose relationship to the other major rock units in the area is controversial (see Discussion). Consequently, the greenstone is provisionally separated from the Ladner Group (Figures 1, 2, and 5). This greenstone unit can be traced discontinuously for 13 kilometres along the eastern side of the Hozameen fault, and now structurally overlies the Ladner Group because of the regional tectonic inversion. Thus, its thickest development, up to 400 metres in outcrop width, occurs on higher ground, while along the bottom of the Ladner Creek valley, south of Carolin mine the unit disappears, and the Ladner Group is in faulted contact with the Coquihalla Serpentine Belt (Figure 1). The greenstone is a highly altered, fine to medium grained rock of probable andesitic composition (Cairnes, 1924). Outcrops vary from massive to very weakly layered and, in places, excellent pillow structures are preserved with some interpillow breccias, which in one instance include chert clasts. Many greenstone outcrops contain numerous dark green angular fragments, in a lighter green matrix which could represent evidence of autobrecciation within the lavas. Some greenstones north of Carolin mine also show evidence of tectonic brecciation and shearing (Shearer, pers. comm.).

In the vicinity of the Emancipation mine, the Ladner Group and the greenstones are separated by a fault whereas further south the contact appears to represent an unconformity. Near the junction of Dewdney Creek and the Coquihalla River, the pillowed greenstones are overlain directly by finely laminated, volcanogenic siltstones of the Ladner Group, but northeast of Serpentine Lake the contact is marked by a coarse conglomerate varying from 1 to 200 metres in outcrop width (Figure 1).

A variety of intrusive rocks cut the Ladner Group. East of Ladner Creek the metasediments are intruded by the Needle Peak Pluton which has been dated at 39 Ma by K-Ar methods (Monger, 1970). The metasediments adjacent to this granodiorite body are characterized by a thermal metamorphic aureole up to 0.75 kilometre wide, which is marked by the growth of biotite and cordierite.

Other intrusive rocks within the Ladner Group are broadly separable into granitic and mafic types. The latter form dykes, sills and sub-rounded masses up to 0.3 kilometre in width that comprise a highly varied suite ranging from leucogabbroic to ultramafic rocks (Figure 1). Granitic intrusive rocks form narrow dykes and sills generally less than 10 metres wide that have been mapped as either quartz or feldspar porphyries; the latter are locally of syenitic composition (Cairnes, 1924). Some dykes contain disseminated pyrite and arsenopyrite and are cut by quartz veining; Cairnes (1924, 1929) considered these bodies to be genetically related to some of the reef-hosted gold in the district.

GEOLOGY AND STRUCTURAL HISTORY OF THE CAROLIN MINE VICINITY

The surface geology around the Carolin mine is shown on Figure 2 and the structural history of the area summarized on Figure 6 and in Table 1. The Hozameen Fault dips steeply northeast, and detailed geological sections across the mine area reveal that most of the stratigraphic sequence, including that hosting the gold-bearing Idaho Zone, is structurally inverted (Figures 3 and 4). After this early F_1 tectonic overturning, the supracrustal rocks were deformed by the F_2 folding and overprinted by a weak to intense slaty cleavage which forms the dominant tectonic foliation in area. Thus, the slaty cleavage was imposed on inverted beds. Several generations of fault movement subsequently occurred, particularly along the F_2 fold axial planes and limbs. An early phase of fault shattering appears to be spatially related to several zones of alteration which are marked by either quartz, calcite, or feldspar veining and pervasive sulphide mineralization (Figure 4). However, most of the fractures shown on Figures 3 and 4 belong to a later phase of generally normal faulting which post-dates and displaces the earlier alteration zones. The Idaho Zone (Figure 4), 150 metres east of the Hozameen fault, forms the largest surface exposure of alteration and is the only one to date in which economic gold mineralization has been found. At a cut-off grade of 0.05 ounce per ton gold it appears to form an irregular, steeply inclined ore body approximately 35 metres wide, 100 metres deep, and over 300 metres in length which is still open down plunge (R. Niels, pers. comm.). The deposit passes upward into unmineralized chloritic schists, and the top of the ore zone plunges gently northward at approximately 25 degrees (W. Clarke, pers. comm.). The predominant mineral assemblage in the zone comprises quartz, plagioclase (An_{4-6}), carbonate, chlorite, pyrrhotite, arsenopyrite, and pyrite; other rarer opaque minerals, in decreasing order of abundance, include magnetite, chalcopyrite, bornite, and gold (Kayira, 1975). In outcrop, the zone is characterized by abundant sulphides, intense hydrothermal alteration which weathers to give a distinctive black or grey-coloured rock, and a multi-stage network of quartz, calcite and albite veining. Many veins are orientated parallel to the slaty cleavage, demonstrating that some alteration in the Idaho Zone post-dates the main F_2 structural event. Mineralization involved the spasmodic introduction of silica, carbonate, Na, Fe, Cu, As, Mo, Sb, and Au, and Table 2 shows the results of some trace element analyses completed on fresh, underground samples collected from mineralized and unmineralized portions of the Idaho Zone. Cochrane (pers. comm.) notes that soils over the surface exposures of the Idaho Zone contain anomalous mercury values, but underground ore samples (Table 2) show no significant enrichment in this element. Thus a vertical zoning of mercury could exist in the deposit.

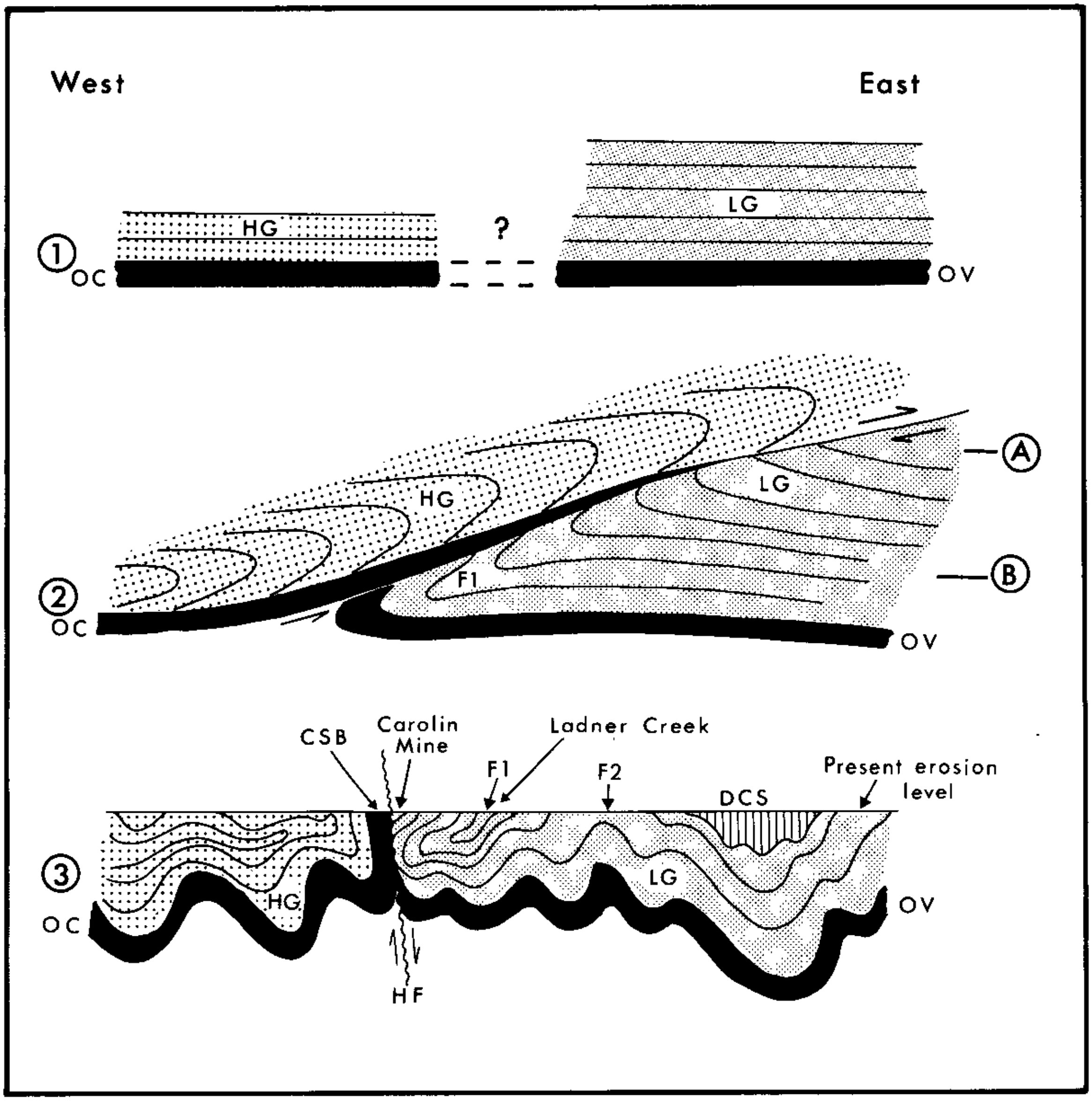

Figure 6. Postulated evolutionary history of the Coquihalla Serpentine Belt:

(1) pre-Triassic to Triassic deposition of the Hozameen Group (HG) oceanic supracrustal rocks (Monger, 1975). Jurassic (Cairnes, 1924; Coates, 1974) deposition of the Ladner Group (LG) arc trench gap sediments onto ocean volcanic rocks (Anderson, 1976). OC = oceanic crust; OV = oceanic volcanic rocks.

(2) eastward overthrusting of the Hozameen Group along a horizon of serpentinized ocean crust causing F_1 structural inversion in the Manning Park area (Coates, 1974); B = present erosion level in the Carolin mine area.

(3) F_2 folding resulting in a steepening of all units including the Coquihalla Serpentine Belt (CSB), with later development of the Hozameen fault (HF). DCS = Dewdney Creek Series (Cairnes, 1924). NOTE: Granitic plutons omitted; length of section 3 approximately 15 kilometres.

TABLE 2. TRACE ELEMENT ANALYSES ON FRESH UNDERGROUND SAMPLES COLLECTED FROM CAROLIN MINE

	Sample No.	Au[1] ppm	Ag[1] ppm	As[2] per cent	Co[2] ppm	Cu[2] ppm	Pb[2] ppm	Sb[2] ppm	Mo[2] ppm	Hg[3] ppb	Sn[4] ppm	Ba[2] ppm
1.	25163M	17.5	<10	6.23	19	89	21	185	75	72	<1	<100
2.	25164M	16.0	<10	0.46	13	81	15	13	20	112	<1	<100
3.	25167M	3.5	<10	1.18	20	161	15	<10	<2	78	<1	155
4.	25169M	17.5	<10	6.27	18	88	20	185	75	82	<1	150
5.	25168M	<1	<10	0.007	12	49	16	<10	<2	76	<1	1184
6.	25165M	<0.3	<10	0.07	3	40	9	<10	5	108	<1	<100
7.	25166M	<0.3	<10	0.005	3	34	27	<10	<2	182	<1	<100

[1]Fire assay; [2]atomic absorption; [3]cold vapour; [4]emission vapour.

1. Idaho Zone material with abundant sulphides and veining; collected from the 900-metre drift.
2. Idaho Zone material with abundant sulphides and veining; collected from the 900-metre slot.
3. Idaho Zone material with abundant sulphides and veining; collected from the 850-metre slot.
4. Idaho Zone material with abundant sulphides and veining; collected from the 900-metre slot crosscut.
5. Unmineralized greywacke adjacent to the Idaho Zone; abundant feldspar and quartz veining but no sulphides; collected from the 835-metre north scram.
6. Sample of 10-centimetre-wide white quartz vein cutting mineralized Idaho Zone; collected from the face of the 900-metre perimeter drift (east).
7. Sample of white calcite veins cutting mineralized Idaho Zone; collected from the end of the 875-metre perimeter drift (west).

Analyses completed at the Analytical Laboratory, British Columbia Ministry of Energy, Mines and Petroleum Resources.

The exact controls of mineralization are unknown. Clarke (pers. comm.) notes that selective replacement has occurred in the ore zone with preferential enrichment of the more brittle, coarse-grained sediments and a tendency for less mineralization to be present in the finer grained argillites. Detailed surface mapping indicates that the Idaho Zone is located close to the disrupted limb of an F_2 fold (Figure 4) and it is noteworthy that the top of the ore zone and the F_2 fold axes both have very similar plunges. Consequently, the Idaho Zone is believed to represent an epithermal replacement deposit (Kayira, 1975) that was laid down along a high-angle reverse fracture of late F_2 age (Figure 7). The presence of carbonaceous metasediments adjacent to the orebody (Cochrane, et al., 1974; Kayira, 1975) could also be significant. Initially this incompetent horizon may have localized the reverse fault movements and later provided a favorable reducing geochemical environment

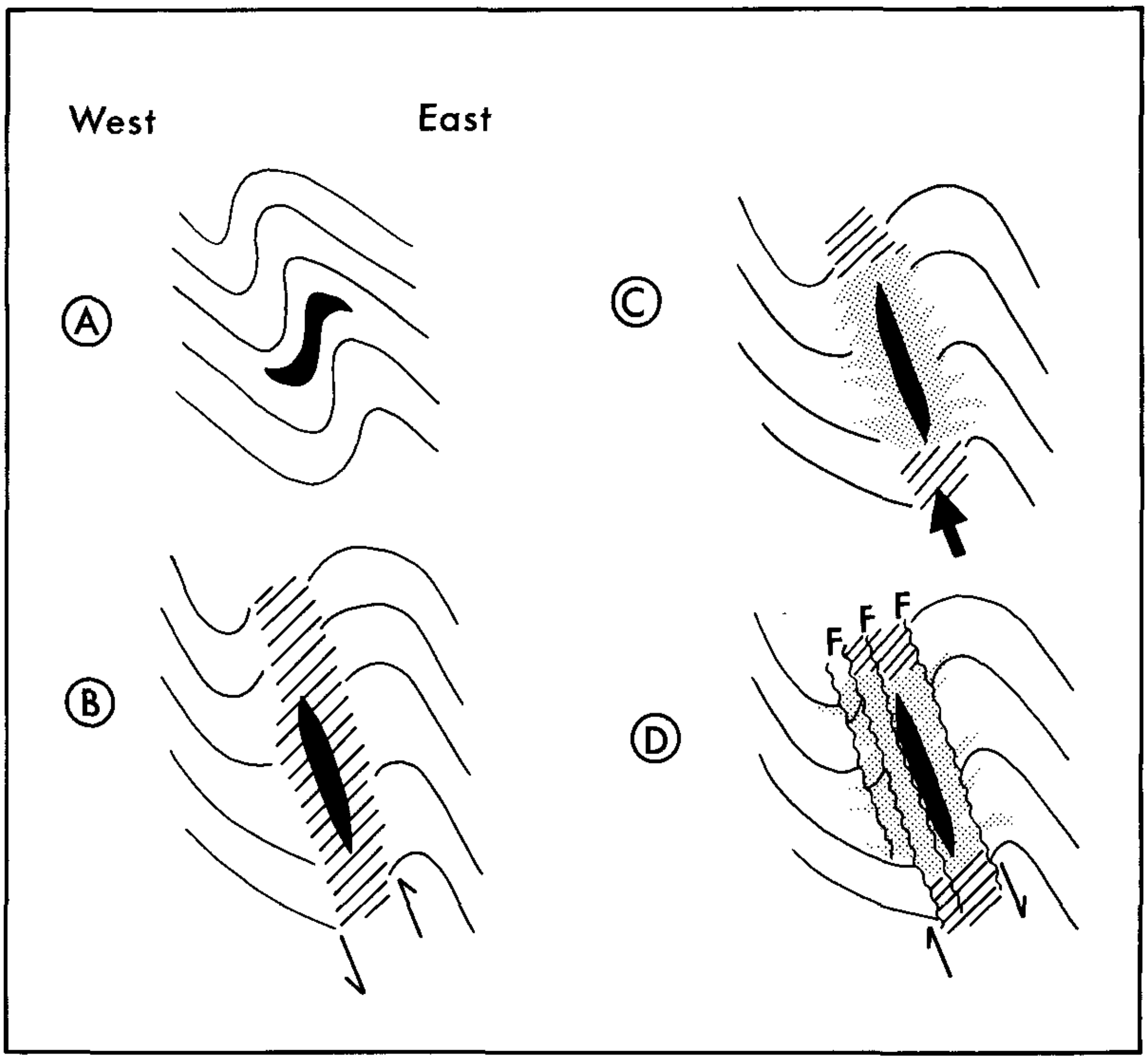

Figure 7. Postulated development of the Idaho Zone, Carolin mine.

for the deposition of sulphides and gold when hydrothermal solutions passed up the fracture (Figure 7). This postulated lithostructural control of the gold mineralization may help outline underground extensions of the Idaho Zone and assist exploration for similar deposits in the region. Subsequent to gold emplacement, late normal faulting rejuvenated the mineralized, pre-existing fracture zone. This intense late faulting cut the orebody (R. Niels, pers. comm.) but apparently played no role in ore genesis (Figure 7).

DISCUSSION

The pillowed volcanic greenstones which separate the Ladner Group from the Hozameen fault in the Carolin mine area are a problematic unit because the following stratigraphic relationships are possible:

(1) They could form part of the oceanic supracrustal Hozameen Group as suggested by Cairnes (1924). However, this seems unlikely because they are separated by the fault-bounded Coquihalla Serpentine Belt, which has probably been the locus of major tectonic movements.

(2) They could belong to the Coquihalla Serpentine Belt, a possible oceanic crustal assemblage, as advocated by Anderson (1976). This interpretation would suggest that relatively minor movements occurred along the Hozameen Fault, and that the Ladner Group unconformably overlies an older oceanic volcanic basement. This possibility is indirectly supported by observations in the Emancipation mine area where the volcanic rocks are intruded by diorite bodies (Cairnes, 1924, 1929) that bear a superficial resemblance to diorites within the Coquihalla Serpentine Belt (Cardinal, pers. comm.), while these intrusives have not been observed cutting the Ladner Group. Furthermore, no proof exists that volcanism occurred during the Ladner Group sedimentation in this area, and the volcanogenic character of the coarsely clastic, lowermost sediments may merely reflect their erosional derivation from an older volcanic terrane.

(3) The greenstones may have no genetic relationship with any rocks west of the Hozameen fault, and instead represent the lowest exposed portion of the Ladner Group, as suggested by Cochrane (pers. comm.). If this is correct, the volcanic-sedimentary unconformity is probably of relatively minor importance.

Detailed structural mapping along the Coquihalla River suggests that the volcano-sedimentary sequence between Ladner Creek and the Hozameen fault occupies the inverted limb of a major F_1 synform which is overturned to the east and whose axial trace probably lies along Ladner Creek (Figure 6). Further southeast, in Manning Park, the Coquihalla Serpentine Belt is absent and the Ladner Group forms an essentially upright sequence even adjacent to the Hozameen fault (Coates, 1974). Thus, the tectonic inversion of the Ladner Group appears to be spatially related to the Coquihalla Serpentine Belt rather than the Hozameen fault. This raises the possibility that the belt and the F_1 recumbent folding share a genetic relationship. One possible explanation is that the Coquihalla Serpentine Belt originated as a thin, sub-horizontal unit of obducted oceanic crust over which the Hozameen Group was thrust in an easterly direction (Figure 6). Serpentinization presumably accompanied this movement with the belt forming the lubricated, sub-horizontal sole below a nappe structure whose easterly transport resulted in the F_1 tectonic inversion of the underlying Ladner Group (Figure 6). This mechanism would explain the absence of a F_1 tectonic foliation in the Ladner Group which was probably unlithified and not deeply buried during this overturning event. Subsequent F_2 deformation caused a refolding of the F_1 synformal structure (Figure 6) and steepened the Coquihalla Serpentine Belt into its present sub-vertical position, as suggested by McTaggart and Thompson (1967) and Anderson (1976). This model implies that major tectonic dislocations occurred along both margins of the Serpentine Belt and that the Hozameen fault is a late, normal and relatively minor fracture lying close to one of the early thrust planes (Figure 6). If this interpretation is correct, other 'Alpine-type' serpentine belts in the region may also represent obducted oceanic material marking early, refolded thrust zones.

CONCLUSIONS

The Carolin mine orebody (Idaho Zone) is hosted in a structurally inverted sequence of Ladner Group sedimentary rocks, close to their faulted contact with the Coquihalla Serpentine Belt.

The Idaho Zone represents hydrothermal replacement mineralization that involved the multistage introduction of silica, carbonate, Na, Fe, As, Mo, Sb, Cu, and Au.

Mineralization was emplaced along an early reverse fault that occupies the disrupted limb of an overturned fold. Incompetent carbonaceous sedimentary rocks lying close to the ore zone may have localized the reverse faulting and geochemically controlled the subsequent gold mineralization.

The widespread tectonic inversion of the Ladner Group appears to be spatially and genetically related to the Coquihalla Serpentine Belt. The Belt could represent oceanic crust that was obducted and serpentinized during easterly directed, subhorizontal thrusting. These movements caused the structural inversion in the Ladner Group and subsequent folding steepened the belt into its present sub-vertical position.

ACKNOWLEDGMENTS

The author wishes to thank the management and staff of Carolin Mines Ltd. and Aquarius Resources Ltd. for their willing cooperation and help in this project, particularly D.G. Cardinal, R.J.E. Niels, P.W. Richardson, and J.T. Shearer. Stimulating discussions in the field with W.E. Clarke, D.R. Cochrane, T. Höy, W.J. McMillan, J.W.H. Monger, and A. Sutherland Brown are gratefully acknowledged while Patrick Desjardins gave invaluable support as a geological assistant.

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AGE OF THE COLDWATER STOCK AND NICOLA BATHOLITH, NEAR MERRITT (92H)

By W.J. McMillan
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and
R.L. Armstrong and J. Harakal,
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The Coldwater stock intrudes Late Triassic Nicola Group volcanic rocks (Figure 1). A previous attempt to date the stock by K-Ar methods gave discordant results of 215 to 234 and 267 Ma (Preto, et al., 1979). Stratigraphically, this apparent age was difficult to reconcile. Consequently, a series of samples was collected (Table 1; Figure 1) and subsequently analysed by K-Ar and Rb-Sr methods (Table 2; Figure 1).

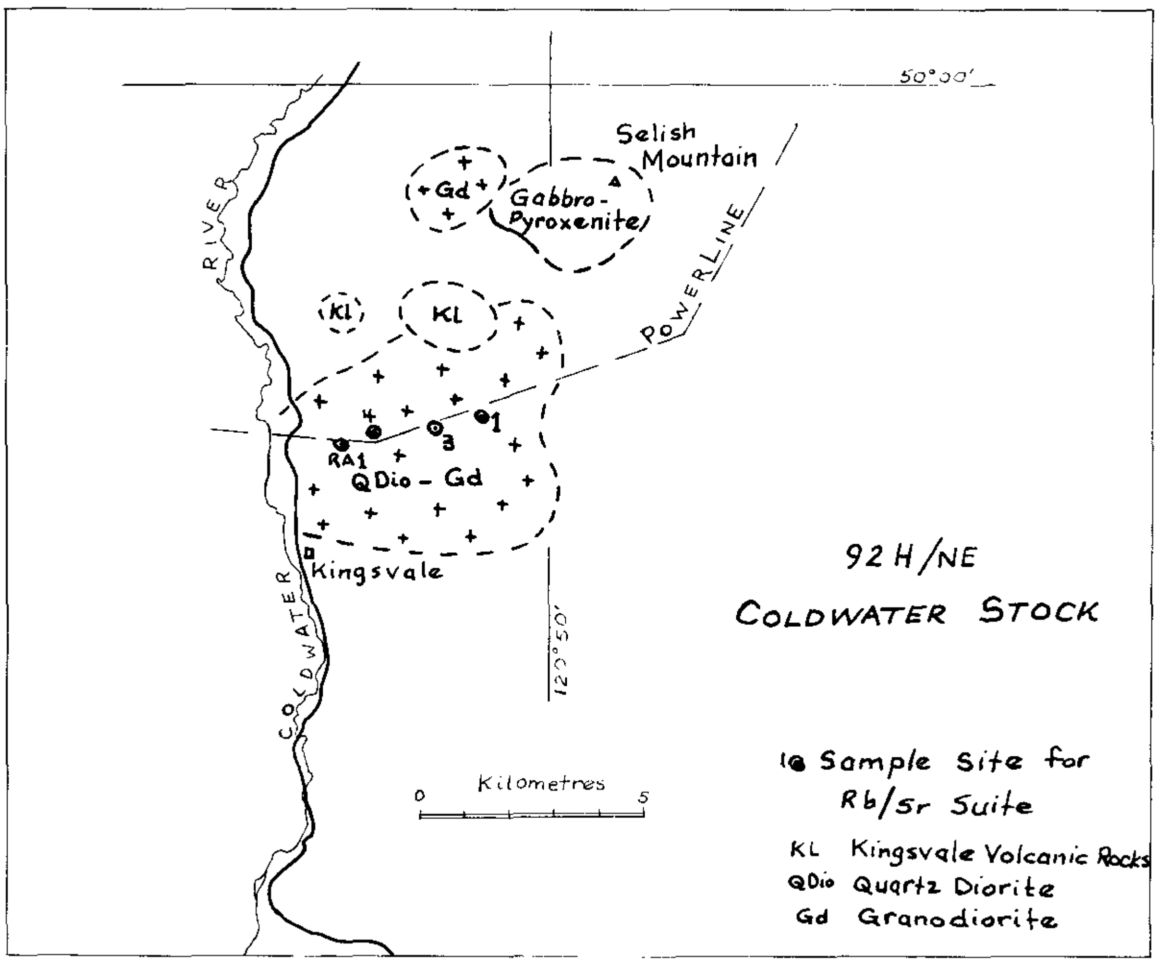

Figure 1. Generalized geological setting and location of age dating sample suite, Coldwater stock.

TABLE 1. SAMPLE DESCRIPTIONS, Rb-Sr COLLECTION

92H/NE, COLDWATER STOCK AREA

CW 79-1	CW 79-3	CW 79-4
Dark grey fine to medium-grained biotite hornblende quartz diorite (CI 30-35). Hornblende pleochroic from green to tan and is secondary after pyroxene and is markedly poikilitic. Tiny actinolite needles, chlorite and epidote, replace hornblende locally. Biotite is pleochroic from dark brown to tan and chloritized along cleavage planes. Plagioclase (andesine) forms subhedral eroded laths. It has remnant complex zoning and weak to moderate sericite alteration. Quartz is interstitial and K-feldspar uncommon. Accessory minerals are magnetite, apatite, sphene, and zircon (?).	Grey medium-grained biotite hornblende quartz diorite (CI 28-35). Hornblende is pleochroic from dark green to tan, poikilitic, anhedral, and generally occurs in clumps of grains. Locally, hornblende is altered to actinolite. Biotite is pleochroic from red-brown to tan and is locally chloritized. Eroded plagioclase (andesine) laths have moderately sericitized cores. Quartz is more abundant than in CW 79-1 and is interstitial. Minor amounts of K-feldspar occur. Magnetite occurs as an accessory mineral.	Relatively leucocratic grey hornblende biotite granodiorite (CI 12-18). Hornblende occurs as fine subhedral to anhedral grains that are pleochroic in green. Biotite is pleochroic from red-brown to tan, medium grained, anhedral, and is altered to chlorite and epidote along cleavage traces locally. Quartz has open interstitial texture and is abundant. K-feldspar is cloudy, interstitial, and locally forms myrmekitic intergrowths at plagioclase contacts. Accessory minerals are magnetite, sphene, and apatite.

TABLE 2. COLDWATER STOCK ISOTOPIC DATING RESULTS

Sample No. (CW 79-)	Description	Sr ppm	Rb ppm	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	Age	Initial $^{87}Sr/^{86}Sr$
1	Biotite hornblende quartz diorite	355	11.9	0.097	0.70384		
3	Biotite hornblende quartz diorite	329	27.5	0.242	0.70420	192±32 @	0.70357±16
4	Biotite granodiorite	273	44.6	0.473	0.70479	194±33 @	0.70356±16
RA 1	Biotite hornblende granodiorite	293	45.1	0.446	0.70488		
						K-Ar bio = 212±7	
RA 1 biotite	------	24.2			0.782	K-Ar hbl = 208±7	
		24.7	220.0	26.3	0.780	207±4 @	0.70347±6
		23.7		27.1	0.7878	219±10 @	0.7035

K-Ar analysis of biotite from sample RA 1 gave an apparent age of 208±7 Ma; hornblende from the same sample gave 212±7 Ma. Rb-Sr results are summarized in Table 1. Samples 1, 3, 4, and RA 1 gave an isochron of 194±10, whereas Rb-Sr in biotite from RA 1 gave age 219±10 Ma at initial strontium ratio 0.7035 (Figure 2). The small range of rubidium and strontium concentrations limits the precision of these results.

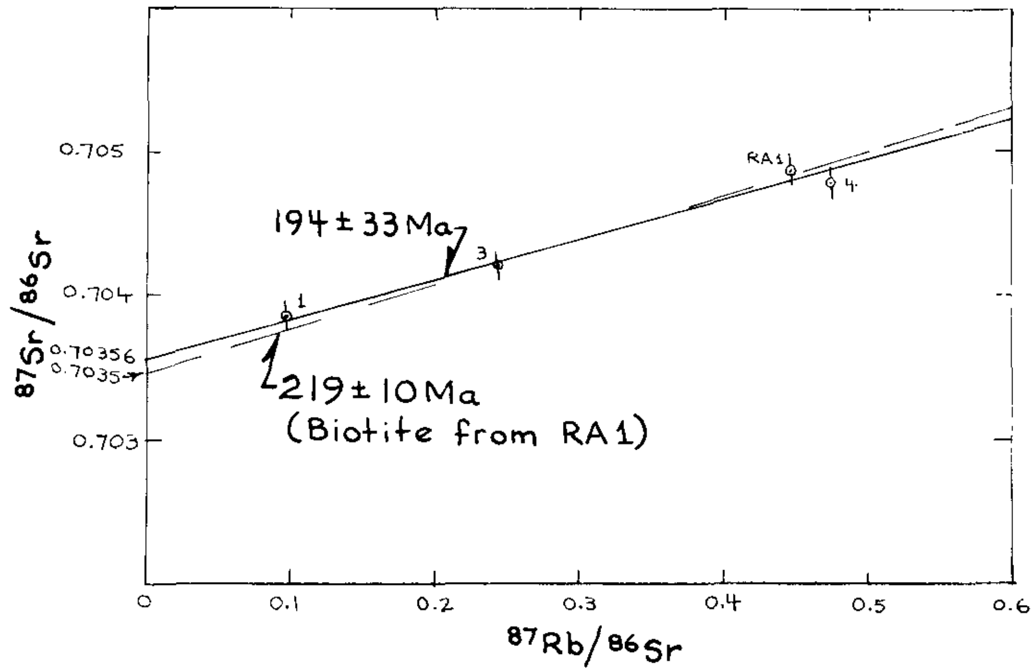

Figure 2. Plot of rubidium-strontium isotopic analyses, Coldwater stock.

In summary, isotopic dating indicates an age of approximately 210 Ma for the Coldwater stock. The age accords well with those from other intrusive bodies that cut Nicola Group rocks and the stock is not anomalously old as suggested by earlier data.

NICOLA BATHOLITH

New Rb-Sr isotopic data from the Nicola Batholith are intriguing. Earlier K-Ar work (Preto, et al., 1979) gave a range of ages for biotites from 37.3 to 59.8 Ma and for hornblendes from 60.2 to 70.6 Ma. Among the samples were two biotite-hornblende pairs that gave nearly concordant results of 56.9 and 63.6 Ma and suggest that the batholith is of Paleocene age. Biotite from a satellitic stock at Rey Lake gave a latest Cretaceous age of 68.9±2.5 Ma (McMillan, 1974).

The new data suggest that at least some of the deformed granitic or gneissic rocks in the Nicola Batholith are Early Jurassic or older (minimum 185 Ma). The younger dates probably represent new magmatic material that intruded the older pluton, although it could be remobilized older material.

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THE BLACK DOME MOUNTAIN GOLD-SILVER PROSPECT

(92O/7E, 8W)

By B.N. Church

This report is an update of an earlier review of exploration for gold and silver in the Black Dome Mountain area, 70 kilometres northwest of Clinton (Geological Fieldwork, 1979, Paper 1980-1, pp. 52-54).

Recent geological studies shed light on the age relationships of the main lithological units. A remnant volcanic vent deposit considered to be younger than the vein mineralization forms the summit of Black Dome Mountain. This consists of basalt lava and agglomerate (No. 1, Table 1)

TABLE 1. CHEMICAL ANALYSES OF VOLCANIC ROCKS FROM THE BLACK DOME MOUNTAIN AREA

	1	2	3	4	5	6
Oxides recalculated to 100-						
SiO_2	50.96	53.92	62.77	64.43	75.46	72.72
TiO_2	3.26	1.79	1.29	1.11	0.38	0.43
Al_2O_3	14.97	18.43	17.09	16.90	14.83	15.12
Fe_2O_3	4.65	4.11	5.46	2.37	1.08	1.65
FeO	5.88	3.15	1.05	2.72	0.51	0.33
MnO	0.14	0.11	0.11	0.08	0.01	0.02
MgO	7.41	4.86	2.33	1.78	0.14	0.18
CaO	8.60	7.65	3.96	3.90	0.16	1.38
Na_2O	3.25	4.03	3.56	4.10	2.96	4.18
K_2O	0.88	1.95	2.37	2.61	4.52	3.99
	100.00	100.00	100.00	100.00	100.00	100.00
Oxides and elements as determined-						
H_2O+	0.13	0.13	1.69	1.63	1.02	0.27
H_2O-	0.27	0.53	0.77	0.25	0.40	0.67
CO_2	0.07	0.07	0.26	0.48	0.07	0.07
S	0.01	0.01	0.01	0.01	0.01	0.01
P_2O_5	0.87	0.97	0.50	0.57	0.08	0.32
SrO	0.13	0.11	0.04	0.02	0.02	0.02
BaO	0.04	0.13	0.13	0.13	0.14	0.16
R.I.	1.590	1.570	1.534	1.534	1.490	1.498

Key to Analyses

1 - Basalt lava, Black Dome Mountain (peak) (BKM-16).
2 - Basaltic andesite lava, Flapjack Peak (summit) (BKM-287).
3 - Hornblende dacitic andesite, west shoulder of Black Dome Mountain.
4 - Dacitic lava 'dome,' on main ridge south of Black Dome Mountain.
5 - Porcupine Creek rhyolite, south of Black Dome Mountain.
6 - Churn Creek rhyolite, above Churn Creek to the east.

having an apparent K/Ar age of 20.5 Ma similar to rocks on Flapjack Peak, 9 kilometres to the southwest, 24 Ma (Table 2).

TABLE 2. RADIOMETRIC AGE DETERMINATIONS

No.	Location	Material	K *per cent*	Ar	Apparent Age Ma
BKM-16	Black Dome Mountain (summit)	whole rock	0.697	0.6552×10^{-6}cc/gm	24.0±0.8
BKM-287	Flapjack Peak (summit)	whole rock	1.49	1.91×10^{-6}cc/gm	20.5±0.8

(Argon determination and age calculation by J.E. Harakal, University of British Columbia).

The principal units hosting the gold-silver veins are hornblende dacitic andesite and rhyolite which are exposed on the lower slopes and the south ridge of Black Dome Mountain. A series of dacitic 'domes' disconformably overlying the rhyolite on the south ridge are now correlated with the hornblende dacitic andesite on the basis of petrographic and chemical similarities (Nos. 3 and 4, Table 1).

In the past year an intensive diamond-drill program has been completed by Blackdome Exploration Ltd. totalling 8 700 metres in 106 holes. The resulting reserve estimate for the No. 1 vein system (MDI No. 0920/053) is 284 000 tonnes averaging 12 ppm gold and 110 ppm silver. Also, a crosscut tunnel has been driven intersecting the 'Ridge Zone' of No. 1 vein 143 metres westerly from a portal at the 1 960-metre level on the east flank of the main ridge south of Black Dome Mountain (Figure 1). Examination of the crosscut shows that the mineralization continues below the rhyolite. The rhyolite dips 15 degrees easterly and has been traversed by the tunnel through to underlying fine-grained dacite at a point about 50 metres west of the portal.

Current plans by Blackdome Exploration Ltd. require 600 metres of drifting and raising to confirm and further delineate an estimated 103 000 tonnes of ore in the 'Ridge Zone' averaging 17.5 ppm gold and 114.5 ppm silver according to the diamond-drill results.

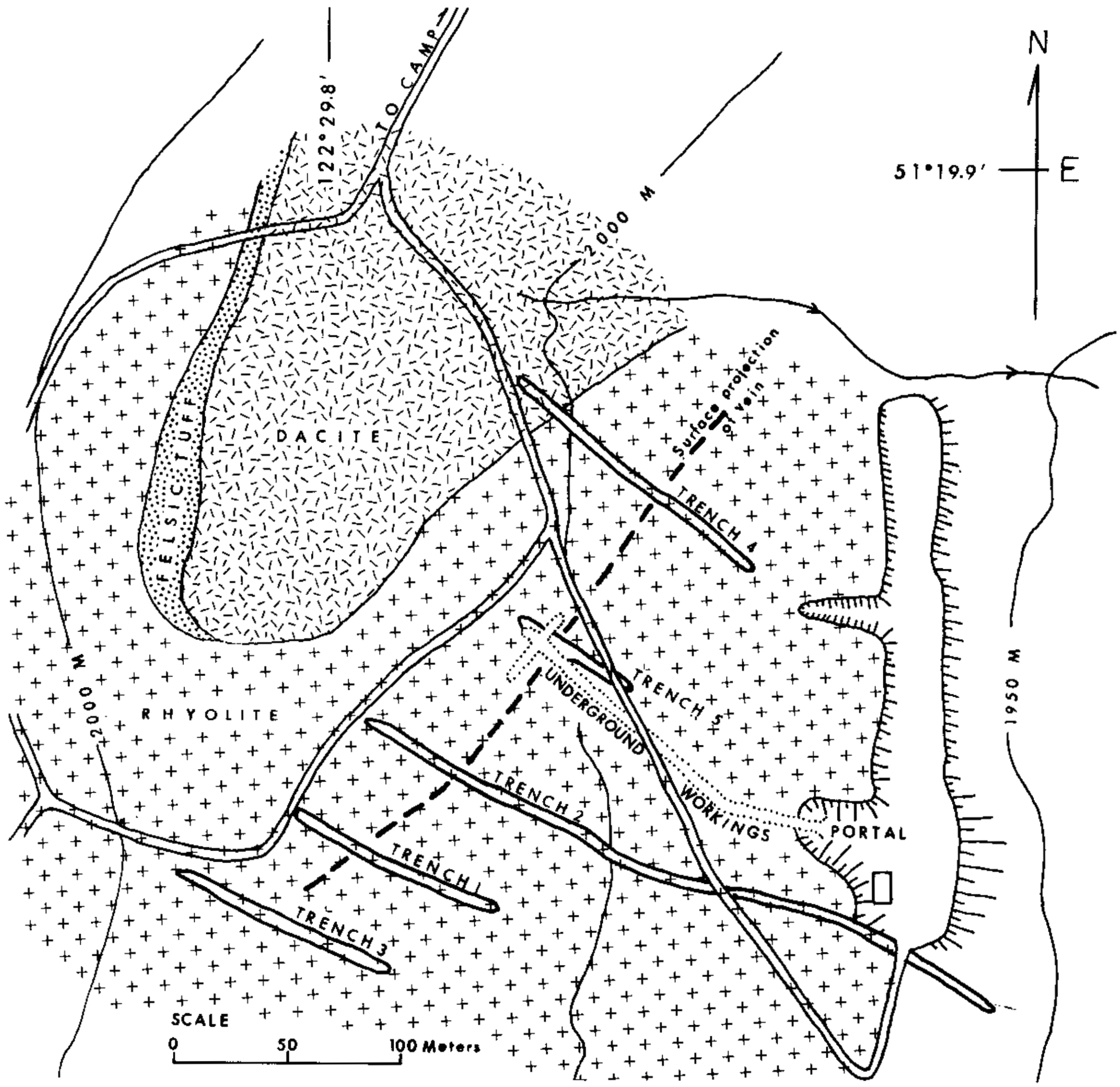

Figure 1. Geology in the vicinity of the Ridge zone of No. 1 vein, Black Dome Mountain prospect.

GEOLOGY AND LITHOGEOCHEMISTRY OF THE CAPOOSE SILVER PROSPECT

(93F/3, 6)

By B.N. Church and L. Diakow

This description is based on recent investigations of the Capoose silver prospect of Granges Exploration (AB) in the Fawnie Range 110 kilometres southeast of Burns Lake. The property is centred on a geochemical anomaly discovered by Rio Tinto Canadian Exploration Ltd. Rio worked on the property from 1969 until 1971.

GEOLOGICAL SETTING AND MINERALOGY

The area is underlain mainly by Jurassic lavas of rhyolite to dacite composition with minor amounts of interlayered argillite. Mineralized areas form conspicuous gossans throughout the Fawnie Range. Recent trenching and drilling has focused on garnetiferous rhyolite lava and breccia on the ridge immediately north and northwest of the Granges campsite (Figure 1). Highest silver values coincide with the occurrence of galena and sphalerite.

LITHOGEOCHEMISTRY

In the course of a geological survey of the Fawnie Range, hand specimens were collected randomly from bedrock exposures. These were subsequently analysed, courtesy of Granges Exploration, for a selection of pathfinding elements. The results on 45 samples are as follows:

	Geometric Mean* ppm	Deviation ppm
Ag	0.6	0.2-5.5
Cu	16	4-90
Pb	16	7-200
Zn	134	40-500
As	9.6	2-75
S	0.16%	0.3-1.30%

*Owing to a range in values through several magnitudes it is necessary to use log transforms to calculate means and standard deviations.

The behaviour of element pairs is demonstrated as follows:

	Ag	Cu	Pb	Zn	As
Cu	0.41				
Pb	0.69	0.46			
Zn	0.65	0.51	0.93		
As	0.02	0.14	-0.01	0.07	
S	0.05	0.01	0.12	0.11	-0.04

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S	0.05	0.01	0.12	0.11	-0.04

There is excellent positive correlation for the Pb-Zn pair, good correlation comparing Ag with Pb and Zn, but only fair comparing Cu with Pb, Zn and Ag. Little correlation is seen comparing these metals and sulphur or arsenic.

Element concentrations (Figure 1) were contoured according to the procedure outlined in Geological Fieldwork, 1980 (Paper 1981-1, p. 27).

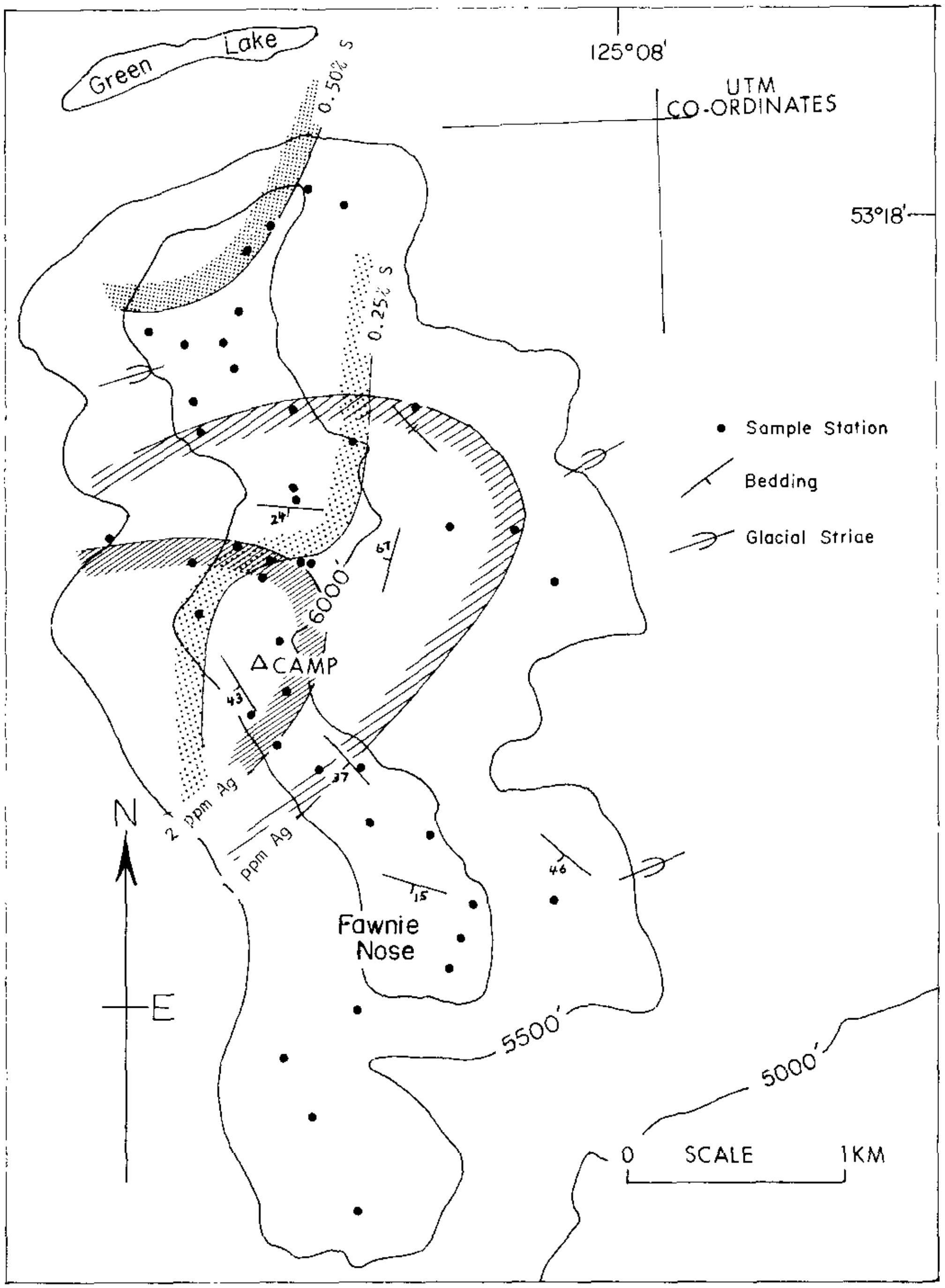

Figure 1. Lithogeochemical contours for silver and sulphur in the vicinity of the Capoose prospect.

Sulphur at the 0.25 per cent level and higher coincides with the gossans and the area of pyritization on the north and west side of the ridge north of Fawnie Nose; sulphur abundance rises toward Green Lake. Silver contours crosscut sulphur contours and define a northeast-trending anomaly with concentrations in excess of 2 ppm in vicinity of the Granges campsite and to the north and west. The patterns for copper, lead, and zinc are similar to that of silver.

DISCUSSION

A broad silver lithogeochemical anomaly has been delineated in the vicinity of current diamond drilling by Granges Exploration near Capoose Lake. This coincides with locally high values for lead, revealed by Rio Tinto Canadian Exploration Ltd. (1970).

The predominantly felsic composition (Figure 2) and subareal and submarine setting of the volcanic rocks give wide scope for a volcanogenic interpretation of the origin of mineralization. However, in the opinion of the senior author, detailed evidence points to the Capoose granitic intrusion, located just west of the map-area, as the ultimate source. As in many porphyry-type deposits, widespread disseminated

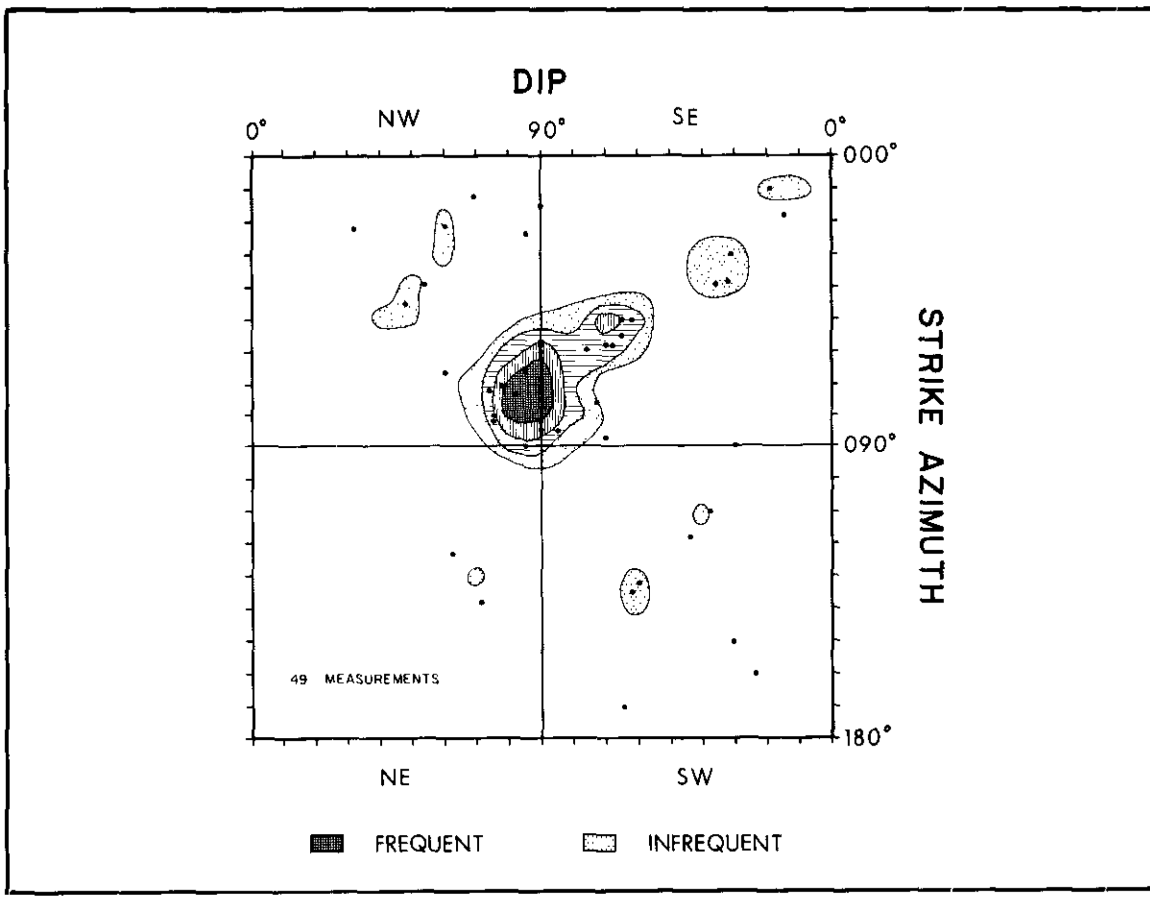

Figure 2. Composition frequency of Capoose prospect.

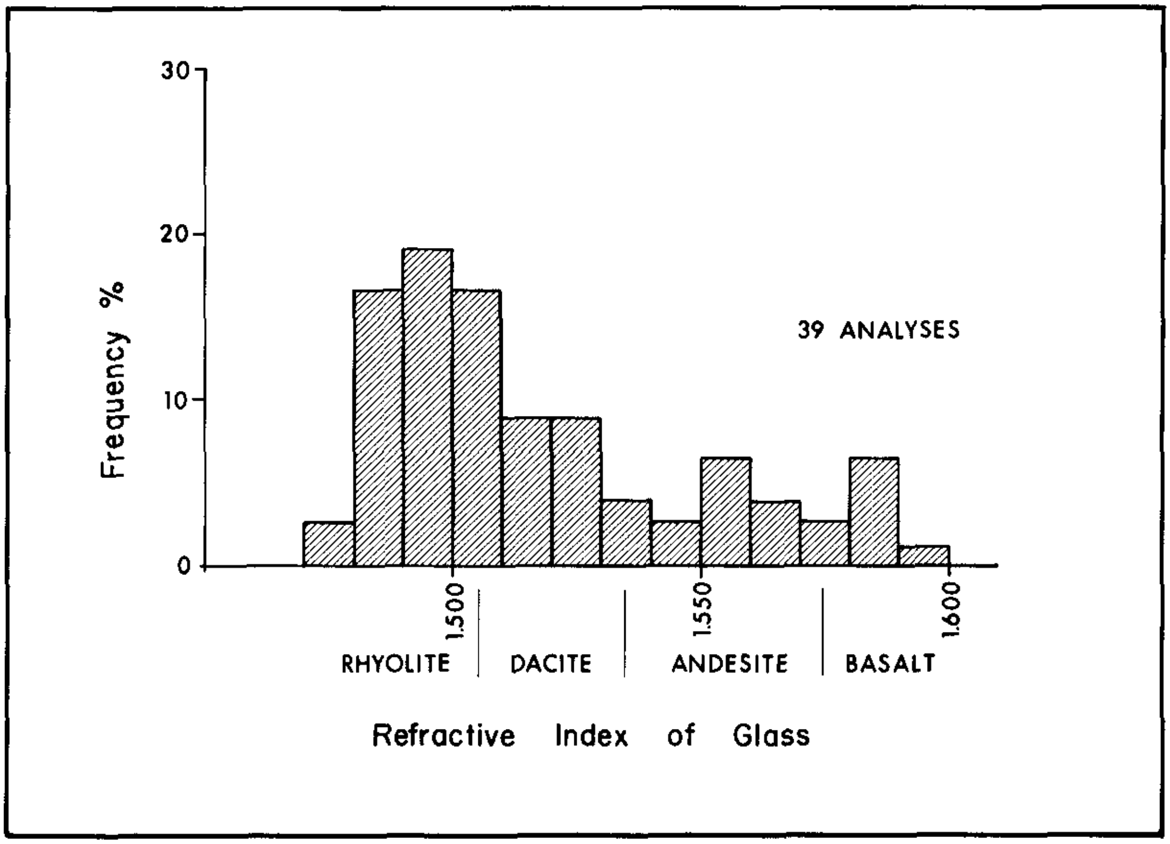

Figure 3. Fracture frequency plot for the area near the Capoose prospect.

pyrite near Green Lake and in the area to the south is peripheral to the granite. The mineralizing solutions were apparently channelled along southwesterly dipping beds (Figure 1) and a set of strong east-northeasterly to northeasterly trending cross-fractures (Figure 3). This mineralizing event is superimposed on the pyritic halo around the granite.

Dispersed, low-grade mineralization combined with the remoteness of the area has hampered exploration of the prospect.

ACKNOWLEDGMENTS

The geochemical data was supplied through cooperation with Granges Exploration (AB). Special thanks are extended to Granges program director Mr. G.W. Zbitnoff and Mr. H. Shear and Mr. W. Lumley who assisted in the field.

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AN INVESTIGATION OF THE PALYNOLOGY OF THE PEACE RIVER COALFIELD, NORTHEASTERN BRITISH COLUMBIA

By Jane Broatch
Department of Geological Sciences
University of British Columbia

INTRODUCTION

Attention has been focussed on the Peace River Coalfield of northeastern British Columbia (Figure 1) as a result of an agreement to sell 115 million tonnes of thermal and coking coal to Japan over the next 15 years. Mining and exploration activities have been accelerated but are hampered by the complex structure and poorly understood stratigraphy of the foothills region.

The 1981 field season was spent sampling Upper Jurassic-Lower Cretaceous coal-bearing strata in the southern half of the coalfield to determine whether fossil pollen, spores, and dinocysts can be used to generate a type-section of microfossils to aid in solving structural and stratigraphic problems and assist in seam correlations.

Rapid evolution of both flora and fauna during the Cretaceous, as well as the appearance of flowering plants (angiosperms) toward the end of the Lower Cretaceous, resulted in diverse species with restricted stratigraphic ranges. Pollen and spores produced by land plants and cysts produced by marine dinoflagellates are extremely durable and their relative abundance in finer grained sediments creates the potential for a fairly complete microfossil record. Marine-influenced coal measures are particularly suited to studies in palynology because of their high plant content, their relatively high proportion of muds and clays, and because marine and continentally derived microfossils overlap as a result of wind transport of pollen and spores. This overlap allows direct correlation between non-marine facies and laterally equivalent marine facies.

PREVIOUS WORK

Studies of Upper Jurassic and Lower Cretaceous macroflora and microflora of the Peace River district have been carried out by Zeigler and Pocock (1960) in the Minnes Group, by Singh (1971), and by McGregor for the Gething Formation as reported by Hughes (1964) and Stott (1968). Studies of the adjacent Plains region have been published by Pocock (1962), Singh (1964), and Norris (1967). Much of this previous work has been concerned with establishing age and regional correlation of strata, not stratigraphy.

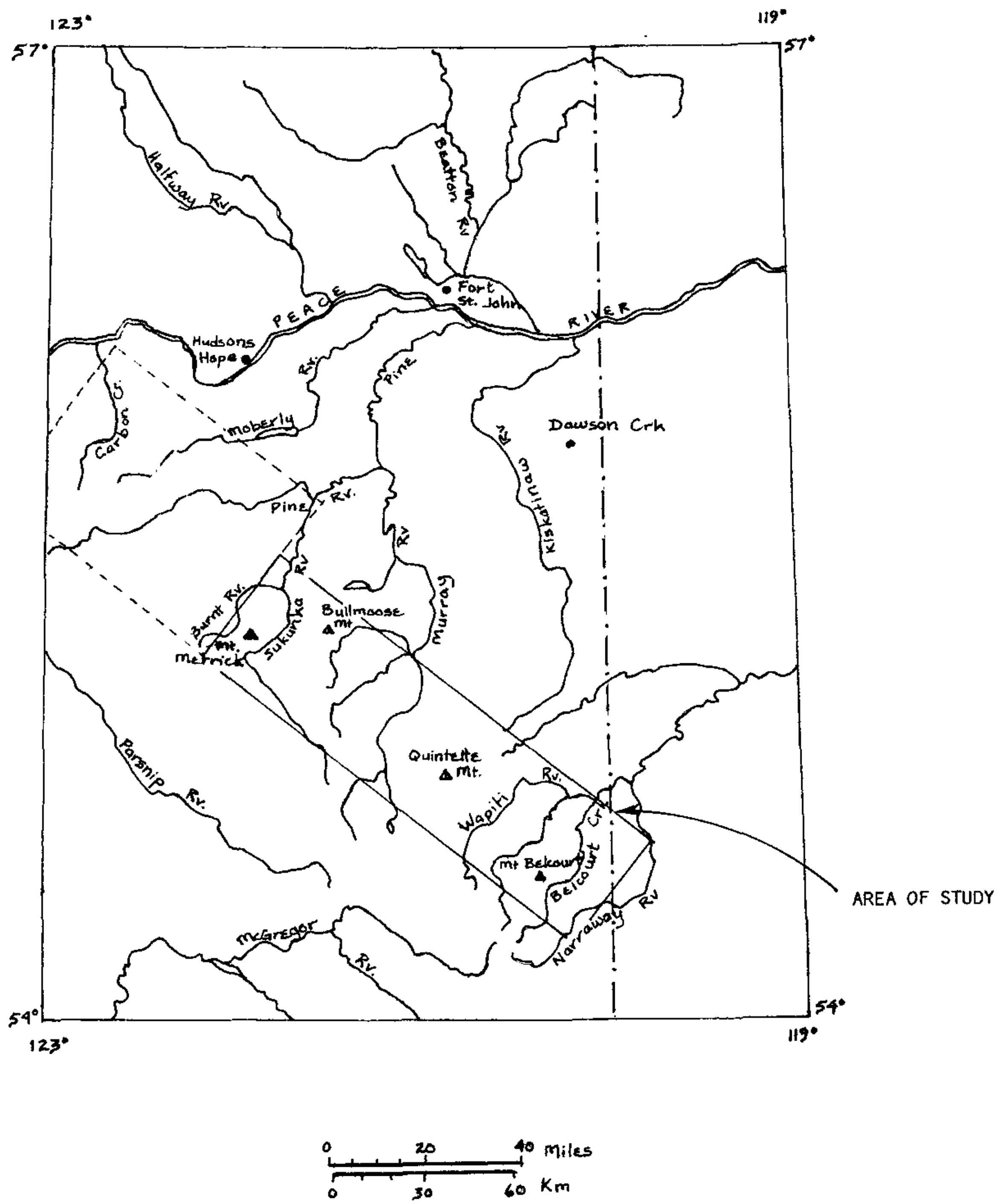

Figure 1. Peace River coal district.

STRATIGRAPHY

The general stratigraphy of the Peace River Coalfield is outlined on Figure 2. In the southeast, coal occurs in economic amounts in the non-marine Gates Member, in the central part in the Gething Formation, and in the northwest in Hughes' Brenot Formation. Non-marine strata have been identified on a gross scale and there are a number of marine incursions which may in part be responsible for the disappearance of coal in some areas (R.D. Gilchrist, pers. comm.). Detailed descriptions of the lithologies and structure may be found in Hughes (1964, 1967) and Stott (1968, 1973). They will only be discussed here in relation to specific stratigraphic problems.

Two sets of terminology (Figure 2) are currently in use in exploration as a result of a number of unresolved problems which include:

(1) A lack of identifiable stratigraphic horizons both locally and regionally. The one exception is the Bluesky Formation. It occurs as a thin (less than 0.5 metre) glauconitic sandstone horizon at the top of the Gething Formation in the eastern part of the coalfield. The Cadomin conglomerate is used as a stratigraphic horizon but varied thickness, rapid fining to the northwest, and close resemblence to the Gething conglomerates, both on surface and in drill holes, make it extremely difficult to identify in many cases. Only its log character appears consistent (R.D. Gilchrist, pers. comm.).

(2) Certain members and formations are difficult to distinguish, for example, the Hulcross Member and Moosebar Formation, the Gates Member and Gething Formation, the Gething and Cadomin conglomerates.

(3) Lateral variations in certain units over the length of the coalfield, specifically the Cadomin/Dresser Formations and the formations that comprise the Minnes Group.

(4) The difficulty of recognizing marine incursions in non-marine sequences because marine macrofossils are scarce.

(5) Determination of the paleoshorelines. Studies in progress reveal that many are not oriented along the strike of the coalfield as was previously believed.

(6) Determination of the nature and significance of the 'unconformity' at the base of the Cadomin Formation (see Stott, 1968).

Until recently workers in the Peace River Coalfield, with the exception of Stott and Hughes, have concentrated on locating economic coal deposits. Attention is now being focussed on stratigraphic problems. New information should eliminate the need for a dual terminology and facilitate future exploration, mine planning, and reserve estimates.

after Stott (1968)

U. Cret	Fort St John Gp	Dunvegan Fm		marine & non-marine sst, shl
Lower Cretaceous	Fort St John Gp	Cruiser Fm		marine shl & sst
Lower Cretaceous	Fort St John Gp	Goodrich Fm		sst,shl & mdst
Lower Cretaceous	Fort St John Gp	Hasler Fm		marine shl with sltst,sst,cong
Lower Cretaceous	Fort St John Gp	Commotion Fm	Boulder Ck Mb	sst,congl; non-marine sst,mdst
Lower Cretaceous	Fort St John Gp	Commotion Fm	Hulcross Mb	marine shl
Lower Cretaceous	Fort St John Gp	Commotion Fm	Gates Mb	marine & non-marine sst; coal
Lower Cretaceous	Fort St John Gp	Moosebar Fm		marine shl
Lower Cretaceous	Bullhead Gp	Gething Fm		glauconitic sst sst,coal,congl
Lower Cretaceous	Bullhead Gp	Cadomin Fm		mass. congl
Jurassic	Minnes Gp	unnamed		qtzose sst; f.g. sst,mdst & carb seds (Stott, 1973)
Jurassic	Minnes Gp	Monach Fm		
Jurassic	Minnes Gp	Beattie Peaks Fm		
Jurassic	Minnes Gp	Montieth Fm		
		Fernie Fm		

after Hughes (1967)

	Dunvegan Fm		non-marine sst, sltst, shl; con
Fort St John Gp	Cruiser Fm		marine shl & md
Fort St John Gp	Goodrich Fm		marine sst,minor congl & shl
Fort St John Gp	Hasler Fm		marine shl, minor sltst & sst
Fort St John Gp	Commotion Fm	Boulder Ck Mb	marine sst,shl & congl some non-marine beds with coal
Fort St John Gp	Commotion Fm	Hulcross Mb	
Fort St John Gp	Commotion Fm	Gates Mb	
Fort St John Gp	Moosebar Fm		marine mdst & shl
Crassier Gp	Gething Fm		coal measures
Crassier Gp	Dresser Fm		coal meas, sst grits & congl
Crassier Gp	Brenot Fm		coal measures
Beaudette Gp	Monach Fm		sst & qtzites marine
Beaudette Gp	Beattie Peaks Fm		marine shl, sst & sltst
Beaudette Gp	Montieth Fm		marine sst,qtzites & shl
	Fernie Fm		

Figure 2. General stratigraphy, Peace River area.

FIELD AND LABORATORY WORK

A sampling program was carried out in the coal-bearing Upper Minnes through Gates section between the Narraway River in the southeast and Burnt River in the northwest. Very fine clastic rocks in seven surface sections and thirteen drill holes were sampled (Figure 3).

Complete, undisturbed surface sections were difficult to find. Extensive thrust faulting and poor outcrop exposure resulted in gaps in surface coverage. Where relatively complete sections are available, steep dips and the recessive nature of the mudstones and shales frequently made it difficult to obtain fresh samples at the desired 30-metre intervals.

Drill holes were selected to compliment the surface sections and were 'pieced together' to obtain a complete sequence of strata. Core samples were obtained from core storage facilities of the British Columbia Ministry of Energy, Mines and Petroleum Resources at Charlie Lake, British Columbia. It is expected that the core samples, which were taken at 15-metre intervals, will provide more complete and reliable results than surface samples. A total of 238 core samples and 89 surface samples was taken.

Processing of the samples is currently underway in a laboratory at the University of British Columbia. The rock must be completely dissolved in acid to release the palynomorphs which are then treated as necessary to concentrate and bleach them for mounting and identification. The general procedures employed are described in the Appendix. To date one complete section of core from the Mount Belcourt area has been processed and mounted.

PRELIMINARY RESULTS

Of the 60 samples processed to date, approximately 85 per cent contain palynormorphs. Twenty samples were examined by Dr. Glenn Rouse: half of the Minnes and Gething samples contain diagnostic spores and/or dinocysts; fewer Moosebar and Gates samples appear to contain diagnostic palynomorphs but exact statistics are not yet available. However, Gates samples apparently contain angiosperm pollen. There has not been time yet to attempt to identify them.

The Minnes samples contain: the diagnostic fern spores Cicatricosisporites dorogensis and C. mohrioides; the conifer pollen Podocarpidites multesimus; and one sample contains the dinocysts Gonyaulacysta cf. exilicristata, G. cf. cretacea and Cyclonephelium distinctum. Correlation with assemblages found in the Quartz Sand-Upper Develle Members of the Mannville Group (Pocock, 1962; Zeigler and Pocock, 1960) suggests a Valanginian to Early Barremian age for the upper 340 metres of the Minnes Group.

The Gething samples contain the diagnostic fern spores Appendicisporites tricornitatus, A. cf. problematicus, Cicatricosisporites australis, and

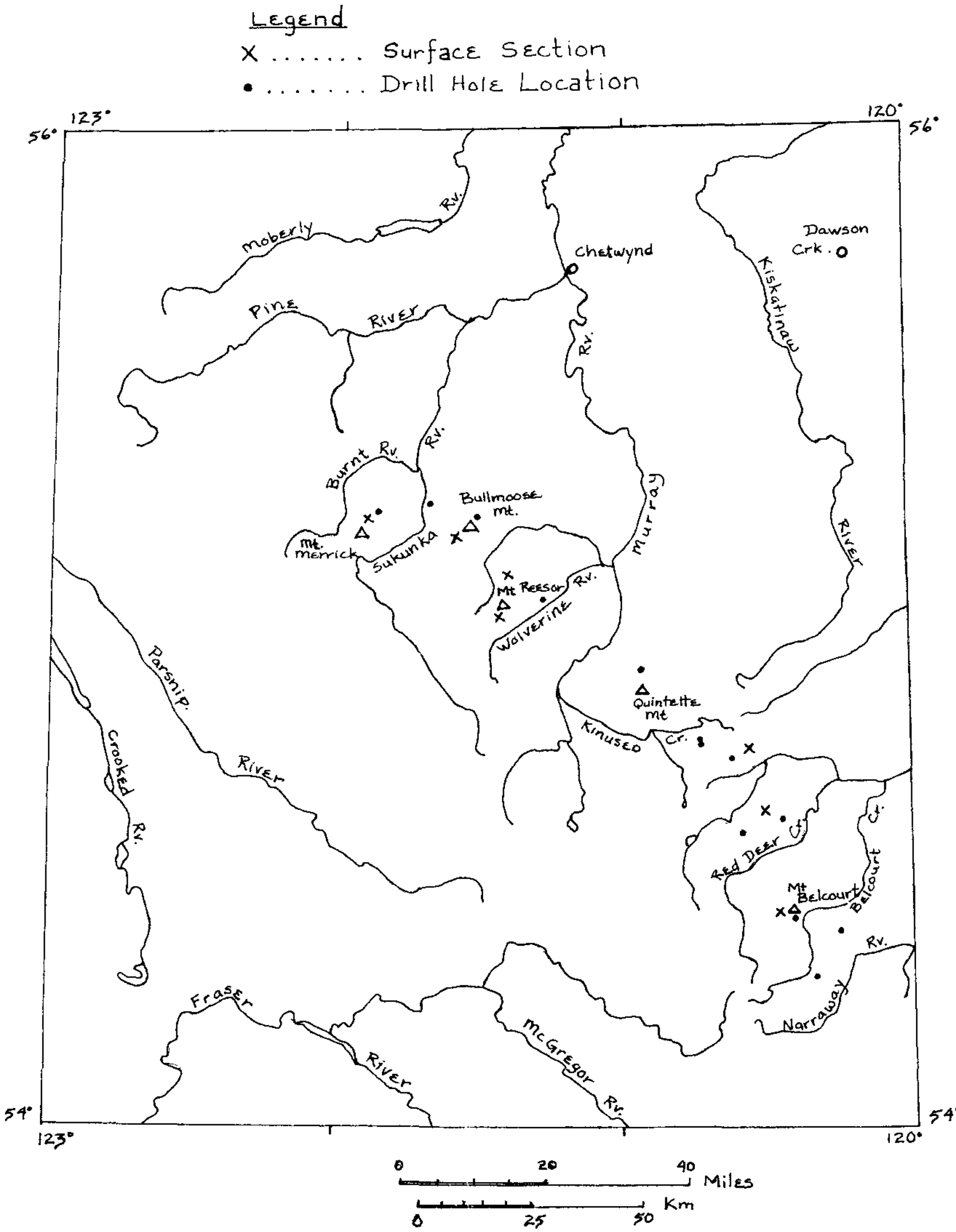

Figure 3. Surface sections and drill hole locations, Narraway River-Burnt River.

Trilobosporites apicerructus. Although the assemblage appears to be dominantly terrestrial the presence of dinocysts in one sample suggests occasional marine incursions. This assemblage correlates with the Calcareous Member of the Lower Mannville Group (Pocock, 1962) and in the Gething and Calcareous Member (Zeigler and Pocock, 1960) suggesting a Late Barremian age.

The presence of dinocysts in several of the Gates samples and one of the Gething samples supports the proposal by Gilchrist that marine incursions have occurred in the non-marine sequences. Macrofossils found in core by P. McL. D. Duff should provide a useful check of the relative ages of the palynomorph assemblages described above.

These preliminary results suggest that the unconformity at the base of the Cadomin Formation does not represent a significant time gap in deposition. Mudstone samples from a coal-bearing lens in the Cadomin to the north may provide a better indication of the temporal relationship of this unit to those above and below.

Only one section has been processed to date and it is not yet possible to recognize palynological or stratigraphic horizons. However, the presence of marine beds in non-marine sequences, and the abrupt appearance of species or assemblages holds much promise for the existence of such horizons.

SUMMARY

Until recently work in the northeast coal block has been concerned primarily with locating economic coal deposits. Complex structure and a poor understanding of the stratigraphy have hampered the search and attention is now being turned to solving these problems. Initial results of a study of the palynology indicate a potential for determining age relationships, locating stratigraphic horizons and laterally correlating strata. Distinct assemblages in the Upper Minnes Group and Gething Formation, and marine units in non-marine sequences have been identified. It is hoped that as processing of samples continues a microfossil type-section will be generated which will serve as a useful tool in its own right and add support to other stratigraphic studies currently in progress.

ACKNOWLEDGMENTS

I would like to thank Dr. G.E. Rouse for his assistance in identifying the assemblages noted in the preliminary results and for his ongoing support, R.D. Gilchrist for providing stratigraphic information based on studies carried out in conjunction with P. McL. D. Duff, and the companies that generously offered information on surface section locations and their time to discuss and examine the geology and stratigraphy of their respective properties, most notably PetroCanada, Denison Mines, BP Exploration, and Gulf Canada Ltd. I am especially grateful to the British Columbia Ministry of Energy, Mines and Petroleum Resources for their support of this project.

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APPENDIX

Extracting Palynomorphs

(1) Wash approximately 50 grams of sample, crush to pea size, and place in plastic beaker; rinse twice to remove clay and damaged palynomorphs.

(2) Test for carbonates using a 10-per-cent solution of HCl; when no more fizzing is evident rinse sample three times with water.

(3) Place beaker with sample in a water bath in a fumehood and add full strength HF acid in small increments (to prevent 'boiling over') until the volume of acid is approximately 10 times that of sample; place on magnetic stirrer, add spin bar, and leave 24 to 48 hours (inside the fumehood).

(4) Remove from stirrer and allow to settle until acid is almost clear; pour spent acid into waste bottle; rinse sample three times in water allowing to settle between each wash so that very fine clay remaining in suspension may be siphoned off.

(5) Rinse through 210 µm sieve to remove coarse fragments retaining the liquid fraction; pour through 20 µm sieve retaining sediment trapped in sieve; rinse into centrifuge tube.

(6) Examine by placing a drop of sample on a glass slide to determine degree of carbonization of palynomorphs (if present) and amount of mineral matter still present.

(7) Bleach black and dark brown palynomorphs to reduce their specific gravity (before carrying out heavy liquid separation) or to lighten to pale to golden yellow for easier identification; rinse three times to remove bleach.

Concentration of bleach and length of bleaching vary for each sample - start with low concentrations (5-10 per cent) for short periods of time (2-5 minutes) and increase as necessary.

(8) Remove unwanted mineral matter by neutralizing in 10 per cent HCl acid and centrifuging in $ZnBr_2$ with a specific gravity of 3.4; pipette organics ('float' material) into a clean test tube, neutralize again with 10 per cent HCl and rinse three times with water.

(9) Bleaching may break down unwanted organics permitting their removal by a second 20 µm sieving.

(10) Stain sample with Safrinin (red); make fine, medium and coarse mount by placing a drop of elvanol on a coverslip with 1 or 2 drops of sample; stir to distribute evenly and dry slowly on hotplate or in dessicator; place a blob of gelva on a glass slide and invert the coverslip with sample onto it; press to spread gelva; label.

TOODOGGONE RIVER

(94E)

By T.G. Schroeter

INTRODUCTION

The Toodoggone River area is situated approximately 300 kilometres north of Smithers. Access is by aircraft because there are no roads into the area. During the 1981 season, a great variety of aircraft were used for supply and freight services to and from the Sturdee strip; these included a Cessna 180, Cessna 206, Beech-18, Otter, Beaver, Goose, Islander, DC-3, and Hercules. All were routed through Smithers. The strip has a useable length of 620 metres and is equpped with landing lights. Du Pont of Canada Exploration Ltd. maintain the strip and have a traffic controller on duty during daylight hours. The area discussed in this report forms a northwesterly trending belt 80 kilometres in length, 35 kilometres in width, and approximately centred on the Baker mine (Figure 1). The area of economic interest may continue several more kilometres to the west-northwest.

During July and August 1981, the writer commenced geologic field mapping with the aid of an especially contracted topographic base map at scale 1:25 000. The area covered by this base map is shown on Figure 1. Property investigations, ongoing since 1974, were continued. Much of the writer's effort was concentrated in the area bounded by the Finlay River on the southeast and Abesti Creek on the northwest. In addition, Andrejs Panteleyev with the British Columbia Ministry of Energy, Mines and Petroleum Resources and Larry Diakow, a graduate student at the University of Western Ontario, joined the project in August and expanded the area of mapping south of the Finlay River (see Panteleyev, this report) and Mount Graves. A preliminary geological map of the Toodoggone area should be available by the spring of 1983.

During 1979-80, approximately 2 000 mineral claim units were staked in the area. In 1981, approximately 1 300 more units were staked. In addition, after part of the area was opened to placer staking in November 1980, a placer staking rush occurred during the winter of 1980-81 (see Figure 1). The reader is referred to Geological Fieldwork, 1980 (Paper 1981-1) for a description of the history of the camp.

GEOLOGY

Typical epithermal mineralization in the camp is related to a period of Early Jurassic intermediate to acidic volcanism. Mineralization occurs both within Late Triassic alkaline andesitic rocks (Takla Group) and Early Jurassic calc-alkaline volcanic rocks (Hazelton Group). The host volcanic rocks were deposited in an island arc environment during the transition period from submarine to subaerial volcanism.

The regional geology is covered in Paper 1981-1 and only minor additions are offered here. The Toodoggone volcanic sequence consists of a pile of complexly intercalated and varicoloured subaerial andesitic, dacitic, and trachytic tuffs, ash flow sheets, and minor epiclastic rocks that is 1 000 metres or more in thickness. They are tentatively correlated with very Early Jurassic rocks of the Hazelton Group. K-Ar and Sb-Sr dates obtained from whole rock and mineral samples, including alunite from Alberts Hump (which is believed to be contemporaneous with the major pulse of epithermal mineralization), range between 179 and 190±7 Ma. This relatively old age compared to similar deposits in Nevada, Colorado, and Mexico may be a particularly important factor in the future discovery of similar epithermal deposits in British Columbia (for example, Premier).

It is worth re-stating that the Toodoggone volcanic rocks and intrusions are probably coeval with associated Omineca Intrusions. It is also significant that porphyry deposits associated with the Omineca Intrusions have anomalous gold and silver contents (Paper 1981-1, p. 128). Quartz feldspar porphyry dykes may in fact be feeders to the Toodoggone volcanic sequence.

Regionally, the lower volcanic division consists dominantly of pyroclastic maroon agglomerate and grey to green to maroon andesitic and dacitic tuffs. It is overlain by the middle volcanic division consisting mainly of rhyolites, dacites, and an intermediate to acidic assemblage of orange crystal to lithic tuffs, minor welded tuffs, and quartz feldspar porphyries. A young, upper volcanic-sedimentary division is locally present. In areas, major structural breaks and mineralizing events (for example, Lawyers) coincide with the contact between the lower and middle volcanic divisions.

STRUCTURE

The structural setting was probably the most significant factor in allowing mineralizing solutions and vapours to migrate through the thick volcanic pile in the Toodoggone area. Major fault systems with attendant splays extend tens of kilometres (for example, McClair, Lawyers - Cliff Creek). Some are postulated to be related to volcanic centres, particularly collapsed ones (for example, Kodah, Alberts Hump).

MINERALIZATION

Styles of mineralization are discussed in Paper 1981-1, pages 128 and 129. The precious and base metal epithermal type are the main exploration targets. Preliminary chemical data (Tables 2 and 3) suggest the following:

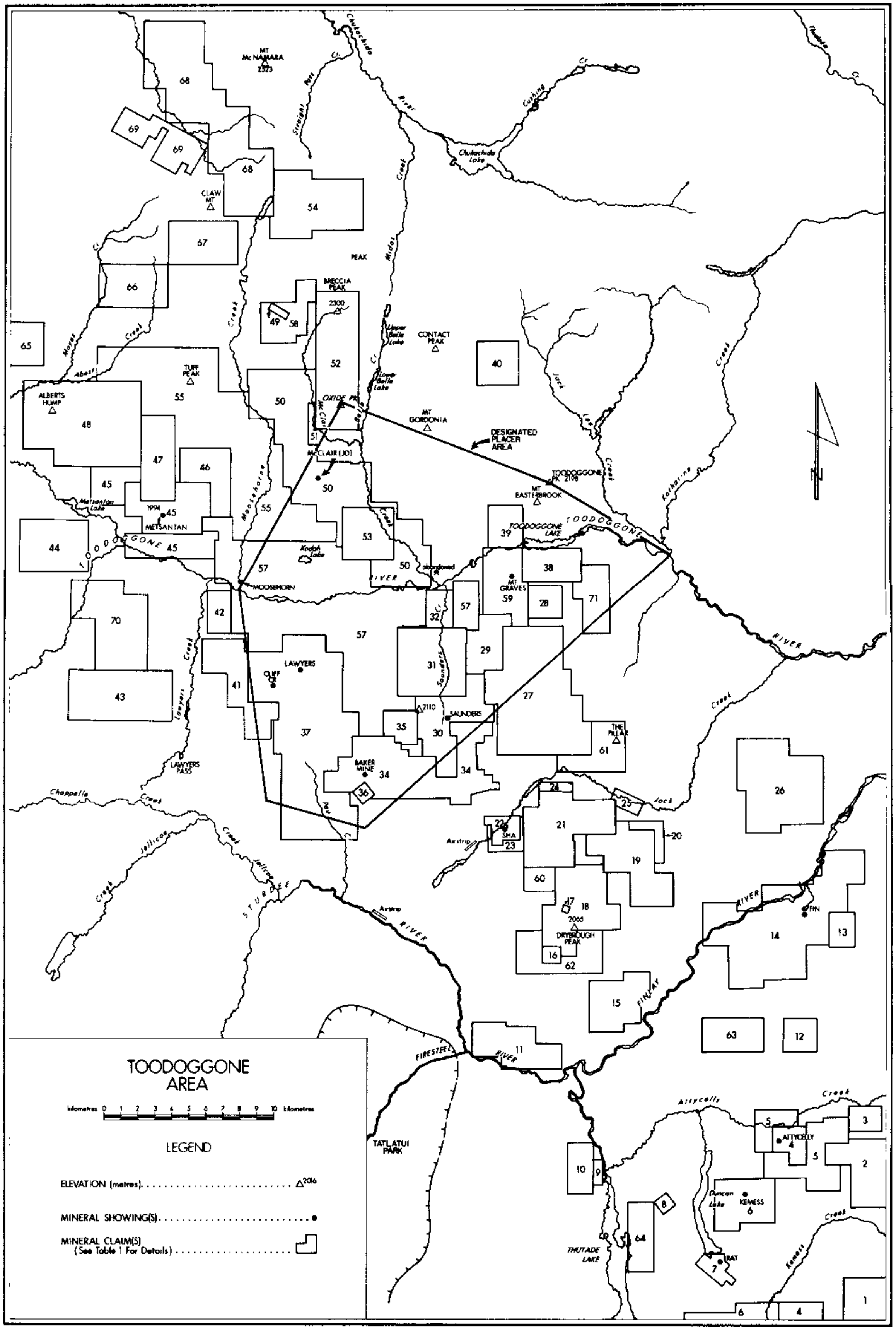

Figure 1. Toodoggone map-area.

TABLE 1. 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	------	Inca Res.
4	Audrey East, Audrey West	22	Inca Res.
5	Kem 1-9	------	Inca Res.
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, Zip, Gem, Kid	16	B. Pearson
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 1-9	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 I-III, Perry 1-2, Mason 1-2, GTW 1-3, plus fractions	64	SEREM Ltd.

No.	Claim Name	MDI 94E	Operator
38	Duke 1-2	------	Serem Ltd.
39	To No. 1	------	Du Pont Expl.
40	Mul 1-2	52	Du Pont Expl.
41	Silver Pond, Silver Creek, Silver Peak, Silver Grizzly	17	C. Kowall
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	------	Kidd Creek Mines
57	GWP 1-43, Doug's Bear	------	Great Western Pet.
58	Horn 1-3	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	------	C. Kowall, G. Auger
66	Hump 1-2	------	C. Kowall, G. Auger
67	Golden Lion 1-2	------	C. Kowall, G. Auger
68	QBX 1-12	------	Taiga Cons.
69	Claw	46	Umex
70	Xenos 1-4	------	Lacana Mining
71	Sun 1-2	------	C. Kowall, G. Auger

TABLE 2. SELECTED CHEMICAL

Lab. No.	Field No.	Field Description	Location	SiO_2	Al_2O_3	Fe_2O_3 Total	Rock Name*	Cu ppm	Pb ppm	Zn ppm	Ag ppm	Au ppm
24233	La 80-6-21 m	Upper crystal tuff	Lawyers	60.21	15.27	5.29	Trachyte	5	14	82	0.4	0.029
24234	La 80-13-21.8 m	Orange crystal tuff without quartz eyes	Lawyers	57.58	14.89	5.29	Trachyte	11	15	71	0.8	<0.02
24235	La 80-13-94 m	Chocolate brown dust tuff	Lawyers	68.02	13.13	3.17	Trachyte	27	41	167	48.0	0.027
24236	La 80-14-116.5 m	Green footwall crystal tuff	Lawyers	56.06	15.06	6.01	Trachyandesite	8	18	113	4.2	0.022
24237	La 80-4-81.7 m	Welded tuff	Lawyers	62.93	14.78	3.34	Trachyte	35	44	118	11.0	0.042
24238	La 80-4-104.5 m	Footwall orange crystal tuff with quartz eyes	Lawyers	64.86	12.91	5.48	Normal dacite	40	41	214	29.0	0.092
24239	La 80-11-11 m	Upper volcanic sedimentary rocks	Lawyers	72.85	12.00	2.65	Normal rhyolite	19	13	61	5.3	0.056
24240	K 74-3-48.5 m	Cemented mud zone	Lawyers	58.94	12.65	6.05	Normal andesite	37	30	82	4.4	0.031
24241	La 80-6-105.4 m	Silicified brecciated mineralized zone	Lawyers	80.97	6.21	2.29	------	69	93	233	34.0	3.36
24242	La 80-5-113.4 m	Green andesitic dyke	Lawyers	46.03	16.68	9.62	Sub-alkaline mafic phonolite	90	12	133	1.0	<0.02
24243	JC 2-80-4	Massive andesite	Northeast of Cliff Creek	59.76	15.39	5.53	Normal andesite	17	3	78	<0.4	<0.02
24244	JC 6-80-24	Porphyritic andesitic flow	Northwest of Marmot Lake	60.40	14.88	5.70	Normal andesite	16	10	77	<0.4	<0.02
24245	Met 80-9	Typical orange crystal tuff	Metsantan	56.38	15.65	6.02	Trachyte	19	10	215	<0.4	<0.02
24246	AH 80-2	Siliceous volcanic pyroclastic	Alberts Hump	55.58	17.43	0.46	Sub-alkaline trachyte	4	26	100	<0.4	<0.02
24247	Pil-w-80-1	Orange crystal tuff	Pillar West (Nub Creek)	62.15	15.96	3.99	Trachyte	7	420	138	<0.4	<0.02
24248	T 80-6	Purple andesite	Above two ponds, crest between Lawyers and Baker	58.20	15.42	5.62	Normal andesite	7	17	77	<0.4	<0.02
24249	La 80-7	Purple andesite	Northeast downslope of Lawyers Knob	49.76	17.43	10.36	Basalt-andesite	33	11	106	<0.4	<0.02
24250	JC 4-80-4	Purple andesite	Duke's Demise - southeast end	61.03	16.92	5.53	Trachyte	8	9	85	<0.4	<0.02
24251	JC 7-80-13	Purple andesite	600 metres west of Marmot Lake	59.42	14.61	5.69	Normal andesite	15	10	68	<0.4	0.068
24252	JC 7-80-15	Green to purple crystal tuff	1 250 metres northwest of Marmot Lake	61.79	15.14	5.58	Trachyte	16	10	85	0.6	<0.02
24253	JC 9-80-6	Flow-banded andesite	Kodah Lake	57.77	17.72	5.97	Normal andesite	4	19	111	<0.4	<0.02

*B.N. Church's classification.

ANALYSES, TOODOGGONE AREA

MgO	CaO	Na_2O	K_2O	TiO_2	MnO	P_2O_5	CO_2	S	H_2O^-	H_2O^+	$(H_2O)T$	Total
2.18	3.07	3.375	5.602	0.562	0.13	0.22	2.42	<0.008	0.79	1.83	1.04	99.36
1.67	3.24	1.593	8.782	0.550	0.085	<0.08	5.10	0.02	0.55	0.85	0.30	99.10
1.50	0.37	0.191	9.026	0.483	0.075	0.11	2.62	0.04	0.14	1.28	1.14	99.88
2.84	1.94	0.878	9.588	0.520	0.142	<0.08	4.88	0.37	<0.1	1.54	1.44	99.73
1.50	0.76	0.848	9.498	0.532	0.073	0.18	3.59	0.042	0.18	1.7	1.52	99.59
2.00	0.68	0.931	6.616	0.435	0.104	0.15	3.30	0.008	0.44	1.26	0.82	98.29
0.23	1.17	0.987	6.683	0.326	0.092	0.15	0.81	<0.008	0.80	1.04	0.24	98.19
3.17	4.30	0.128	4.293	0.459	0.143	0.13	6.34	0.012	1.33	1.03	-0.30	96.91
1.64	0.51	0.060	2.934	0.156	0.072	<0.08	2.86	0.04	0.15	0.19	0.04	97.74
5.91	2.30	4.533	2.041	1.151	0.257	0.13	7.37	0.014	1.84	3.31	1.47	97.49
2.80	4.30	2.971	3.514	0.617	0.158	0.23	1.39	0.008	1.38	3.00	1.62	98.28
2.66	2.68	3.476	3.523	0.566	0.133	0.23	0.95	0.008	1.88	5.04	3.16	98.36
1.56	2.00	0.210	10.64	0.610	0.274	0.18	4.81	0.016	0.34	0.66	0.32	98.68
<0.08	<0.22	0.335	3.832	0.139	<0.002	0.09	0.18	6.19	0.17	7.13	6.96	91.50
1.32	2.18	3.823	6.266	0.437	0.132	0.18	1.43	<0.008	0.29	0.97	0.68	98.58
1.92	5.34	3.457	3.096	0.579	0.141	0.22	2.57	0.014	0.96	2.38	1.42	97.98
3.93	7.87	3.025	3.688	1.040	0.182	0.30	<0.10	0.012	0.73	1.59	0.86	98.43
1.99	2.85	4.841	3.318	0.518	0.152	0.13	0.99	0.008	0.53	1.83	1.30	99.56
1.33	4.44	4.155	3.367	0.572	0.146	0.23	3.28	<0.008	1.21	1.29	0.08	97.32
2.82	1.56	2.242	6.608	0.561	0.142	0.19	0.70	0.04	0.50	1.94	0.44	97.82
2.19	5.24	3.536	4.039	0.562	0.158	0.15	<0.10	0.008	0.33	1.55	0.22	97.54

Hg ppb	SrO per cent	BaO per cent	As ppm	Sn ppm	Se ppm	Te ppm	W ppm	Th ppm	U ppm
40	0.02	0.15	18	2.0	8	6	5	8	3
45	0.02	0.18	28	1.8	3	6	5	9	5
47	0.02	0.18	26	<1.0	3	3	14	<7	6
<10	0.02	0.19	24	1.8	5	4	6	<7	7
67	0.02	0.13	30	<1.0	5	4	6	<7	6
37	0.02	0.13	20	1.8	3	6	8	9	<3
45	0.02	0.19	<10	<1.0	<3	6	3	7	6
42	0.07	0.19	23	2.4	5	8	4	<7	5
37	0.01	0.04	23	2.7	<3	5	8	<7	4
42	0.02	0.14	21	5.3	5	6	5	<7	<3
25	0.05	0.19	18	3.7	3	8	<2	11	3
47	0.02	0.19	20	2.2	5	4	<2	8	4
<10	0.01	0.17	14	<1.0	3	4	6	13	5
18	0.08	0.03	21	<1.0	5	<3	2	7	6
29	0.02	0.20	<10	1.2	3	4	2	<7	6
29	0.08	0.21	<10	2.2	5	3	2	9	<3
27	0.16	0.23	<10	3.5	3	9	<2	<7	4
13	0.03	0.16	22	1.5	3	3	<2	<7	4
10	0.02	0.20	18	<1.0	5	7	<2	<7	6
25	0.01	0.20	<10	<1.0	3	4	2	<7	6
35	0.05	0.17	<10	<1.0	3	8	2	<7	9

TABLE 3. GEOCHEMICAL RANGE OF SELECTED HIGH-GRADE SPECIMENS FROM TOODOGGONE EPITHERMAL PROSPECTS
(All values in ppm unless otherwise indicated.)

As	<10 to 30	Ga	<3 to 10	Se	<5 to 272
B	<2	Ge	<5	Sn	<1 to 5.3
Ba	8 to 2 140	Hg	60 to 2 800 ppb	Sr	<2 to 250
Be	<1	La	<10	Te	5 to 45
Bi	<3 to 17	Li	7 to 76	Th	<7 to 16
Cd	<0.2 to 388	Mo*	2 to 91	U	<3 to 5
Co	<1 to 16	Ni	9 to 31	W	<2 to 16
Cr	19 to 52	Pb	24 to 0.835%	Zn	45 to 6%
Cs	<4 to 8	Rb	<5 to 150		
Cu	35 to 0.94%	Sb	<3 to 8		

*Excluding one high-grade sample at Baker mine with 0.23% Mo.

(1) There are three main classes of rocks: varicoloured, andesitic, and dacitic pyroclastic tuffs overlain by trachytic pyroclastic tuffs.

(2) The ratio K_2O/Na_2O increases toward mineralization.

(3) Sulphur values are very low - average <0.04 per cent S.

(4) Trace elements are not enhanced near mineralization (Table 2). However, there is some hope for mercury as a pathfinder element.

(5) The overall Ag:Au ratio is approximately 20:1.

There are three stages of of veining. A pre-ore stage consists of thin bands of amethyst and adularia with very minor amounts of calcite. This was followed by the ore-bearing stage consisting of open space fillings, and post-ore deposition of coarsely crystalline calcite and minor amounts of zeolites.

ALTERATION

Typical lateral and vertical alteration patterns for epithermal deposits exist. There is an outer propylite zone, consisting of chlorite, epidote, calcite, and pyrite that grades inward to an argillic-phyllic zone consisting of sericite, montmorillonite, illite, and silica and finally there is a silicified core zone that is adjacent to the vein system and consists of silica, adularia, and/or albite. Hematite is ubiquitous but appears to be especially abundant in mineralized zones, as does manganese oxide. Locally there are zones of intense kaolinite+silica±alunite±sulphate alteration (for example, Alberts Hump area). Similar zones occur at the upper, low pH regions of other epithermal systems. Native gold, hematite, and minor pyrite have been observed in these silica-rich rocks. When they are mapped on a regional scale, they occupy a crude concentric fracture system and are indicative of a major collapse structure.

Bleaching appears to be more common in the hangingwall; chlorite is more common in the footwall. Epidote, pyrite, and laumontite are abundant in regionally altered zones.

GEOCHEMICAL SIGNATURES

Regional and detailed follow-up silt, soil, and rock geochemical surveys have been key tools in exploring for and delineating mineral deposits. They rank second only to good prospecting. Analyses for gold and silver alone have proven successful but lead, zinc, and copper are also useful. Values of anomalous gold in silts range from 20 ppb to 1 500 ppb, and silver from 3 ppm to 400 ppm. Silification is accompanied by anomalous values in rock geochemistry.

As mentioned earlier, these mineralized systems appear to be relatively free of contaminants such as arsenic and antimony. On a detailed basis, the writer believes that mercury might be a useful pathfinder, especially if the analyses were properly done in the field.

PROPERTIES

BAKER MINE (previously Chappelle)(MDI No. 094E/026)

The Baker gold-silver mine, formerly Chappelle, is currently operating at a rate of 100 tons per day. Published mineable reserves are 100,000 short tons containing 0.92 troy ounce of gold and 18.7 troy ounces of silver per ton. During the fall of 1980, surface cut mining down to about 6 metres was carried out. Since then underground mining has been in progress from the 5500 level and development work has proceeded on the 5400 level.

Seven quartz vein systems, mostly occupying fault zones, have been identified in the area of the mine. The main vein (Vein A) actually consists of two or more subparallel veins that have been traced more than 435 metres, have a width of 10 to 70 metres, and have a vertical depth of at least 150 metres. Individual veins within the system vary from 0.5 metre to greater than 9 metres in width. A variety of quartz vein textures and crosscutting relationships indicate a complex history of mineralization with multiple stages of deposition. Fine-grained acanthite, pyrite, electrum, chalcopyrite, bornite, native gold, sphalerite, galena, chalcocite, covellite, polybasite, and stromeyerite occur in this highly fractured and brecciated quartz system in Takla Group andesite and dacite (see Barr, 1980 for detailed description). Higher grade mineralization is most obviously associated with grey quartz, some of which contains visible acanthite. Alteration minerals include pervasive laumontite, chlorite, pyrite, anhydrite, and silica. It is interesting to note that one sample of high-grade ore assayed 0.23 per cent molybdenum. During 1981, dore bullion with a 95-per-cent precious metal content that contained approximately 950 ounces per ton silver and 50 ounces per ton gold, with minor copper, lead, and zinc, was shipped directly from the minesite by air to Vancouver. Results from an additional surface diamond-drilling program totalling over 1 500 metres on surrounding quartz vein systems were discouraging.

LAWYERS

The Lawyers gold-silver deposit is located approximately 15 kilometres north of Baker mine and is now connected by a four-wheel-drive access road. To date some 40 surface diamond-drill holes on a three-tier system have been completed and the Amethyst gold breccia zone has been traced over a north-south length of 610 metres, a width of 60 to 75 metres, and a vertical depth of 75 metres. Recently Serem Ltd. completed an underground program consisting of approximately 730 metres of adit, five crosscuts, and minor drifting from the 1750 level approximately 110 metres below the highest surface expression.

This preliminary underground work has outlined mineralization along a length of 200 metres with a maximum width in any single silicified system of 20 metres. Underground drilling is planned for next season.

Fine-grained acanthite, electrum, and native silver, with minor pyrite, chalcopyrite, galena, and sphalerite, occur in a gangue of amethystine to white quartz and adularia with minor amounts of calcite. Secondary minerals include malachite, chalcocite, and cerussite. The structurally controlled, steeply dipping, brecciated, silicified, and mineralized zones are located in a sequence consisting of green quartz-eye footwall andesitic tuff overlain by aphanitic chocolate brown tuff, welded tuff, and orange trachyte. The orange trachyte generally occurs at stratigraphically and topographically high elevations within the Toodoggone area. Younger altered mafic phonolite dykes cut the entire sequence. Specular hematite and manganese oxide are common alteration products. Typical open-spaced epithermal textures occur within the fissure zone. Grades of mineralization are erratic but some assays exceed 20 ounces per ton gold and 700 ounces per ton silver.

The geologic environment at Lawyers in particular has many similarities to epithermal deposits in Nevada, Colorado, and Mexico.

The Cliff Creek breccia zone is located approximately 2 kilometres west of the Amethyst gold breccia zone. It has been traced for several kilometres on surface. Assay results are good and this zone represents an interesting target for drilling. To date only a few holes have been drilled. The geologic setting is identical to that at Lawyers.

JD (McClair) (MDI No. 094E/032)

The Schmitt and Carbonate Breccia showings on the Texasgulf (Kidd Creek Mines Ltd.) JD claim are located on a ridge immediately south of McClair Creek and north of Kodah Lake. Fissure zones of rebrecciated, mineralized rock occur within a sequence of massive, varicoloured green, grey, brown, and maroon feldspar and hornblende porphyritic andesite, trachyte, and latite tuffs of the middle volcanic division of the Toodoggone volcanic series. Locally, tuffaceous agglomerate and volcanic breccia exist. Attendant alteration zones include kaolinite, gypsum, and pyrite with conspicuous manganese oxide and jaspery hematite. Rounded to subangular fragments of quartz, chert, jasper, and sulphides (including galena, sphalerite, chalcopyrite, and pyrite) occur in a fine-grained matrix of brecciated and silicified tuff. Assays are erratic with some as high as 9.5 ounces per ton gold and several hundred ounces per ton silver. Gangue minerals include amethystine to white quartz, calcite, and minor amounts of barite. To date, only limited surface blasting has been carried out; a much more aggressive program including diamond drilling is planned for next year.

ALBERTS HUMP, GOLDEN FURLONG, RIDGE

The Alberts Hump area includes an area bounded by Alberts Hump - Tuff Peak and the Metsantan prospect. It may be underlain by a collapsed structure (for example, volcanic core) which is now expressed on the surface by a roughly concentric broken ring of massive silica±kaolinite±sulphate-bearing rocks. These may be examples of ancient hot springs indicative of the uppermost part or 'cap' of an epithermal or high-level hydrothermal system. Hematitic fracturing with erratically distributed native gold exists. The host rocks include typical hornblende-feldspar andesitic tuffs of the middle volcanic division of the Toodoggone volcanic series. Significant zones containing alunite (especially Alberts Hump) occur within this area. A K-Ar age date on alunite from Alberts Hump yielded 190±7 Ma. This date for alteration is compatible with other age dates obtained for Toodoggone volcanic rocks in the area. Consequently, these deposits are Early Jurassic, significantly older than most other epithermal deposits. Erratic gold and silver values have been obtained from altered zones but much more detailed work is required to fully understand this area.

METSANTAN

The Metsantan prospect is located on the southeast flank of a mountain immediately east of the abandoned Indian village of Metsantan. During 1980-81 Lacana Mining Corporation identified six zones of mineralization. They have an overall northwesterly trend, having been traced over 1 100 metres in length and 300 metres in width and may have a vertical range of 200 metres. Zones of higher grade mineralization range from 4 to 7 metres in width. Present indications are that higher gold values at surface give way to higher silver values at depth. Base metal mineralization, which includes chalcopyrite, galena, and sphalerite, is associated with orange trachytic tuff and appears to be more abundant at Metsantan than elsewhere in the Toodoggone. Gold and silver values are associated with pyrite, specular hematite, and sericite. The largest zone, the Metsantan gold breccia zone, has been traced and sampled by hand-dug and blasted trenches along a length of 600 metres and across a width of 120 metres. Diamond drilling is planned for next year. Gangue minerals include amethystine to white quartz, kaolinite, and barite.

MOOSEHORN

The Moosehorn prospect of Great Western Petroleum Corp. is in Moosehorn gulley, approximately 2 kilometres upstream from the junction with the Toodoggone River. Amethystine to white quartz and pyrite occur in two silicified zones that are 450 metres in length and 1 to 5 metres in width. The veins are in typical Toodoggone hornblende-feldspar andesitic tuffs.

OTHER PROSPECTS

Other epithermal prospects in the belt with surface showings include:

(1) Mount Graves - a quartz-amethyst stockwork in Toodoggone and Hazelton volcanic rocks.

(2) Silver Pond - a large altered zone which may represent a leached cap zone.

(3) Mess - a massive barite-galena vein.

(4) Kem (Attycelly) - a galena, sphalerite, and barite 'vein.'

(5) Shas - gold-silver mineralization in a stockwork.

(6) Saunders - a gold anomaly and chalcopyrite, pyrite, sphalerite, and molybdenite in quartz veins in Toodoggone volcanic rocks.

(7) Pillar West - gold-silver mineralization in a silicified zone in Toodoggone volcanic rocks.

PLACER GOLD

Tamarik Ltd. conducted preliminary studies that included shallow blasting and overburden drilling on many placer leases covering the McClair and Toodoggone Rivers. Gold found is very fine. Work is scheduled to continue next year.

ACKNOWLEDGMENTS

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TOODOGGONE VOLCANICS SOUTH OF FINLAY RIVER

(94E/2)

By A. Panteleyev

Systematic geologic mapping was started in August in the Toodoggone map-area, 94E, in order to describe lithologies, stratigraphy, structure, and mineralization of the 'Toodoggone volcanics' (Carter, 1971). A major objective of this program was to determine the extent of the volcanic belt south of Finlay River. Work in the area was done in conjunction with T.G. Schroeter, District Geologist, Smithers (see accompanying report, this volume) and L.J. Diakow, currently a graduate student at the University of Western Ontario. In 1982 this cooperative mapping will be concentrated in the area north of Finlay River and extend toward the northern boundary of the Toodoggone volcanics near the Chukachida River.

GEOLOGY

The Toodoggone volcanics form a distinct regional map unit consisting mainly of airfall ash tuffs with subordinate ashflows, coarse pyroclastics, lava flows, and lenses of epiclastic sedimentary rocks. This assemblage forms a northwesterly trending belt at least 90 kilometres long and 25 kilometres wide along the northeastern margin of the Sustut basin. From Finlay River Toodoggone rocks were traced as a continuous map unit for 27 kilometres southward. They extend beyond the boundary of map-area 94E and continue for about 2 kilometres into McConnell Creek map-area, 94D (see Figure 1).

At its southern and southwestern boundary, rocks of the Toodoggone volcanic belt appear to be structurally conformable with Takla rocks. Alternatively, they may overlie them with gentle angular unconformity. Elsewhere Toodoggone volcanics are generally in fault contact with bedded Takla, bedded Hazelton or Omineca intrusive rocks. At least locally, Omineca granitic rocks intrude Toodoggone volcanics. Along its southeast boundary the Toodoggone volcanic belt is overlapped by Paleozoic Asitka and Triassic Takla rocks. The contact area is a series of stacked thrust plates. In this region Toodoggone rocks dip steeply and Z-shaped northerly trending folds with amplitudes of at least 20 metres occur. This is in marked contrast to the area further north in the volcanic belt where gently dipping beds in tilted fault blocks or broad open folds with horizontal axes are the norm.

In detail, six stratigraphic subdivisions of Toodoggone volcanic rocks were made south of Finlay River. These are based on general outcrop appearance, rock mineralogy, texture, and mode of deposition. The geologic section there is probably the most complete section exposed anywhere in the Toodoggone volcanic belt. The basal unit (unit 1) is

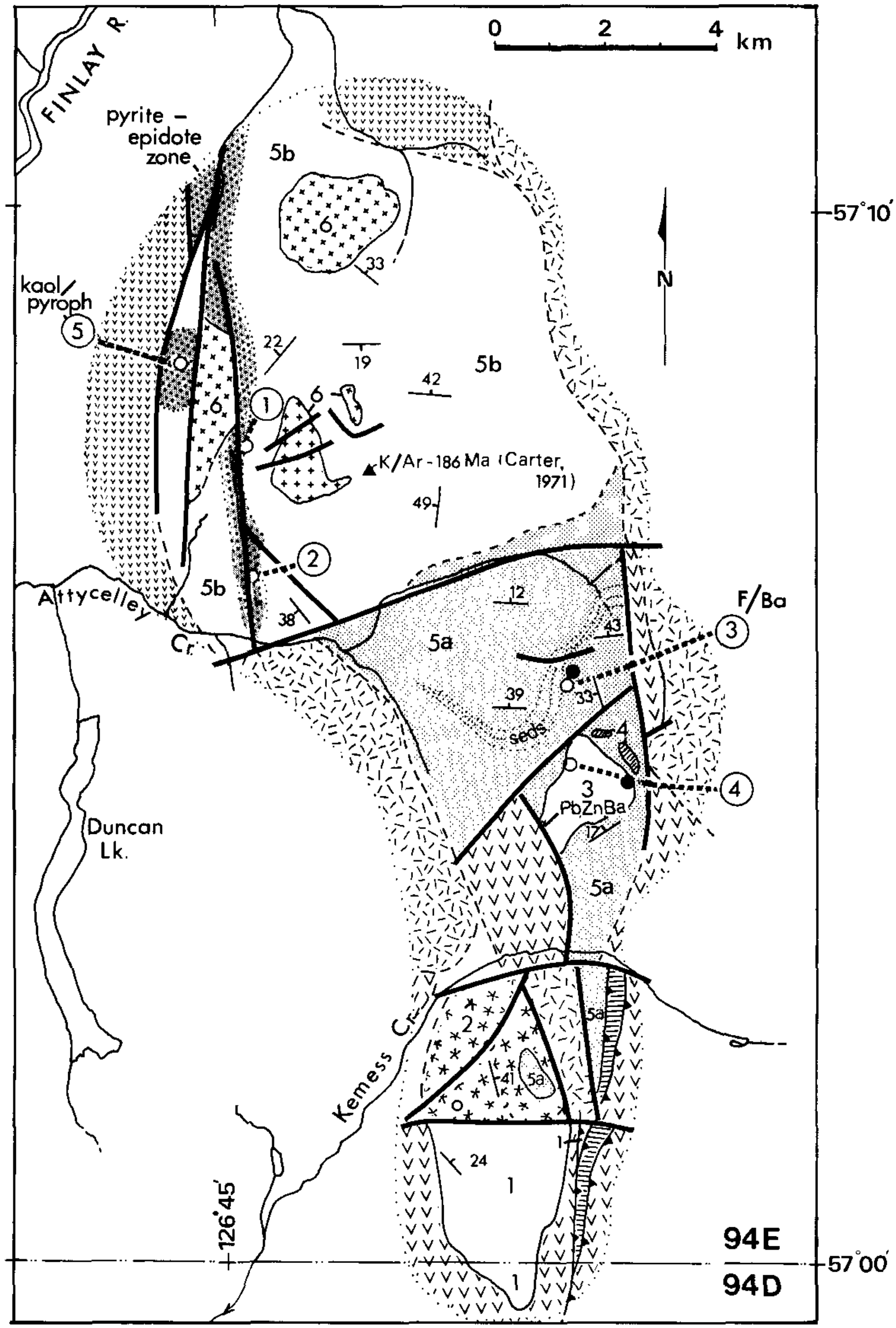

Figure 1. Geology of the area south of Finlay River, showing southward extension of Toodoggone volcanics.

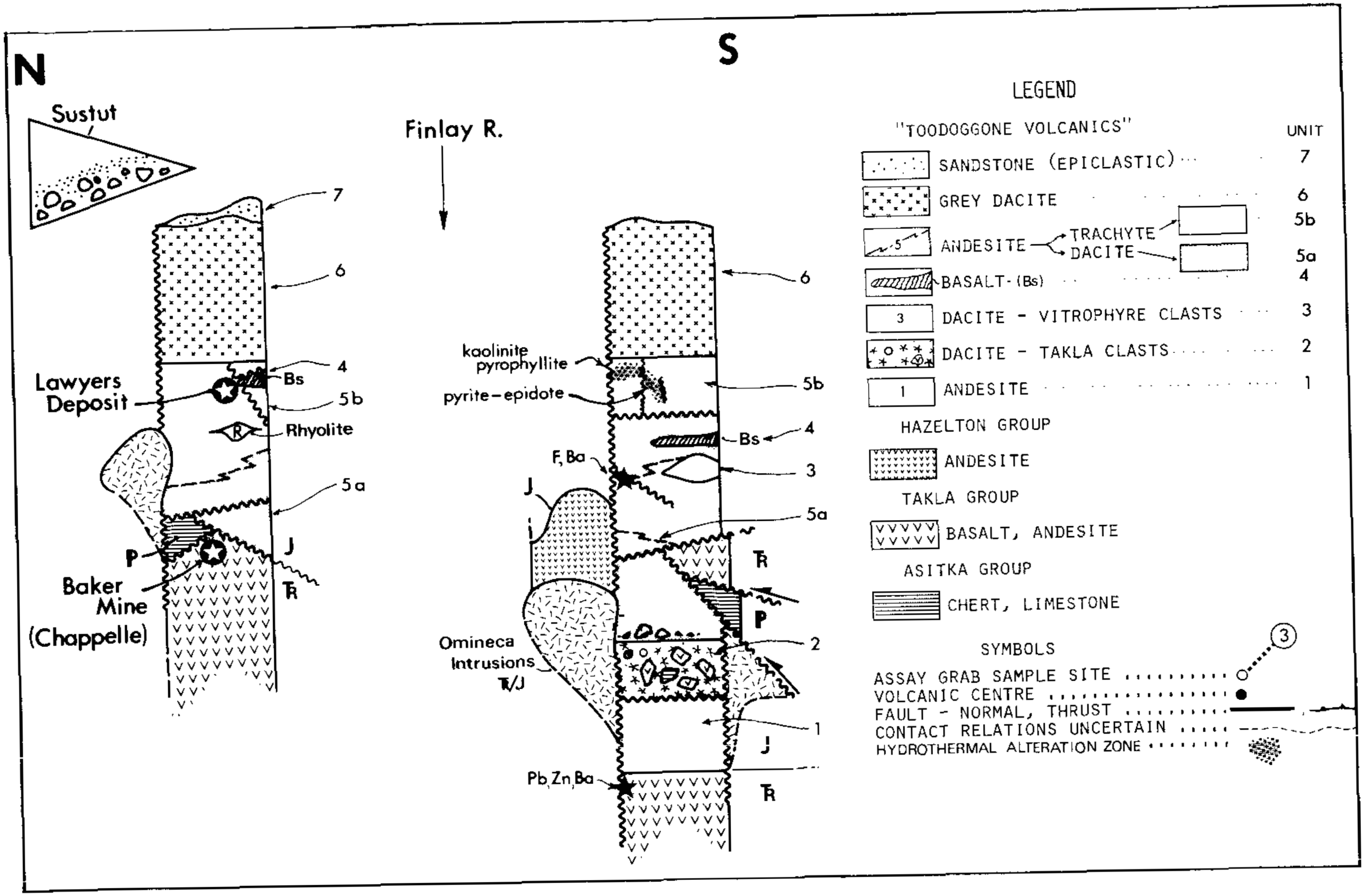

Figure 2. Generalized stratigraphic sections, Toodoggone area.

exposed southeast of Kemess Creek; successively younger map units crop out to the north. The section is as follows:

Unit 1: Andesite - purple to brown and maroon, fine-grained hornblende feldspar porphyry flows. Closer to the southern boundary flows are interfingered with recessive mauve to pink airfall crystal ash tuff. Along the southern contact crystal ash tuff forms a thin veneer on Takla 'basement.'

Unit 2: Dacite - grey to pale green lithic ash to lapilli tuff and crystal-lithic ash tuff. Outcrops are resistant, dark grey in colour, and massive in appearance. There is no obvious bedding. Some indication of layering is given by alignment of lapilli and breccia-sized clasts. Characteristically this unit has clasts of Takla rock; rarely it carries Asitka clasts.

Unit 3: Dacite - the rock is variably brown to orange or grey, biotite (chloritized) quartz feldspar crystal-lithic ash and lapilli tuff. The orange clasts consist of medium-grained feldspar phenocrysts set in a vitrophyric matrix. In thin section, the vitrophyre consists of radiating spherules of quartz-adularia-stilbite. The unit also includes crystal ash tuff, lapilli tuff, and rare lahar lenses.

Unit 4: Basalt - dark green to maroon, amygdaloidal feldspar porphyry flows that are up to 50 metres in total thickness. These cap up to 10 metres of flow or coarse pyroclastic breccia. Mafic phenocrysts are pervasively chloritized.

Unit 5: Andesite (Dacite, Trachyte) - grey, purple, and pink, predominantly hornblende-biotite-quartz-bearing feldspar crystal ash and crystal-lithic ash tuffs with some lapilli tuff and lahar deposits and rare agglomerates. Immature sandstone and conglomerate, that is in part fanglomerate, form epiclastic lenses up to 50 metres in thickness but of local extent. Deposition of tuffs was mainly from airfall deposits. Outcrops are stratified, poorly consolidated, and recessive. Despite their recessive nature, rocks of map unit 5 form the thickest and most extensive unit in the Toodoggone area; its total thickness apparently exceeds 600 metres.

Unit 6: Dacite - grey to grey-green rocks that weather dark grey to brown. The rocks form resistant outcrops that commonly give rise to blocky jointed scarps. The rocks are relatively homogeneous with biotite-hornblende-quartz-feldspar-dacite porphyry clasts set in crystal-ash tuff matrix of similar composition. The clasts are oriented so they impart a faint foliation to the rock. Compaction is locally evident, but there is no evidence of welding in this unit. The unit apparently represents a subaerial ash flow sheet that was up to 150 metres in thickness.

Map units 3, 4, and 5 are largely penecontemporaneous. Each was deposited from separate, adjoining volcanic vents. Map units 3 and 4 are very localized but unit 5 is widespread.

Two small volcanic centres were recognized and are shown on Figure 1 as solid black dots. The smaller centre in map unit 3 is approximately 35 metres in diameter and consists of finely comminuted dark brown powdery dust and ash vent filling with bombs up to 60 centimetres in size. The larger volcanic centre near sample site AXT 3 has a 100-metre-wide feldspar porphyry intrusive neck emplaced along the margin of an eruptive vent of about the same size. This centre is surrounded in a 1-kilometre-sized area by agglomerate and breccia. Outward from the coarse pyroclastic rocks are flanking aprons of lithic lapilli tuff grading to ash tuff. In both volcanic centres solfataric alteration rims up to 10 metres wide mark the periphery of the volcanic vent.

Map units 5 and 6 are known to occur north of Finlay River. Both units are found east and northeast of Baker mine and map unit 5 forms the country rock in the area of the Lawyers deposit. Lacustrine epiclastic sedimentary rocks (unit 7) are found in a few localities north of Finlay River. Map units 5, 6, and 7 as described here correspond to map units 1 to 4 as described by Schroeter (Geological Fieldwork, 1980, Paper 1981-1, p. 125). The correspondence is as follows:

Map unit (this study, Figures 1 and 2)	Map unit (Schroeter, 1980)
5a	1 Lower Volcanic Div.
5b	2 Middle Volcanic Div.
6	3 Upper Volcanic-Intrusive Div.
7	4 Volcanic-Sedimentary Div.

DISCUSSION - MAP UNIT 5

Preliminary chemical data for Toodoggone volcanic rocks (see Schroeter, this report) show that the majority are andesitic. However, the amount of quartz, commonly as quartz crystals in ash tuff, varies from negligible to as much as 15 per cent. Therefore, when modal quartz was conspicuous in a series of outcrops, the rocks were mapped as 'dacite.' For example, the area dominated by purplish quartz-bearing volcanic rocks was distinguished as map unit 5a (Figure 1). Elsewhere, and probably overlying map unit 5a, quartz-poor rocks are andesitic (map unit 5b). Within these rocks Schroeter has found areas containing more than 10 per cent K_2O. The 'andesites,' therefore, of map unit 5b are, at least in part, trachyte.

The geologic map (Figure 1) is generalized and simplified. The northern part (unit 5b) is predominantly andesitic crystal tuff and the southern part (unit 5a) quartz-bearing lithic-crystal tuff and, therefore, 'dacitic.' In reality there are significant vertical and lateral variations in map unit 5. Quartz-bearing and quartz-poor rocks interfinger because slightly different rock types were erupting penecontemporaneously from adjoining eruptive centres. In the southernmost part of the map-area much of the basal part of unit 5a is crystal-lithic tuff. The matrix is quartz-rich crystal ash tuff which carries numerous granitic clasts.

ALTERATION AND MINERALIZATION

Hydrothermal alteration in the mapped area is fracture controlled and consists mainly of the zeolites laumontite and stilbite with calcite; it may be deuteric. Calcite, natrolite, and thompsonite fill amygdales in dyke rocks but, overall, are rare. Intergranular calcite is pervasive in the epiclastic rocks. Throughout the district large areas of tuffs contain epidote clots and feldspars are altered to a pink colour.

Zones in which fine-grained pyrite accompanies the epidote are of more economic interest. One such area occurs in a strongly faulted zone in map-unit 5b between Attycelley Creek and Finlay River. A large area of pervasive clay alteration is developed in the most westerly fault bounded block in this vicinity. Clay minerals identified by X-ray diffraction include kaolinite and pyrophyllite. A composite sample of rock chips grabbed from a tenuous quartz stockwork-veinlet system in the clay-altered zone yielded 676 ppb gold (sample AXT 5). Other composite grab samples comprised of chips of quartz-veined material from silicified volcanic rocks contain trace amounts of gold. Values are shown in Table 1 (see Figure 1 for locations).

TABLE 1. COMPOSITE GRAB SAMPLES FROM SILICIFIED ZONES

Sample	Au ppb	Ag ppm
AXT 1	26	<10
AXT 2	162	<10
AXT 3	202	<10
AXT 4	39	<10
AXT 5	676	<10

Two occurrences of vein or breccia mineralization are known in the map-area. One is at sample site 3 (AXT 3) where green fluorite and barite accompanies hematitic chalcedony and calcite in a fault zone. The fault may be a radial structure related to the larger of the two small volcanic centres described previously. The second occurrence (shown on Figure 1 as Pb, Zn, Ba) is a quartz-calcite vein with base metal-barite mineralization. It occurs along the faulted contact between Toodoggone rocks and Takla rocks containing a porphyritic syenite dyke.

CONCLUSIONS

The 'Toodoggone volcanics' form a distinctive sequence of subaerial volcanic rocks that can be readily subdivided into a number of lithologically similar map units. Some map units are distributed throughout the volcanic belt, others are very localized.

Published radiometric dates vary from 179 to 189 Ma (Gabrielse, et al., 1980). These, as well as a new date on hydrothermal alunite of 190 Ma (see Schroeter, this volume), suggest an Early Jurassic age of deposition and related mineralization. These age data are compatible with the observation that Toodoggone volcanics rest directly on Triassic Takla rocks and can be correlated in age with older parts of the Hazelton Group.

The region south of Finlay River has similar lithologies, fault zones, and evidence of hydrothermal activity as the mineralized terrane of the Toodoggone epithermal gold-silver camp north of Finlay River. The area shown on Figure 1 appears to offer bountiful opportunities for additional epithermal deposits. Close attention should be paid to larger fracture/fault zones with associated hydrothermal alteration, particularly if there is silicification. Attention should also be paid to bleached clay or alunite-bearing zones that might represent low-pH cappings over buried precious metal deposits. All silicified zones, including breccias and weakly developed chalcedonic veinlet systems and stockworks, should be sampled for gold.

ACKNOWLEDGMENTS

Bema Industries Limited provided expert expediting services from Smithers and Serem Limited offered logistic support in the Sturdee airstrip vicinity. Mitch Mihalynuk ably assisted the writer throughout this program.

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AKIE RIVER PROJECT

(94F)

By D.G. MacIntyre

The mapping project, which was initiated in the Driftpile Creek-Akie River Ba-Zn-Pb district in 1979, was continued during the 1981 field season. This year the project involved two helicopter-supported mapping crews operating from a base camp at Pretzel Lake. The following work was completed:

(1) Detailed mapping and measurement of stratigraphic sections in the vicinity of the Kwadacha barite deposit (94F) (see separate report, this publication).
(2) Continuation of regional 1:50 000-scale mapping south of the Akie River* (94F/1W, 2E; Figure 1).
(3) Sampling of strategic Devonian sections for a lithogeochemical study by J. Lowey at the University of Calgary.
(4) Examination of Esso Resources Reb prospect (94C/16W).

LEGEND

MIDDLE TO UPPER DEVONIAN

muD	Shale, silty shale, minor siltstone, sandstone, conglomerate, limestone; chert, siliceous argillite, pyritic and baritic shale

LOWER TO MIDDLE DEVONIAN

lmD	Fossiliferous limestone; minor calcarenite, calcareous siltstone, and quartzite.

ORDOVICIAN TO SILURIAN

ROAD RIVER FORMATION

OS	Dolomitic siltstone, graptolitic black shale, calcareous siltstone; minor limestone, quartz, chert

KECHIKA FORMATION

CO	Nodular phyllitic mudstone, wavy banded, limestone, platy calcareous siltstone

Symbols

High-angle fault; ball on downthrown side ....

Thrust fault ....

Antiform; synform ....

Mineral occurrence ....

Exhalite horizon ....

*To be released as a Preliminary Map, Spring 1982.

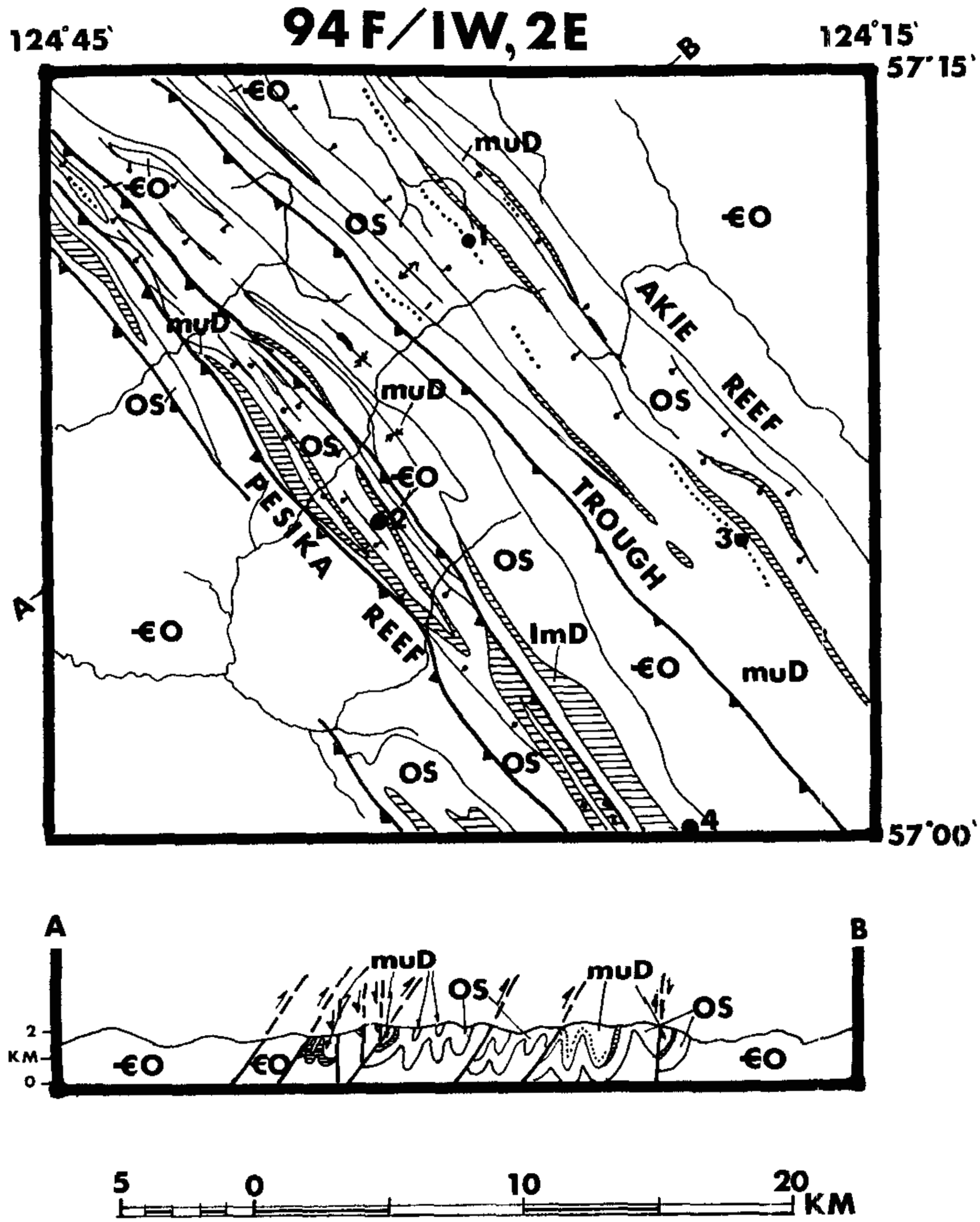

Figure 1. Generalized geology of 92F/1W, 2E.

In addition, L. Diakow spent 10 days mapping and sampling the Kwadacha barite deposit (see separate report, this publication). Tentative plans for the 1982 field season are to continue regional mapping in the area between Kwadacha Park and the Driftpile Creek occurrence. Geochemical, paleontological, and petrographic studies are currently in progress on samples collected to date and results will be published when all work is completed.

STRATIGRAPHIC AND STRUCTURAL SETTING

The Devonian stratigraphy and structure of the Akie River area have been discussed in two previous reports (MacIntyre, 1980, 1981). In general, the Devonian consists of a lower succession of quartzose and calcareous turbidites and shallow water carbonates that typically grade basinward into finer grained reduced silty shales and siltstones. These rocks, which on interbasin rises have been removed by a Middle Devonian erosional event, range in age from Early to Middle Devonian and are unconformably overlain by a distinctive unit of rhythmically bedded black chert, siliceous argillite, carbonaceous black shale, and minor limestone. These rocks in part correlate with Middle Devonian shelf carbonates of the MacDonald Platform and carbonates of the Akie and Pesika Reefs. These reefs, which apparently grew on the uplifted edges of westward tilted fault blocks, divided the Devonian basin into parallel troughs during Early and Middle Devonian time (MacIntyre, 1981), thus profoundly influencing Devonian sedimentation.

The Devonian stratigraphy in the current map-area (Figure 2) is a continuation of that observed to the north (MacIntyre, 1981). The lower part of the succession locally includes a unit of medium to thick-bedded quartz siltstone, sandstone, and conglomerate turbidites (unit 1) that unconformably overlies grey, pink, and red weathering platy siltstones and black cherts at the top of the Silurian section. The quartzose unit grades up section into interbedded calcarenites, limestone debris flows, and graptolitic (Pragian) black shale (unit 2). These turbidites presumably grade into the Lower Devonian limestone unit (unit 2a) found at the base of both the Akie and Pesika Reefs (Figure 3). Basinward the calcareous turbidites grade into black silty shales that have minor black chert and pelagic limestone intercalations (unit 3). The vertical succession of rocks suggests progressively deeper water conditions with time, perhaps due to an Early Devonian episode of crustal subsidence.

Where it has not been removed by erosion, the Lower Devonian transgressive cycle (units 1, 2 and 3) is overlain by a unit of medium to thick-bedded shallow water limestone that varies in thickness from over 200 metres in the core of the Pesika and Akie Reefs to less than a metre in adjacent troughs. Bioclastic beds rich in crinoid ossicles with double axial canals ('2 holers') typically occur near the top of the unit. The abundance of such ossicles indicates a probable early Middle Devonian age (Taylor and MacKenzie, 1970).

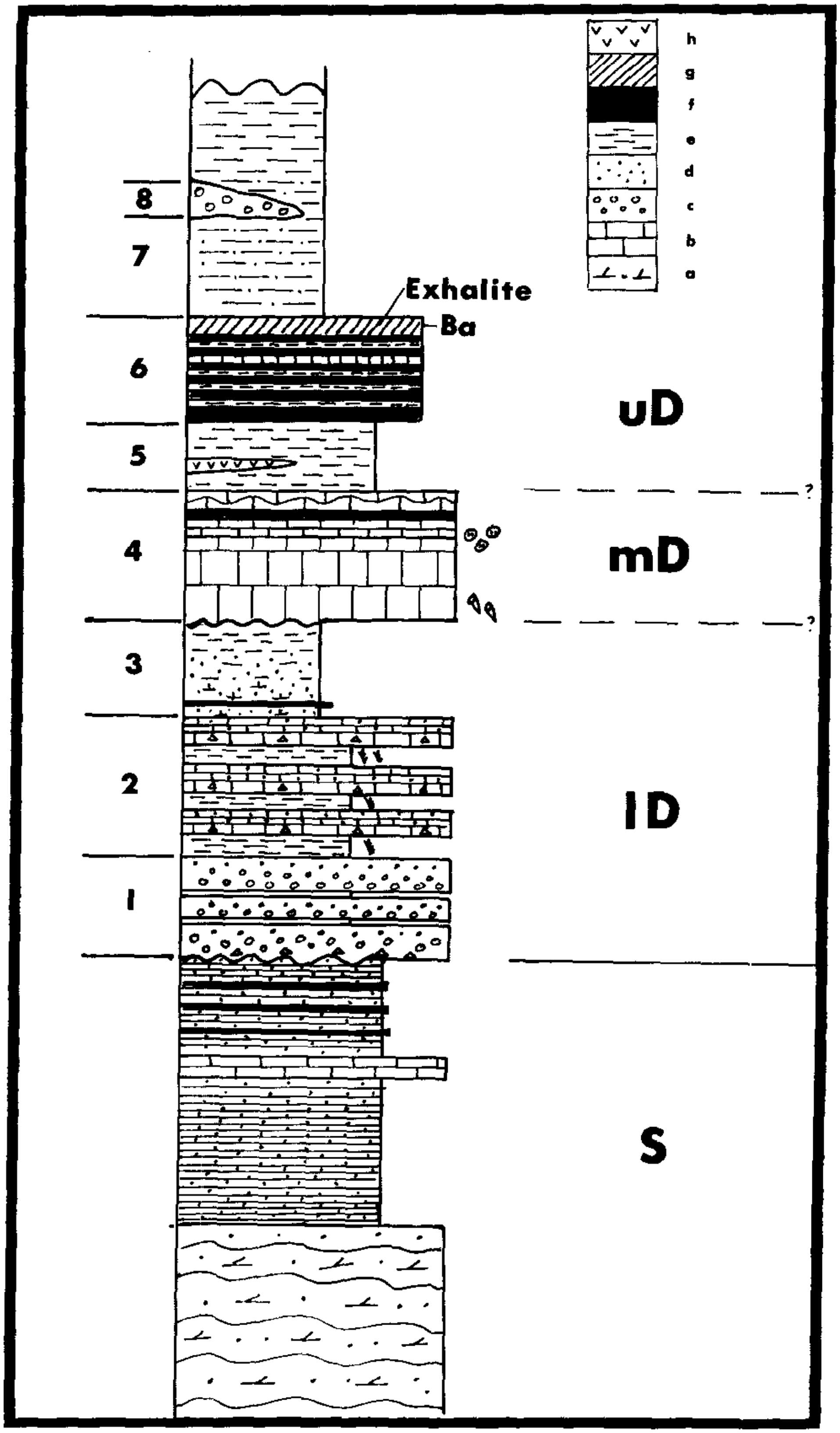

Figure 2. Idealized stratigraphic column for the Pesika Creek area showing apparent position of siliceous exhalites (black bands) and barite mineralization (cross hatched).

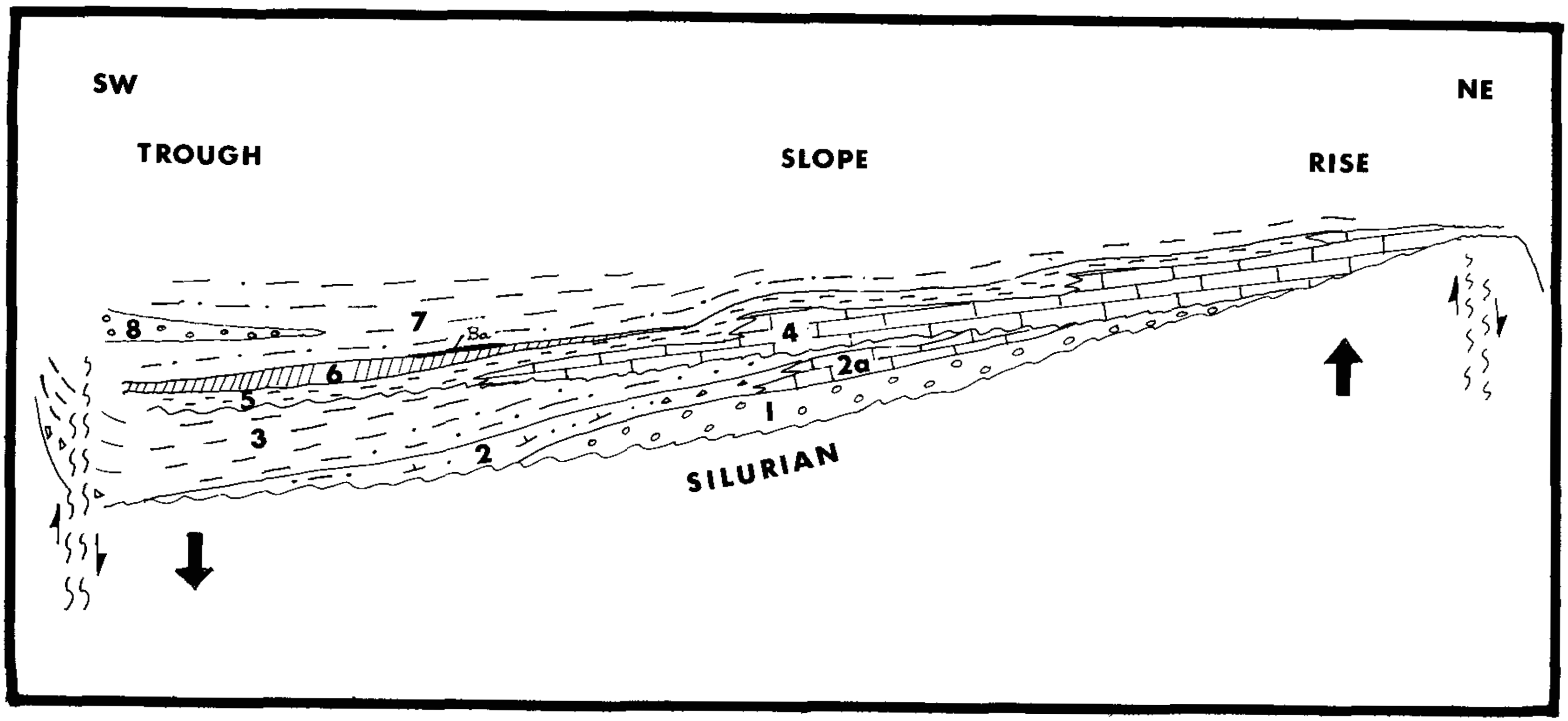

Figure 3. Idealized facies relationships between the Pesika Creek area and inferred depositional environments.

In contrast to the succession north of the Akie River, the Middle Devonian limestone in the current map-area is overlain by a relatively resistant unit of black rusty weathering shale that locally exceeds 100 metres in thickness (unit 5). The siliceous argillite, chert and shale unit (unit 6), which host the bedded barite and massive sulphide deposits of the Akie River district, lies stratigraphically above the rusty shale unit in the eastern part of the map-area but appears to be discontinuous in the westernmost shale belts. Where present, the siliceous unit is overlain by bluish grey to brownish grey-weathering banded silty shales of probable Late Devonian to Mississippian age (unit 7). In the westernmost exposures of the Devonian section thin units of sandstone and siltstone turbidites (unit 8) occur stratigraphically above the siliceous unit in the Late Devonian transgressive shale sequence. In the same area a 1-metre-thick greenish grey to orange-weathering pyritic tuff bed occurs within unit 5, a few metres above the Middle Devonian limestone. Units 4 and 5 may represent a short-lived transgressive cycle that preceded a period of tectonic and exhalitive activity that heralded the beginning of a major episode of progressive, eastward advancing crustal subsidence in Middle to Late Devonian time. Concommitant crustal uplift and volcanism occurred to the west but shifted eastward during Mississippian time. This uplift may be related to the beginning of accretion of oceanic terranes further west at the leading edge of the continental plate.

MINERAL OCCURRENCES

The widespread Late Devonian baritic and/or pyritic siliceous exhalite unit, which is ubiquitous north of the Akie River, appears to be only locally present in the current map-area. This unit is exposed on Cyprus Anvil's Gin claims and Cominco's Pesika claims but surface mineralization is restricted to thin beds and laminae of nodular and massive barite. These occurrences (Nos. 1 and 3 on Figure 1) are on strike with a long belt of barite-sulphide occurrences that extends northward to the Driftpile creek district. The deposits appear to have formed in a linear structurally controlled trough bounded by the Akie and Pesika reefs.

Two other showings are also located within or near the 1981 map-area. Cominco's Ern showing (No. 2, Figure 1) comprises stratabound massive pyrite in a brecciated quartzite host. The quartzite is interbedded with dark grey calcareous siltstones, black chert, and limestone. Similar rocks have been observed elsewhere in the map-area; typically they occur near the top of the Silurian section, immediately below the Lower Devonian quartzite unit (unit 1, Figure 2). A similar stratigraphic position is suggested for the Ern showing.

Esso's Reb prospect (No. 4, Figure 1) is located slightly south of the area mapped in 1981. The showing is located in a small creek valley and consists of several finely laminated pyrite bands in a sequence of interbedded black shale, chert and siltstone. Graptolites collected from an outcrop of shale upstream from the showing indicate an Ordovician age for the mineralization. The Ordovician section on the Reb property appears to be anomalously thick relative to those to the north, suggesting the presence of a local sedimentary basin or trough.

ACKNOWLEDGMENTS

The author would like to thank Riocanex Exploration and Dick Woods of Vernon Helicopters for providing logistical support for the mapping project. In addition, Alf Stewart of Esso Resources provided a very informative tour of the Reb property. Mike Fournier, Karen Downing, and Jennifer Lowey ably assisted in the mapping project and their work is gratefully acknowledged.

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KWADACHA BARITE DEPOSIT

(94F/10W)

By D. MacIntyre and L. Diakow

INTRODUCTION

During the 1981 field season the Kwadacha barite deposit, which is located immediately north of the confluence of the Kwadacha and North Kwadacha Rivers within Kwadacha Wilderness Park, was the subject of detailed regional and property scale mapping. This work was done over a 10-day period in late June and involved three two-person field crews. The deposit, which is well exposed in a series of fault and fold repeats along the crest of a north-trending ridge, is accessible only by helicopter.

REGIONAL GEOLOGY

The geology in the vicinity of the Kwadacha barite deposit is shown on Figure 1. This part of the Rocky Mountain Fold and Thrust Belt is underlain by Cambrian to Late Devonian clastic and carbonate rocks (MacIntyre, 1981). Northeast of the deposit, shelf carbonates of the MacDonald Platform predominate and these grade westward into time equivalent clastic facies. The rocks have been folded into a series of northwest-trending asymmetric, overturned antiforms and synforms that have both southwest and northeast-dipping axial surfaces. The latter are somewhat enigmatic in that structural transport is generally to the northeast with most of the thrust movement occurring along the southwest-dipping axial surfaces of major fold structures. Folds with northeast-dipping axial surfaces are interpreted to result from gravity back-sliding of an incompetent thrust plate as it moved upward along a southwest-dipping fault surface rooted in competent shale units. Some of the high-angle normal faults, which typically have downthrown blocks to the west, may also be related to back-sliding and break up of the overthrust plate.

STRATIGRAPHIC SETTING

The stratigraphic setting of the Kwadacha barite deposit is similar to that of other barite-sulphide deposits in the Driftpile Creek-Akie River District (see MacIntyre, 1981). In general, the baritic zone occurs near the top of a resistant unit of rhythmically bedded black chert, siliceous argillite, silty shale and minor limestone. This unit is overlain by a thick section of monotonous black shale and underlain by shallow water medium to thin-bedded grey fossiliferous limestones and calcarenites. Several beds within this limestone unit are rich in crinoid ossicles,

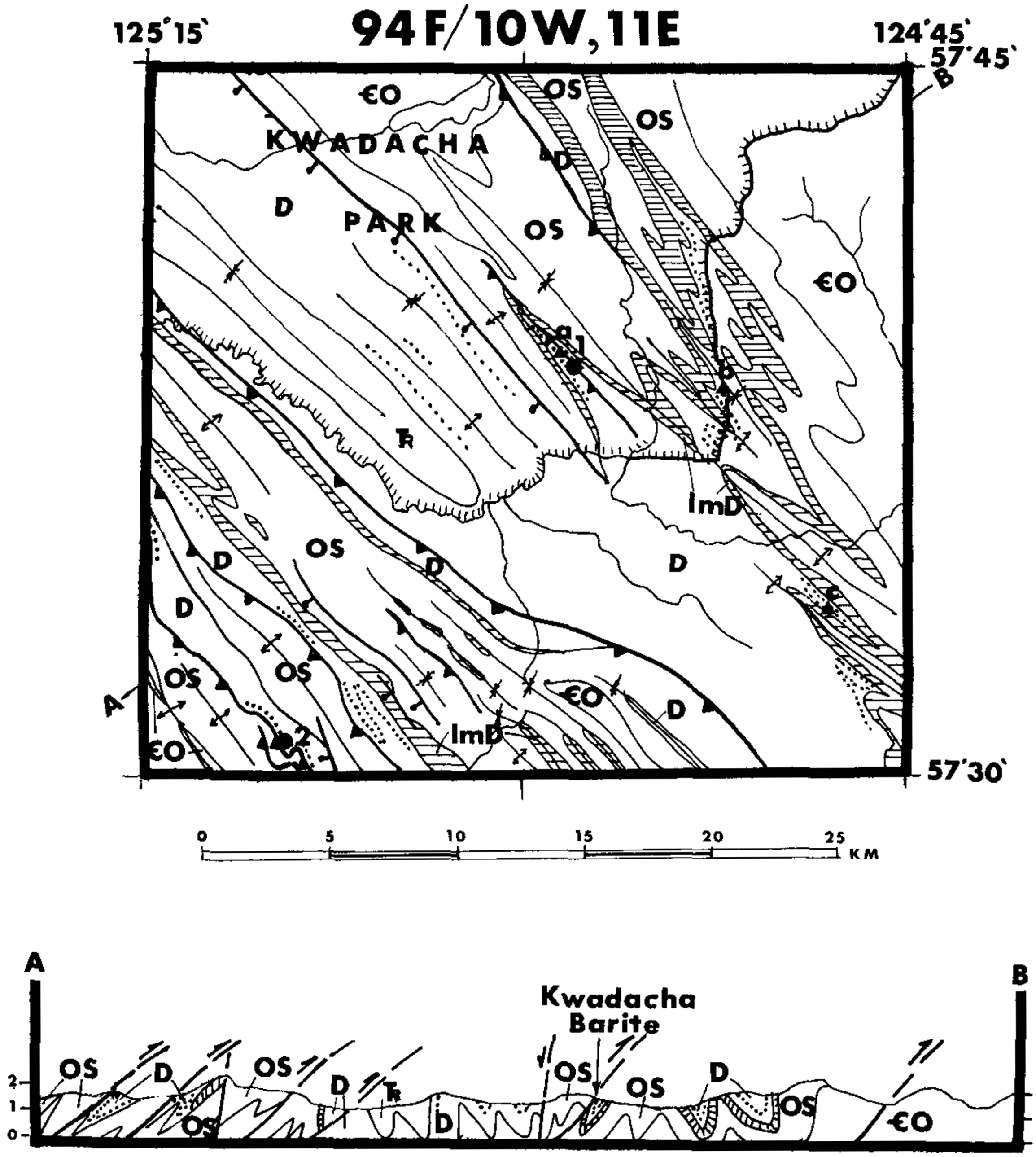


Figure 1. Generalized geology in the vicinity of the Kwadacha barite deposit.

LEGEND

DEVONIAN

D Shale, siltstone, chert, siliceous argillite; minor limestone

LOWER TO MIDDLE DEVONIAN

lmD Fossiliferous limestone, calcarenite; quartz sandstone, quartz siltstone, conglomerate; minor shale.

ORDOVICIAN TO SILURIAN

OS Dolomitic siltstone, graptolitic black shale, calcareous siltstone, limestone, dolostone; minor chert, mafic volcanic rocks

CAMBRIAN TO ORDOVICIAN

CO Nodular phyllitic mudstone, calcareous siltstone; minor shale, limestone, calcarenite

Symbols

Geologic contact ....

Thrust fault ....

Normal fault (ball on downthrown side) ....

Anticline; syncline ....

Known surface trace of baritic and/or pyritic exhalite horizon ....

Stratigraphic section location ....

Barite-sulphide deposit, 1 - Kwadacha; 2 - Cirque ....

Boundary of Kwadacha Wilderness Park ....

some with double axial canals ('2 holers') indicating a probable Middle Devonian age (Taylor and MacKenzie, 1969).

The basal part of the Devonian succession consists of graded beds of quartz sandstone and siltstone which are locally crosslaminated and contain angular shale rip-up clasts. These quartz-rich rocks unconformably overlie a unit of pink, grey, and red platy weathering laminated siltstone with minor limestone and chert intercalations that is apparently the uppermost part of the Silurian section. The quartzose unit is less than 10 metres thick in the vicinity of the Kwadacha barite deposit (section a, Figure 2) but is more than 50 metres thick on the ridge immediately east of the deposit (section b, Figure 2). A similar westward thinning is noted for the limestone unit; overlying siliceous rocks, on the other hand, apparently thicken westward. Westward thinning and fining are characteristic of most of the Lower Devonian units that occur along the shelf margin, suggesting these sediments were deposited by turbidity currents moving down a westward dipping slope. Basinward thickening of the siliceous unit, on the other hand, suggests accumulation of silica-rich sediments was favoured in the deeper water, more euxinic environment. Some of the silica may have been introduced by submarine exhalitive activity that preceded and accompanied formation of

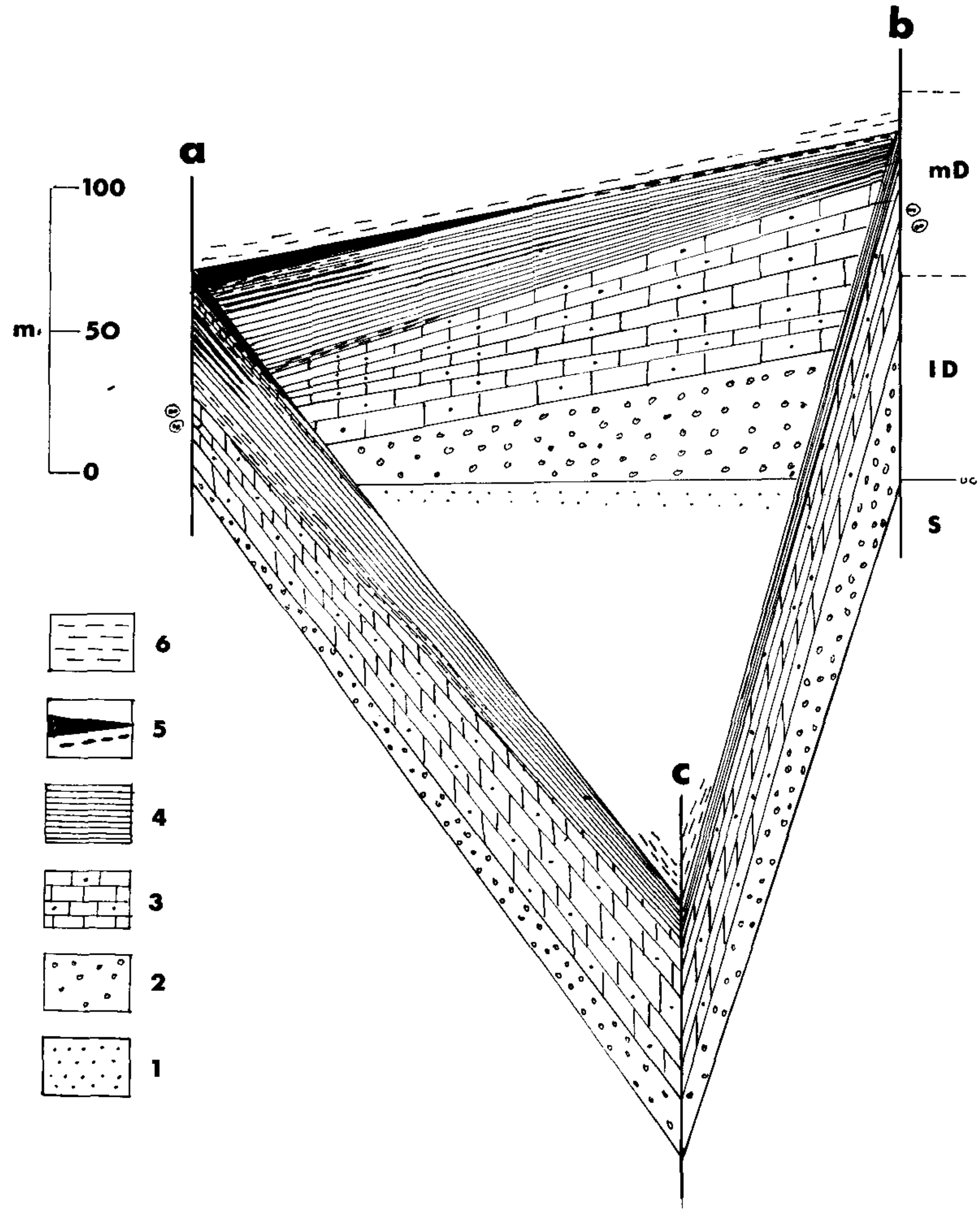


Figure 2. Stratigraphic fence diagrams showing thickness variations in Devonian units and stratigraphic position of the Kwadacha barite deposit: 1-dolomitic siltstone, minor chert, and limestone; 2 - quartz sandstone, siltstone, and conglomerate; 3 - thin-bedded limestone, calcarenite, and calcareous siltstone; 4 - interbedded black chert, siliceous argillite, and shale; 5 - massive bedded barite, nodular barite; 6 - black shale (see Figure 1 for location of sections).

the Kwadacha barite deposit. Overall, the vertical stratigraphic succession from near shore high energy quartz-rich sandstones upward into reduced black shale and progressive onlapping of these units eastward with time are evidence for a major marine transgression that began in Early Devonian time. This transgression was probably the result of eastward advancing crustal subsidence.

BARITE MINERALIZATION

Bedded barite is repeated by imbricate thrust faults and folding along the crest of a north-trending ridge (Figure 3). The barite is resistant and outcrops as a series of jagged, low-amplitude, southwest-dipping hog backs. Two barite zones are present separated by a 10 to 15-metre-thick interval of recessive black shale with a thin grey weathering limestone interbed. The lower zone consists of several 10 to 15-centimetre-thick intervals of laminated and nodular barite that occur in the upper 10 to 15 metres of the interbedded chert, siliceous argillite and shale unit. The upper zone, which varies from 1 to 10 metres in thickness, consists of massive, finely laminated barite with thin argillaceous partings. A colour gradation from light grey-white barite at the base to dark grey barite at the top of the zone was noted and is attributed to an increase in admixed argillaceous material up-section.

The upper barite zone contains no visible sulphide mineralization but thin laminae of very finely disseminated pyrite were found in the underlying siliceous shale unit. Outcrops of barite were sampled along the entire length of the ridge from stratigraphic bottom to stratigraphic top and are being analysed to determine variations in major and trace element content throughout the unit. Results will be published when the analytical work is completed.

Thin, discontinuous beds of discrete and coalescing barite nodules in a black shale host occur close to the base of the siliceous unit and in black shales immediately overlying the upper massive barite zone. These beds probably originated from the precipitation of $BaSO_4$ from meteoric solutions liberated during diagenesis.

DEFORMATION

Deformation related to northeast-directed supracrustal shortening is readily apparent in the vicinity of the Kwadacha barite deposit. Silurian and Lower Devonian fine clastic and chemical sedimentary rocks have been folded into major upright and overturned southeast-plunging anticline-syncline pairs. In contrast, the less competent shale-rich Middle and Upper Devonian units are characterized by tightly appressed or isoclinal folds with a penetrative axial planar cleavage. The upper massive barite unit, which is underlain and overlain by shale, behaved plastically during deformation and internal folding and thickening in the hinge area of folds is commonplace.

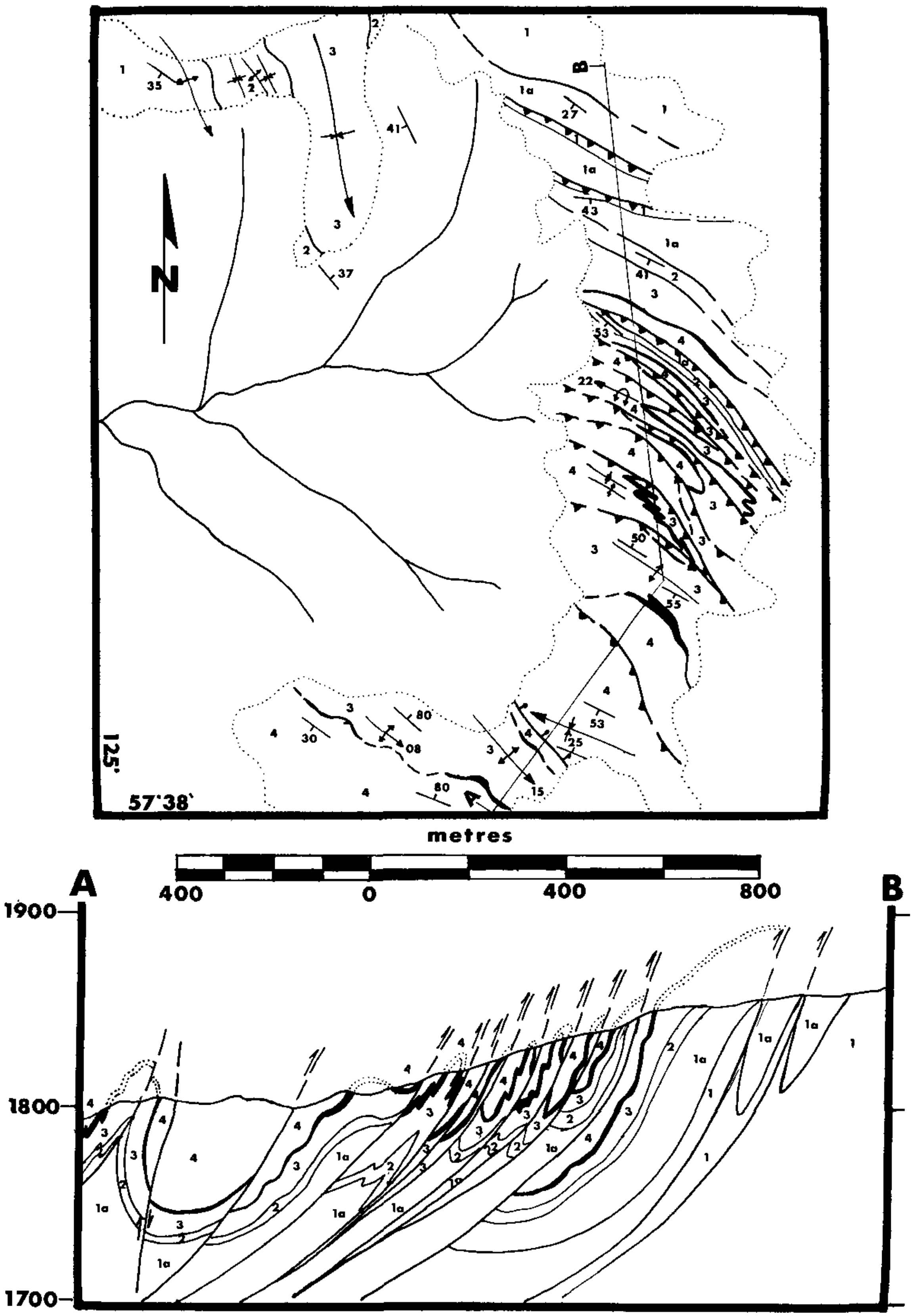


Figure 3. Geology of the Kwadacha barite deposit (mapping by L. Diakow).

LEGEND

MIDDLE TO UPPER DEVONIAN

4	Black silty shale; minor limestone, chert
3	Interbedded black-banded chert, siliceous argillite, and black carbonaceous shale; minor limestone

LOWER MIDDLE DEVONIAN

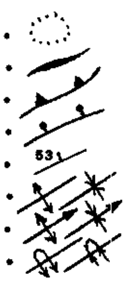
2	Thin-bedded fossiliferous limestone, calcarenite; minor shale; includes thin basal quartz sandstone and siltstone unit

SILURIAN

1a	Platy banded siltstone and laminated silty shale; minor limestone and chert
1	Medium to thick flaser-bedded dolomitic siltstone; minor limestone

Symbols

Area of outcrop ....
Massive laminated barite ....
Thrust fault ....
Normal fault ....
Bedding ....
Anticline; syncline ....
Plunging anticline; plunging syncline ....
Overturned anticline; overturned syncline ....



Numerous subparallel, southwest-dipping thrust faults along the hinges of shear folds produced a stacked succession of single-limb half folds. The frequency of faulting is greatest in the shale-rich sections and at the base of a thin limestone bed underlying the upper massive barite unit. In this stress regime, limestone acts rigid and detaches easily from the underlying shales.

Structural thickening of incompetent shale sections and dragging of beds adjacent to fault planes is widespread.

ACKNOWLEDGMENTS

The writers would like to thank John Mawdsley, Mike Fournier, Karen Downing, and Jennifer Lowey for their very capable and cheerful assistance in the field.

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CASSIAR GOLD DEPOSITS
McDAME MAP-AREA

(104P/4, 5)

By A. Panteleyev and L.J. Diakow

INTRODUCTION

A study of the Cassiar gold deposits initiated in 1980 was continued during July of 1981. Additional fill-in geological mapping at scale 1:10 000 was done west of Quartzrock Creek and north of Troutline Creek, along Finlayson Creek, to the south of McDame Creek, and along the northern boundary of the 1980 map-area (see Figure 1, this report and Figure 18, Geological Fieldwork, 1980, Paper 1981-1, p. 56).

Particular attention was paid to delineating major quartz vein systems. A number of northeasterly to east-northeasterly trending fracture zones containing quartz veins are outlined on Figure 1. Within these zones, mineralized areas and individual veins of economic interest were mapped at 1:1000 scale.

Mining and exploration activity in the Cassiar gold belt was brisker during 1981 than in previous years. For the third consecutive year mining and exploration were conducted on Table Mountain by Erickson Gold Mining Corporation (Jennie vein MDI No. 104P/029). Two new mills were commissioned in August. On August 14th the United Hearne - Taurus Resources Limited's plant turned over at the Hanna gold mine (Cornucopia, Benroy, Copco) (MDI No. 104P/012), 8 kilometres east of Cassiar. On August 17th Plaza Mining Corporation started milling at their plant that adjoins the Cassiar road 3 kilometres southeast of Hanna mine. Mill feed for start-up of both new mills came from stockpiled ore. At Hanna mine (Cornucopia), ore was provided by underground development work whereas at Plaza it came from a small open pit located at the eastern extension of

SYLVESTER GROUP (MISSISSIPPIAN TO ? PERMIAN)

2	GREENSTONE–CHERT ASSEMBLAGE: MASSIVE PALE TO DARK GREEN ANDESITE FLOWS, TUFF, IN PART FINE–GRAINED DYKES AND SILLS, SOME CHERT, INCLUDES PORPHYRITIC FELDSPATHIC ANDESITE FLOWS (AND ? SILLS)	4	BASALT: WIDESPREAD PILLOWS, SOME BRECCIA, TUFF, AND MINOR ARGILLITE; IN SOUTHEAST, ABUNDANT BRECCIA, TUFF, AND SMALL LIMESTONE PODS
2a	CHERT, TUFFACEOUS CHERT, INCLUDES SOME ARGILLITE; IN NORTHEAST WELL–LAYERED CHERT–PHYLLITE, TUFFACEOUS CHERT, RIBBONED CHERT, AND ARGILLITE	3	SILTSTONE, ARGILLITE, GREYWACKE, PEBBLE CONGLOMERATE, QUARTZ ARENITE, CALCAREOUS SILTSTONE, LIMESTONE
1	ARGILLITE, SILTSTONE, CHERT, QUARTZITE, LIMESTONE, PEBBLE CONGLOMERATE, TUFF; INCLUDES NUMEROUS DIABASE AND ANDESITE SILLS		VEIN SYSTEM

LEGEND TO ACCOMPANY FIGURE 1.

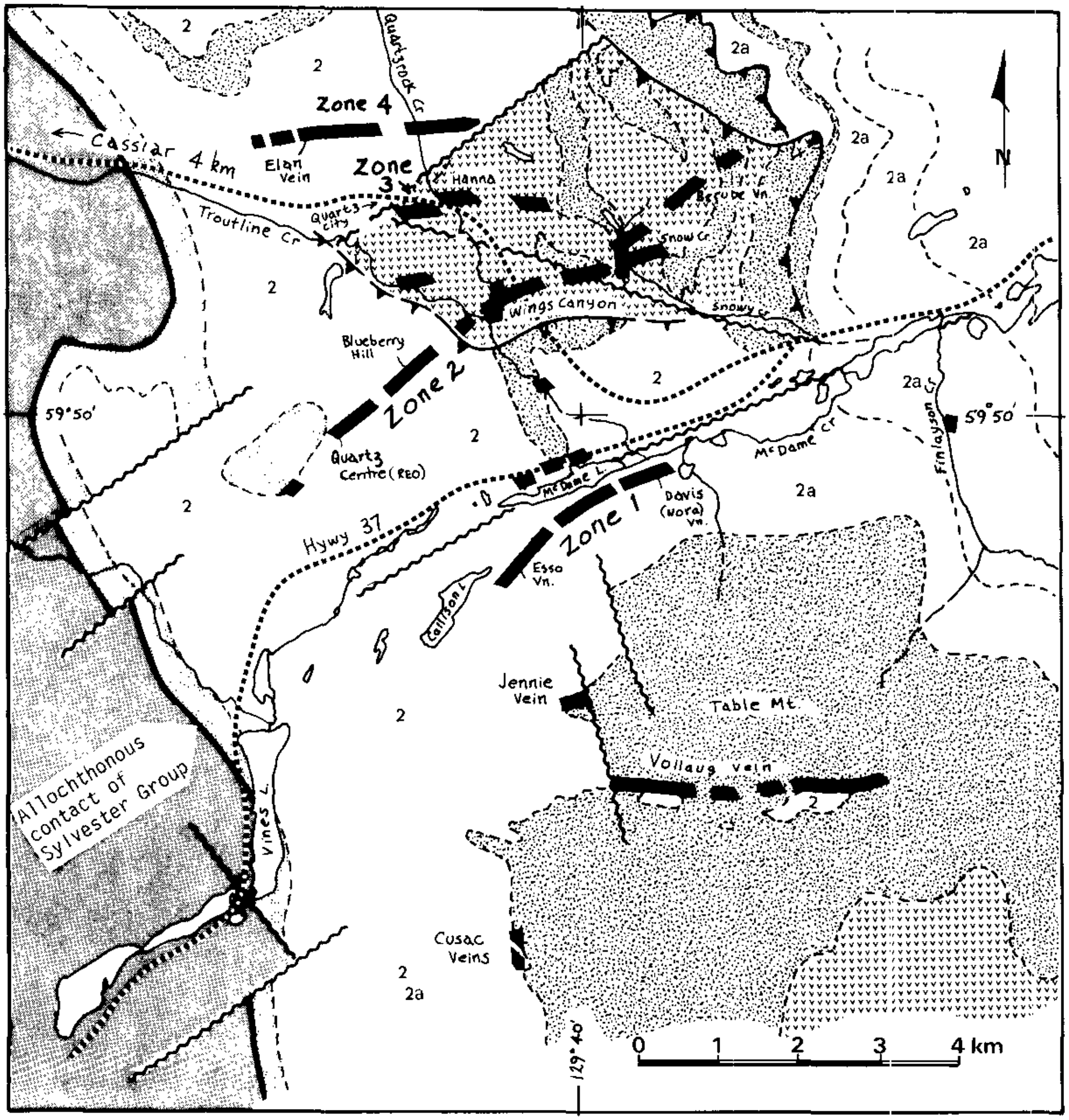

Figure 1. Geology of the McDame map-area.

also occur (Bruce Spencer, pers. comm.). These suspected thrust faults are seen in new underground workings and diamond-drill cores. If these structures are part of the same fault that is present in outcrops south and west of Snowy Creek, then a major flat fault or series of faults underlie the lower reaches of Troutline and Quartzrock Creeks.

QUARTZ VEIN SYSTEMS

Auriferous quartz veins and placer deposits in the Cassiar region have been described in considerable detail by Mandy (1931, 1935, 1937). These the Vollaug vein (MDI No. 104P/019) on Table Mountain. All three of the operating mills in the Cassiar gold belt have rated capacity of 100 to 150 tonnes per day.

GEOLOGY

Fill-in mapping affirmed the stratigraphic and structural interpretations presented in Geological Fieldwork 1980 (Paper 1981-1). During current mapping map units described in 1980 were extended; chert and tuffaceous chert of map unit 2A was found to underlie the northeastern part of Table Mountain along Finlayson and McDame Creeks, and greenstones, clastic rocks, and basalt of map units 2, 3, and 4 were noted to the north of the previously mapped area.

The presence of at least one major, westward dipping thrust fault was confirmed by mapping ridges north of Snowy (Snow) Creek and east of Quartzrock Creek. Other flat-lying to locally eastward dipping faults reports provide a historical record of exploration as well as sound descriptive and assay data.

Few new veins, with possible exceptions of the Cusac, Esso, and Berube vein systems, have been found as a result of recent work. However, much information has been gained from new exposures of known veins. A geologic map (Figure 1) shows the locations and current names of the main quartz vein systems.

In this study veins were divided into two fundamental types. Type 1 veins are hosted by 'greenstone' and Type 2 veins occur at bedding contacts between greenstone and argillite.

TYPE 1 VEINS

The host rocks for Type 1 veins are mainly metamorphosed andesitic flows or tuffs, pillowed basaltic flows, and rarely diabasic dykes, sills, or flows. These rocks are now greenstones as a result of greenschist metamorphism or propylitic alteration. Type 1 quartz veins consist of fine to coarse granular milky white quartz with small amounts of erratically distributed ferroan carbonate and rare vugs with clear, terminated quartz crystals. The veins occupy sets of steeply dipping, generally northeast to east-northeasterly trending, subparallel fractures or en echelon gashes. Type 1 veins are generally short and narrow. Even those in the larger shear zones tend to pinch and swell along strike. Many veins are arcuate or cymoid (sigmoidal) and terminate either by pinching out, by splaying into 'horsetails,' or locally by forming bulbous quartz 'knots' that are generally less than 1 metre in diameter. Where a vein terminates in quartz 'knots,' it is common to see another quartz vein developed in the hangingwall of the first vein. These hangingwall veins are wispy and thin near the quartz 'knots' but increase in thickness along strike. A typical Type 1 quartz vein would be up to 1 metre wide and as much as 60 metres in length; rare veins are up to 5 metres wide and persist for hundreds of metres (for example, the Elan vein system). En echelon veins and ladder veins which commonly show preference for certain beds are generally short, rarely more than 10 metres in length.

Type 1 veins have characteristic bleached wallrock alteration envelopes. The alteration envelopes are commonly 5 to 10 times as wide as the quartz veins that they surround and mostly have sharp, knife-edged margins. In some cases alteration zones up to 100 metres wide surround small discontinuous quartz veinlets, such as in the Hanna mine (Cornucopia)-Quartzrock Creek area.

The alteration zones serve as excellent exploration guides because they give rise to distinctive orange-brown soils over buried vein systems. The bleached altered greenstone consists of albite, carbonate, clay minerals, pyrite crystals and rare chlorite and epidote. The quartz veins in the most highly altered zones contain sericite and tourmaline in addition to ankeritic carbonate.

Type 1 veins occur in four main zones as shown on Figure 1. From south to north these include:

Zone 1: Callison - McDame Lakes system (MDI No. 104P/017, 018): The vein system includes the Esso, Gold Hill, and Davis (Nora) veins in a zone that trends at 055 degrees for at least 2 500 metres. Most veins have a short strike length and are controlled by 040 to 050 degrees trending joint sets. The recently discovered Esso vein is one of the few veins that follows shear joints; it trends 020 degrees. The Davis (Nora) vein strikes at 070 to 085 degrees, the most common trend of the larger veins in the McDame map-area.

Zone 2: Quartz Centre - Wings Canyon - Snowy Creek System (MDI No. 104P/013, 014, 015): This is the most persistent of the vein systems. It gives rise to a mineralized belt approximately 5 kilometres long and 150 metres wide. This system includes the Reo, Blueberry Hill, Wings Canyon (Red Rock), and Snowy Creek veins including the Rich vein, Snow Creek, and Berube veins. The Reo veins are unusual in this district in that two ages of quartz are evident. Older veins are massive and trend 090 to 115 degrees; younger veins trend at 045 degrees and truncate the older veins.

Zone 3: Quartz City - Upper Snowy Creek System (MDI No. 104P/011, 012): This belt is marked by a wide alteration zone with a large number of small quartz veins. The larger veins include the Quartzrock Creek (Mack, Mac) veins, and the Hanna mine (Cornucopia) vein system.

Zone 4: Elan vein system: A number of large quartz lenses up to 8 metres wide occupy a shear zone that trends east-westerly over a strike length of 3 kilometres.

TYPE 2 VEINS

This second type of quartz vein occurs at bedding contacts of greenstone and argillite. Invariably greenstone is in the footwall and argillite in the hangingwall. Most Type 2 veins occupy the bedding plane contact; locally the veins are entirely in greenstone or splay into strands, some of which pass in and out of greenstone. Where the quartz veins pass into argillite, they become ribboned with abundant graphitic lamellae and commonly pinch or feather out. In some workings, the quartz veins are split by basic dykes about 1 metre wide. Within the veins the dykes are pervasively bleached and carbonate altered and become 'felsite.'

Movement took place along many of the bedding plane contacts before and after emplacement of Type 2 veins. For example, on Table Mountain blocks of dyke rock and dismembered limestone beds are contained in contorted argillites that overlie the plane of decollement. Mandy (1937) considered this setting to be a major thrust fault in which the Vollaug vein was developed.

The Vollaug vein, a graphitic, ribboned quartz vein, is a good example of a Type 2 vein. It is an east-westerly trending, gently northward dipping, vein up to 2 metres in width that has been traced nearly 2 kilometres as a semi-continuous structure. The east-northeast-trending, more steeply Jennie vein is another example. The Cusac veins occur at the same major greenstone-argillite contact but consist of a number of small quartz veins that are confined mainly to steep fractures in the footwall greenstone. Other Type 2 veins are found individually or in groups along the contact of map units 2 and 3 on Troutline Creek, or near map unit 2A and 3 contacts with unit 4 in the Snowy Creek area.

Alteration in the footwall greenstones associated with Type 2 veins is similar to that in Type 1 veins, though less intense. In hangingwall argillites, there is little alteration evident other than a thin zone of carbonate veining and a slight increase in pyrite content.

MINERALOGY

Both vein types contain free gold, small amounts of pyrite, tetrahedrite, chalcopyrite, and arsenopyrite, and traces of sphalerite and galena. Covellite, azurite, and malachite occur in weathered zones. In some veins, for example the Reo, Elan, and West Hope (Hopeful), tetrahedrite is the main ore mineral. Tetrahedrite is erratic in its distribution but locally can be so abundant that it produces spectacular silver grades. Gold in Type 1 veins is associated with pyrite, ankeritic carbonate, and arsenopyrite. In weathered specimens free gold occurs as grains in cellular boxworks or plates cavity walls. In Type 2 veins, gold accompanies tetrahedrite or occurs with graphite. The average gold/silver ratio in Type 2 veins is 1:1.

QUARTZ-CARBONATE-MARIPOSITE ROCK (LISTWANITE)

Numerous bodies of listwanite that vary from a few metres to 700 metres in length have been noted. They appear to be endemic to the gold-bearing region but have no direct spatial relationship to auriferous quartz veins. Listwanites are metasomatized zones formed along faults and bedding contacts. Boundaries are sharp or gradational. These peculiar rocks are derived mainly from basic flows but also from tuffs and tuffaceous sediments. Locally they accompany serpentine bodies. In the area mapped these small serpentine bodies constitute lenses that also appear to be derived from the basic volcanic wallrocks.

The relationship of quartz veins, listwanite bodies, and rare serpentine lenses appears to be largely a structural one - they occupy the same fracture zones.

AGE OF GOLD MINERALIZATION

Hydrothermal white mica from a tourmaline-bearing auriferous vein from Snowy Creek yielded a potassium-argon age date of 131±5 Ma. In view of the 73-Ma Late Cretaceous dates reported for the closest granitic intrusions west of the Cassiar gold belt (Panteleyev, 1980), the gold mineralization appears to be related to structure-metamorphic events that pre-date and are independent of major granitic emplacement.

ACKNOWLEDGMENTS

The cooperation and logistic support offered by Cassiar Asbestos Corporation Limited is acknowledged. We thank the following gentlemen for access to properties and for the information they provided: Al Beaton, Camille Berube, Chris Bloomer, Tim Riordan, Bruce Spencer, and Bill Storie.

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MIDWAY OCCURRENCE

(104O/16W)

By D.G. MacIntyre

INTRODUCTION

The Midway stratabound massive sulphide discovery which is located approximately 96 kilometres west of Watson Lake, Yukon Territory, was examined on September 9 and 10. The property comprises 240 Yukon claims

LEGEND

CRETACEOUS

CASSIAR BATHOLITH

Kqm Quartz monzonite, granodiorite

MISSISSIPPIAN AND LATER

Mu Serpentinite, dunite, peridotite

UPPER DEVONIAN TO MISSISSIPPIAN

SYLVESTER GROUP (UPPER)

DMv Greenstone, agglomerate; dacitic tuff; minor chert, metadiorite

MIDDLE TO UPPER DEVONIAN

SYLVESTER GROUP (LOWER)

uD Slate, argillite, chert, siltstone, chert-arenite, greywacke, chert pebble conglomerate, minor limestone

MIDDLE DEVONIAN

McDAME GROUP

mD Dolomite, fossiliferous limestone

CAMBRIAN, ORDOVICIAN, AND SILURIAN

€OS Dolomite, dolomitic sandstone and siltstone, graptolitic black shale, platy siltstone, calcareous phyllite, phyllitic limestone skarn, hornfels, limestone, quartzite

Symbols

High-angle fault; ball on downthrown block ....
Antiform ....
Contact: defined; assumed ....
Road ....
Stratabound barite .... □
Stratabound massive sulphide .... ◆
Mineral occurrence in carbonate rocks .... ●
Exhalite horizon ....

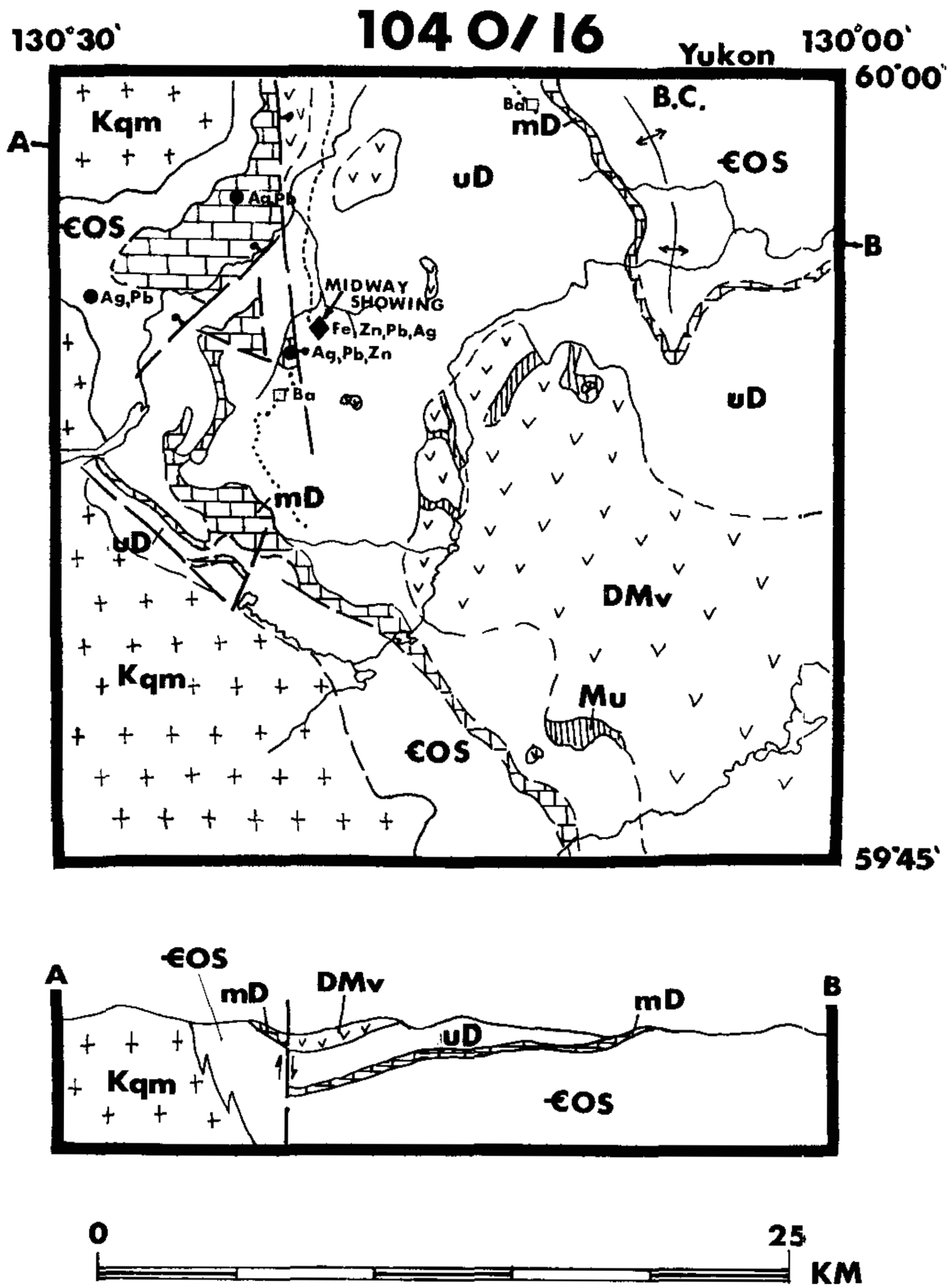

Figure 1. Generalized geology in vicinity of the Midway showing, Jennings River map-area; geology and legend modified from Gabrielse (1969).

and 881 British Columbia claim units accessible via a rough four-wheel-drive road that connects with the Alaska Highway near Rancheria (Milepost 702). The property was acquired by Cordilleran Engineering on behalf of Regional Resources Ltd. during 1980 and is currently under option to Amax of Canada Ltd.

STRUCTURAL SETTING

The Midway showing is located within a north-trending belt of Middle to Late Devonian basinal facies sedimentary rocks (Figure 1). These rocks are preserved within the core of a major synclinorium that is bounded and intruded by the Cretaceous Cassiar Batholith (Kqm) to the west and the Lower Cambrian carbonates of the Atan Group to the east (Gabrielse, 1969). Unlike areas east of the Rocky Mountain Trench, deformation within the synclinorium is relatively minor and broad open folding is the predominant structrual style. The stratigraphic succession is locally offset by high angle normal and reverse faults.

STRATIGRAPHIC SETTING

The host rocks for the Midway showing are black silty shales and siliceous argillites of the lower part of the Sylvester Group. These rocks conformably overlie Middle Devonian McDame limestone (mD) (Gabrielse, 1969) and therefore are probably late Middle to Early Late Devonian in age. Detailed mapping and measurement of stratigraphic sections by Cordilleran Engineering and Amax Exploration geologists has defined three major coarsening upward sedimentary cycles (units 1, 2, and 3, Figure 2) in the lower part of the Sylvester Group (uD) (Figure 2). These cycles, that typically begin with a relatively thin sequence of interbedded shale, silty shale and baritic and/or pyritic exhalite, grade up section into progressively coarser, thicker, and more calcareous turbidites. These coarsening upward cycles suggest an increasing proximity to a source area with time, perhaps as a result of eastward advancing crustal uplift. Coarse clastic rocks of unit 3 are overlain by mafic to felsic volcanics of the upper part of the Sylvester Group (DMv). These volcanic rocks appear to be largely subaerial in origin.

MINERAL OCCURRENCES

Trenching on the property has exposed a zone of stratabound recrystallized massive pyrite that averages 2 metres in thickness over a strike length of approximately 40 metres. High-grade concentrations of zinc mainly as diffuse bands of blonde-coloured sphalerite occur locally within the massive pyrite. Minor amounts of galena are also present. Elsewhere on the property several baritic and pyritic exhalite horizons have been discovered that can be traced for considerable distances north and south of the showing. A 4-metre-thick bedded barite occurrence (Ewen barite) was

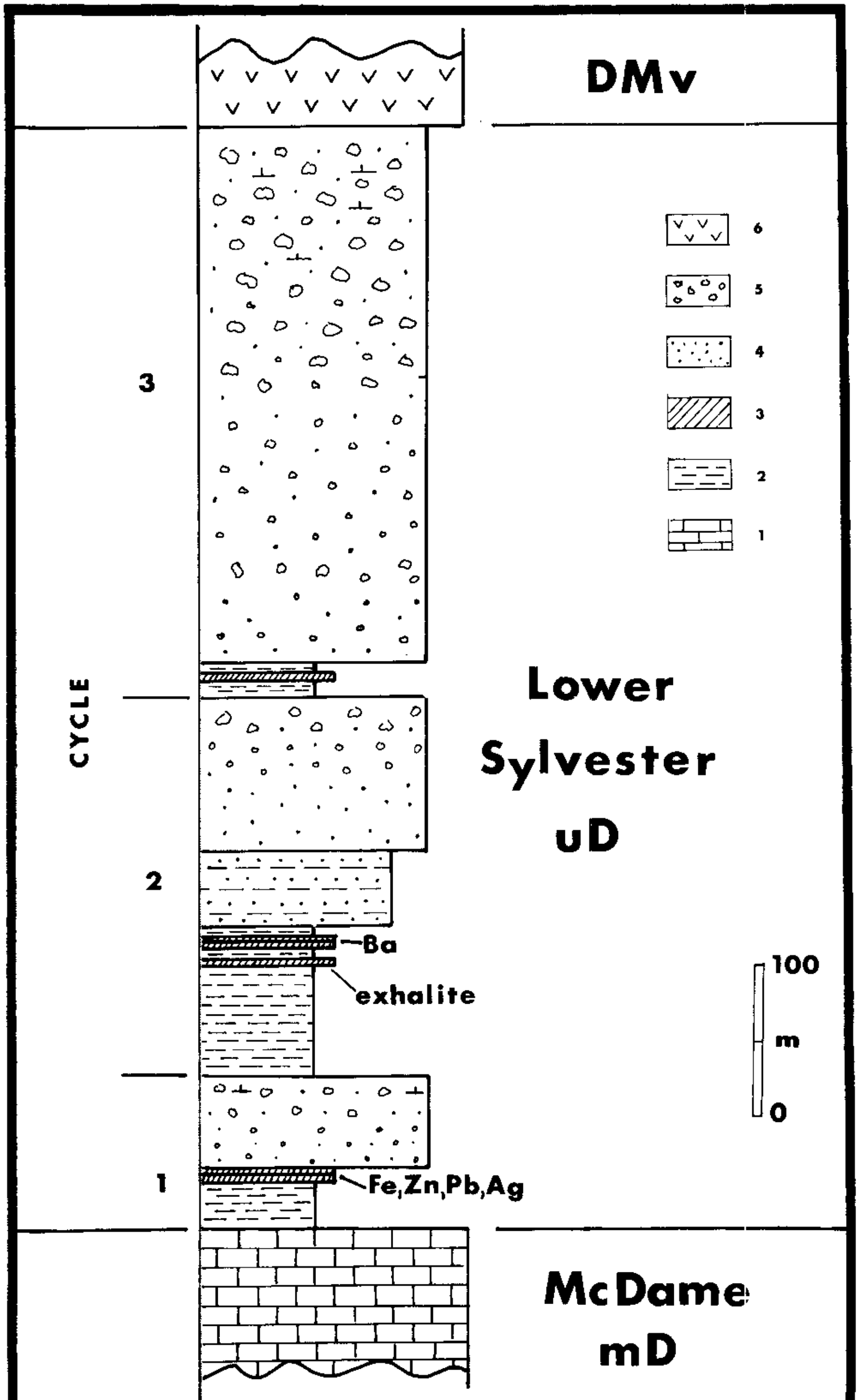

Figure 2. Idealized stratigraphic column for the Midway property showing location of exhalite zones (cross hatched) and sulphide and barite mineralization (black lines). 1 - limestone; 2 - shale, silty shale; 3 - siliceous exhalite, chert; 4 - siltstone, sandstone; 5 - conglomerate, sandstone; 6 - mafic to felsic volcanic rocks.

discovered in the northeast corner of the property near the British Columbia-Yukon boundary.

Six diamond-drill holes, totalling 853 metres, were completed late in the year in the vicinity of the Discovery showing (see Regional Resources News Release, November 23, 1981). Results of this work indicate the presence of three southeast-dipping mineralized zones. The Lower Zone which is locally absent overlies Middle Devonian dolostone, varies from 1 to 2.5 metres in thickness, and has combined zinc-lead grades ranging from 2.65 to 23.39 per cent and silver values ranging from 1.24 to 22.59 ounces per ton. This zone is locally lead-rich.

The Lower Zone is overlain by 70 metres of argillites and sandstones which are the footwall rocks of the Middle or Discovery Zone. Drill intersections indicate that this zone varies from 4.6 to 11.2 metres in thickness and has combined zinc-lead grades ranging from 4.56 to 13.36 per cent and silver grades ranging from 1.26 to 5.03 ounces per ton. Ten to 12 metres above the Discovery Zone is the Upper Zone which ranges from 0.43 to 3.2 metres thick and has combined lead-zinc grades ranging from 2.62 to 13.15 per cent and silver grades ranging from 0.63 to 6.52 ounces per ton. Both the Discovery and Upper Zones are predominantly zinc-rich. Interbedded argillites and sandstones overlie the Upper Zone.

ACKNOWLEDGMENTS

The author would like to thank Cordilleran Engineering and Amax Exploration for the opportunity to visit the Midway occurrence and for their generous hospitality and logistical support during the examination of the property. Discussions with Mr. S.E. Parry were particularly valuable as an introduction to the regional stratigraphic setting of the mineral occurrence. Mr. M. Fournier ably assisted in the field.

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O T H E R   I N V E S T I G A T I O N S

MULTIVARIATE MODELS FOR RELATIVE MINERAL POTENTIAL SLOCAN SILVER-LEAD-ZINC-GOLD CAMP

(82F)

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ABSTRACT

One hundred and thirty-eight vein deposits forming the western part of Slocan camp are used to develop statistical models based on known ore production and average grades of production. Relative size of deposits as estimated by the biased variable 'production' (short tons of ore) is used as a relative value measure to (a) serve as a dependent variable for multiple regression models, and (b) form the basis for subdividing data into low, medium, and high-tonnage groups for discriminant analysis models. Both types of models appear useful judging by their ability to forecast known production for a target production of deposits from the eastern part of Slocan camp. Results suggest that multiple regression is more useful than is discriminant analysis in classifying deposits with respect to potential size.

INTRODUCTION

Statistical methods have been applied over a wide range of scales in attempts to develop a rigorous approach to measuring absolute or relative resource potential (Kelly and Sheriff, 1969; Sinclair and Woodsworth, 1970; Orr and Sinclair, 1971; Godwin and Sinclair, 1979). Comparable approaches are used widely in evaluating oil and gas potential (for example, Harbaugh, et al., 1977). Little effort has been expended on the application of statistical models to the evaluation of specific polymetallic mineral deposits in terms of grades of economically important metals, particularly in vein camps.

Such models have two important applications viz:

(1) Newly located deposits can be sampled and the average grades used to estimate potential size and thereby provide an evaluation of the usefulness of additional exploration.

(2) A statistical model may identify known deposits with low productivity that have grade characteristics of large deposits, thus indicating specific known deposits that appear to warrant more detailed examination.

Orr and Sinclair (1971) attempted to use multiple regression in Slocan City vein camp as a means of estimating relative value of a deposit. Average production grades for silver, gold, lead, and zinc were used as the independent variables and recorded production tonnage was the relative value indicator (dependent variable). Statistically significant models were described but no data existed by which the geological validity of a model could be tested. Furthermore, their models were of little practical interest because they pertained to a camp in which deposits were very small and of little general interest.

More than 200 vein deposits in Slocan camp have produced from 1 to 700,000 tons of ore for which average grades of total recorded production are more or less completely known (Orr and Sinclair, 1971). These data provide an unusually comprehensive information base for testing the validity of various statistical approaches to the estimation of 'value' of a deposit, and the potential of such models as an exploration tool.

PROCEDURE

Deposits in Slocan camp were divided into two groups for the purpose of this study. One hundred and thirty-eight deposits forming the western two-thirds of the camp were taken as a training set for the development of statistical models to determine relative 'value' of individual deposits. The eastern part of the camp contains 65, more dispersed deposits that form a target population. Averge production grades and tonnages are known for these 65 deposits so real values can be compared with values calculated according to various models, and a rigorous test of the predictive capability of a model can be conducted.

RELATIVE VALUE MEASURE

Sinclair (1979) has discussed the problem of relative value measures for multi-commodity deposits. Metal content is an ideal value estimator for single commodity deposits but where several commodities contribute significantly to total value of a vein deposit, for example, size is commonly a more meaningful relative value measure. Production ore tonnage, despite obvious limitations, can be used as an adequate estimator of relative deposit size, and therefore of relative value.

We never know the true size (volume or tonnage) of a deposit because we are never sure that it has been completely worked out or had all the reserves outlined. Consequently, ore production tonnage is a biased estimator of size and of relative value that is always low relative to the true value. Furthermore, the bias may not be the same for all sizes because of selective mining, hand sorting, and so on. Nevertheless, as a relative measure, production tonnage is still adequate except for:

(1) many pairs of deposits with identical or nearly similar production tonnages (a trivial case), and
(2) some deposits that really are large despite the fact they have produced only small amounts of ore to date.

this latter case is not a problem, rather it is a situation that we hope exists so that such deposits can be recognized eventually by our predictive models.

In the present case, production tonnage is accepted as an adequate relative value measure. A probability graph for production tonnages shown on Figure 1 for both the training set and the target population, indicates close similarity of statistical density functions between the two areas. Two populations are present in identical proportions in each area, although the average size is somewhat lower in the target population than in the training set. The probability graph for the training set has been partitioned into two populations with mean sizes that differ by several orders of magnitude. This fact emphasizes the desirability of a numerical model that would allow distinction between high tonnage deposits of economic interests and the low tonnage population of little economic interest.

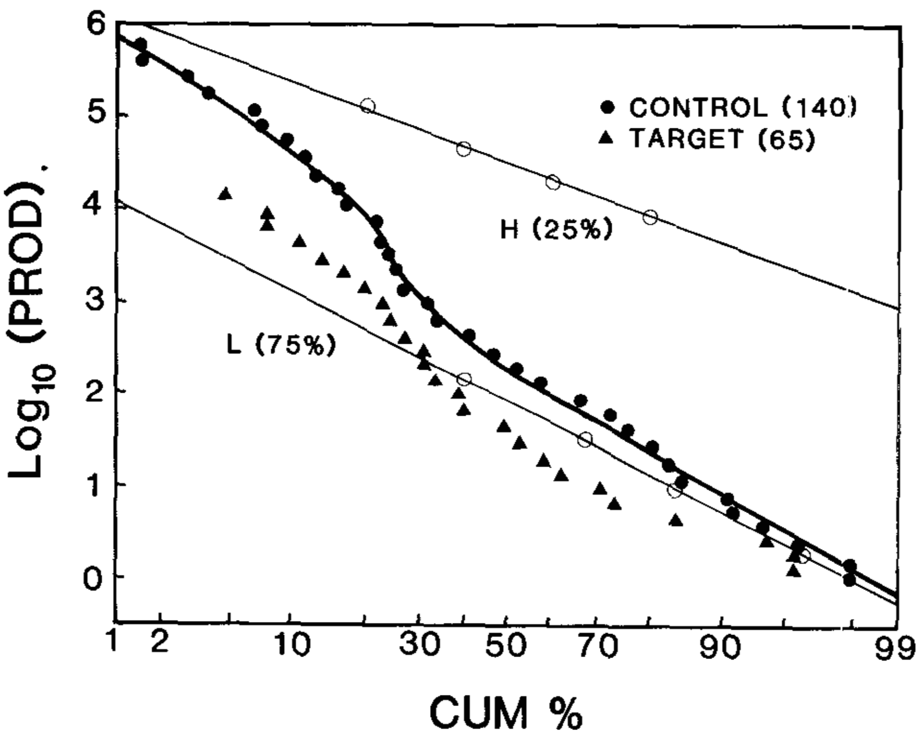

Figure 1. Probability graphs of ore production tonnage for the training set (filled circles) and the target population (filled triangles). Two straight lines are the two interpreted lognormal populations drawn through construction points (open circles) derived from the training serve curve.

The principal metal contributor to value in Slocan camp is silver, which is plotted versus production tonnage on Figure 2. From this diagram it is difficult to ascertain whether two distinctive populations exist, each with its own average grade and dispersion of average grades, or whether, on average there is a continuous variation in metal content and size (production tonnage). Both possibilities will be tested, the continuous case using multiple regression and the discontinous case using discriminant analysis.

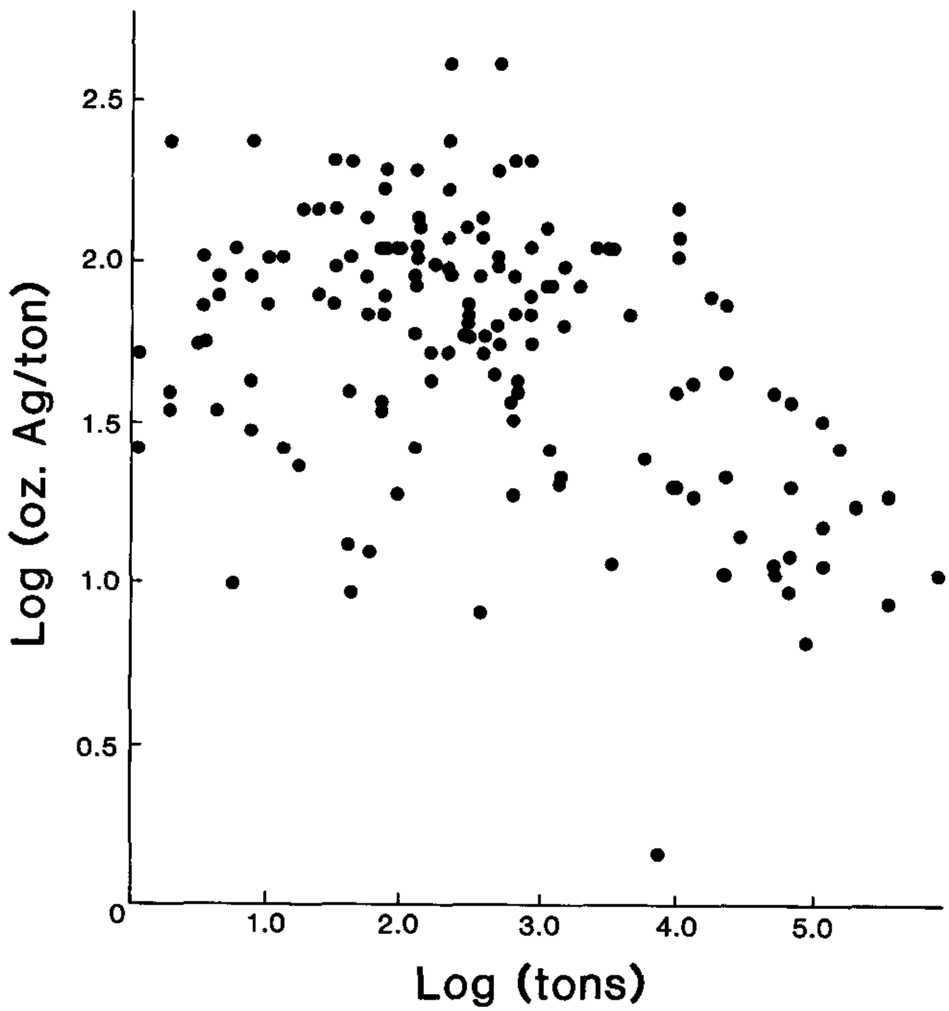

Figure 2. Scatter diagram of average Ag grade versus ore production (tonnage for training set).

MULTIPLE REGRESSION MODELS

Multiple regression models have the form

$$V = \beta_0 + \beta_1 X_1 + \beta_2 X_2 \text{ ----- } \beta_n X_n + e,$$

where V is a dependent variable (value measure in our case), β's are constants, e is the standard error, and X's are independent (geological) variables. We have examined a variety of potential models and quote two here to illustrate the variation in results. Model 1 relates ore production tonnage to the four metal grades (silver, gold, lead, zinc);

model 2 relates ore production tonnage to three metals (silver, lead, zinc), and the percentage of vein sulphides.

Model 1

$$\text{Log (tons)} - 1.6853 - 0.4222 \log (\text{Ag}) - 0.0146 (\text{Pb}) - 0.2607 \log (\text{Zn}) - 1.0429 \log (\text{Au})$$

$$R^2 = 0.6565$$

$$S^2 = 0.9770$$

Model 2 (omitting Au)

$$\text{Log (tons)} - 3.836 - 1.1784 \log (\text{Ag}) - 0.0140 (\text{Pb}) - 0.4518 \log (\text{Zn}) + 1.151 \log (\%\ \text{sulphides})$$

$$R^2 = 0.3467$$

$$S^2 = 1.1489$$

In both models log transformations were used where dictated by the form of the density function. Statistically the results are significant. However, we want to know if the models have practical application over their entire range.

The five highest calculated and observed ore tonnages for the training set are shown as a scatter diagram (Figure 3) for model 1. The fit is

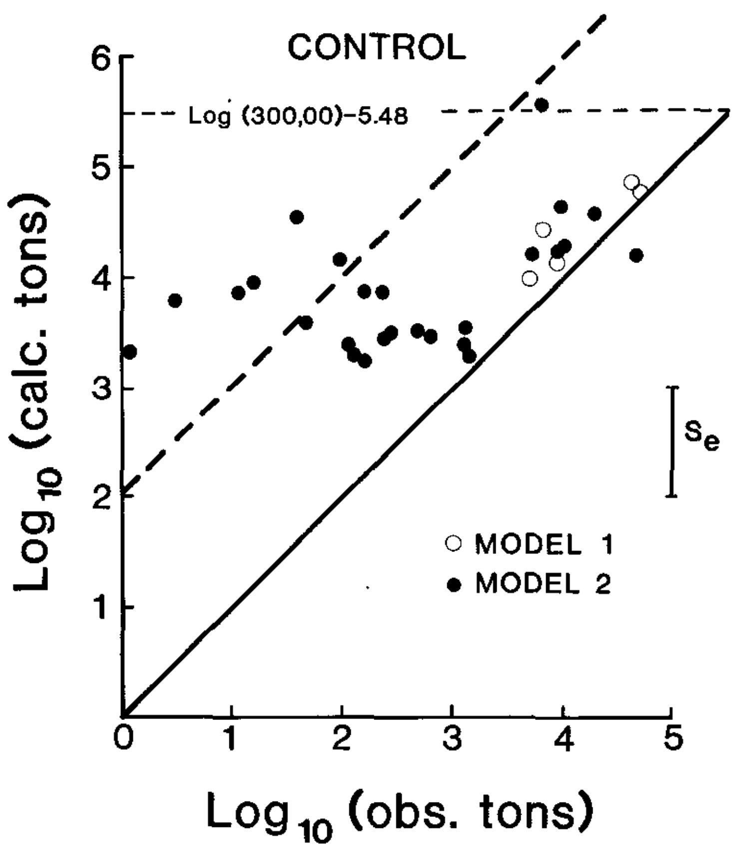

Figure 3. Observed versus calculated ore production for highest values of models 1 and 2, Slocan camp training set.

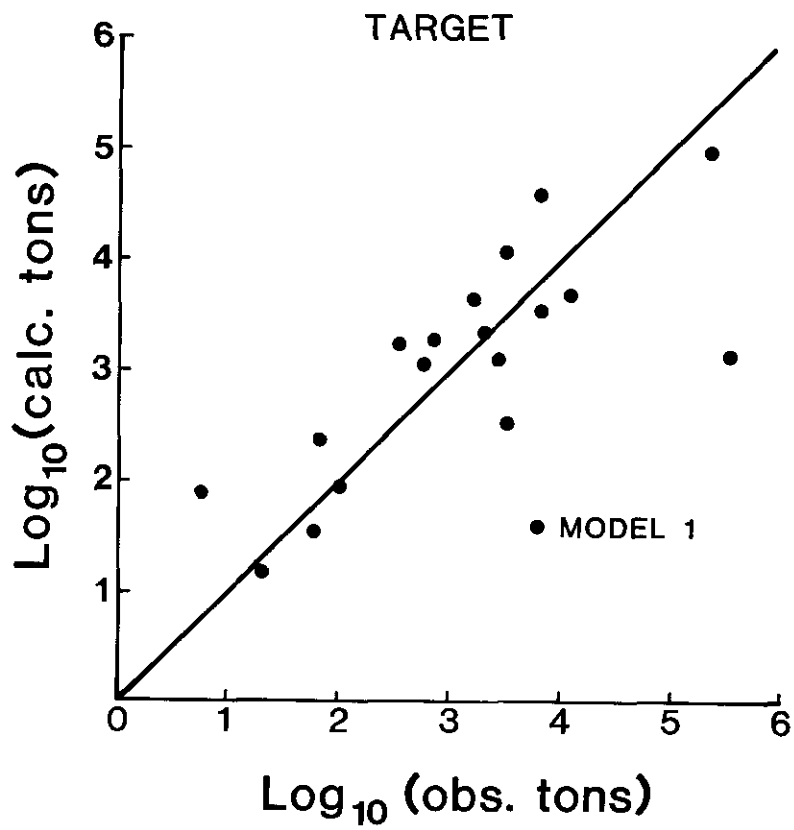

Figure 4. Observed versus calculated ore production tonnages for 19 deposits in the target area, Slocan camp.

reasonably good visually and Figure 3 provides a quantitative appreciation of the internal consistency of the model for large tonnage potential. However, a proper test of the model involves application to the target population, a set of data not used in developing the model. Such a comparison is shown on Figure 4 for the 19 deposits in the training set for which average grades were available for all silver, gold, lead, and zinc. It is apparent that the model is a relatively good forecaster! Other multiple regression models (for example, model 2) were not so successful and results will not be discussed here, although high values for model 2 are plotted on Figure 3.

The model has been shown to be an adequate forecaster of relative value (ore production tons) of individual veins in Slocan camp. Unfortunately application of the model is limited because average grades of the four metals incorporated in the model are available only for about one-third of the deposits in the camp. It was for this reason that we attempted to develop models omitting gold (for example, model 2). It is unfortunate that gold grades are not available for more of the deposits because this work has shown that gold is by far the most important single component in our models. Gold assays, along with silver, lead, and zinc, should be an integral part of evaluating any vein deposit in Slocan camp.

DISCRIMINANT ANALYSIS

Discriminant analysis is a method by which k clusters of data in n-dimensional space are separated as efficiently as possible by (k-1) n-dimensional lines. These 'discrimination' lines are arranged between pairs of clusters such that the two clusters project onto the line with a minimum overlap (Figure 5, from Klovan and Billings, 1967).

Slocan data were divided into high-tonnage, medium-tonnage, and low-tonnage groups based on thresholds of 1,000 tons and 16,000 tons selected using the probability graph of Figure 1. The two groups of average production grades corresponding to high and low-tonnage groups were transformed as in the multiple regression study and linear 'discriminant'

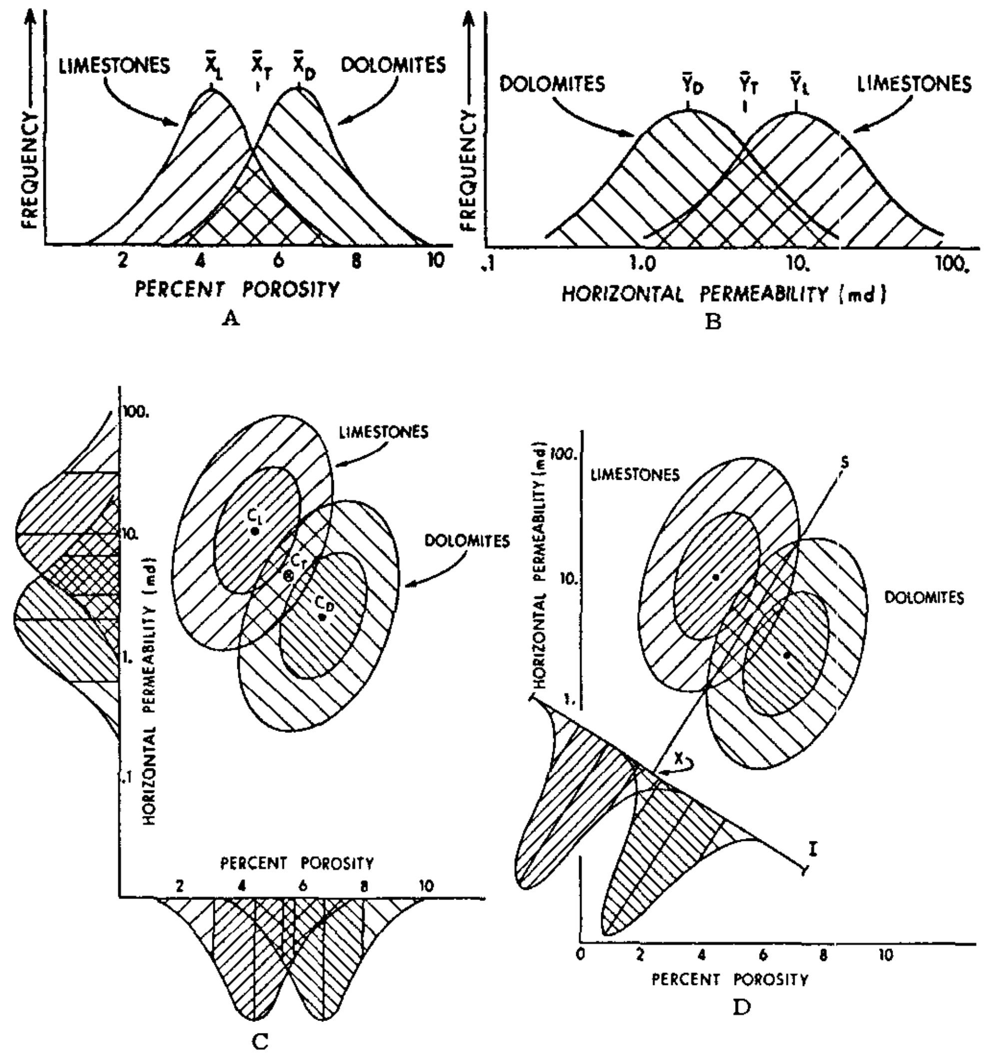

Figure 5. Conceptual model of discriminant function analysis as a more efficient means of separating clusters in two-dimensional space than either of the variables alone; from Klovan and Billing (1967).

functions were calculated between adjoining data clusters. These functions were then used to classify deposits into high-tonnage and low-tonnage categories. Results for both the training set and the target population showed very high proportions of apparently correct classifications (that is, >80 per cent correct) when the discriminant classifications were compared with the corresponding known ore production tonnages.

The misclassifications of particular interest are those thought to be small based on low ore production tonnages, but which appear to be high tonnage according to the discriminant classification. Such deposits are listed in Table 1 for the training set. Of course, these results must be interpreted in light of the validity of the model. Consequently, the model has been applied to the same subset of 19 deposits that formed the basis of a test of the multiple regression model. Results are summarized in Table 2 where it is apparent that more ambiguity exists than is apparent in the multiple regression model. Consequently, results of the discriminant analysis must be viewed cautiously and further validation is desirable.

TABLE 1

Deposits with low known production classed as having high-tonnage potential, by discriminant function analysis of training set deposits, Slocan camp.

Deposit Name	Production	Probability*
Silver Ridge	395	0.99
Grey Copper	66	0.86
Freddy Lee	817	0.91
Deadman	616	0.73
Leadsmith-Noonday	383	0.72
Echo and Graphic	896	0.69

*The probability that a deposit falls within the high-tonnage category according to a discriminant model based on average grades of Ag, Pb, Zn, and Au.

TABLE 2

Low-tonnage (<1,000 tons) and medium-tonnage (1,000-1,600 tons) deposits in target production classed as having high-tonnage potential (>16,000 tons) by discriminant model, Slocan camp

Deposit Name	Recorded Production (short tons)	Probability*
Doherty	6,097	1.00
Black Fox	1,577	1.00
Highland Surprise	3,027	0.96
Jackson	6,314	0.98
Gibson-Daybreak	676	0.92
Flint	351	0.85
Wellington	1,961	0.74

*Probability that the deposit falls in the high-tonnage category according to the discriminant model.

CONCLUSIONS

Statistical modelling of relative value of vein deposits appears an attainable goal providing data of adequate quality are available. The study reported here is only a small part of much more extensive research into exploration modelling. The principal application of statistical models is in (1) identifying deposits with high tonnage potential which, to date, have produced only small tonnages, and (2) evaluating newly found deposits in the camp to which a model applies. Multiple regression appears a more appropriate approach to exploration modelling in Slocan camp than does discriminant analysis. Gold assays should form an integral part in the evolution of all deposits in the Slocan camp.

ACKNOWLEDGMENTS

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RAPID ANOMALY RECOGNITION AND RANKING FOR MULTI-ELEMENT REGIONAL STREAM SEDIMENT SURVEYS

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INTRODUCTION

As part of our continuing study of rapid, thorough evaluation procedures for multi-element stream sediment data (for example, Sinclair and Fletcher, 1979; Matysek, et al., 1980), we have developed a systematic, computer-oriented method of recognizing and ranking anomalous samples. Our detailed procedure utilizes the type and quality of data incorporated in various regional programs undertaken by the British Columbia Ministry of Energy, Mines and Petroleum Resources but can be adapted easily for data for other programs.

Regional multi-element stream sediment surveys of the type carried out in British Columbia under terms of the Uranium Reconnaissance Program contain coded information on the principal rock unit forming the provenance region of each sample. Consequently, the following procedure for determining multi-element background models is intended to be applied to sample subsets based on provenance (rock type). Rock-type coding for this purpose is never perfect: some basins may be underlain by two or more important rock types, other drainage basins may be miscoded, perhaps because of the scale of geological base maps available. In any case it is apparent that some apparently anomalous metal concentrations arise from incorrect assignment of the dominant rock type or from mixing of sediments derived from several rock types.

GENERAL METHODOLOGY

Our general approach to recognition and ranking of anomalous samples is summarized on Figure 1. In brief the method involves the following steps:

(1) Sorting of data into provenance groups, that is, predominant rock type in drainage basin above the sample.

(2) Evaluation of simple statistics and probability graphs for each element in each provenance group.

(3) Threshold selection using the method of Sinclair (1976) to isolate anomalous samples from background samples.

(4) Selection of one or more elements to serve as the focus of the study (for example, zinc).

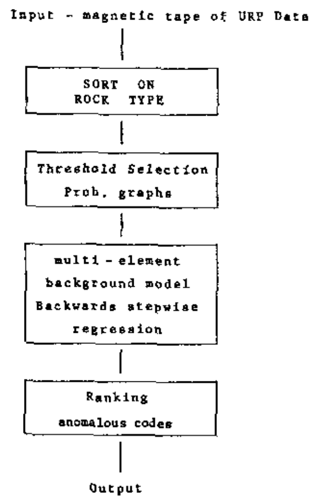

Figure 1. Sequential approach to anomaly recognition and ranking.

(5) Backward stepwise regression of each provenance group to develop background models for zinc in terms of other elements.

(6) Ranking individual samples in terms of (a) their contamination code and (b) the regression model and threshold.

(7) Output of sample information in a manner convenient for practical use in follow-up examination.

SORTING INTO PROVENANCE GROUPS

Data for each provenance group should be dealt with separately. Means and standard deviations of all raw and log-transformed metal abundances provide insight into levels of abundance, dispersion, and general aspect of population densities (histogram). Correlation coefficients indicate metal associations of geological importance (for example, Sinclair and Tessari, 1980). If only background values are considered, these associations commonly reflect differences in background environments and are not related directly to anomalous samples.

THRESHOLD SELECTION

Separation of background and anomalous samples is essential to our method because it leads directly to statistical models for background metal abundances. Consequently, the method of threshold recognition is important. We have adopted the probability graph approach of Sinclair (1976) because this procedure is systematic and has been shown by numerous examples to provide effective thresholds for many types of geochemical data.

ELEMENT SELECTION

We must decide which element or elements are of direct concern to our search problem. Are we interested in silver-lead-zinc, copper-molybdenum, tungsten-uranium, or others? Of course, we may want to investigate many associations of the sort listed, but in our approach each association would be dealt with separately. Within a particular metal association it may not be necessary to deal thoroughly with all elements because some may be redundant, others may not show adequate geochemical contrast, and still others may present limitations resulting from analytical problems. In our case we will use zinc data as a basis for evaluating regional silt samples in terms of silver-lead-zinc and lead-zinc associations typical of our study area (map-area 82F).

MULTIVARIATE MODELLING OF BACKGROUND VALUES

Multiple regression has been shown by many to be an effective method of demonstrating empirical relationships between a particular element (dependent variable) and a group of other elements (independent variables). In many cases a high proportion of the variability of the dependent variable is explained in terms of variations in the independent variables (Sinclair and Fletcher, 1980). Where such methods are applied to background samples only, the abundance of a dependent variable (for example, zinc) can be expressed as a linear combination of the abundances (or logarithms of abundances) of many other elements to provide a multivariate background model.

We have experimented with two approaches to the selection of samples used to establish a multiple regression model. In our first attempts sample selection was based on the dependent variable for a single provenance group with only those values below the threshold (based on probability graphs) being selected. In a later refinement we edited the data base for a single provenance group by omitting samples that were also obviously anomalous with respect to any of the independent variables.

The specific method we use for multivariate background modelling is backward, stepwise regression which starts with all independent variables in the data base and sequentially drops those that make no statistically significant contribution to explaining the variability of the dependent variable. Eventually a point is reached where all remaining variables are statistically significant (at the 0.05 level, for example) and an equation is obtained of the form

$$\text{Log (Zn)} = \beta_0 + \beta_3 \log (X_3) + \beta_4 \log (X_4) + \beta_9 \log (X_9) \text{ etc.}$$

where β's are constant and X_i's are abundances of metal i.

RECOGNITION AND RANKING OF ANOMALOUS SAMPLES

For each sample we determine a series of ranks from 0 to 3 by comparing the observed value of the dependent variable with the values calculated by each of the provenance group multivariate models. Significance of the rank numbers is shown on Figure 2. We then calculate a 4-digit ranking code for each sample where the first digit is the number of rock types for which rank 3 was obtained, the second digit is the number of rock types for which rank 2 was obtained, and so on. If there are seven rock types all with very high zinc values (rank 3) the ranking code would be 7000; in another case rank might be (3) for two rock types, (2) for three rock types, (1) for two rock types, and (0) for one rock type to give a ranking code of 2321.

The main advantage of this procedure is as a refinement in the selection of anomalous values relating to the probability graph procedure and the assigning of relative priorities to anomalous samples. Values above t_1 (Figure 2) are recognized as being anomalous without the aid of multiple

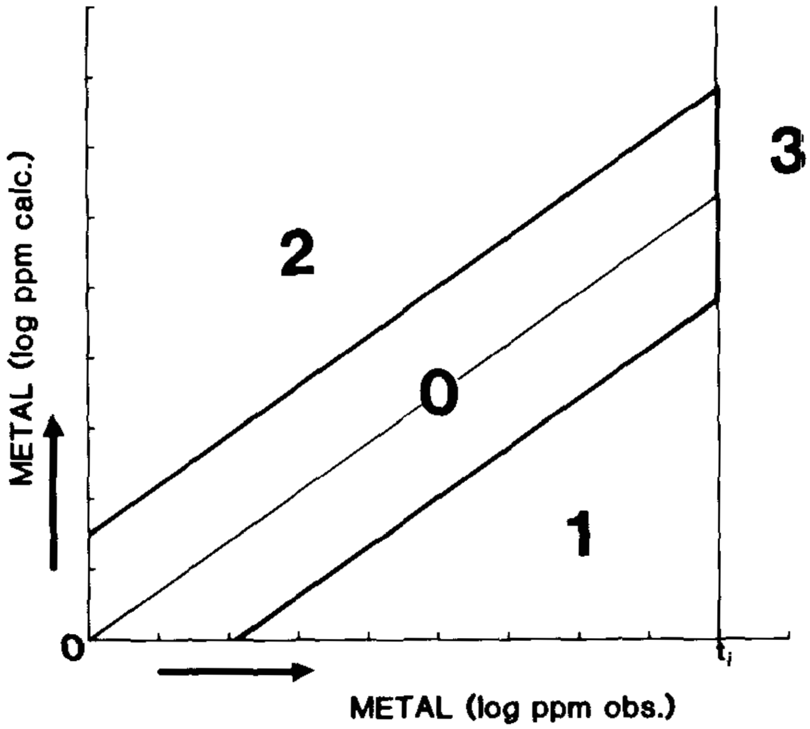

Figure 2. Sample ranking in relation to fields on a plot of observed value versus a value calculated from a multivariate model.

regression. In addition, however, values below t_1 that depart substantially from the expectation according to a multiple regression model (1 and 2 on Figure 2) are also out of the ordinary and warrant examination. In particular, we are interested in those values below t_1 that are much higher than the corresponding calculated values. Such samples are anomalous in one element, relative to a linear combination of other elements. On Figure 2 the suggestion is made graphically that samples are anomalous if observed values are more than two standard errors greater than values calculated according to the multiple regression model.

OUTPUT PROCEDURES

We have designed an output system by which samples can be ordered in terms of decreasing priority for follow-up exploration. All anomalous samples recognized by the foregoing procedures are ranked according to the estimated likelihood of sample contamination from such factors as known mines, man-made metallic features, or fertilizer, on a scale of 0 to 3. Our first rank of anomalous samples is based on this coded parameter, zero contamination being of most interest. Within this group we code a sample for each background model as 3, 2, 1, or 0 as described previously and a 4-digit ranking code is used to list samples within each contamination group in order of decreasing ranking code. Locations for each sample are listed as is the observed abundance of the dependent variable and the sample number. These items are arranged in such a manner as to promote efficiency of evaluation of each sample. In addition, we use plot locations of anomalous samples with their identification number and ranking code.

CASE HISTORY (MAP-AREA 82F)

Multi-element data are available for sample sites in map-area 82F at an approximate sample density of one sample per 12 square kilometres. Samples are analysed for zinc, lead, nickel, cobalt, manganese, copper, mercury, tungsten, and molybdenum. Samples were grouped initially on the basis of coding as to dominant rock type in the provenance region. Data for each element in each provenance group were examined as a probability graph and a threshold selected separating two populations (presumably anomalous and background) using the method of Sinclair (1976). We chose to examine zinc as the dependent variable described here because of the association silver-lead-zinc in known vein deposits in the area. Background multivariate models for zinc in terms of other elements were obtained for each of the seven provenance groups for which we have adequate samples. Three of these models are summarized in Table 1 to illustrate the type of results obtained. Statistics for all seven provenance group models for zinc are given in Table 2 to illustrate the statistical quality of the background models.

All samples coded in one of the seven provenance groups for which we could calculate background models were treated by each of the background equations separately. The calculated zinc background according to a given model was then compared with expectations for that model so that for each background model a sample received a ranking from 0 to 3 inclusive (compare Figure 2). In our case each sample was ranked seven times, once for each model. These rankings were accumulated into a single ranking code. Samples recognized as anomalous or potentially anomalous were divided into three contamination classes with priority decreasing as certainty of contamination increases. For each contamination category samples are ranked according to decreasing numeric value of the ranking code. An example is shown in Table 3, where a small part of the 0-contamination category is listed.

GRANITE

$$\text{Log (Zn)} = 0.4726 + 0.0713 \log(\text{Cu}) + 0.2420 \log(\text{Pb}) + 0.0529 \log(\text{Ni}) + 0.3994 \log(\text{Mn}) + 0.4189 \log(\text{Fe}) - 0.2334 \log(\text{Co})$$

$R^2 = 0.62$

$S_e = 0.1277$

$n = 393$

QUARTZITE

$$\log(\text{Zn}) = 1.1020 + 0.2721 \log(\text{Pb}) + 0.1316 \log(\text{Ni}) + 0.4891 \log(\text{Fe}) + 0.1412 \log(\text{Mo}) + 0.0399 \log(\text{Hg})$$

$R^2 = 0.74$

$S_e = 0.0915$

$n = 287$

SCHIST

$$\log(\text{Zn}) = 0.8392 + 0.4100 \log(\text{Pb}) + 0.2244 \log(\text{Ni}) + 0.5603 \log(\text{Fe}) + 0.2412 \log(\text{W})$$

$R^2 = 0.76$

$S_e = 0.1008$

$n = 27$

TABLE 1. EXAMPLES OF MULTIVARIATE REGRESSION BACKGROUND MODELS FOR ZINC
MAP-AREA 82F

	PROVENANCE GROUP						
	GRNT	QRTZ	SLTE	ANDS	ARGL	GNSS	SCST
n	393	287	100	57	56	53	27
R	.79	.86	.84	.84	.92	.85	.87
R^2	.62	.74	.70	.70	.85	.71	.76
S_e	.1277	.0915	.1184	.1031	.0812	.0940	.1008

TABLE 2. SUMMARY STATISTICS FOR MULTIVARIATE BACKGROUND ZINC MODELS
SEVEN PROVENANCE GROUPS
MAP-AREA 82F

	UTME	UTMN	GNSS	QRTZ	GRNT	SLTE	ANDS	SCST	ARGL	TOTALS (3210)	ZN (PPM)	ROCK TYPE	CONTAM	URPS (82F) ID #
27	536212	5457758	3	3	3	3	3	3	3	7000	354	QRTZ	0	773128
28	507056	5518882	3	3	3	3	3	3	3	7000	359	SCST	0	777314
29	476055	5450823	3	3	3	3	3	3	3	7000	345	ANDS	0	771076
30	482531	5461513	3	3	3	3	3	3	3	7000	314	ANDS	0	779126
31	501399	5526605	3	3	3	3	3	3	3	7000	309	SLTE	0	777274
32	489602	5443727	3	3	3	3	3	3	3	7000	304	SLTE	0	773056
33	484807	5528468	3	3	3	3	3	3	3	7000	295	GRNT	0	771198
34	487496	5456216	3	3	3	3	3	3	3	7000	295	SLTE	0	773086
35	476166	5487364	3	3	3	3	3	3	3	7000	299	GRNT	0	777198
36	480507	5487605	3	3	3	3	3	3	3	7000	299	GRNT	0	777236
37	476597	5458297	3	3	3	3	3	3	3	7000	274	ANDS	0	771103
38	475075	5488439	3	3	3	3	3	3	3	7000	279	GRNT	0	777302
39	502653	5508315	3	3	3	3	3	3	3	7000	279	SLTE	0	777259
40	479646	5455841	3	3	3	3	3	3	3	7000	264	ARGL	0	771100
41	494963	5528152	3	3	3	3	3	3	3	7000	255	SLTE	0	777306
42	474792	5452528	3	3	3	3	3	3	3	7000	244	ANDS	0	771077
43	489916	5458581	3	3	3	3	3	3	3	7000	239	SLTE	0	775116
44	509423	5500800	3	3	3	3	3	3	2	6100	224	SCST	0	773237
45	524924	5447471	3	3	3	3	3	3	2	6100	214	QRTZ	0	775100
46	448185	5533845	3	3	3	3	3	3	2	6100	214	SCST	0	779163
47	462164	5538222	3	3	3	3	3	3	2	6100	209	GRNT	0	775328
48	487885	5451555	3	3	3	3	3	3	2	6100	191	GRNT	0	777112
49	489443	5499269	3	3	3	3	3	3	2	6100	198	GRNT	0	777212
50	549914	5512200	3	3	3	3	3	3	0	6001	191	QRTZ	0	777182
51	482276	5463771	3	3	3	2	2	3	2	4300	186	ARGL	0	771084
52	484487	5484729	3	3	3	2	2	3	2	4300	187	GRNT	0	777203
53	441779	5442706	3	3	3	0	0	3	0	4003	186	GNSS	0	775015

TABLE 3. PART OF A TABLE LISTING ANOMALOUS SAMPLES IN ORDER OF DECREASED RANKING CODE*

From a total of 1 259 samples, this procedure produced 115 anomalous samples in the 0-contamination category. Our procedure is to list these samples in tabular form in Table 3 and to produce computer-drawn plots of anomalous sample locations as illustrated on Figure 3.

In addition to ranking information, original raw data, and coordinates, the output table contains a simple consecutive numeric identifier used for clarity on the map output and permitting easy combined use of the tabulated data and the output map. The output map is of particular use because it identifies the most obvious anomalous samples (for example, 7000) from those that might escape detection (for example, 0520). The scale of the location plot should be identical to geological base maps of the area so the two can be studied together without ambiguity. We tested sensitivity of the regression procedure for determining a multivariate background for zinc by establishing such models based on two training

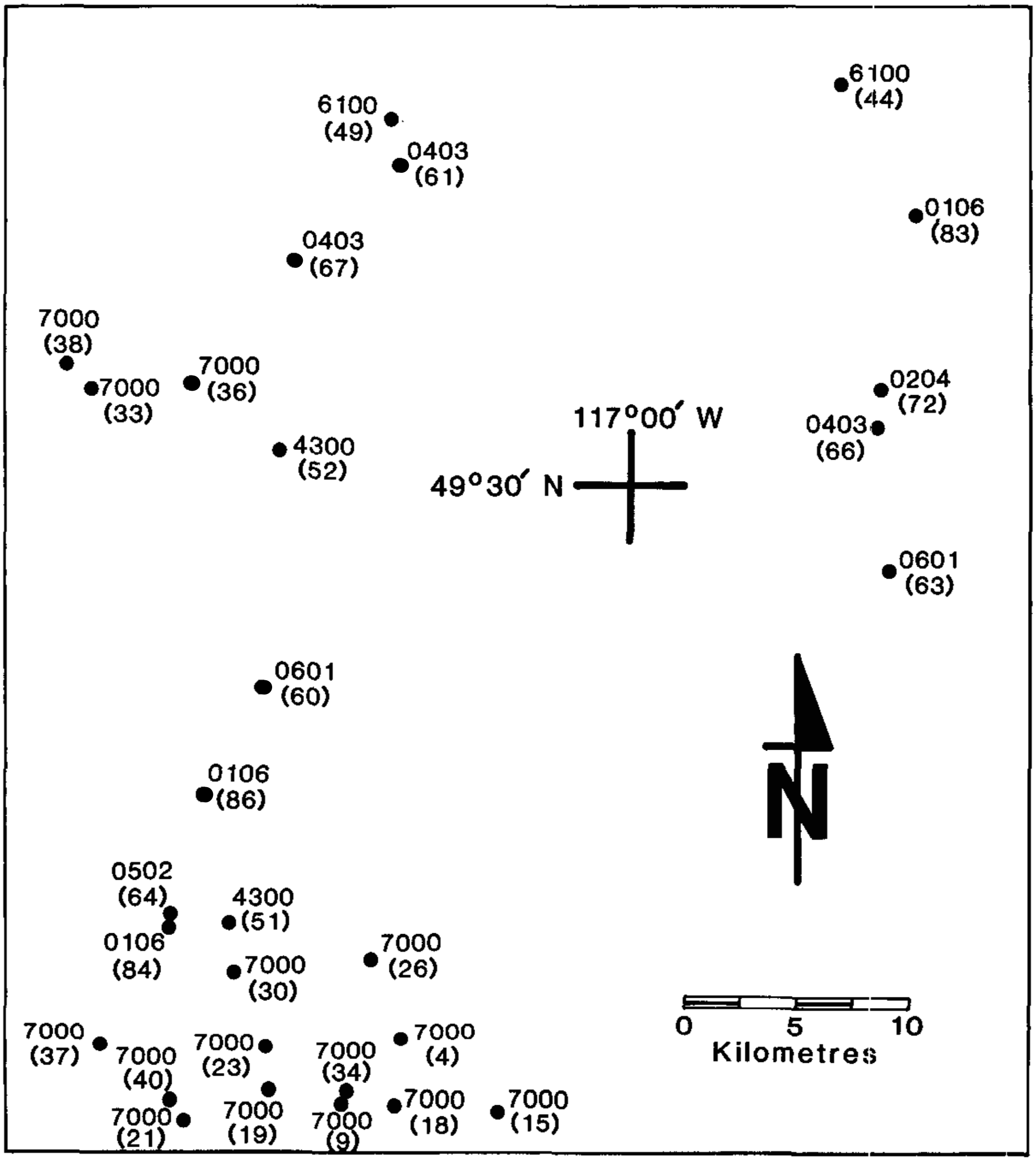

Figure 3. Plot of an area of anomalous samples redrafted from computer output.

sets: (1) all samples indicated as having background zinc values, and (2) the same data set minus any samples that appeared to be anomalous in any element other than zinc. Tables 1 and 2 are based entirely on the second training set. Figures 4 and 5 illustrate the contrasting results obtained in background definition. It is clear that the 'cleaner' data set (number 2 previously) leads to a better multiple regression relationship, that is, with less scatter of calculated and observed values. The problem with using the second training set is that more work is required to set it up and more samples will be included in the anomalous category.

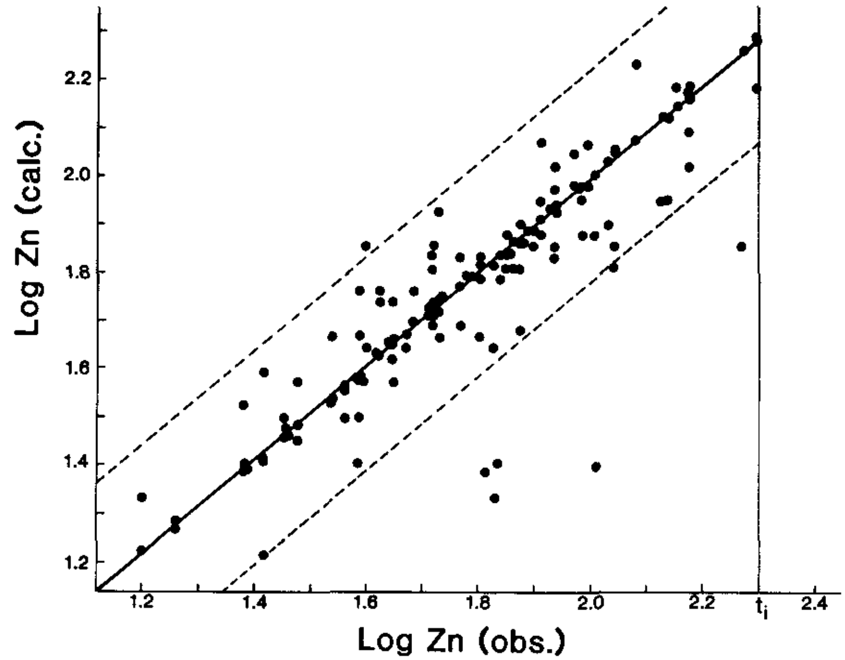

Figure 4. Observed versus calculated zinc values for provenance group, 'ARGL,' map-area 82F; calculated values based on a model determined from all samples with background zinc values.

DISCUSSION

The methodology described here would appear to have a wide range of applications to geochemical data evaluation, perhaps with minor modifications to suit particular data sets. For example, many geochemical surveys may not record the likelihood that a sample is contaminated, and this level of ranking might have to be omitted. The precise limits to the coding regions illustrated on Figure 2 can be changed to suit a particular bias to anomaly selection, resulting in a slightly different listing of anomalous samples.

One of the serious problems is the question of initial grouping of data on the basis of dominant rock type that underlies the drainage basin of each sample, a classification which is fundamental to our procedure. A substantial amount of effort is required to code this rock-type information even if the data are available. If rock type has not been coded it may be necessary to use some less satisfactory method of grouping data, such as the use of factor analysis to provide an approximation of background geology for each sample. In some environments, of course, some other parameter may be more useful than rock type for grouping data.

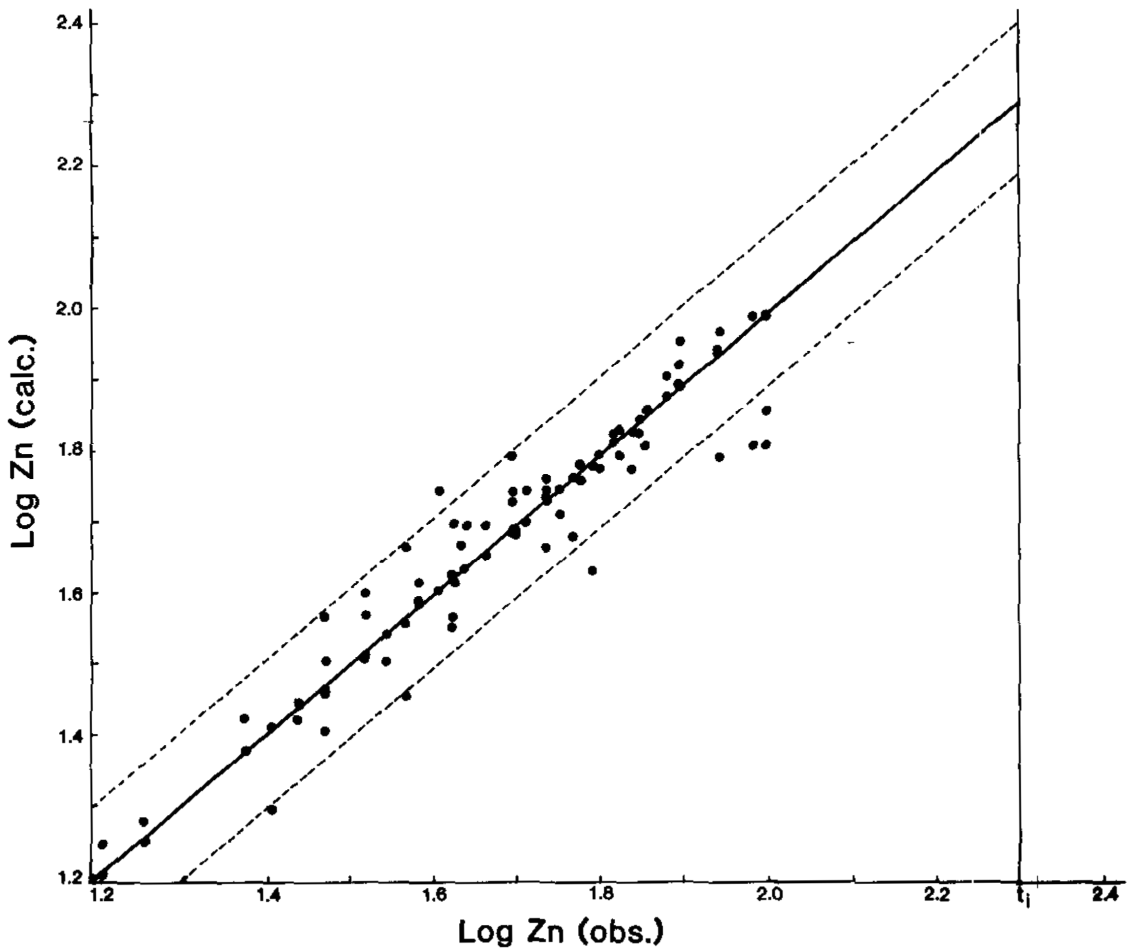

Figure 5. Observed versus calculated zinc values for provenance group, 'ARGL,' map-area 82F; calculated values based on a model determined from those samples with zinc background values that also are not anomalous in any other element (that is, a 'cleaner' subset of the data used for Figure 4).

CONCLUSIONS

A method of anomaly selection and ranking for multi-element regional stream sediment data has been described. The procedure offers the following advantages:

(1) The method is rigorous in making use of established statistical methods for treating geochemical data such as a probability graph analysis and backward stepwise regression.

(2) The procedure is computer based and is rapid and thorough.

(3) The methodology ensures that some anomalous values which are not obvious (that is, are not higher than a simple threshold) will be recognized.

(4) A novel ranking procedure is described that assigns relative priorities to samples for further investigation. Details of the ranking procedure are subjective but a system of ranking codes clearly describes the manner in which a sample is anomalous.

(5) Because samples are tested against every rock type, the procedure incorporates an evaluation as to whether other rock types might be contributing to the provenance area of a particular sample. Possible additional rock types are identified and can be compared with available geological maps.

ACKNOWLEDGMENTS

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STRUCTURAL SETTING ALONG THE NORTHWEST FLANK OF FRENCHMAN CAP DOME MONASHEE COMPLEX

(82M/7)

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INTRODUCTION

The Monashee Complex of southeastern British Columiba is one of many metamorphic core complexes in the internal zone of the western Cordillera (see Crittenden, Coney, and Davis, 1980). The Monashee Complex consists of Aphebian basement gneiss and mantling metasedimentary rocks which are exposed in an elongate fenster within Proterozoic to Middle Mesozoic cover sequences of the Selkirk Allochthon (as defined by Read and Brown, 1981; and shown here on Figure 1).

Frenchman Cap dome, the northernmost of four structural culminations with the Monashee Complex, records an extensive history of complex folding, overthrusting (D_1, D_2, and D_3) and late-stage arching (D_3/D_4) believed to be associated with Jurassic to Late Cretaceous/Early Tertiary (?) periods of crustal shortening (Read and Brown, 1981). Superposed on this structural setting is a prominent set of northerly trending fractures, dyke swarms, and normal faults (D_4) related to a regional, more brittle episode of Early Tertiary crustal extension (Price, et al., 1981).

Middle to upper amphibolite facies regional metamorphism is associated with second generation folding in the north-central Frenchman Cap dome (D_2) and is believed to be correlative with Middle Jurassic regional metamorphism developed in structurally overlying rocks of the Selkirk Allochthon (for further discussion, see Read and Wheeler, 1976; Pigage, 1977; Read and Brown, 1981).

Coherent lithostratigraphic successions (Brown and Psutka, 1979; Höy and Brown, 1981) and major structural and tectonic elements (Wheeler, 1965; Höy, 1979; Brown, 1980) have been successfully traced around the northern margin of Frenchman Cap dome from the Columbia River fault zone to the Cottonbelt region north of Ratchford Creek (Figure 2). A similar lithostratigraphic succession has been traced around the southern margin of the dome from the polydeformed Jordan River area (Fyles, 1970; Brown and Psutka, 1979) to the headwaters of Perry River and Myoff Creek (Höy, 1980; Höy and McMillan, 1979; McMillan, 1973). These studies have demonstrated both stratigraphic and structural control on the occurrence of stratiform lead-zinc mineralization within mantling metasediments of Frenchman Cap dome.

The purpose of this study is to complete stratigraphic and structural correlations along the west flank of Frenchman Cap dome as shown on

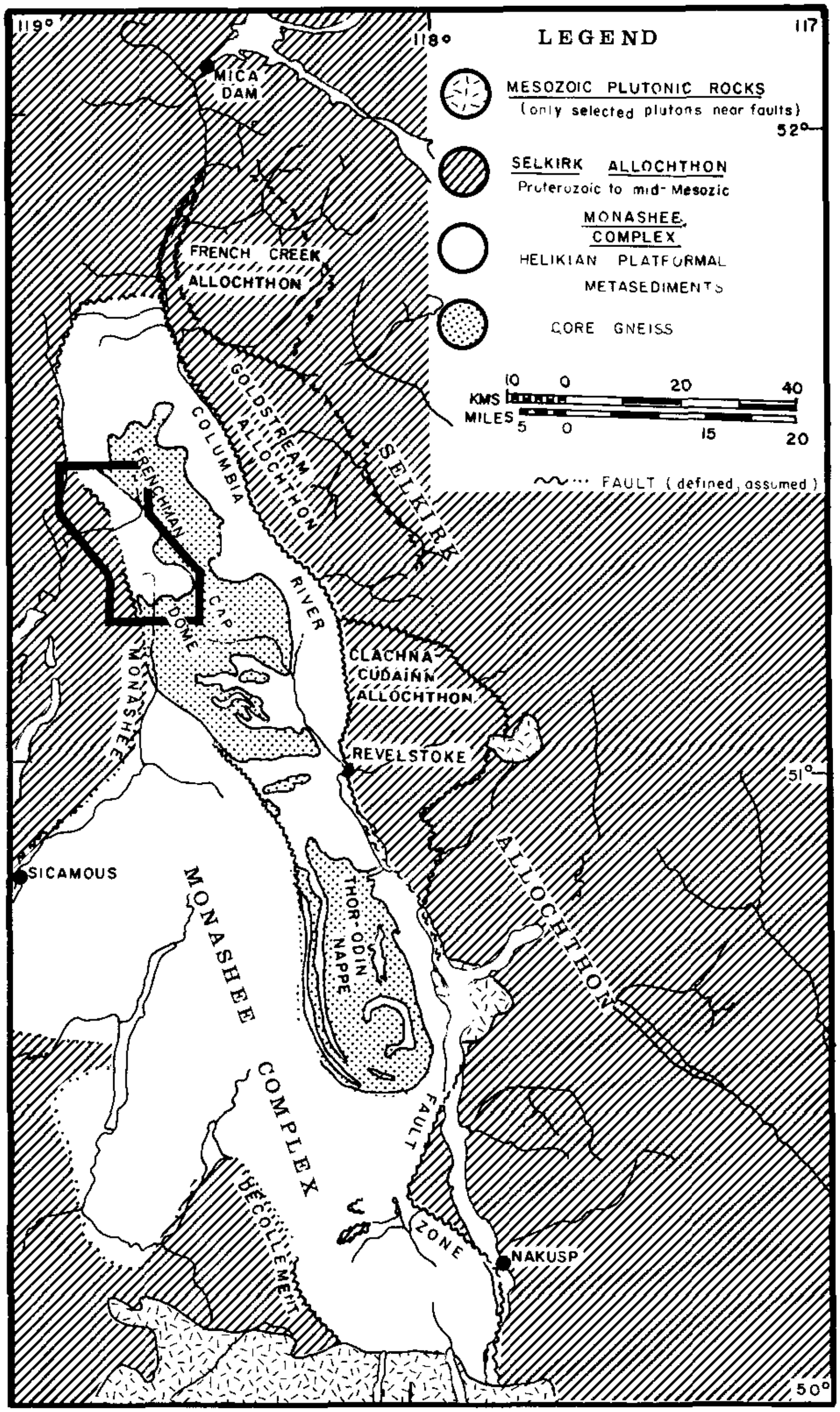

Figure 1. Regional geological map of the north-central Shuswap Complex showing the exposure of basement gneiss and mantling metasedimentary rocks which compose the fault bounded Monashee Complex. The Monashee décollement, which is arched over the culmination of the eastern Shuswap Complex, exposes these Aphebian and Helikian (?) rocks in an elongate fenster within Proterozoic to Lower Mesozoic cover sequences of the Selkirk Allochthon (after Read and Brown, 1971). Location of Figures 3 outlined in black.

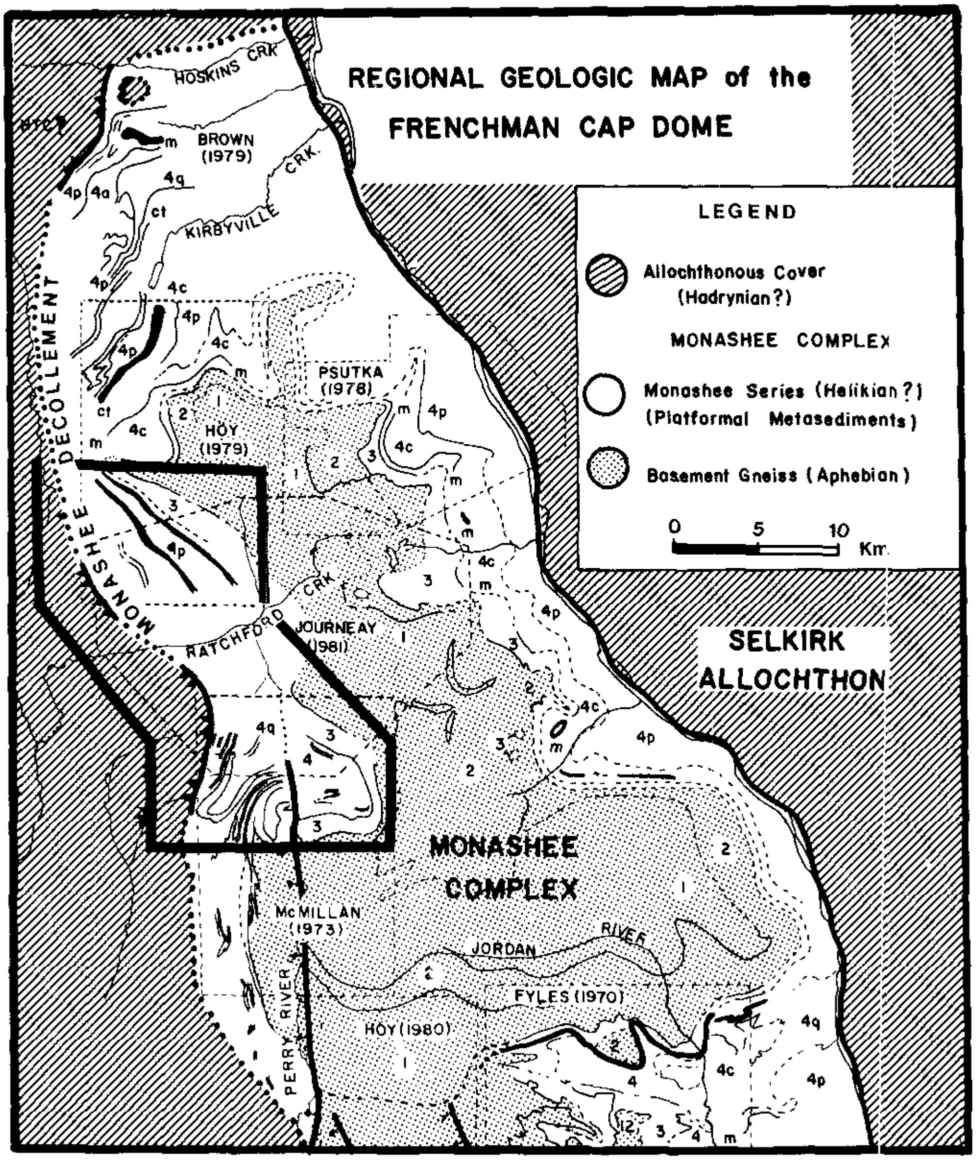

Figure 2. Regional geologic map of the Frenchman Cap dome delineating sources of detailed mapping data, and major lithostratigraphic, structural, and tectonic elements; modified from a recent regional geologic compilation map of the eastern margin of the Shuswap Complex (Höy and Brown, 1981). Map units are referenced on Figure 3. The results of Journeay (this report) are not included for the north-central Frenchman Cap dome.

Figure 2. Specific objectives are: (1) to map the mineralized 'Cottonbelt sequence' from its type locality on Grace Mountain (Höy, 1979) to the headwaters of Perry River; (2) to trace the Kirbyville-Grace Mountain syncline (Wheeler, 1965; Höy, 1979) into refolded structures of the Perry River-Myoff Creek region (McMillan, 1973); (3) to extend mapping of the Monashee décollement (Brown, 1980a, 1980b) as far south as possible; and (4) to present preliminary interpretations of the deformation and structural evolution of the northwest Frenchman Cap dome.

This report is based on the results of detailed mapping in the Cottonbelt (Höy, 1979), Perry River (McMillan, 1973), and Ratchford-Myff Creek regions (Journeay, this study) combined with three-dimensional structural modelling by the author during the 1980/81 seasons (Figure 2). The results of this study are part of an M.Sc. thesis on the structural evolution of the north-central Frenchman Cap dome in progress at Queen's University under the joint supervision of John M. Dixon, Dugald M. Carmichael, and Richard L. Brown (Geotex Consultants Ltd.).

STRATIGRAPHY

Three main lithostratigraphic subdivisions are recognized along the west flank of Frenchman Cap dome (Brown and Psutka, 1979; Höy and McMillan, 1979; Höy and Brown, 1981; and Figures 2 and 3). Exposed in the deepest structural levels of the dome is a sequence of intercalated orthogneiss and paragneiss yielding Rb-Sr whole rock ages of 2.17 Ga (Armstrong and Brown, in prep.). Unconformably overlying this basement complex is a mantling sequence of platform-type metasedimentary rocks locally intruded by a suite of alkalic gneiss tentatively dated at 773 Ma (Okulitch, et al., 1981). These data suggest possible time-stratigraphic correlation of mantling metasediments with the Purcell Supergroup (Okulitch, et al., 1981). The Monashee décollement separates mantling metasediments from an allochthonous sequence of pegmatite-laced feldspathic paragneiss and amphibolite that may be correlative with Hadrynian sequences of the Horsethief Creek Group (Brown, 1980).

APHEBIAN CORE GNEISS

Aphebian core gneiss can be subdivided into lower paragneiss, intermediate orthogneiss, and upper paragneiss in the Ratchford-Bourne Creek region (Journeay, in prep.). The structurally lowest exposed unit (1A) consists of intercalated biotite-quartz-feldspar paragneiss, pelitic and semi-pelitic schist, and quartzofeldspathic gneiss of unknown thickness, and is overlain and locally intruded by alkali-feldspar augen gneiss (1B). Feldspar augen gneiss grades upward into intercalated garnet-hornblende-clinopyroxene gneiss and alaskitic gneiss (1C), banded and migmatitic biotite-hornblende leucogneiss (1D), and homogeneous biotite-quartz-feldspar gneiss (1E). The upper paragneiss (2) unit consists of a heterogeneous sequence of semi-pelitic schist, quartzofeldspathic gneiss, amphibolite, biotite-feldspar augen schist, and some quartzite. Biotite-feldspar augen schist is locally absent due to erosion prior to deposition of overlying autochthonous cover rocks.

AUTOCHTHONOUS COVER (HELIKIAN ?)

Mantling metasedimentary rocks along the west flank of Frenchman Cap dome attain a stratigraphic thickness of nearly 2 kilometres. The succession consists predominantly of quartzite, quartz-mica schist, semi-pelitic and pelitic schist, biotite-quartz-feldspar paragneiss, calc-silicate, and thin but laterally continuous marble horizons. Within this sequence,

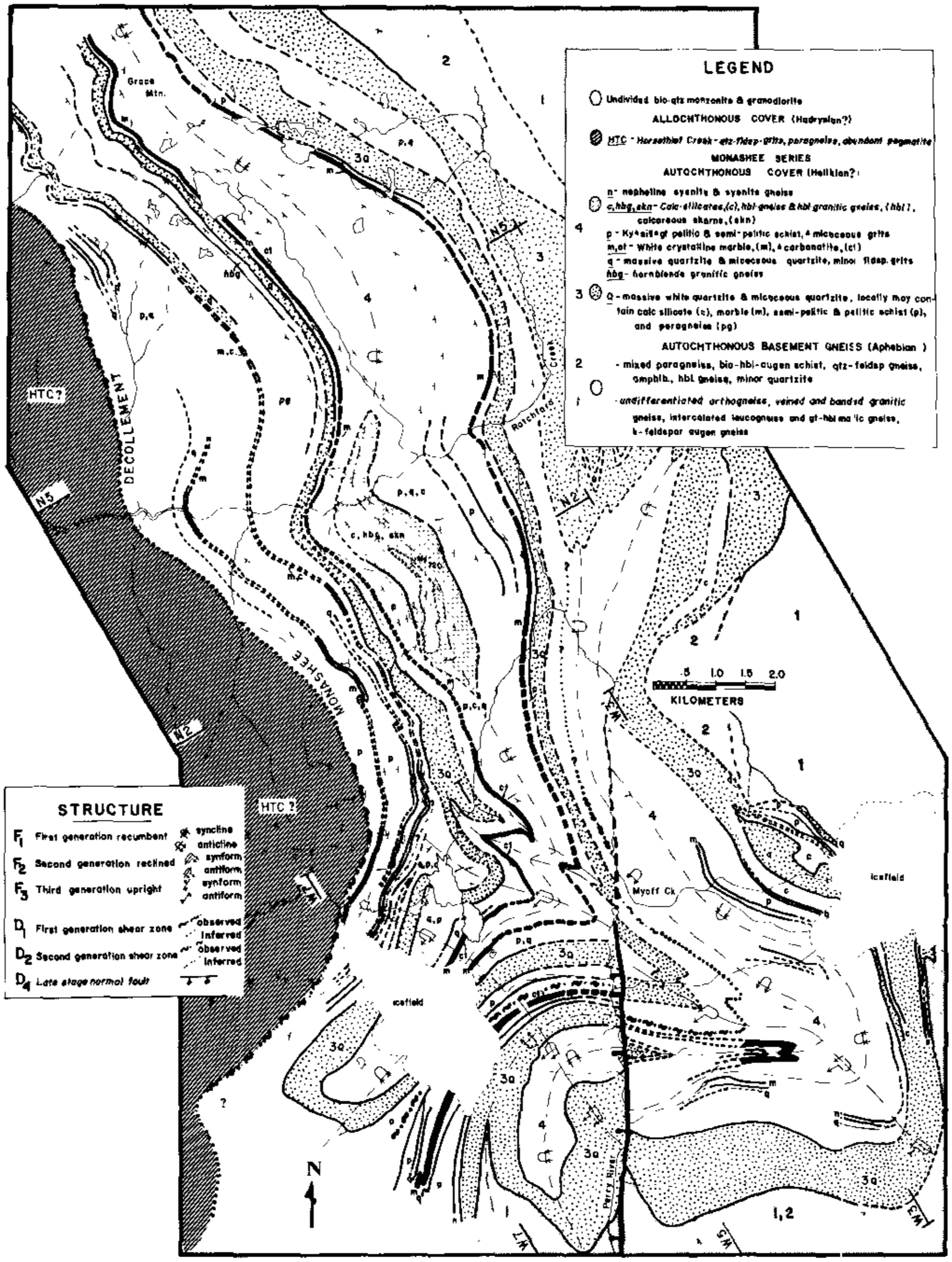

Figure 3. Geologic compilation map of the northwest flank of Frenchman Cap dome; geology after McMillan (1973), Höy (1979), and Journeay (this report). Sources of data are referenced on Figure 2.

basal quartzite (3q) and marble layers (Wheeler, 1965; Fyles, 1970; McMillan, 1973) and locally carbonatite and mineralized layers (McMillan, 1973; Höy, 1979) are used as marker units to delineate major structural elements. Detailed sections of particularly useful marker horizons, and their position in a stratigraphic succession due south of Ratchford Creek, are presented on Figure 4. Locally defined stratigraphic sections in remaining portions of the platform sequence exhibit lateral facies variations that prohibit detailed regional correlation.

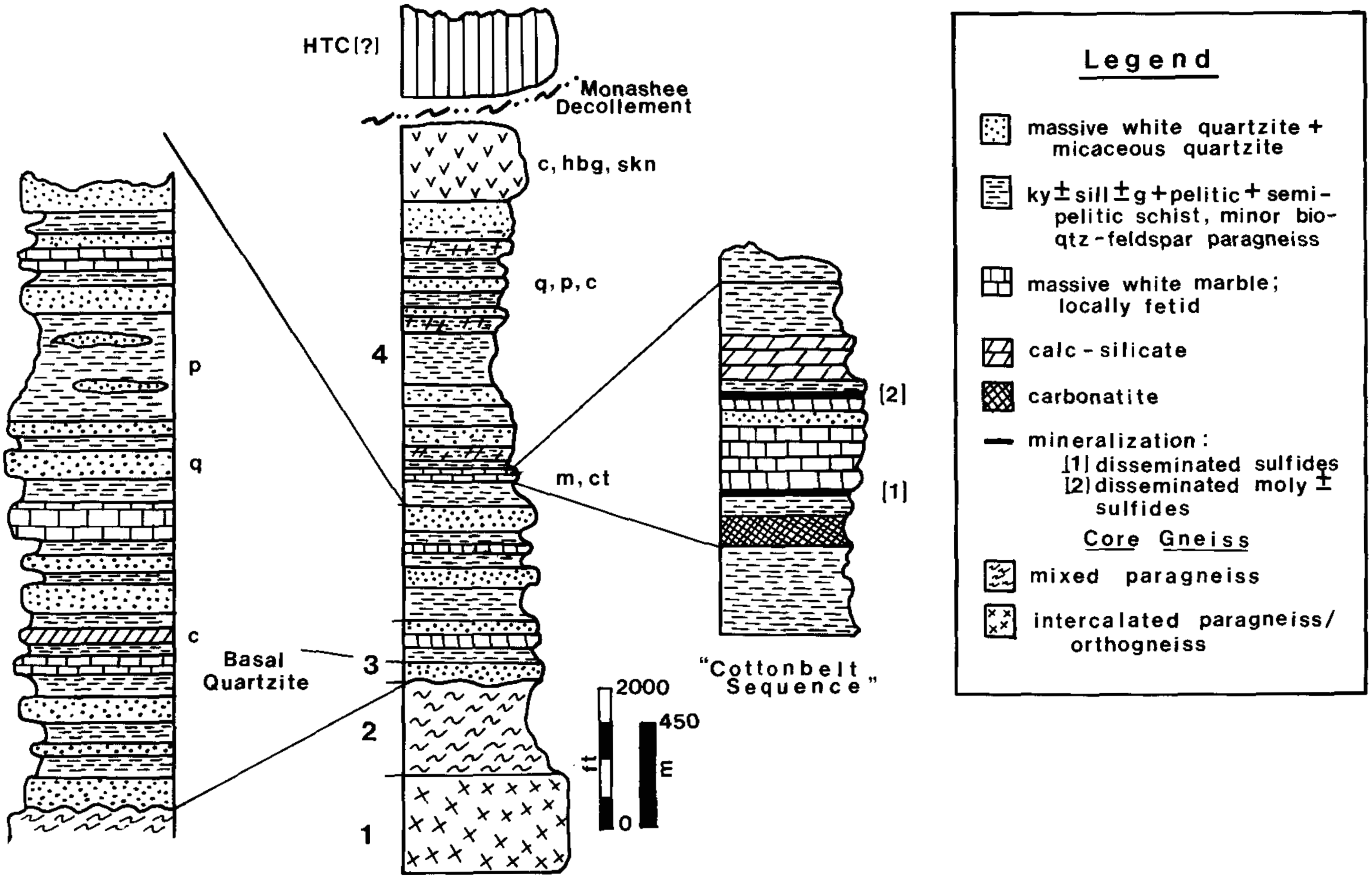

Figure 4. Detailed sections of useful marker horizons, enveloping metasedimentary units, and their stratigraphic position in a lithostratigraphic succession due south of Ratchford Creek. This succession was compiled from stratigraphic sequences on both limbs of the Grace Mountain syncline using marble-carbonatite (4m, ct) and lower quartzitic (3) units as reference horizons. The boundary between map units 3 and 4 is interpreted to be the lower contact of a thick pelitic schist and underlying quartzite unit several hundred metres below the marble-carbonatite marker.

An instructive example of lateral facies changes occurs along the upper limb of the Kirbyville-Grace Mountain syncline between Grace Mountain and Ratchford Creek (Figure 3). Calc-silicate and micaceous schist near Grace Mountain grade laterally into fine-grained biotite-quartz-feldspar paragneiss and biotite schist to the south. It is unlikely that these are structurally induced lithologic variations because of the perseverance of both a marble-carbonatite marker to the east and marble-quartzite horizons to the west. Primary sedimentary structures indicating stratigraphic top directions are poorly preserved in complexly deformed zones throughout the field area. Crossbedding has been locally observed in basal quartzite units above the basement-cover contact and confirms the structural interpretation.

ALLOCHTHONOUS COVER (HADRYNIAN ?)

Allochthonous cover sequences have not yet been mapped in detail but consist primarily of feldspathic grits, amphibolite, hornblende gneiss, micaceous schist, and calc-silicate, abundantly laced with both concordant and discordant pegmatite. This distinctive sequence forms the hanging wall of the Monashee décollement along the west flank of Frenchman Cap dome and is apparently traceable into known exposures of Horsethief Creek Group along the northern margin of the dome (Brown, 1980).

DEFORMATION

Structural analysis in the north-central Frenchman Cap dome has outlined three generations of penetrative deformation that are believed to be associated with Jurassic to Late Cretaceous/Early Tertiary (?) periods of crustal shortening (Read and Brown, 1981). Each generation (D_1, D_2, and D_3) represents a period of progressive deformation which can be recognized in the field by the relationship of minor structures to regional metamorphic mineral assemblages, and by consistent overprinting relationships on both macroscopic and mesoscopic scales. The oldest recognizable structures in the north-central Frenchman Cap dome deform both Aphebian basement gneiss and autochthonous metasedimentary rocks that unconformably overlie them. This suggests that pre-Helikian (?) deformation has either been pervasively overprinted by younger orogenesis or is non-existent. Structures related to all three generations of deformation are superposed and modified by a prominent set of northerly trending fractures, dyke swarms, and normal faults associated with a younger episode (D_4) of regional crustal extension (Price, et al., 1981). A similar hierarchy of deformation is manifest in adjacent parts of Frenchman Cap dome and has been previously described by Wheeler (1965), Fyles (1970), McMillan (1973), Psutka (1978), Brown and Psutka (1978), Höy (1979), Brown (1980a, 1980b), and Read and Klepacki (1981).

Serial cross-sections and sequential deformation diagrams presented in Figures 5 and 6 summarize both the geometry and interpreted structural evolution of the northwest Frenchman Cap dome.

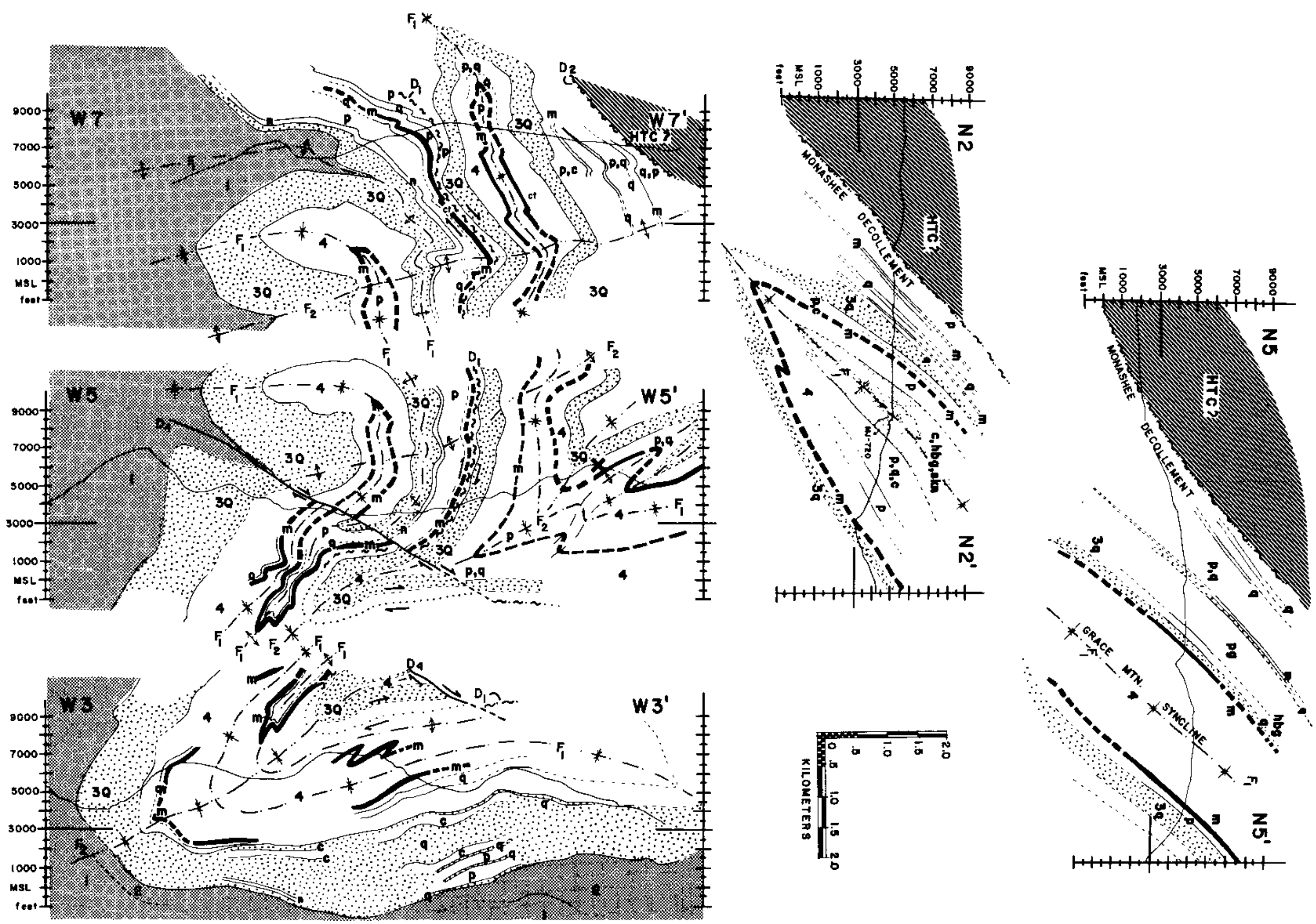

Figure 5. Serial cross-sections through the northwest flank of Frenchman Cap dome. These vertical sections are located on Figure 3 and are based on surface map data (Figure 2) and three-dimensional structural modelling.

D_1 STRUCTURES

First generation megascopic folds are characterized by easterly verging, shallow plunging isoclines that have been variably reoriented by subsequent deformation. Two orders of first generation isoclinal folds are recognized in the field area and can be traced into adjacent parts of the north-central Frenchman Cap dome (Journeay, in prep.).

The Kirbyville-Grace Mountain syncline (Höy, 1979; Brown, 1980) has exposed limb lengths in excess of 7 kilometres and dominates the structural setting of the northwest flank of Frenchman Cap dome (Figures 3 and 5). This structure is defined by stratigraphic facing directions in lower quartzites of unit 3, and by the repetition of a distinctive marble-carbonatite marker in unit 4 (Höy, 1979). The axial surface trace of the Kirbyville-Grace Mountain syncline extends from the southern headwaters of Kirbyville Creek (Hoy, 1979; Brown, 1980a), through the Cottonbelt region (Hoy, 1979), and has been projected south of Ratchford Creek by Höy and McMillan (1979). Both limbs of the Kirbyville-Grace Mountain syncline have now been traced to the west branch headwaters of Myoff Creek and Perry River where they are refolded by macroscopic second generation folds (Figures 3 and 5). The closure of the Kirbyville-Grace Mountain syncline is correlated with the westernmost isoclinal fold closure of McMillan (1973).

Second order, first generation isoclines are well exposed in the hinge of a major second generation fold near the headwaters of Perry River and Myoff Creek (Figures 3 and 5). Basal quartzite of unit 3 delineates a refolded anticline-syncline pair (McMillan, 1973) with limb lengths of 3 to 4 kilometres. These first generation isoclines structurally underlie the southern extension of the Kirbyville-Grace Mountain syncline. Axial surfaces of these second order D_1 structures can be traced around the hinges of major second generation folds in the Perry River-Myoff Creek area (McMillan, 1973; and Figure 5), and extend into the north-central Frenchman Cap dome where they become periclinal in character (Journeay, in prep.). The apparent vergence and limb length of this first generation anticline-syncline pair suggests that it may be either a second order structure on the lower limb of the Kirbyville-Grace Mountain syncline, or related to an episode of D_1 deformation prior to or synchronous with emplacement of the Kirbyville-Grace Mountain syncline (Figure 6).

A homotaxial northwest-facing sequence of lower quartzite (3q), calc-silicate (3c), interlayered pelite-quartzite (4p, q) and marble-carbonatite (4m, ct) is exposed on adjacent limbs of two first generation isoclinal folds near the western headwaters of Perry River (Figure 3). The repetition of this distinctive sequence strongly suggests that the Kirbyville-Grace Mountain syncline may have been displaced northeastward along a low-angle thrust fault relative to underlying D_1 isoclinal folds (Figures 5 and 6). Displacement along this fault clearly pre-dates D_2 deformation and Middle Jurassic regional metamorphism. The lateral extent and timing of this fault with respect to the development of second order D_1 isoclinal folds have not yet been determined.

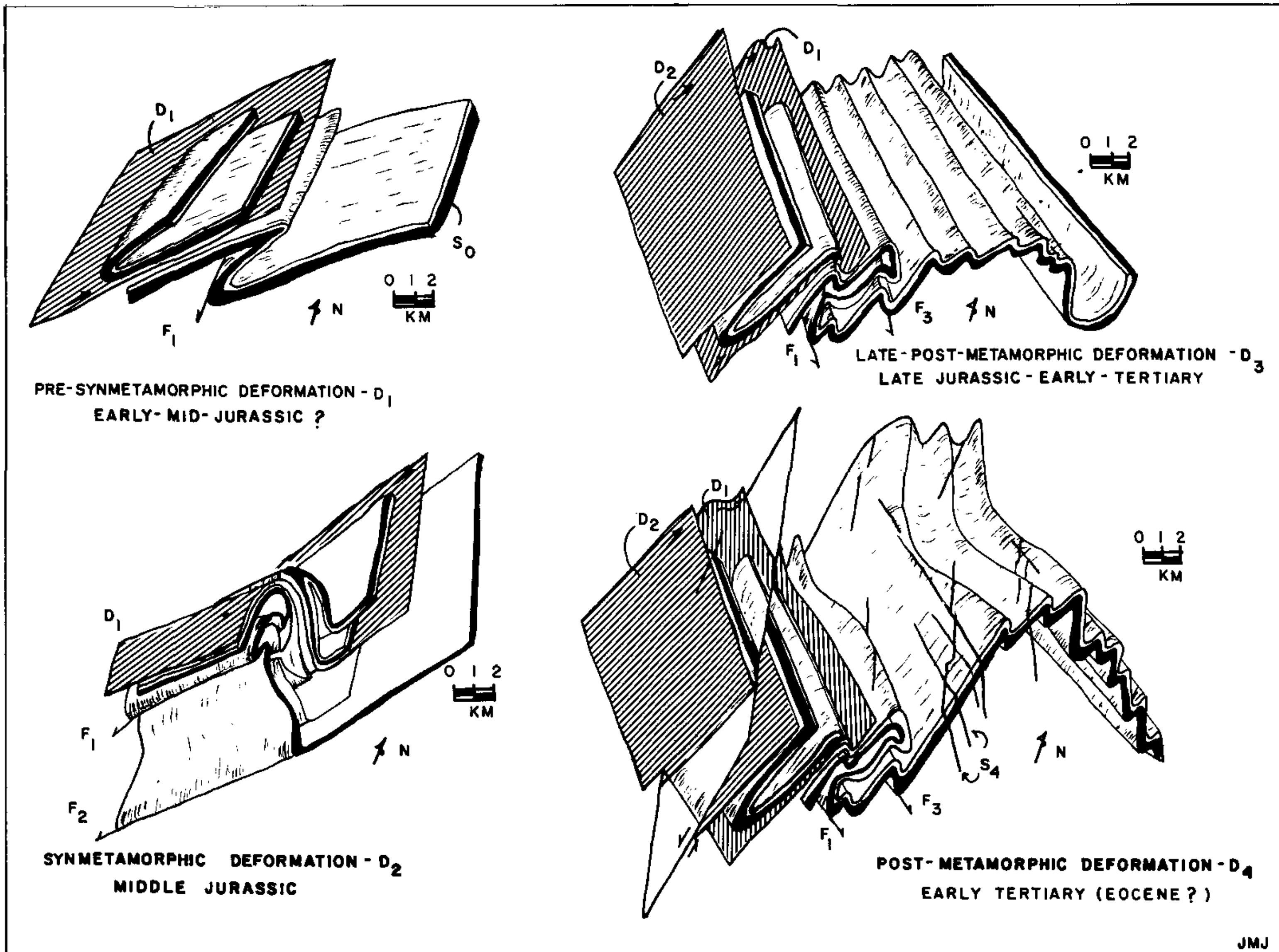

Figure 6. Sequential deformation diagrams illustrating respective generations of deformation and the interpreted structural evolution of the north-central Frenchman Cap dome. The effects of D_2 deformation have been removed for clarity in the representation of post-metamorphic deformation. D_3 and D_4 deformation diagrams refer to structures along an east-west cross-section through the north-central Frenchman Cap dome.

On a mesoscopic scale, first generation folds generally contain an axial planar fabric that is subparallel to compositional layering along attenuated fold limbs. This axial planar fabric is defined by the flattening of quartz and feldspar, and by the preferred orientation of platy metamorphic minerals. This suggests that first generation folds were developed either during initial stages of Early-Middle Jurassic regional metamorphism or an older episode of low-grade metamorphism. The possibility of multi-episodic first generation folding is recognized, but has not yet been documented.

D_2 STRUCTURES

The notable transition from first and second order D_1 isoclinal folds along the northwest flank of Frenchman Cap dome to the complexly refolded structures south of Ratchford Creek reflects the spatial distribution of macroscopic second generation folds below the Monashee décollement. Basal quartzite of the mantling platform sequence (3q) outlines two broad reclined, second generation fold closures which form a distinctive Z-shaped structure adjacent to the headwaters of Perry River and Myoff Creek (Figures 3 and 5). This reclined fold structure (McMillan, 1973) is characterized by west-southwest dipping axial surfaces and west-southwest-plunging fold axes that are subparallel to a prominent southwest-northeast-stretching lineation in all units below the Monashee décollement. A nearly identical fold style is observed on a mesoscopic scale and is well developed throughout the northern Frenchman Cap dome.

Axial surface traces of megascopic D_2 folds are truncated along the western margin of Frenchman Cap dome by the Monashee décollement and associated secondary shear zones. Second order D_2 asymmetric folds can be traced over the culmination of north-central Frenchman Cap dome where they reverse their plunge direction and are overprinted by northerly trending third generation folds (Journeay, in prep.). A very similar set of second generation reclined folds are documented by Read and Klepacki (1981) in the structural depression between Frenchman Cap dome and Thor-Odin nappe.

Consistent overprinting relationships on both macroscopic and mesoscopic scales indicate that D_2 folds were developed during Middle Jurassic syn-metamorphic deformation (Figure 6). This interpretation is supported by the widespread occurrence of medium grade metamorphic minerals such as kyanite and sillimanite that are oriented with their long axes subparallel to second generation fold axes and prominent southwest-northeast-stretching lineations.

The Monashee décollement (Brown, 1980a, 1980b; Read and Brown, 1981) is defined along the western margin of Frenchman Cap dome by a wide zone of mylonitized feldspathic grits and semi-pelitic metasedimentary rocks. The fault zone appears to be a major structural discontinuity separating platform-type metasediments in the footwall from rocks that may be correlative with the Horsethief Creek Group in the hangingwall (for further details see Read and Brown, 1981). Preliminary fabric analyses of fault zone mylonites from several alpine localities south of Ratchford Creek suggest an easterly sense of displacement of hangingwall with respect to footwall rocks. This interpretation is based on the asymmetry of minor folds, and the angular relationship of flattening fabrics with respect to mylonitic foliations in the fault zone.

D_3 and D_4 STRUCTURES

Third generation folds are easterly verging, post-metamorphic structures with northwest-trending axial surfaces (Figure 6). In the north-central Frenchman Cap dome, third generation fold axes are refolded by broad, westerly trending open folds that are believed to be associated with subsequent arching events. Along the western margin of Frenchman Cap dome, third generation folds are well developed north of Ratchford Creek but decrease in amplitude and intensity toward the polydeformed Myoff Creek-Perry River region. Fold styles vary from asymmetric kink folds and crenulations in well layered metasedimentary rocks to broad open folds and warps in massive quartzofeldspathic gneiss of the basement complex. This variation in fold style may reflect a competency contrast between a rigid basement and a thinly layered metasedimentary cover that was accentuated during waning stages of regional metamorphism. On a mesoscopic scale, third generation folds crenulate medium grade metamorphic minerals and deform prominent southwest-northeast stretching lineations indicating a late to post-metamorphic age of deformation (believed to be younger than Late Jurassic and older than Eocene).

Late stage arching, which produced the overall domal character of the northern Monashee Complex, apparently post-dates third generation deformation (Figure 6). No minor structures associated with this arching event are recognized in the field area (Figure 3) west of Myoff Creek or the headwaters of Ratchford Creek.

Overprinting all earlier structures in the northern Frenchman Cap dome is a prominent set of northerly trending brittle extension fractures and associated bimodal dyke swarms. These fractures rarely exceed 3 to 5 metres in width and are commonly filled by undeformed lamprophyre dykes and/or granitic pegmatites. Overprinting relationships in one alpine locality indicate that the emplacement of lamprophyre dykes (Eocene ?) post-dates the intrusion of granitic pegmatites.

The Perry River fault (Figures 3 and 5) is the only major normal fault exposed in the field area, and clearly post-dates earlier generations of deformation. Displacement of second generation macroscopic fold axes in the Perry River-Myoff Creek region indicates several hundred metres of relative west-side-down normal movement across the westerly dipping fault surface.

Similar brittle extension features have been described throughout the Frenchman Cap dome (Wheeler, 1965; Fyles, 1970; McMillan, 1973; Psutka, 1978; Brown and Psutka, 1978; Read and Klepacki, 1981) and apparently record a transition from periods of crustal shortening (D_1, D_2, and

D_3) to periods of crustal extension (D_4). The nature of this transition and its tectonic implications for the Early Tertiary evolution of Frenchman Cap dome are not yet fully understood.

MINERALIZATION

A sphalerite-galena-magnetite layer occurs as part of the stratigraphic success ('Cottonbelt sequence') in both limbs of the Kirbyville-Grace Mountain syncline north of Ratchford Creek (Höy, 1979). In tracing this marble-carbonatite-bearing sequence (unit 4m, ct) south of Ratchford Creek, two additional exposures of disseminated oxide-sulphide mineralization were discovered. The first showing occurs on the upper limb of the Kirbyville-Grace Mountain syncline and consists mainly of disseminated molybdenite, pyrite, chalcopyrite, and hematite immediately adjacent to a thin marble unit of the 'Cottonbelt sequence.' This showing is located near the hinge of a first order D_2 fold near the western headwaters of Perry River, and is marked by an 'x' on Figures 3 and 5.

Oxide-sulphide mineralization also occurs in a sequence of calcareous skarns near the hinge zone of the Grace Mountain syncline, approximately 1.75 kilometres south of Ratchford Creek (MJ-720, Figures 3 and 5). Mineralization appears to be zoned and consists primarily of glomeroblastic magnetite, pyrite and minor sphalerite in the centre, and grades outward into disseminated pyrite-molybdenite along its margins.

Assay values for two grab samples within this mineralized zone are presented below.

Sample No.	Au oz./ton ore	Ag oz./ton ore	Pb per cent	Cu per cent	Zn per cent	Mo per cent	WO_3 per cent
MJ-720 A	trace	0.25	0.02	trace	0.04	trace	0.04
MJ-720 B	trace	0.10	0.02	trace	0.03	trace	trace

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PRELIMINARY EXAMINATION OF GOLD METALLOGENY IN THE INSULAR BELT OF THE CANADIAN CORDILLERA USING GALENA-LEAD ISOTOPE ANALYSES

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ABSTRACT

Lead isotope data from quartz-gold vein deposits and volcanogenic and related deposits in the Insular Belt group fall in four distinct clusters on Pb-Pb plots. Each cluster corresponds to a specific deposit type and host rock category. Two parallel evolutionary trends in the lead isotopic composition exist: (1) Sicker-hosted volcanogenic deposits to Sicker-hosted veins, and (2) Karmutsen and Bonanza-hosted volcanogenic or paramagmatic deposits to Karmutsen and Bonanza-hosted veins. The trends indicate a genetic relationship between host rock and isotopic composition. These observations favour a host rock source for the lead in vein deposits and, by association, a comparable source for gold. Plutonic or abyssal direct sources of metals are not consistent with the lead isotopic data.

We suggest that the gold was extracted from the country rock, concentrated as veins by hydrothermal activity related to Tertiary plutons. Vein deposits are isotopically distinct from volcanogenic and related deposits, providing a model for distinguishing syngenetic from epigenetic deposits in a general way. Karmutsen and Bonanza-hosted deposits are more depleted in ^{207}Pb than similar deposits in Sicker Group rocks, indicating significantly different sources for volcanic components of these two important rock units.

INTRODUCTION

Galena-lead isotope data from mineral deposits in British Columbia have been compiled at the University of British Columbia since 1978 as part of a systematic study of galena-lead isotopes applied to metallogeny in the Canadian Cordillera. One aspect of that data considered here concerns isotopic compositions of lead from volcanogenic and related deposits and quartz-gold veins in the Insular Belt, as they relate to the metallogeny of gold-bearing deposits.

All the data used in this study are listed in Table 1. Information regarding the geological setting, mineral associations, and deposit type was extracted from MINDEP and MINFILE computer files of mineral deposits, annual reports of the British Columbia Ministry of Energy, Mines and Petroleum Resources, and assessment reports submitted to the British Columbia government. The appendix describes the 18 deposits used in this

TABLE 1. LEAD ISOTOPE ANALYSES ON GALENA FROM MINERAL DEPOSITS

Insular Belt, B.C.

Sample Number	Deposit Name	Map Name	Lat° North	Long° West	Lead Isotope Data (relative 1 S error as %) $^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$
Cluster 1: Pennsylvanian - Permian							
G79CL -001	Cowichan Lake	CL	48.7	124.3	18.646(.03)	15.581(.05)	38.276(.10)
G79CL -002	Cowichan Lake	CL	48.7	124.3	18.666(.02)	15.589(.07)	38.396(.10)
G79CL -003	Cowichan Lake	CL	48.7	124.3	18.702(.07)	15.546(.10)	38.086(.30)
*average for Cowichan Lake					18.671(.04)	15.572(.07)	38.252(.16)
*G79IC -001	Iron Clad	IC	48.85	123.68	18.682(.08)	15.581(.07)	38.304(.12)
G79LN -001	Lenora	LN	48.87	123.78	18.534(.04)	15.538(.09)	38.216(.04)
G79LN -002	Lenora	LN	48.87	123.78	18.562(.08)	15.572(.08)	38.23 (.09)
*average for Lenora					18.548(.06)	15.555(.08)	38.223(.06)
*G79TY -001	Tyee	TY	48.87	123.78	18.558(.08)	15.577(.07)	38.123(.11)
G79WM -001	Western: Myra	WM	49.57	125.59	18.506(.06)	15.579(.04)	38.186(.07)
G79WM -002	Western: Myra 2	WM	49.57	125.59	18.488(.07)	15.554(.07)	38.089(.06)
G79WM -003	Western	WM	49.57	125.59	18.484(.06)	15.551(.09)	38.115(.03)
*average for Western					18.493(.06)	15.561(.07)	38.130(.05)
Average for Cluster 1 (n=5)					[18.595(.06)]	[15.569(.07)]	[38.206(.10)]
Standard deviation = S					0.081	0.011	0.079
Standard error = $Sn^{-\frac{1}{2}}$					0.036	0.005	0.035
Cluster 2: Upper Triassic - Jurassic							
*30335 -001	Nutcracker	335	49.75	124.59	18.609(.07)	15.521(.09)	38.048(.10)
*30366 -001	Bon	366	50.26	126.67	18.587(.06)	15.526(.04)	38.086(.10)
30314 -001	Starlight	314	49.02	124.71	18.592(.07)	15.562(.09)	38.196(.05)
Average for Cluster 2 (n=2)					[18.598(.07)]	[15.524(.07)]	[38.067(.08)]
Standard deviation = S					0.016	0.004	0.027
Standard error = $Sn^{-\frac{1}{2}}$					0.011	0.003	0.019
Cluster 3: Tertiary							
30317 -001	Lone Star -ReyOro	317	50.02	126.79	18.940(.08)	15.569(.03)	38.445(.07)
30317 -001	Lone Star -ReyOro	317	50.02	126.79	18.950(.10)	15.571(.06)	38.378(.03)
*average for Lone Star-ReyOro					18.945(.09)	15.57 (.05)	38.411(.05)
*30318 -001	White Star	318	50.03	126.81	18.867(.10)	15.499(.04)	38.245(.05)
*30320 -001	Peerless	320	50.04	126.84	18.986(.06)	15.56 (.10)	38.453(.08)
*30334 -001	Lucky Strike	334	50.06	126.84	18.827(.05)	15.532(.03)	38.405(.09)
*30349 -001	Privateer	349	50.03	126.81	19.011(.08)	15.581(.09)	38.505(.06)
G79AB -001	Alpha and Beta	AB	48.73	124.09	18.882(.03)	15.581(.05)	38.406(.07)
Average for Cluster 3 (n=5)					[18.926(.07)]	[15.548(.06)]	[38.411(.05)]
Standard deviation = S					0.078	0.033	0.099
Standard error mean = $Sn^{-\frac{1}{2}}$					0.035	0.015	0.044

* Asterisk denotes analysis used in calcualtion of averages.

TABLE 1 (Continued)

Sample Number	Deposit Name	Map Name	Lat° North	Long° West	Lead Isotope Data (relative 1 S error as %) $^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$
Cluster 4: Tertiary?							
*30313 -001	Golden Eagle	313	49.11	124.59	19.007(.08)	15.621(.07)	38.577(.12)
*30315 -001	Victoria	315	49.18	124.66	18.828(.04)	15.646(.04)	38.733(.04)
30323 -001	Fandora	323	49.25	125.68	18.856(.07)	15.526(.04)	38.290(.04)
*30355 -001	Cream Lake	355	49.49	125.54	19.171(.04)	15.585(.04)	38.796(.07)
Average for Cluster 4 (n=3)					[19.002(.05)]	[15.617(.05)]	[38.702(.08)]
Standard deviation = S					0.172	0.031	0.133
Standard error mean = $Sn^{-\frac{1}{2}}$					0.099	0.018	0.065

* Asterisk denotes analysis used in calculation of averages.

study and lists the chief sources of information for each. Locations of the deposits are shown on Figure 1.

ANALYTICAL TECHNIQUES

Lead in galena from the samples was dissolved using HCl. Purified lead was obtained using anion columns and anodic electro-deposition. Samples were analysed using single-filament silica gel techniques on a 90-degree, 12-inch, solid source mass spectrometer. In-run precision, reported in the tables as per cent standard deviation within the brackets following mean isotopic ratios, is generally better than 0.1 per cent at one standard deviation. Multiple analyses of Broken Hill No. 1 standard shows that the reproducibility of sample analyses is about 0.1 per cent at one standard deviation. All data in the tables have been normalized to the Broken Hill No. 1 standard; normalizing procedures assumed the following composition for this standard: $^{207}Pb/^{204}Pb = 15.389$, $^{206}Pb/^{204}Pb = 16.003$, $^{208}Pb/^{204}Pb = 35.657$. All analyses were done in the Geology-Geophysics Laboratory, the University of British Columbia.

DATA

Galena-lead isotope data from Table 1 fall into four distinct clusters on the Pb-Pb plots of Figures 2 and 3. Each cluster corresponds to a deposit type and host rock group. Vein deposits are consistently more enriched in ^{206}Pb than are volcanogenic and related deposits. Sicker-hosted deposits are generally more enriched in ^{207}Pb than the Karmutsen and Bonanza-hosted deposits. The clusters, numbered 1 to 4 (Figures 2 and 3), are described in more detail below.

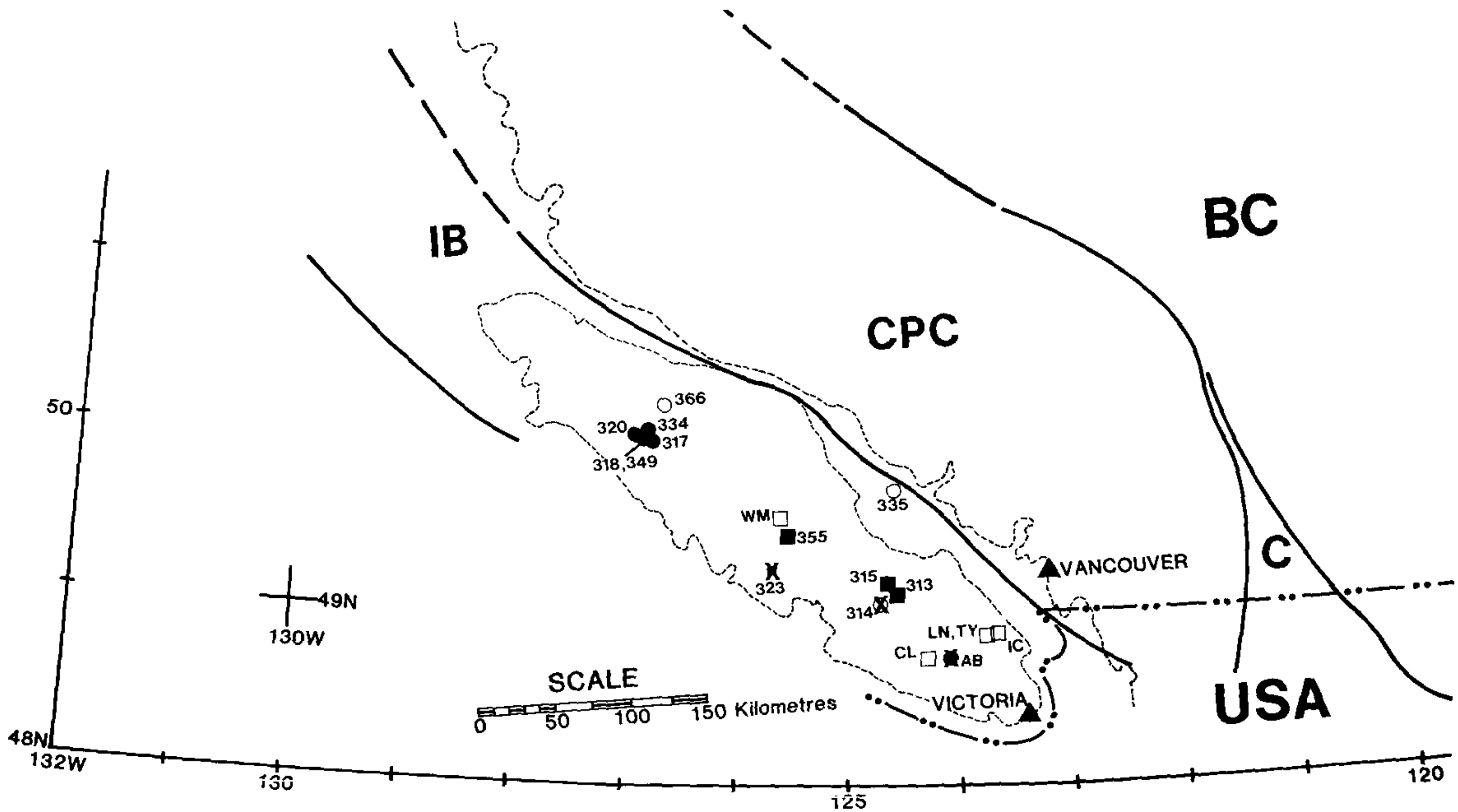

Figure 1. Location of galena-lead isotope analyses (Table 1) in Insular Belt, Canadian Cordillera; symbols are described on Figure 2.

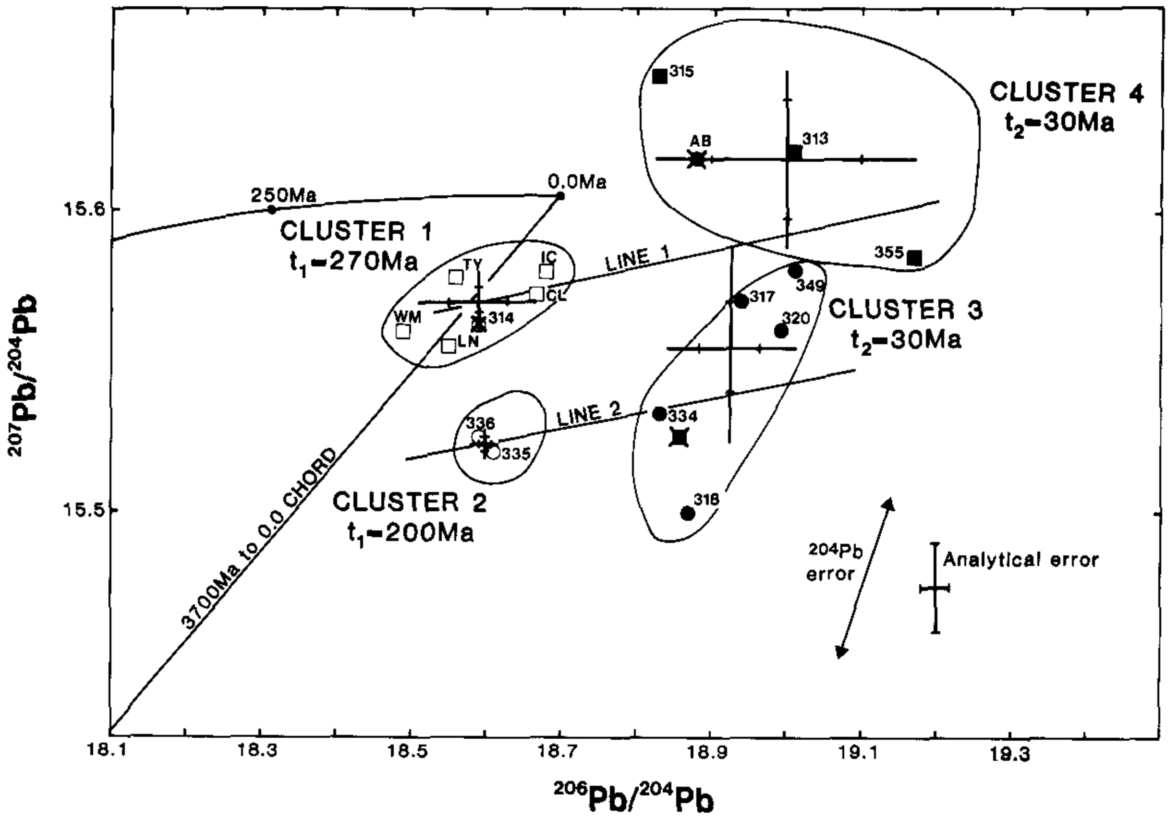

Figure 2. Galena-lead plot of $^{207}Pb/^{204}Pb$ versus $^{206}Pb/^{204}Pb$ (Table 1). Open symbols are used for veins; circles denote deposits related to Karmutsen or Bonanza Group rocks; square symbols are for deposits related to Sicker Group rocks. Unreasonable analyses are crossed and are not used in our interpretation. Bars mark standard error of the mean and lines extends to standard deviation. Lines 1 and 2 represent the evolution of lead from t_1 to t_2 for varying values of μ; t_2 for Cluster 4 is not known with certainty (see text). The average growth curve shown is Stacey and Kramers (1975) curve for average crustal lead growth.

CLUSTER 1: SICKER GROUP VOLCANOGENIC AND RELATED DEPOSITS

The Sicker Group is made up of dominantly andesitic volcanic rocks and interbedded sedimentary and limestone units of Carboniferous-Permian age (Northcote, et al., 1972). On the basis of paleontological evidence (Muller and Carson, 1969), an age of 270 Ma has been assigned in this study to the deposits which make up this cluster.

Several volcanogenic massive sulphide deposits (and related showings) are contained in the Sicker Group, the best known being Western Mines (Figure 1). Lead isotope data from these deposits form a tight cluster in the Pb-Pb plots (Cluster 1, Figures 2 and 3) centred below the Stacey and Kramers (1975) curve for average crustal lead growth, but within the field of 'ocean volcanics' described by Doe and Zartman (1979). The compositions are too enriched in ^{206}Pb and too depleted in ^{207}Pb to plot on any 270-Ma isochron of the Stacey and Kramers (1975), Cumming and Richards (1975), or Doe and Zartman (1979) lead evolution models.

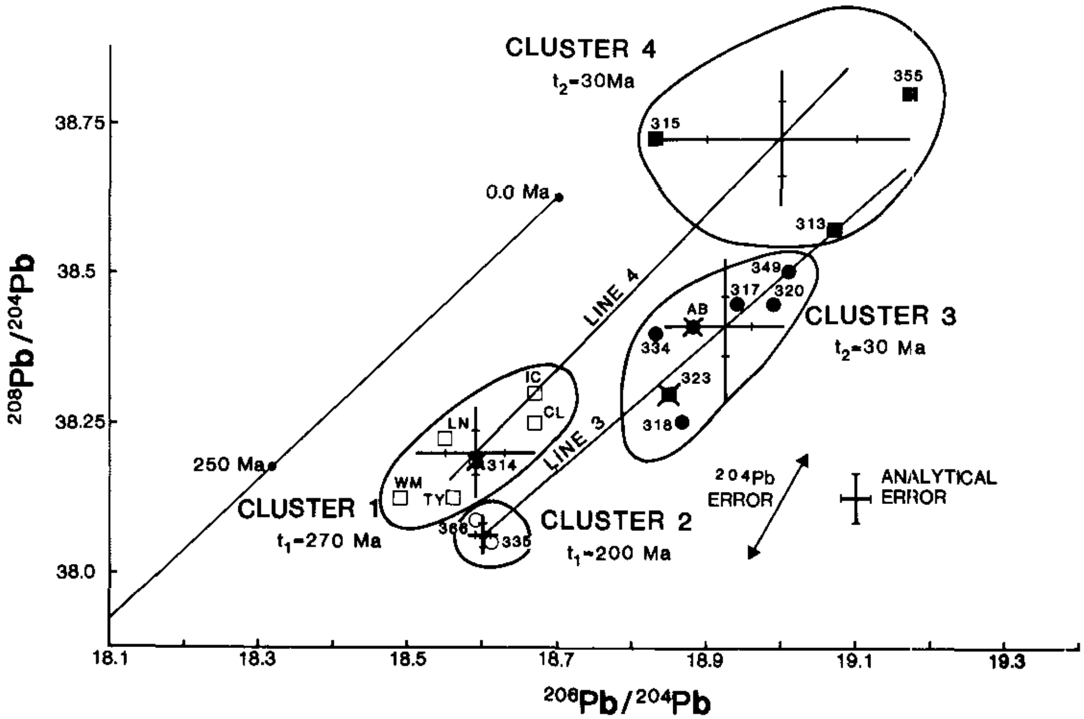

Figure 3. Galena-lead plot of $^{208}Pb/^{204}Pb$ versus $^{206}Pb/^{204}Pb$ (Table 1); for symbol description see Figure 2. Lines 3 and 4 represent the evolution of lead from t_1 to t_2 for varying values of ω if K is 3.3 and 3.9 respectively (Table 2).

The Iron Clad deposit (Appendix) has not been classified previously as volcanogenic. We note that the composition of the lead is the same as other volcanogenic deposits in the Sicker Group. Consequently, we believe this deposit to be cogenetic with volcanogenic deposits within the Sicker Group.

CLUSTER 2: KARMUTSEN AND BONANZA GROUP VOLCANOGENIC AND RELATED DEPOSITS

Karmutsen Group volcanic rocks form a thick sequence of Triassic (circa 200 Ma) tholeiitic pillow basalts, flows, and breccias, which are similar in chemistry to those of mid-ocean ridges (Monger, et al., 1972). Muller (1971) and Souther (1977) suggested that they are volcanogenic arc rocks which formed close to a trench. They overlie the Sicker Group island arc assemblages and lack gabbro, chert, and ultramafic rocks which usually are associated with ocean basalts. In other words, they probably represent volcanic rocks generated above a Benioff zone during early stages of subduction.

Bonanza Group volcanic rocks are flows and pyroclastic layers ranging in composition from basalt to rhyolite. They overlie the Karmutsen Group and are dated as Middle Jurassic (circa 160 Ma) on the basis of radiometric ages from coeval granitic plutons (Muller and Carson, 1969).

Two deposits define Cluster 2; both are enclosed by Karmutsen volcanic rocks; consequently, an age of 200 Ma was assigned to both deposits for our purposes in interpreting lead isotopic data. Cluster 2 plots below the growth curve of Stacey and Kramers (1975) for average crustal lead (Figure 2) and is more depleted in ^{207}Pb than Cluster 1. If the age difference between Clusters 1 and 2 is taken into account, the difference in isotopic composition would be more pronounced, since Cluster 2 would have been even less radiogenic at 270 Ma.

The two deposits which define this cluster are not demonstrably volcanogenic and the term paramagmatic (White, et al., 1971) may be more suitable. Paramagmatic is the name given to epigenetic deposits which can be shown to be an integral part of a magmatic event. The lead isotopic composition of such a deposit probably reflects the composition of lead in the magma at its time of formation. We think that the relatively non-radiogenic Pb-isotope character of Cluster 2 reflects the isotopic characteristics of the enclosing Karmutsen volcanic rocks. The Starlight deposit (Table 1, Appendix) might belong to this cluster, but no mention is made in the literature of its host rock group, although the lead-isotopic composition plots within an area underlain by the Karmusten Group on regional geological maps (Muller, 1963). We exclude this deposit in our calculations but inclusion of this datum would make little difference to the mean position of Cluster 2.

CLUSTER 3: TERTIARY VEINS IN KARMUTSEN OR BONANZA GROUP VOLCANIC ROCKS

Bonanza and Karmutsen Group volcanic rocks are host to several quartz-gold veins from which, galena-lead isotope data were obtained. These veins vary in width. They are predominantly of quartz with minor carbonate and generally contain pyrite, sphalerite, chalcopyrite, galena, arsenopyrite, and gold. Spatially they are closely related to Tertiary quartz diorite stocks (Northcote and Muller, 1972). Three of the veins are within the Eocene Zeballos pluton (Appendix). Consequently, an age of 30 Ma was assigned to this cluster (Bancroft, 1940; Stevenson, 1950; Wanless, et al., 1967).

Galena from the veins which make up Cluster 3 has a uniform lead composition, the average of which is depleted in ^{207}Pb relative to Cluster 1, but is enriched in ^{206}Pb, ^{207}Pb, and ^{208}Pb relative to Cluster 2. The data plot beneath the Stacey and Kramers (1975) curve for average crustal lead and the average has a future model age.

Alpha and Beta deposit (Table 1, Appendix) belongs with Cluster 3 on geological evidence, but was excluded from calculations because of a highly anomalous $^{207}Pb/^{204}Pb$ value (Figure 2). It plots with Cluster 3 on Figure 3 but with Cluster 4 on Figure 2. Its high value in ^{207}Pb possibly results from analytical error which is greater for ^{207}Pb than for ^{206}Pb and ^{208}Pb.

CLUSTER 4: TERTIARY VEINS IN SICKER GROUP ROCKS

Quartz-gold veins in Sicker Group rocks that form Cluster 4 on Figures 2 and 3 have the same general appearance and mineralogy as those of Cluster 3 (Muller and Carson, 1969).

Although Cluster 4 forms a distinctly different group relative to Cluster 3, there are only three data points which are quite widely scattered on the Pb-Pb plots. The average composition of the cluster is more radiogenic than the average for any of the other clusters. Although the age of those veins is not known with certainty an age of 30 Ma was assigned on the basis of the similarity in ^{206}Pb content with Cluster 3, and the assumption that they are related to the same phase of intrusive activity. Victoria showing (Table 1, Appendix) may be an older deposit related to the Jurassic Island Intrusions. The age t_2 of Cluster 4, however, is not crucial to the hypothesis proposed in this study. Fandora deposit (Table 1, Appendix) belongs to this group on geological grounds, but was not included in the discussion because of its anomalously low radiogenic lead contents; the sample is to be re-analysed.

LEAD ISOTOPE MODELS

Distribution of the four clusters on Figure 2 gives the appearance of two parallel trends. One is from Sicker-hosted volcanogenic to vein deposits (line 1, Clusters 1 and 4), the other from Karmutsen and Bonanza-hosted volcanogenic and related deposits to vein deposits (line 2, Clusters 2 and 3).

Four possible explanations for these groupings are:

(1) vein lead is unrelated to the volcanogenic lead,
(2) vein lead lies on an isochron with the volcanogenic lead,
(3) vein lead lies on a growth curve with volcanogenic lead, and
(4) vein lead lies close to a growth curve with volcanogenic lead but is preferentially enriched in radiogenic lead.

The first hypothesis appears unlikely on the general grounds that the relative plot positions of the two 'volcanic' clusters are identical with the relative plot positions of the two younger vein clusters. One 'volcanic' and one vein cluster have evolved in environments with low uranium/lead ratios (Clusters 2 and 3) compared with the other volcanic-vein pair of clusters. This seems an unreasonable coincidence. It is more likely that volcanic-vein pairs of clusters are somehow genetically related. The relationship was tested by calculating the slopes of the lines that pass through Clusters 1 and 2 (Figure 2, Lines 1 and 2), with pairs of ages 270 and 30 Ma, and 200 and 30 Ma respectively, using Equation 3 (Table 2). In both cases the lines pass through their respective vein clusters but not through the averages of the vein clusters (Figure 2). This result shows that the parallel trend is significant and therefore hypothesis one can be eliminated.

Equation 1: $$\left[\frac{^{206}Pb}{^{204}Pb}\right]_{t_2} = \left[\frac{^{206}Pb}{^{204}Pb}\right]_{t_1} + \mu(e^{\lambda_1 t_1} - e^{\lambda_1 t_2})$$

Equation 2: $$\left[\frac{^{207}Pb}{^{204}Pb}\right]_{t_2} \quad \left[\frac{^{207}Pb}{^{204}Pb}\right]_{t_1} + \frac{\mu(e^{\lambda_2 t_1} - e^{\lambda_2 y_2})}{137.88}$$

Equation 3: $$M_{207-206} = \frac{1}{137.88} \left[\frac{\left[^{207}Pb/^{204}Pb\right]_{t_2} - \left[^{207}Pb/^{204}Pb\right]_{t_1}}{\left[^{206}Pb/^{204}Pb\right]_{t_2} - \left[^{206}Pb/^{204}Pb\right]_{t_1}}\right]$$

$$= \frac{e^{\lambda_2 t_1} - e^{\lambda_2 t_2}}{e^{\lambda_1 t_1} - e^{\lambda_1 t_2}}$$

Equation 4: $$M_{208-206} = k\,\frac{(e^{\lambda_3 t_1} - e^{\lambda_3 t_2})}{(e^{\lambda_1 t_1} - e^{\lambda_1 t_2})}$$

$\mu = {}^{238}U/^{204}Pb$ $\quad$ $k = {}^{232}Th/^{238}U$ $\quad$ $w = k\mu$

$\lambda_1 = 0.155125 \times 10^{-9}$ (Jaffey et al., 1971)

$\lambda_2 = 0.98485 \times 10^{-9}$ (Jaffey et al., 1971)

$\lambda_3 = 0.049475 \times 10^{-9}$ (LeRoux and Glendenin, 1963)

$M_{207-206}$ and $M_{208-206}$ are slopes of isochrons on the Pb-Pb plots.

TABLE 2. EQUATIONS USED IN LEAD ISOTOPE MODEL CALCULATIONS

Hypothesis two can be dismissed on geological grounds since there is clearly a large age difference between the syngenetic volcanogenic deposits and epigenetic veins. The distinction between vein and volcanogenic lead in $^{206}Pb/^{204}Pb$ ratio is marked and provides a method for distinguishing epigenetic versus syngenetic deposits in the Insular Belt. All the epigenetic deposits have $^{206}Pb/^{204}Pb$ ratios greater than 18.8, and the syngenetic deposits have ratios less than 18.7. Iron Clad is an example of one showing which was thought to be epigenetic but which is likely syngenetic on the basis of its isotopic composition.

Hypothesis three can be tested by calculating the apparent $^{238}U/^{204}Pb$ (μ) value which would be required to produce the vein lead compositions from the volcanogenic lead compositions in the time intervals 270 to 30 Ma and 200 to 30 Ma, using equations 1 and 2 (Table 2). This method is based on the assumption that the volcanogenic lead is representative of the composition of the lead in the volcanic host rocks at their time of formation (t_1) to the time of vein mineralization (t_2). The amount of change in the ratios over any time interval depends on the value of $^{238}U/^{204}Pb$ (μ) and $^{232}Th/^{204}Pb$ (ω). Apparent μ values were calculated and found to be high relative to expected values (Faure, 1977; Doe and Zartman, 1979). Thus, the veins are more enriched in radiogenic lead than would be expected if they fell on growth curves with the volcanogenic lead. This causes us to reject hypothesis three. The apparent high μ values noted above, however, might be because radiogenic lead is more easily removed from source rocks than is common lead (because of its unstable position in mineral lattices). An ore-forming fluid would therefore be able to scavenge more radiogenic lead than common lead and so would give rise to a lead deposit with an artifically high apparent μ. This process of radiogenic enrichment has been observed at Beaverdell (Watson, et al., in preparation) and in the Mississippi Valley (Heyl, et al., 1974) and supports hypothesis four.

Strong support for hypothesis four comes from the observations that lines 3 and 4 (Figure 3), which pass through the centres of both pairs of clusters, have slopes which give geologically reasonable $^{232}Th/^{238}U$ (k) values. k values were calculated using equation 4 (Table 2) and found to be 3.9 for line 3 and 3.3 for line 4. These values are close to those listed for volcanic rocks by Faure (1977).

SOURCE OF GOLD

The source of gold in vein deposits is controversial. Boyle (1979) summarized three possibilities:

(1) gold comes from an abyssal source such as the mantle,
(2) gold comes from a plutonic source, and
(3) gold comes from the host rocks by processes such as metamorphic secretion or hydrothermal extraction and deposition.

Each of these hypotheses is discussed with respect to the lead isotope data, based on the assumption that the origin of the lead is the same as that of the associated gold.

Lead from an abyssal source would have a depleted isotopic composition due to the absence of uranium and thorium-rich minerals in the mantle (Faure, 1977). Galena in the Bonanza and Karmutsen-hosted veins (Cluster 3, Figures 2 and 3) is notably depleted in ^{207}Pb and must therefore have a source which is less radiogenic than the Sicker volcanic rocks (Cluster 1, Figures 2 and 3). If this source was the mantle, then all the quartz-gold veins of the same age and within a limited geographical area, would have a uniform lead composition irrespective of host rock group. Recognition of two groups of veins with different isotopic compositions, corresponding to different host rock groups, tends to negate this hypothesis. The unradiogenic nature of the Karmutsen and Bonanza volcanic rocks (Cluster 2, Figures 2 and 3) provides an adequate source for the lead without appealing to an abyssal source.

Cluster 3 (Figures 2 and 3) deposits (Privateer, White Star, and Lone Star) are all spatially related to the Zeballos pluton, the latter two occur within the pluton itself (Appendix). If the source of the metals in each vein was plutonic, then one might expect to see either a uniform composition of lead in the veins, unrelated to host rock, or variations in the vein lead compositions corresponding to different plutons. The close correlation between vein composition and host rock group is too persuasive to allow for all of the metal to have been introduced from plutons.

Close spatial association of the quartz-gold veins to Tertiary quartz diorite intrusions suggests that the plutons play a role in the mineralizing process. We suggest that the plutons provided a heat source that circulated hydrothermal fluids through the host rocks; these fluids extracted radiogenic lead and gold from the volcanic terrane and precipitated these metals in quartz veins. This model is in accord with Boyle's third proposition, namely that the host rocks provided the metals which were mobilized and concentrated by igneous, hydrothermal activity. Consequently, the isotopic composition of the lead in the veins is a reflection of its host rock.

CONCLUSIONS

Lead isotope data from volcanogenic and quartz-gold vein deposits in the Insular Belt suggest that the gold in veins was derived from their host rocks. Extraction, concentration, and deposition were probably by hydrothermal fluids mobilized in geothermal cells generated adjacent to Tertiary plutonic centres.

Lead isotopic compositions for quartz-gold veins of the southern Insular Belt are depleted in ^{207}Pb relative to silver-bearing veins in the Yukon Tertiary (Godwin, et al., in press), reflecting the more primitive volcanic source terrane of the Insular Belt. The uniformity of the vein lead compositions of Cluster 3 contrasts with the linear patterns of data for vein deposits elsewhere in the Cordillera (Doe and Zartman, 1979; Godwin, et al., in press). There is also evidence that radiogenic enrichment of lead in veins, noted in the Insular Belt quartz-gold veins, occurred in other silver-gold veins, for example, in the Beaverdell camp in south-central British Columbia (Watson, et al., in preparation).

From a practical point of view, isotopic analyses of galena appears useful in distinguishing young epigenetic vein deposits from older volcanogenic deposits (perhaps with related veins). This distinction will have an effect on the approach to detailed exploration within the Insular Belt.

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APPENDIX

Western Mines:	Lat. 49•57°; Long. 125•59°; 92F/12E
Sample Nos.:	G79WM-001, 002, and 003.
Description:	It is a kuroko-type massive sulphide deposit. Lenses, veins, and mosses of pyrite, chalcopyrite, sphalerite, and galena occur in Sicker Group rhyolitic volcanic rocks.
Metals Recovered:	Copper, zinc, lead, gold, silver, cadmium, and barite.
Reference:	MDI No. 092/071.

Lenora:	Lat. 48•87°; Long. 123•78°; 92B/13W
Sample Nos.:	G79LN-001 and 002.
Description:	This is described as a 'replacement' ore, but is probably a volcanogenic massive sulphide in Sicker Group folded tuffs. Two ore types occur: barite ore is a fine-grained mixture of pyrite, chalcopyrite, sphalerite, and galena in a barite, calcite, and quartz gangue; and quartz ore is mainly quartz and chalcopyrite.
Metals Recovered:	Zinc, copper, silver, barite, and lead.
Reference:	MDI No. 092F/001.

Tyee:	Lat. 48•87°; Long. 123•78°; 92B/13W
Sample No.:	G79TY-001.
Description:	This is described as a 'replacement' ore, but is probably a volcanogenic massive sulphide in Sicker Group folded tuffs. Two ore types occur: barite ore is a fine-grained mixture of pyrite, chalcopyrite, sphalerite, and galena in a barite, calcite, and quartz gangue; and quartz ore is mainly quartz and chalcopyrite.

Cowichan Lake:	*Lat. 48•7°; Long. 124•78°; 92C/16W*
Samples Nos.:	G79CL-001, 002, and 003.
Description:	Permo-Carboniferous Buttle Lake Formation limestone (Sicker Group) is underlain by Sicker Group cherts, tuffs, and breccias and overlain by Karmutsen Formation basalt and diabase.
References:	B.C. Ministry of Energy, Mines & Pet. Res., Bull. 40, p. 46; Bull. 37, p. 16.

Iron Clad:	Lat. 48•85°; Long. 123•68°; 92B/13E
Sample No.:	G79IC-001.
Description:	Sphalerite, pyrrhotite, and chalcopyrite mineralization occurs in a shear zone of quartz-sericite schist of Sicker Group.
Metals Recovered:	Zinc and copper.
References:	Minister of Mines, B.C., Ann. Rept. 1904, p. 253; Assessment Report 19.

Bon:	Lat. 50•27°; Long. 126•67°; 92L/7E
Sample No.:	30366-001.
Description:	The Bon mineral occurrences are in predominantly volcanic rocks of the Karmutsen Formation in the type area (GEM, 1970, pp. 274-278). Principal showings are replacements of certain volcanic layers by skarn with either magnetic or pyrrhotite. One conflicting report suggests that Bon is in Bonanza Group rocks (Assessment Report 1821).
Metals Recovered:	Iron and copper.
References:	B.C. Ministry of Energy, Mines & Pet. Res., GEM, 1970, pp. 274-278; Assessment Report 1821.

Nutcracker: Lat. 49•75°; Long. 124•59°; 92F/10E

Sample Nos.: 30335-001.
Description: Brown porphyrite (Karmutsen ?) is traversed by several fissure zones 3 to 4 feet wide, rarely completely filled with quartz. Usually narrow veinlets occupy the zones. A contact with the Marble Bay Limestone occurs to the southeast. Galena and chalcopyrite occur in the quartz.
References: MDI No. 092/359; Assessment Report 6414.

Starlight: Lat. 49•06°; Long. 125•54°; 92F/3E

Sample Nos.: 30314-001.
Description: Fine-grained free gold is associated with galena that is finely disseminated through extensively altered diabase.
Metal Recovered: Gold.
References: MDI No. 092/216; Geol. Surv., Canada, Map 49-1963.

Cream Lake: Lat. 49•49°; Long. 125•54°; 92F/5E

Sample No.: 30355-001.
Description: Veins of quartz with lesser siderite and calcite contain values in silver, gold, zinc, and copper. They are underlain by volcanic rocks and lesser sedimentary rocks of Permian age and overlain by Karmutsen volcanic rocks. A distinct band of Permian limestone occurs between the two. The Western Mines' orebodies lie to the north within this belt.
Metals Recovered: Gold, silver, copper, and zinc.
Reference: Assessment Report 1884.

Golden Eagle: Lat. 49•11°; Long. 124•59°; 92F/2E

Sample No.: 30313-001.
Description: Gold occurs in a vein of ribbon quartz and pyrite with other minor sulphides in a small intrusion of feldspar porphyry.
Metal Recovered: Gold.
References: MDI No. 092F/080; Geol. Surv., Canada, Paper 68-50.

Victoria: Lat. 49•18°; Long. 124•66°; 92F/2E

Sample No.: 30315-001.
Description: Gold and pyrite are associated with quartz veins in sheared sections of andesitic flows and tuffs. The rock groups observed were placed tentatively in the Sicker Group, though government geologists left them in the Island series. The deposit is adjacent to a stock related to the Coast Range Batholith (that is, this vein is probably an older vein than the others).
Metals Recovered: Gold, silver, and copper.
References: MDI No. 092F/079; Geol. Surv., Canada, Paper 68-50; Assessment Report 4914.

Fandora: Lat. 49•25°; Long. 125•68°; 92F/5E

Sample No.: 30323-001.
Description: Gold and silver-bearing veins of quartz with some carbonate, finely crystalline pyrite, and rarely lerite cut altered volcanic rocks near andesitic dykes in one working close to a small mass of intrusive quartz diorite.
Metals Recovered: Gold, silver, copper, lead, and zinc.
References: MDI No. 092F/040; Geol. Surv., Canada, Paper 68-50.

White Star: Lat. 50•30°; Long. 126•81°; 92L/2W

Sample No.: 30318-001.
Description: Quartz diorite of Eocene Zeballos pluton is cut by feldspar porphyry dykes and subsequently jointed in three directions. Quartz veins with pyrite, galena, arsenopyrite, sphalerite, and gold occur in gangue and breccia zones along which fault movement has taken place. The sulphides are usually concentrated in bands along the walls of the veins.
Metals Recovered: Gold, silver, lead, and zinc.
References: MDI No. 092L/010; Geol. Surv., Canada, Paper 40-12.

Lone Star-Rey-Oro: Lat. 50•02°; Long. 126•79°; 92L/2W

Sample No.: 30317-001.
Description: *Quartz diorite of Zeballos pluton is cut by aplite and andesitic and* feldspar porphyry. Many quartz veins with galena, arsenopyrite, gold, chalcopyrite, and sphalerite occur in shears in jointed quartz diorite and the dykes.
Metals Recovered: Gold, silver, zinc, lead, and copper.
References: MDI No. 092L/015; MINDEP 05841.

Peerless: Lat. 50•04°; Long. 126•84°; 92L/2W
Sample No.: 30320-001.
Description: A quartz vein 5 centimetres wide follows a contact between a feldspar porphyry dyke and feldspathized andesite of Lower Jurassic Bonanza Group. Quartz contains abundant calcite and small amounts of sphalerite and chalcopyrite.
Metals Recovered: Gold, zinc, and copper.
References: MDI No. 092L/025; MINDEP 05851.

Privateer: Lat. 50•03°; Long. 126•81°; 92L/2W

Sample No.: 30349-001.
Description: Quartz veins with pyrite, sphalerite, galena, arsenopyrite, pyrrhotite, and native gold cut massive Bonanza Group volcanic rocks, lime silicates, and small bodies of Jurassic intrusive quartz diorite.
Metals Recovered: Silver, gold, copper, and lead.
References: MDI No. 092L/008; Geol. Surv., Canada, Paper 1940-12.

Alpha, Beta: Lat. 48•73°; Long. 124•09°; 92C/9E

Sample No.: G79AB-001.
Description: Franklin Creek (Karmutsen Formation) andesite and lenses of Quatsino limestone are cut by dykes of granodiorite, granite porphyry, and diorite porphyry. Limestone, andesite, and granodiorite are partly altered to garnet-epidote-pyroxene skarn with chalcopyrite, magnetite, and pyrite locally.
References: MDI No. 092C/039; B.C. Ministry of Energy, Mines & Pet. Res., GEM, 1970, p. 291; 1971, p. 226.

Lucky Strike: Lat. 50•06°; Long. 126•84°; 92L/2W

Sample No.: 30334-001.
Description: *The Vancouver-G 1 shear, which follows a feldspar porphyry dyke in* diorite and granodiorite breccia, contains lenses of quartz 5 to 7.5 centimetres wide with pyrite and free gold.
Metals Recovered: MDI No. 092L/030; MINDEP 05856; Geol. Surv., Canada, Mem. 272, p. 59.

PLATINOIDS IN THE TULAMEEN ULTRAMAFIC COMPLEX

(92H)

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INTRODUCTION

The Tulameen Ultramafic Complex is approximately 22 kilometres west of Princeton, and 48 kilometres north of the Canada-United States border. The complex has a surface of about 57 square kilometres and is largely concordant with the regional northwest-southeast structural grain. It has been tentatively dated as Late Triassic (Findlay, 1969).

The Tulameen River area has been known to be a gold and platinum producer for more than one hundred years. Essentially all of the precious metal production has been from placers in the Tulameen River and its tributaries. No hard-rock mining of platinum has been attempted, mainly because information about the platinum distribution within the complex is lacking. The purpose of this project is to establish the distribution of the platinum group elements (PGE) and determine if they have any mineralogical associations. This research is being conducted as part of the requirements for an M.Sc. degree at the University of Alberta.

REGIONAL GEOLOGY

The Tulameen Complex intruded Late Triassic Nicola Group metavolcanic and metasedimentary rocks. The intrusion took place at the same time as major folding was in progress in the Nicola Group (Findlay, 1963). The Eagle granodiorite lies just west of the margin of the complex. This acidic intrusion is slightly younger than the Tulameen, and may contact the ultramafics at depth (Findlay, 1963).

The Tertiary Princeton Group, which consists of terrestrial coal-bearing sedimentary rocks, volcanic rocks, and basalt flows, unconformably overlies the eastern margin of the Complex (Findlay, 1963). In addition, glacial deposits cover much of the ultramafic, making outcrops scarce, especially in the southern half of the area.

GEOLOGY OF THE COMPLEX

As shown on Figure 1, the Tulameen Complex is oval with long axis trending northwest. It is imperfectly concentrically zoned. The general pattern of zonation, from core to margin is: dunite, (peridotite), olivine clinopyroxenite, hornblende clinopyroxenite, syenogabbro, and syenodiorite (Findlay, 1963, 1969). Because they are common along the southeastern coast of Alaska ultramafics with this type of zoning are

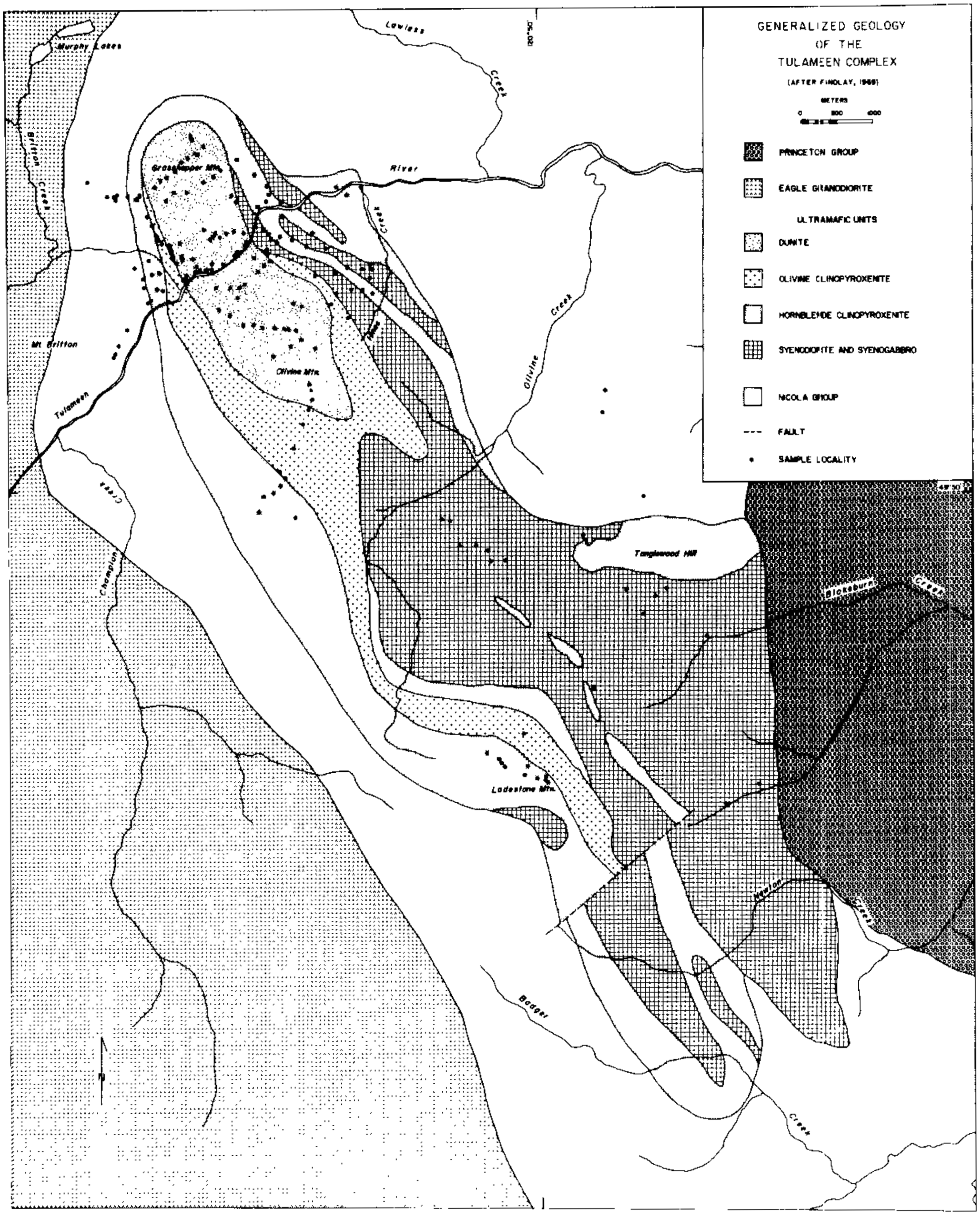

Figure 1. Generalized geology of the Tulameen Complex.

called Alaskan peridotites. The Alaskan peridotites are a special variety of alpine peridotites but they differ in zoning and chemistry. Both are found in geosynclinal orogenic zones (Wyllie, 1967). In addition to the zoning, Alaskan intrusions characteristically lack orthopyroxene and feldspars, and contain highly magnesian olivine, on the order of Fo_{75-93} (Wyllie, 1967). In the Tulameen Complex the bulk Fe ratio increases from core to margin, feldspars are only present in the gabbroic units, and no orthopyroxene has been found (Findlay, 1963).

The dunite unit occurs at the northwest end of the complex and is also elongated to the northwest. It contains chromite in variable quantities, generally ranging from 2 to 20 volume per cent. Serpentine and magnetite are common. Serpentine generally constitutes less than 50 per cent of the rock and is commonly in zones of deformation and at contacts.

Peridotite is volumetrically insignificant and does not constitute a mappable unit. Olivine/serpentine and diopside comprise 45 to 90 per cent of the rock. The peridotite is generally located at the dunite-olivine clinopyroxenite contact, but also occurs within the olivine clinopyroxenite (Findlay, 1963).

Olivine clinopyroxenite partly envelopes the dunite unit on the south and extends southward as a single zone. It consists of 70 to 80 per cent diopside, 10 to 25 per cent olivine and serpentine, some magnetite, and local chromite.

Hornblende clinopyroxenite comprises the outer unit around most of the complex. It contains 30 to 75 per cent diopside, 5 to 70 per cent hornblende, 5 to 25 per cent magnetite, and accessory biotite.

Gabbroic rocks comprise a large mass along the eastern part of the complex. The syenogabbro generally contains 30 to 50 per cent diopside, 25 to 35 per cent plagioclase, 15 to 20 per cent K-feldspar, and minor biotite and magnetite. Syenodiorite contains 10 to 25 per cent diopside and hornblende, 35 to 55 per cent andesine plagioclase (An_{40}), 15 to 35 per cent K-feldspar, and accessory biotite, magnetite, and apatite (Findlay, 1963). These two units are typically saussuritized, and altered areas resemble one another in outcrop.

Contacts between gabbroic and ultramafic rocks are sharp. However, the ultramafic rocks grade into one another (Findlay, 1963). In general, contacts between ultramafic units are marked by xenoliths of one type in the other. Near contacts, hybrid mixtures of the two contacting units are common (Findlay, 1963).

The Tulameen Complex is geologically interesting for a number of reasons. It is one of the very few Alaskan peridotites found in Canada (one of the others being the Turnagain Complex, northern British Columbia). Also, it is unusual in that the Tulameen gabbroic rocks are potassic, whereas those of other Alaskan peridotites are tholeiitic. In addition, both ultramafic and gabbroic rocks of the Tulameen suite are undersaturated in silica (Findlay, 1969). Finally, platinum in Tulameen placers is part of a special class; it occurs as nuggets. Other placers of this type are found in the Ural Mountains and in Alaska.

PLATINUM GROUP ELEMENTS

Findlay (1963) performed some analyses for platinum and palladium in the Tulameen Complex. However, he did not analyse for the other platinoids, and did not develop a detailed picture of the PGE distribution. Raicevic and Cabri (1976), Cabri, Owens, and LaFlamme (1973), and Cabri and Hey (1974) examined PGE from Tulameen placers. They recognized one new PGE mineral (tulameenite) and helped establish some of the platinoid chemistry and mineralogy.

Alaskan peridotites are characterized by high Pt/(Pt+Os+Ir) ratios and high Pt/Pd ratios, relative to large layered ultramafic intrusions (Raicevic and Cabri, 1976). It should be noted that Pd is rare in the Tulameen material (Raicevic and Cabri, 1976; Findlay, 1963).

Overall, Findlay (1963) found the highest concentrations of Pt in dunite and peridotite. In rock samples, he found the highest Pt content to be 0.225 gram per short ton in dunite on Olivine Mountain. The background Pt content in the dunite is 0.08 to 0.09 gram per short ton (Findlay, 1963). Chromite segregations within the ultramafic rocks returned the highest value of 7.34 grams per short ton Pt. Findlay (1963) also found that Pt is enriched in the magnetic fraction of chromite samples relative to the non-magnetic fraction.

Although Findlay (1963) gives a brief sketch of the distribution of platinum within the Tulameen Complex, he has not systematically determined the overall PGE distribution or mineralogical/chemical associations for the PGE. The author hopes to establish both of these.

During the 1981 field season some 300 rock samples from the Complex were collected (Figure 2). Most weighed 4 or 5 kilograms. The samples represent all the major units of the complex, although the greatest sampling density was in the Olivine-Grasshopper Mountain area. The sampling distribution is largely a function of access and outcrop availability.

Analysis for all six PGE and gold will be carried out on the University of Alberta slowpoke reactor. A selective group separation scheme for radiochemical neutron activation, described by Nadkarni and Morrison (1977), will be used. This technique allows for precise precious metals determinations to less than 20 ppb levels of concentration. About 150 samples will be analysed in this manner.

Once the PGE concentration in the samples is known, reflected light and transmitted light microscopy will be used to determine mineralogical associations. Electron microprobe analysis will be used to supplement this work. These observations will be of interest not only with respect to the Tulameen Complex, but also to those seeking PGE in other Alaskan ultramafic complexes.

ACKNOWLEDGMENTS

I would like to thank Drs. Roger Morton and Bruce Nesbitt, Department of Geology, University of Alberta, for their help and supervision of this research. The author was ably assisted by Mr. Harry Nelson and Mr. Donald Dingwell during parts of the 1981 field season. Thanks are also extended to claim holders in the study area for their assistance during the field work, including Mr. David Javorsky, Mr. Bill Halliday, and Mr. Richard Davies. Special thanks to Mr. Ernie North who has been extremely helpful in the field and in discussion. The support of the British Columbia Ministry of Energy, Mines and Petroleum Resources is gratefully acknowledged.

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MANTLE PROCESSES AS DEDUCED FROM ALPINE ULTRAMAFICS

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INTRODUCTION

This study of mantle processes, as deduced from alpine ultramafics, has been initiated in the hope that some positive statements may be made concerning the predictability and conditions of occurrences of chromite deposits within British Columbia. Several well-exposed alpine ultramafic bodies have been chosen for study. They are all within Upper Paleozoic rocks and thus may be slices of the same original mantle material that have since been welded to the craton.

Interpretation of conditions of equilibrium and deformation processes depend upon accurate determination of geothermometry and geobarometry of the constituent phases. Methods for calculation of these conditions are based upon calibrated exchange equilibria among olivine, pyroxene(s), and spinel. These require accurate probe analyses of fresh material. Thus, we have examined three alpine ultramafic bodies whose rock type distribution has been mapped previously in some detail. These are the Bridge River ultramafic (Wright, 1974), the northern end of the Shulaps ultramafic complex (Leech, 1953), and the Blue River ultramafic (Wolfe, 1965) north of Cassiar.

GENERAL DESCRIPTION

These ultramafics were chosen because they reportedly lack or have only a moderate degree of serpentinization. Complete structural sections were mapped across each of the bodies and samples collected for thin section and probe analysis.

At this time, preliminary examination of thin sections indicates that the Bridge River and Shulaps ultramafics are remarkably similar. Both are composed essentially of harzburgite with interlaminated dunite and very minor websterite and wehrlite. Where they are interdigitated, dunite and harzburgite are present in almost equal proportions and individual layers vary in thickness from a few centimetres to several metres. Macroscopic layering defined by complex interdigitations of harzburgite and dunite is the earliest recognizable structure, and in some instances it is possible to infer the original facing direction of crystallization. At several localities this layering is involved in tight folds, some near isoclinal. These folds are on the outcrop scale (Figure 1) and in many instances elongate orthopyroxenes outline a foliation that is locally parallel to their axial surfaces.

Field sketch (perspective view):
Dunitic and pyroxenitic bands outline tight to isoclinal folds in harzburgite. Locality: Pioneer ultramafic body, NW side of ridge crest at coord. 5619.180m/516.620m/7250ft.
50° 43′ 35″ N / 122° 45′ 52″ W

Figure 1. Field sketch.

On a regional scale, the layering and orthopyroxene foliation are folded into broad open structures with angles between their limbs of approximately 60 degrees and whose axes appear to be coaxial with those of the earlier tight folds. Near the core regions of these open folds elongate orthopyroxenes are very well aligned parallel with the axial surfaces of these later folds.

It is frequently observed that small stringers of orthopyroxene and dunite also parallel the axial surfaces of the two fold sets, whereas chromite, where present in any concentration, appears aligned only with the earliest fold set elements.

The general petrographic and early structural character of the Blue River ultramafic appears to be similar to that just described. Owing to subsequent intrusion of the Cassiar Batholith (Wolfe, 1965), however, there are notable differences in later development. The northern portion of this ultramafic body, as well as adjacent sedimentary rocks and andesites, are thoroughly contact-metamorphosed by the batholith and locally display a series of clearly defined isograds. These have been mapped along several structural traverses. Within the contact aureole pervasive recrystallization partly destroyed mesoscopic structural elements and obliterated microscopic features. The southern part of the body, however, provides some material that can be directly compared to specimens from the other two bodies. However, serpentinization is much more intense here and outcrop conditions are generally poorer.

OUTLINE OF LABORATORY INVESTIGATIONS

The sample material collected this summer is presently being examined petrographically, specifically with the aim of identifying sections most suitable for geothermometric and -barometric work and for microstructural characterization. The extent and detail of these further studies will depend to a large degree on the consistency of the picture emerging. Particular questions we hope to answer include the following:

(1) What were the physico-chemical and rheologic conditions of (de-) formation of the mantle assemblages and mineral fabric?
(2) How did the crustal emplacement affect these conditions and what conditions prevailed during and after emplacement?
(3) What controls the occurrence, abundance, and composition of chromite (as pods, stringers, or in disseminated form) in these ultramafics?

ACKNOWLEDGMENTS

Peter van der Heyden and Michiel Dronkert provided able and cheerful assistance. Brian Cranston prepared the thin sections. John Watkins and Doug Whalen (Canadian Superior Exploration Ltd.) offered free helicopter support at Blue River.

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BOWRON RIVER PROGRESS REPORT

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This study of the Bowron River coal deposit, supported by grants from the British Columbia Ministry of Energy, Mines and Petroleum Resources and contributing to an M.Sc. degree, is now in the final stages. It includes two and a half seasons of work in the Bowron River valley under I. Borovic in association with Norco Resources Ltd. and combines a compilation of previous work and present drill results. The most recent results included were obtained during the spring and summer of 1981. Prior to this drill program there was insufficient information to conduct a meaningful study of the stratigraphy and lithologies of the coal deposit. Data collection time was lengthy due to spacing of the drill programs and adverse drilling conditions.

During the two seasons of drilling 22 holes were attempted(10 rotary and 12 diamond-drill holes). Also during this period limited seismic and geomagnetic surveys were conducted. Further drilling is required to accurately delineate the fault contact between the sedimentary rocks and the underlying volcanic rocks, and to resolve problems regarding faulting versus lithofacies changes. Norco Resources Ltd. plans to continue drilling late this fall.

Between drilling programs, the lithologies and stratigraphy of the sediments were analysed at the University of British Columbia. These studies included definition of the lithologies and associated sedimentary structures, analysis and mapping of the lithofacies, determination of the lithofacies, determination of the subsurface structure, maceral and reflectivity analysis of the coals, X-ray diffraction analysis of some of the shales, and petrology of the conglomerates and sandstones. Some of the results obtained from these studies are as follows:

(1) Thirteen distinct lithologies exist within the Bowron River basin. The lithologies may occur singly, or in combinations of several types. Two lithologies of the Mountain Group Slide crop out in the basin. These are greenstones of the Antler Formation and two different limestones which have been assigned to the Greenberry Limestone Member of the Guyet Formation.

(2) Sediments in the Bowron River basin can be broadly separated into three facies groups. These are a lacustrine facies, an alluvial fan to plan facies, and a transitional facies which contains elements of both lacustrine, and alluvial facies.

(3) A predictable stratigraphy is best developed in the lacustrine facies, and most poorly developed in the alluvial fan to plan facies.

(4) Subsurface structure involves little folding except locally along fault contacts. The structure is dominated by high-angle block faults. Two patterns of faulting exist: one set of faults parallel to the trend of the basin. The other trends northeastward across the basin. The general form of the basin appears to be a faulted, asymmetrical syncline.

(5) The coal has sub-bituminous rank. Maceral and reflectivity analysis are in general agreement with previous work by Donaldson of the Geological Survey of Canada. The coal consists of vitrinite, vitrinite precursors (telinite and collinite), and various exinites of which resisite and cutinite were the most abundant. Reflectivity values were variable but generally agreed with those obtained by Donaldson. There was no apparent increase in reflectivity with depth of burial.

(6) Examination of some of the shales, particularly those with swelling properties, showed that they consist of quartz chlorite, illite, and micas. Despite the swelling or disaggregating nature of these shales on exposure to rain water, only one sample contained abundant smectites.

(7) Shales from the lacustrine facies were tested for palynomorph content. Most possessed an abundant palynomorph assemblage that correlates with Middle to Late Paleocene assemblages. The flora represents a warm to temperate, wet paleoclimate. This is the first documented Paleocene assemblage described in British Columbia.

(8) Conglomerates and sandstones were sampled and examined under a petrologic microscope. They consist of quartz of various types, argillitic and phyllitic clasts, limestone clasts, and carbonaceous materials. On the basis of composition the most likely sources for the Bowron River sediments are the Guyet Formation and the upper Cariboo Group.

PRELIMINARY RESULTS OF A FLUID INCLUSION STUDY OF SAM GOOSLY DEPOSIT EQUITY MINES LTD., HOUSTON

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INTRODUCTION

Sam Goosly copper-silver deposit (MDI No. 093L/001) of Equity Mines Ltd. is 35 kilometres southeast of Houston. The deposit was put into production in 1980 with about 35 million tonnes of reserves grading 0.33 per cent copper, 87 grams silver per tonne, and small but significant amounts of gold and antimony. Recent studies (Wetherell, 1979; Wetherell, et al., 1979; Wodjak, 1974; and Ney, et al., 1972) have led to proposal of several genetic models. Our fluid inclusion work has been undertaken to obtain information concerning the ore-forming process as a means of establishing a genetic model for the deposit. Samples used in our study were obtained from a collection made originally by Wetherell (1979) representing all principal stages of the paragenetic sequence that he described. It also includes samples from all the principal centres of mineralization known on the property.

Four mineralized zones are located on the property. The Main and Southern Tail zones are the most important deposits; present production is entirely from the Southern Tail zone. The Tourmaline Breccia zone and a small porphyry-type copper-molybdenum zone in the quartz monzonite stock are of special interest because they may be genetically related to ore (Wetherell, 1979).

Sulphides in both ore zones consist mainly of pyrite, tetrahedrite and chalcopyrite with less abundant arsenopyrite, galena, sphalerite, pyrrhotite, and various sulphosalts. These minerals occur mostly as stockworks, veins, and disseminations. Locally they form massive zones. Dominant gangue minerals are quartz and sericite with lesser amounts of chlorite, tourmaline, corundum, andalusite, calcite, and pyrophyllite. The two ore zones are part of a single, larger mineralized zone that is apparently epigenetic and crosscuts stratigraphy.

METHOD OF STUDY

Twelve samples were selected for detailed fluid inclusion study, seven from the Southern Tail zone, one from the Main zone, two from the Tourmaline Breccia zone, one from a vein at the contact of the quartz monzonite stock, and one from the porphyry-type occurrence within the quartz monzonite stock. Doubly polished plates were prepared for each sample to locate fluid inclusions and several chips containing fluid inclusions were selected from each doubly polished plate for heating and freezing experiments. Filling and last melting temperatures were determined using a Chaixmeca stage. Temperature measurements were producible to about 0.1 degrees C with the freezing stage and to less than 5 degrees C with the heating stage. Inclusions in quartz were studied most commonly because of the ease with which they could be examined and the presence of quartz in most stages of the paragenetic sequence. Associated minerals and indications of any stages of deposition were noted. Several samples of sphalerite and calcite and one of vein andalusite were also examined.

RESULTS

Three types of inclusions are recognized based on phase relations at room temperature.

Type I: Two-phase inclusions consisting of liquid and a small gas bubble generally comprising 10 to 20 volume per cent of the inclusion.

Type II: Two-phase inclusions consisting of a large bubble and a condensed liquid. The bubble generally occupies more than 60 volume per cent of the inclusion.

Type III: Multi-phase inclusions consisting of liquid, a small bubble (about 15 volume per cent of the inclusion), and one or more (up to four) solid phases. Solid phases are most commonly halite although hematite has been identified and sylvite is suspected in some cases.

Primary inclusions are recognized in all paragenetic stages examined, largely by relations to crystal growth zones. In many cases, however, individual inclusions cannot be proved with certainty to be primary or secondary. Many inclusions are clearly secondary relative to their host mineral, although it seems likely that many of these may represent younger stages in the primary paragenetic sequence.

A histogram of filling temperatures is shown on Figure 1 where peaks correspond to specific stages in the paragenetic sequence. The filling temperatures are not corrected for pressure, but indicate a regular decrease in filling temperature (and therefore temperature of deposition) with increasingly young stages of mineralization. Most of the filling temperatures represented on Figure 2 are for quartz from various paragenetic stages. However, it is of interest to note that calcite is late in the paragenetic sequence and filling temperatures in it are all relatively low. Similarily, inclusions in pale sphalerite have relatively low filling temperatures, comparable to those in calcite, but with a more restricted range. A single inclusion from vein andalusite has a filling temperature of about 305 degrees C.

Freezing temperatures (Figure 2) indicate a wide range of salinities. In general, the lower temperature stages of mineralization have higher

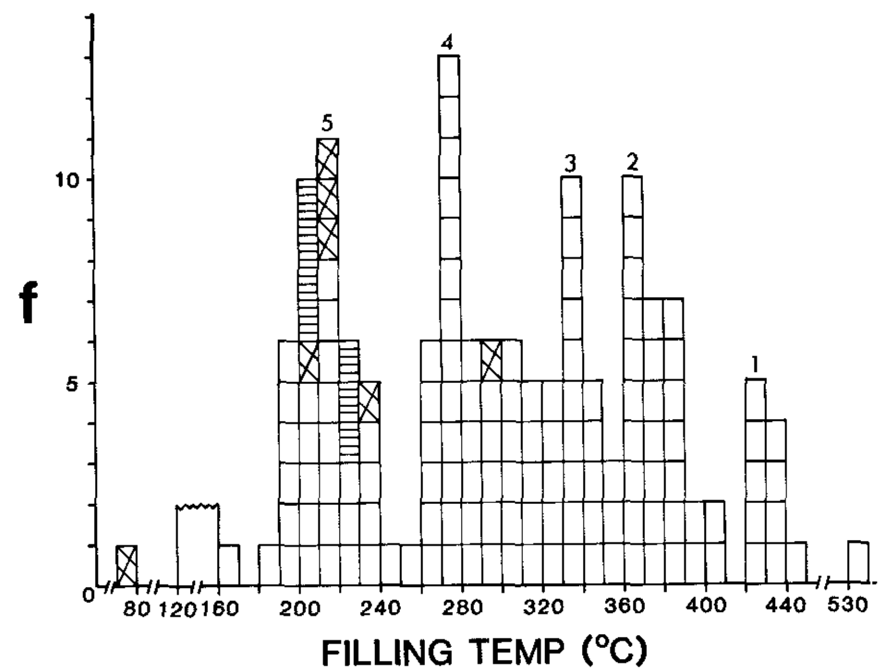

Figure 1. Filling temperatures for 147 inclusions, Sam Goosly deposit. Most are for quartz (blank); other symbols are defined on Figure 2. Numbered peaks related to specific mineral assemblages as follows: 1 - porphyry-type mineralization, 2 - Tourmaline Breccia zone, 3 to 5 - Main and Southern Tail zones.

melting temperatures and therefore lower salinities. Highest salinities are indicated for fluid inclusions from the porphyry-type occurrence for which halite crystals dissolved between 360 degrees C and 425 degrees C.

Intermediate salinities were obtained for fluid inclusions from the Tourmaline Breccia, and a range of low salinities is indicated for most of the stages of mineralization in the Main and Southern Tail zones.

DISCUSSION

The temperature of filling of primary inclusions decreased with time, as shown by the relationship with paragenetic sequence illustrated on Figure 2. In addition, there is a spatial component to variations in filling temperatures. Highest temperatures are for porphyry-type mineralization directly associated with a quartz monzonite stock. Somewhat lower filling temperatures relate to a Tourmaline Breccia zone north of the ore zones and a wide range of filling temperatures closely related to paragenetic sequence exists within the Main and Southern Tail zones.

These data are consistent with the model proposed by Wetherell (1979) in which the quartz monzonite stock just west of the principal ore zones provided the energy to drive a circulating geothermal system. Periodic fracturing during mineralization combined with a generally decreasing temperature regime led to a clearly defined paragenetic sequence of veining.

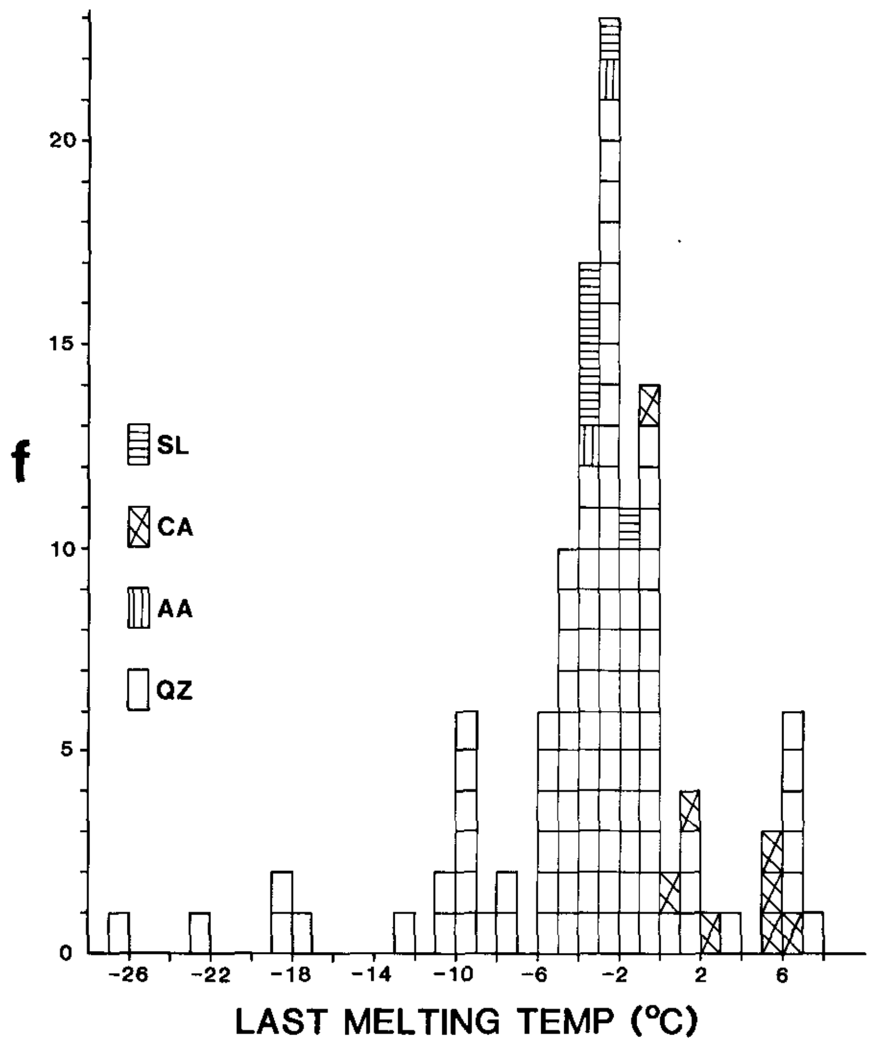

Figure 2. Freezing (last melting) temperatures for 115 fluid inclusions, Sam Goosly deposit.

Freezing data indicate high salinity for mineraliztion within the quartz monzonite stock, moderate salinity for mineralizing fluids of the Tourmaline Breccia zone and a range of lower salinities for the Main and Southern Tail zones. In the Wetherell model, the quartz monzonite is the centre of the mineralizing system. These salinity data indicate that high salinity fluids came from within the quartz monzonite stock, whereas a substantially more meteoric water component was involved elsewhere in the hydrothermal system.

CONCLUSIONS

A preliminary evaluation of fluid inclusion data for the Sam Goosly deposit suggests that all of the principal mineralized zones formed during a single episode of mineralization. The hydrothermal system was apparently centred on and driven by the quartz monzonite stock which lies just west of the two principal ore zones. Mineralization proceeded under conditions of gradually decreasing temperature and intermittent fracturing so a well-defined sequence of veining resulted. High salinity fluid inclusions that contain halite as a daughter product suggest that a very small proportion of the ore fluid had an igneous origin. Most of the ore fluid, however, was of relatively low cut variable salinity indicating that meteoric water was the dominant component in the hydrothermal system.

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CHROMITE OCCURRENCES IN MITCHELL RANGE ULTRAMAFIC ROCKS OF THE STUART LAKE BELT CACHE CREEK GROUP

(93N)

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INTRODUCTION

The Mitchell Range map-area, located 240 kilometres northwest of Prince George, is within the Stuart Lake Belt of the Cache Creek Group (Permian). The Cache Creek Group consists predominantly of massively bedded carbonate rocks with minor amounts of laminated chert-siltstone and shaly siltstone. The carbonate succession extends from the Mitchell Range 120 kilometres southeastward to the Fort St. James area where it attains a thickness of 8 kilometres (Armstrong, 1949).

The southeast-striking carbonate succession is folded into an open anticline-syncline pair immediately south of the Mitchell Range ultramafic rocks. The open folds have subhorizontal east-southeast-trending fold axes suggesting compression from the south-southwest associated with thrust faulting and obduction of the Mitchell Range allochthonous rocks.

Chromite occurrences in the Mitchell Range were documented in Armstrong's 1949 memoir. Little (1947) described ultrabasic and associated rocks of the Middle River Range, approximately 70 kilometres southwest of the Mitchell Range ultramafic rocks. Since then various companies and individuals have shown an interest in the chromite and nephrite ('British Columbia jade') potential in the area.

PREVIOUS WORK

Previous geological work was of a reconnaissance nature, primarily by geologists of the Geological Survey of Canada. Selwyn (1872) examined the area between Quesnel and Peace River, followed a few years later by Dawson (1878, 1881). McConnell (1896) reported on the areas drained by the Finlay and Omineca Rivers and also visited the placer gold fields at Germansen Landing and Manson Creek, northeast of the Mitchell Range ultramafic rocks. Camsell (1916) reported on the northern interior of British Columbia, Hanson (1925) on the area from Prince Rupert to Burns Lake, and Lay (1926-1939), of the British Columbia Department of Mines, examined numerous mineral deposits and placer fields in the northeastern mineral survey district. In 1934 Kerr examined placer deposits at Manson and Slate Creeks. Regional mapping of the Fort St. James area began in 1936 and ended in 1944; it was coordinated by J.E. Armstrong (1949).

GENERAL GEOLOGY

MITCHELL RANGE ALLOCHTHON

Allochthonous rocks within the Mitchell Range consist primarily of harzburgite with minor dunite (Figure 1); they are everywhere serpentinized. Sparse pre-tectonic orthopyroxenite veins and gabbro dykes are deformed and reflect internal deformation presumably developed during obduction. Alteration dykes of albitite-rodingite are similarily deformed. Chromitite layers and layers with disseminated chromite exhibit variable degrees of deformation within the harzburgite, from isoclinal folds to brittle segmented planar layers.

Xenoliths of Cache Creek Group rocks up to several square kilometres in area that occur in the serpentinized ultramafic rocks (Figure 1) appear to have been rotated during transport. Contacts between harzburgite and xenoliths regularly exhibit a 0.5-metre-thick, highly fissile zone; rarely, a 1 to 2-metre-thick amphibole-rich alteration zone is developed in the harzburgite.

Later intrusions are now seen as meta-gabbro (Figure 1) and meta-diorite dykes. Clinopyroxene in the dykes has been altered to amphibole but primary sub-ophitic and equigranular medium-grained textures are preserved. These dykes may be derived from the dioritic-granodioritic Mitchell Range Batholith (Armstrong, 1949) which occurs 2.5 kilometres west of the ultramafic body.

STRUCTURE

The Mitchell Range ultramafic allochthon is bounded by north-northeast and east-trending lineaments (Figure 1). Rocks of the Cache Creek Group occur to the south and east, Takla Group volcanic rocks (Upper Triassic to Upper Jurassic) crop out to the north, and the Mitchell Batholith (Upper Jurassic to Lower Cretaceous; Armstrong, 1949) has intruded to the west.

Serpentinized harzburgite of the Mitchell Range allochthon exhibits a strongly developed penetrative north-northeast-trending ductile shear foliation (Figure 2). Dip of the foliation changes from westerly in the western part of the area to easterly in the east. The contour maxima on Figure 2 indicate a preferred north-northeast foliation but they are centred about an east-southeast great circle girdle, indicative of a broad north-northeast-trending antiform. Internal breccia zones occur in the harzburgite with well-rounded, randomly oriented, pebble to cobble-sized fragments set in a finely comminuted serpentinized matrix. The northeast and east-central areas of the ultramafic massif are underlain by tectonic breccia (Figure 1). The breccia has sub-angular fragments up to 2 metres in size that are predominantly of harzburgite with minor amounts of dunite. This coarse tectonic breccia appears to represent the sole of the allochthonous ultramafic rocks.

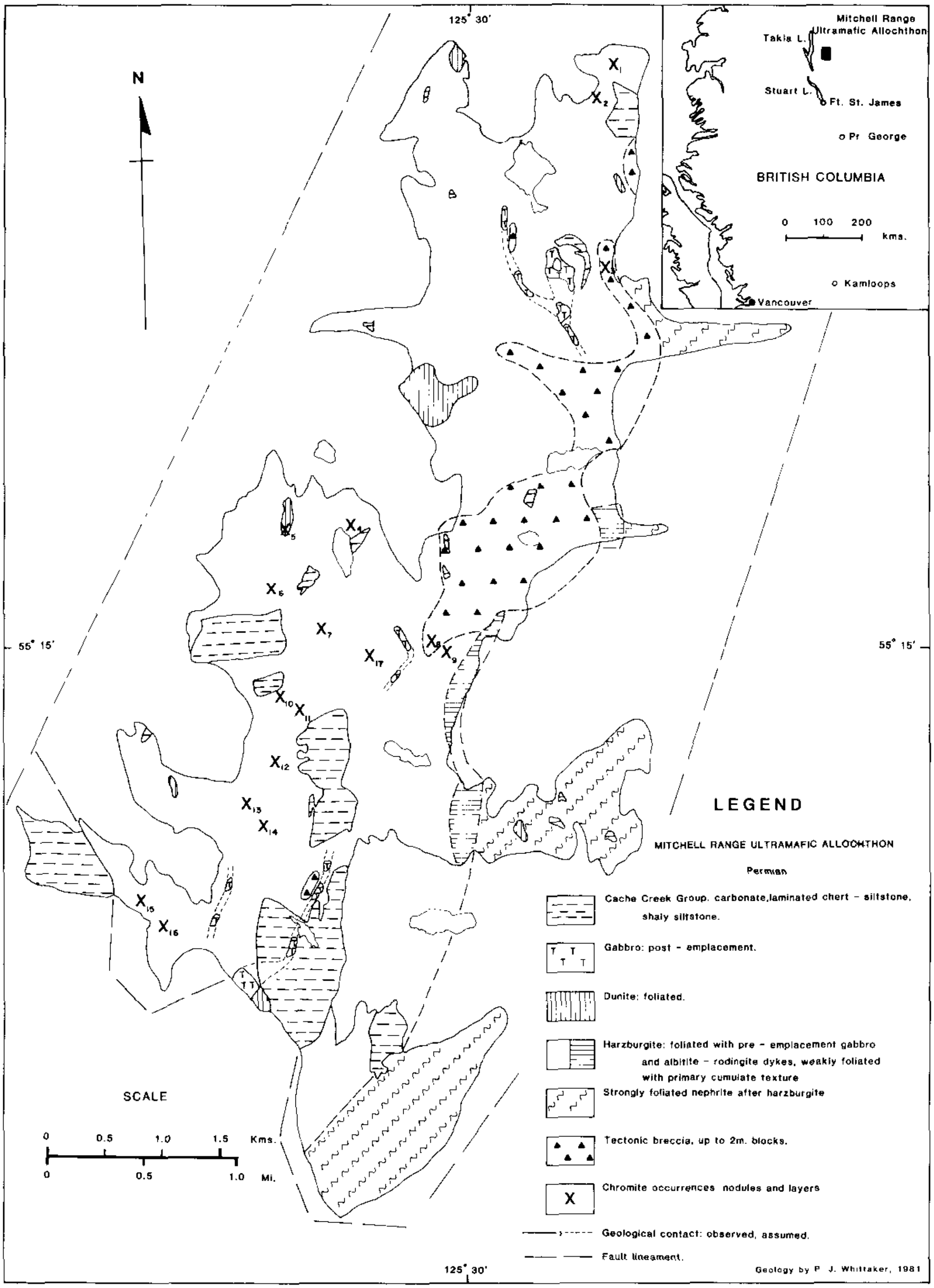

Figure 1. Geology of the Mitchell Range ultramafic allochthon.

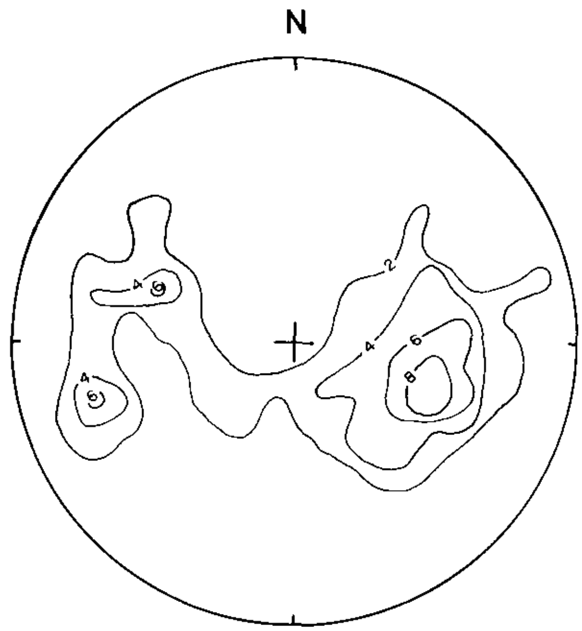

Figure 2. Contoured stereo-projection of poles to foliation planes, Mitchell Range (135 poles); contour interval, 2 per cent per 1-per-cent area.

TECTONIZED HARZBURGITE

Tectonized and serpentinized harzburgite comprise approximately 90 per cent of outcrop in the Mitchell Range allochthon. Its mottled, foliated weathered surface is deep brown with pale silvery brown talcose patches. On fresh surfaces it is mottled black-green to black-brown. Talcose patches are 0.5 to 1.5 centimetres in size and are pseudomorphic after sheared orthopyroxene. Intense shearing in some outcrops has resulted in mechanical segregation of orthopyroxene and olivine into granular, 1.0 to 1.5-centimetre-thick, discontinuous layers. A braided, rippled weathered surface results because orthopyroxene-rich layers are more resistant than olivine-rich layers. More extensive shearing led to development of well rounded 2 to 10-centimetre augen-shaped clots of coarse-grained orthopyroxene pseudomorphed by talc. Orthopyroxene augen in fine-grained olivine-rich harzburgite usually exhibit length to width ratios of 3:1.

Less intensely foliated harzburgite showing pre-tectonic cumulate texture crops out discontinuously in a narrow zone along the east-central part of the ultramafic massif. It is variably medium to coarse-grained with subhedral orthopyroxene and anhedral olivine. On the northeast ridge, very coarse-grained harzburgite exhibits primary magmatic olivine poikilitically enclosed in orthopyroxene; both are anhedral.

Harzburgite hosts all but one of the layered and nodular aggregate and massive chromitite occurrences. Disseminated accessory chromite occurs throughout the ultramafic rocks and varies from a trace to 2 per cent of the rock.

Chromite Occurrence	Form	Texture	Trend	Dimensions (cms)	Host Rock
X_1	nodule	a. c.	027	8 x 4	H.
X_2	nodules (4)	a. c.	in loose talus blocks	6 x 3	H.
X_3	nodules (3)	a. c.	145	4 x 3 6 x 4 7 (diameter)	H. H. H.
	schlieren	d. c. (50%)	145/45NE	300 x 15	H.
X_4	nodules (2)	a. c.	010	12 x 3 6 x 4	H. H.
X_5	layers	a. c.	---	30 x 1-3	D.
X_6	layers	a. c.	155/45SW	200 x 2 15 x 1.5	H. H.
	nodules	m. c.	"	30 (diameter) 20 "	H. H.
X_7	nodules	a. c. m. c.	025	50 x 20 40 x 20 10 x 6 50 (diameter) 30 "	H. H. H. H. H.

Chromite Occurrence	Form	Texture	Trend	Dimensions (cms)	Host Rock
X_8	layer	m. c.	122/33N	150 x 40	H.(breccia)
X_9	layer	m. c.	151/66NE	200 x 75	H.
X_{10}	nodules	m. c. & a. c.	073	10 x 3 10 x 2 5 x 2 4 x 1 12 (diameter)	H. H. H. H. H.
X_{11}	nodule	d. c. rim on m. c. core	---	130 x 100	H.
X_{12}	nodule	a. c.	121	7 x 3	H.
X_{13}	nodule	a. c.	126	4 x 2	H.
X_{14}	nodules	a. c. & m. c.	012 038 155 ---	50 x 10 40 x 15 40 x 10 8 x 3	H. H. H. H.

Chromite Occurrence	Form	Texture	Trend	Dimensions (cms)	Host Rock
X_{15}	nodule	a. c.	---	10 x 4	H.
X_{16}	layers (2)	d.c.	015/V 022/66E	300 x 2-25 100 x 3	H. H.
X_{17}	layer nodules (2)	a. c. a. c.	103/47N ---	25 x 4 5 (diameter) 4 "	H. H. H.

Abbreviations used in table:

a. c.; aggregate chromitite.
d. c.; disseminated chromite.
m. c.; massive chromitite.
H. ; harzburgite (serpentinized).
D. ; dunite "
cms ; centimetres.
X ; location of chromite occurrence on Fig.1.

TABLE 1. CHROMITE OCCURRENCES IN THE MITCHELL RANGE

DUNITE

Dunite occurs in approximately 1 to 2 per cent of the outcrop area as contorted, irregularly shaped patches that reflect the internal deformation in the ultramafic body. A planar dunite layer, 15 metres long and 30 centimetres thick is one exception. Dunite weathers with a smooth, orange-brown surface and is waxy brownish green on fresh surfaces. It consists of fine to medium-grained anhedral olivine. It is foliated so is finely fissile on weathered surfaces. Accessory chromite is fine to medium grained and subhedral. With the exception of one chromitite layer (Table 1, location X_5) no other anomalous concentrations of chromite were observed in the dunite.

PRE-EMPLACEMENT GABBRO

Segmented and deformed gabbro dykes occur primarily in the central and southwestern parts of the Mitchell Range allochthon. They are fine grained, serpentinized, and vary in thickness from 5 centimetres to 1.5 metres. Dyke segments or boudins are up to 3 metres long and form open to isoclinal folds. The dykes have associated dyke-like alteration zones with planar or 'pinch and swell' to boundinaged structures. These alteration zones consist of rodingite and are very fine grained to aphanitic and equigranular. Colour varies from bone white to pastel shades of brown, green, and pink. Contacts between harzburgite and the alteration zones are sharply defined with a 1 to 3-centimetre aphanitic black-green selvage.

POST-EMPLACEMENT GABBRO

Generally north-south-trending gabbro dykes (Figure 1) up to 15 metres thick intrude the harzburgite in the north, central, and southern parts of the massif. This gabbro is fine to medium grained with sub-ophitic to equigranular texture and is not serpentinized. In places clino-pyroxene has been altered to amphibole, and pale green plagioclase was saussuritized.

CACHE CREEK GROUP

Xenoliths of the Cache Creek Group (Figure 1) up to 1 square kilometre in area, occur in the southern part of the massif. Smaller xenoliths of 10 to 300 square metres are distributed through the northern part. The xenoliths consist of limestone and dolostone, siltstone with chert laminae, and shaly siltstone.

Limestone xenoliths are thickly bedded and fine grained with equigranular texture. Small, 2 to 10-centimetre, chert nodules in the carbonate blocks are contorted with thin, 1 to 3-millimetre, quartz veins originating from them. Black siltstone xenoliths have grey 0.5 to 2-millimetre chert laminae which are highly contorted and brecciated.

CHROMITE OCCURRENCES

Chromite occurrences (Figure 1, Table 1) are concentrated in the central and southwestern parts of the Mitchell Range allochthon, although several occurrences are scattered on the northeast ridge. The Bob and Simpson deposits described by Armstrong (1949) were examined and sampled.

Chromite occurs in disseminated and layered form, as aggregate and massive chromitite in layers, and as discrete nodules (Figure 3). Chromite nodules exhibit both aggregate and massive chromitite textures.

Accessory chromite is widely disseminated throughout the ultramafic rocks and varies from a trace to 2 per cent. In this form it is very fine to fine-grained and subhedral to euhedral. Medium-grained, disseminated chromite occurs rarely and is either anhedral or forms aggregates of two to four grains.

Layered chromite (Table 1; $X_{5,\ 6,\ 8,\ 9,\ 16,\ 17}$) consists of massive chromitite and aggregate chromitite; as well as concentrations of disseminated chromite.

Outcrops of massive chromitite are smooth textured and freshly broken surfaces display coarse hackly fracture and sub-metallic black-blue lustre. These layers range in thickness from 2 (Table 1; X_6) to 75 centimetres (Table 1; $X_{8,\ 9}$) and are truncated by joints (Figure 3c) or breccia zones in host harzburgite. Layer contacts with harzburgite are sharply defined and they are usually parallel to the foliation.

Aggregate chromitite and disseminated chromite layers consist of disseminated fine to medium-grained chromite. Aggregate chromitite layers (Table 1; $X_{16,\ 17}$) contain greater than 75 per cent chromite and exhibit sharply defined contacts with harzburgite. Internally they display a fine to medium-grained subhedral to anhedral texture. Layers are plastically deformed into open and isoclinal folds and display pinch and swell structures. Granular, fine to medium-grained chromite fragment trains extend from the ends of deformed layers. Brittle deformation has resulted in some layers being faulted into angular 2 to 5-centimetre fragments with displacements of 10 to 20 centimetres.

Disseminated chromite layers, 2 to 25 centimetres thick, responded to deformation in a ductile fashion because silicate minerals between chromite grains absorbed most of the strain. Contacts between disseminated chromite layers and harzburgite are gradational over 2 to 3 millimetres and are gently undulatory. Pinch and swell structures are developed as well as both open and isoclinal folds. Along strike from the ends of disseminated chromite layers, detached chromite augen may occur.

Thicker massive chromitite layers (Table 1; $X_{8,\ 9}$) contain irregularly shaped 3 to 10 centimetre coarse-grained patches of aggregate chromitite. These consist of anhedral 1-centimetre chromite grains in an open framework separated by approximately 10 per cent interstitial blue-grey aphanitic serpentine. The coarse-grained patches are highly irregular.

Chromite and aggregate chromite to massive chromitite nodules display fine to medium-grained subhedral to anhedral textures. Nodules range in size from 1 centimetre to 1.3 metres and are rounded to augen-like. Some appear to be thin (0.5 centimetre) selvages on shear surfaces whereas most extend to depths of at least several centimetres. Chromitite nodules exhibit massive, aggregate, and disseminated textures. Brittle fracturing is more evident in increasingly massive chromitite. Larger nodules (Table 1; $X_{7, 10, 11, 14}$) usually have a massive chromitite core with discontinuous rims of disseminated chromite. Rims pinch and swell from 0.5 to 5 centimetres and most are offset by late jointing and small-scale faulting. All the textures observed in layered occurrences also occur in chromite nodules.

The progression from open isoclinal folding in chromite layers, to pinch and swell structures, and finally to detached segments of chromite layers (Figure 3a, b) strongly suggests that chromite-chromitite nodules result from the shearing of primary chromite-chromitite layers. Abundant nodules, the largest being 1.3 metres in size (Figure 3d), and remnant chromitite layers up to 75 centimetres thick (Table 1) suggest that extensive primary chromite-chromitite layering existed. This has since been disrupted and redistributed by ductile shearing during tectonic emplacement of the Mitchell Range allochthon.

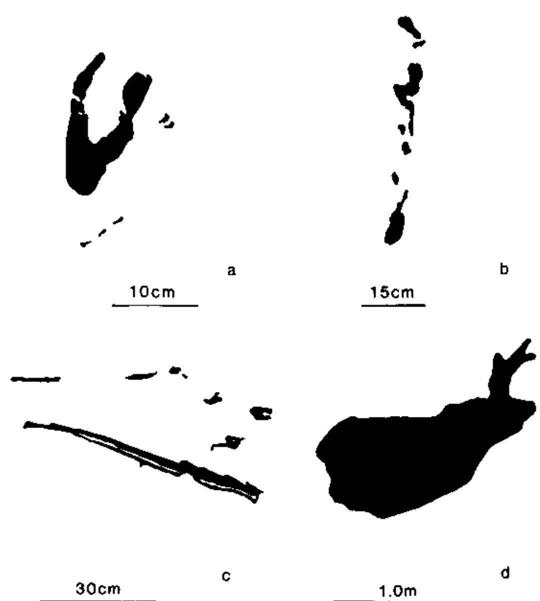

Figure 3. Sketches from photographs of chromite occurrences: (a) deformed nodule, (b) deformed layer with 'pull-apart' structure, (c) planar layered couplet with angular truncations, and (d) deformed massive chromitite nodule.

SUMMARY

Extensive brecciation and penetrative ductile shear foliation within the Mitchell Range allochthon suggests extensive transport of these rocks while in a solid, but perhaps still hot plastic state. Final movement resulted in brecciation along the sole of the ultramafic massif. Similar emplacement breccias at the soles of allochthonous ultramafic bodies occur in the Table Mountain and St. Anthony Complex ophiolites (R. Talkington, pers. comm., 1981).

The proximity of the Mitchell Range ultramafic rocks to a thrust zone, the predominance of massive harzburgite with only minor patches of dunite, and the suggestion of primary chromite-chromitite layers indicate that the Mitchell Range allochthon consists of rocks from below the cumulate dunite-layered zone as observed at Murray Ridge (Whittaker and Watkinson, 1981) and represent a low stratigraphic level in the ophiolite succession.

RECOMMENDATIONS

Detailed mapping of the Mitchell Range allochthon revealed additional chromite occurrences not previously noted. Additional work on chromite occurrences in other large ultramafic massifs, such as Mt. Sydney-Williams and Tsitsutl Mountain to the southwest, should therefore be considered. In addition this would aid in reconstructing the ultramafic part of the now fault-dissected ophiolitic rocks of the Stuart Lake Belt of the Cache Creek Group.

ACKNOWLEDGMENTS

The author would like to express his thanks and appreciation to H. Kukal for capable and cheerful field assistance and to R. Talkington and Dr. D.H. Watkinson for helpful discussions. Financial support for field work from the British Columbia Ministry of Energy, Mines and Petroleum Resources and from the Geological Survey of Canada (Grant 203/4/81) to Dr. D.H. Watkinson is acknowledged with thanks.

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DEPOSITIONAL ENVIRONMENTS AND PALEOCURRENT TRENDS IN THE GATES MEMBER NORTHEAST COALFIELD

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INTRODUCTION

The Lower Cretaceous Gates Member is an important coal-bearing stratigraphic unit in the Rocky Mountain Foothills of northeastern British Columbia. During the past two years, depositional environments in the Gates have been studied between the Wolverine River and the Mount Belcourt area, using outcrop, core, and geophysical log data. In this paper, some of the preliminary results of this study are presented.

LITHOSTRATIGRAPHIC NOMENCLATURE

The lithostratigraphic nomenclature of the Lower Cretaceous in the Foothills and the stratigraphic equivalents in the subsurface to the east, is illustrated on Figure 1. In the Foothills, south of the Pine River, the Gates, together with the Hulcross and Boulder Creek, are members of the Commotion Formation. In the subsurface to the east the stratigraphic equivalents to the Gates are the Falher and the Notikewan Members.

In recent years, two new terms have come into informal use: Transition Beds, to describe an interval of thinly bedded sandstones and claystones between the underlying Moosebar Formation and the Gates; and the Torrens Member, for a thick, regionally extensive, marine sandstone in the lower part of the Gates. Neither of these units has been formally described.

TECTONIC SETTING AND REGIONAL PALEOGEOGRAPHY

During Early Cretaceous time, northeastern British Columbia occupied part of the Rocky Mountain foredeep basin, a rapidly subsiding sedimentary trough that was bounded to the southwest by the Columbian Orogen and to the northeast by the Interior Platform. A thick sequence of molasse was deposited in the foredeep; it was derived mainly from the tectonically active area to the southwest. The sediments were deposited in both marine and non-marine environments.

During the Early Cretaceous, a major embayment of the Boreal Sea lay to the north (Douglas, et al., 1976). A series of major transgressive/regressive cycles show that this sea transgressed southward on several occasions. Wide areas of marine muds and silts were deposited during major transgressions whereas non-marine deposition was more widespread during regressions. The Gates Member, which consists of non-marine and

<table>
<tr><th colspan="2">PINE RIVER FOOTHILLS, BC.</th><th colspan="2">PEACE RIVER PLAINS, ALBERTA</th></tr>
<tr><td rowspan="5">COMMOTION FM.</td><td rowspan="2">BOULDER CREEK MBR.</td><td rowspan="3">PEACE RIVER FM.</td><td>PADDY MBR.</td></tr>
<tr><td>CADOTTE MBR.</td></tr>
<tr><td>HULCROSS MBR.</td><td>HARMON MBR.</td></tr>
<tr><td rowspan="2">GATES MBR.</td><td rowspan="3">SPIRIT RIVER FM.</td><td>NOTIKEWAN MBR</td></tr>
<tr><td>FALHER MBR.</td></tr>
<tr><td colspan="2">MOOSEBAR FM.</td><td>WILRICH MBR.</td></tr>
<tr><td colspan="2" rowspan="2">GETHING FM.</td><td colspan="2">BLUESKY FM.</td></tr>
<tr><td colspan="2">GETHING FM.</td></tr>
<tr><td colspan="2">CADOMIN FM.</td><td colspan="2">CADOMIN FM.</td></tr>
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Figure 1. Lithostratigraphic nomenclature of the Lower Cretaceous in the Foothills and the stratigraphic equivalents in the subsurface to the east; from Stott, 1968.

nearshore marine sediments, was deposited during a general period of regression.

DUMB GOAT MOUNTAIN SECTION

Dumb Goat Mountain* is located in the southern part of the area, approximately 3 kilometres northwest of Mount Belcourt. Outcrop is good and a fairly complete section was measured from the base of the Moosebar Formation to the top of the Hulcross Member (Figure 2). The intervals are described as follows:

(1) Moosebar Formation: Twenty-seven metres of grey, silty claystones, deposited in a marine environment. The lower contact with the Gething Formation is abrupt and represented by a thin, 10 to 20-centimetre-thick conglomerate overlying 1 metre of bioturbated sandstones. This conglomerate was deposited during the marine transgression which occurred at the base of the Moosebar.

*Dumb Goat Mountain - an informal name used by coal company geologists in the area.

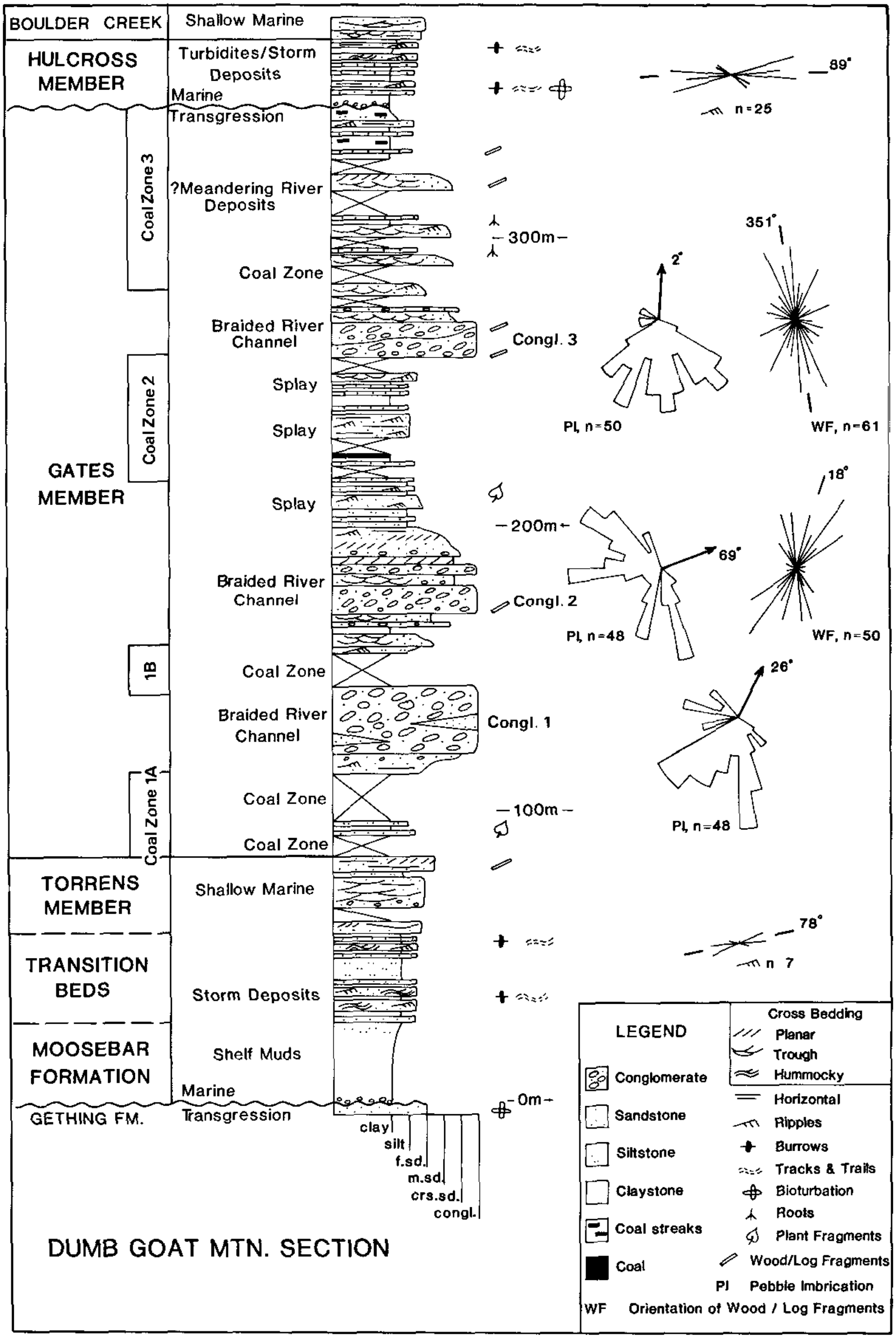

Figure 2. Moosebar, Gates, and Hulcross section on Dumb Goat Mountain.

(2) Transition Beds and Torrens Member: The Moosebar Formation is overlain gradationally by two major coarsening-up cycles in the Transition Beds and Torrens Member. The lowermost cycle consists of thinly bedded, very fine-grained sandstones, and interbedded, silty claystones. The sandstones occur as individual units 15 to 30 centimetres thick, or as composite units up to 2.5 metres thick. Contacts are generally abrupt or slightly erosional, as indicated by the presence of small clay rip-up clasts. Bedding is predominantly hummocky cross stratification (HCS) but there is some horizontal bedding. Symmetrical wave ripples are occasionally present on the top surfaces of the sandstones, as are burrows, tracks, and trails.

The second coarsening-up cycle consists initially of thinly bedded HCS sandstones and siltstones like those in the lower cycle, but they are overlain by a thick unit of fine to medium-grained sandstone. The thinly bedded sandstones and siltstones in the lower cycle and the lower part of the second cycle are assigned to the Transition Beds; the thick sandstone at the top of the second cycle is assigned to the Torrens Member. On the basis of sedimentary structures, three units are recognized in the Torrens. The lowermost is fine-grained sandstone that is 4.6 metres thick. It has large, shallow troughs, horizontal to low-angle bedding, and occasional planar crossbedding similar to swaley cross stratification (Walker, 1981). The overlying 10.8-metre-thick unit consists of large scale, trough crossbedded and horizontally bedded, fine-grained sandstones. It has occasional pebbly streaks near the base. The upper unit consists of 5.4 metres of horizontally bedded, and occasional planar crossbedded, medium-grained sandstone. Small wood fragments occur along the bedding planes.

The Transition Beds and Torrens Member are interpreted to be marine deposits formed during a period of coastal regression. Thin-bedded HCS sandstones in the lower part are interpreted to be offshore storm-generated deposits, whereas thick sands of the Torrens Member were deposited closer to shoreline.

(3) Non-Marine Part of the Gates: The main part of the Gates section is a 259-metre-thick sequence of non-marine sandstones, siltstones, claystones, and occasional coal seams (mostly covered), that includes three major conglomerate intervals.

The conglomerates occur as massive units 10 to 24 metres thick. Their lower contacts are erosional and impressions of large tree trunks are common near the base. Up section the conglomerates are interbedded with coarse, pebbly trough and planar crossbedded sandstones which grade upward into fine-grained rippled to horizontally bedded sandstones and siltstones. A coal seam generally caps these fining-up sequences.

The conglomerates are mainly clast supported with coarse sand in the matrix. Most of the pebbles are rounded and show considerable variation in size. The largest clast measured was 16 by 7 by 7 centimetres; the average pebble diameter is 1 to 3 centimetres. Bedding is uncommon but pebble imbrication zones are very common and locally impart a weak horizontal stratification.

Comparison with the Donjek vertical profile model (Miall, 1977) suggests that these conglomerates were deposited in a braided river environment. In the Gates, the conglomerates are associated with fairly thick overbank deposits. In braided river deposits, overbank deposits may result from lateral channel restriction on the floodplain, coupled with rapid subsidence (Miall, 1977).

In the upper part of the Gates, there are several fining-up sandstone units. Their vertical profile and sedimentary structures suggest that they are channel deposits. However, they represent a smaller and lower energy river system (? meandering) compared to the underlying conglomerate channels.

Although they are largely covered, coal seams in the section are inferred from coal bloom and occasional pieces of coal in float. The thickest coal zones are in the lower part of the sequence, above the Torrens Member. Above the upper conglomerate coals occur at the top of fining-up sequences. These coal seams appear to be thinner, but more numerous, than those in the lower part of the Gates.

(4) Hulcross Member: The marine transgression at the top of the Gates is marked by a 30-centimetre-thick, clast supported conglomerate. The conglomerate rests on a thin coal seam and is overlain by 2 recognized; the top cycle resulted in the development of a thick, fine to medium-grained marine sandstone (basal Boulder Creek unit).

The sandstones in the Hulcross are 5 to 50 centimetres thick and predominantly massive to horizontally bedded. They have abrupt bases and tops. Hummocky cross stratification is present in some and symmetrical wave ripples are common on the top surfaces. Small load structures may be present on basal surfaces. The thinly bedded sandstones are interpreted to be offshore storm deposits and turbidites, while the thicker sandstone at the top represents relatively nearshore conditions.

REGIONAL CORRELATION OF THE MOOSEBAR FORMATION, GATES AND HULCROSS MEMBERS

A regional correlation of the Moosebar Formation and Gates and Hulcross Members for a distance of 85 kilometres from Dumb Goat Mountain in the south to the Murray area in the north is shown on Figure 3. Marine and non-marine intervals in the Gates are shown on this section together with the locations of major non-marine conglomerates and the major coal zones. This correlation illustrates the following important points:

(1) The non-marine part of the Gates thickens to the south, while the marine Moosebar to Torrens and Hulcross intervals thin in that

direction. Also the number of coarsening-up marine cycles in the Transition Beds/Torrens Member increases from two on Dumb Goat Mountain to five in the Murray area.

(2) Two major marine transgressions are present within the Gates Member. Both come from a northerly direction and extended as far south as the Monkman area. These transgressions are essentially nondepositional, most of the marine sediments were deposited during the following phase of regression.

(3) Three major non-marine conglomerates are recognized. All occur at consistent stratigraphic levels throughout the area. In the case of conglomerates 1 and 3, deposition was followed by periods of marine transgression.

The marine unit in the upper part of the Gates has not previously been formally recognized or described. It is well developed in the Babcock and Murray areas, where it consists of a laterally extensive 25 to 40-metre-thick unit of sandstones with occasional conglomerates and thin claystones. These, together with the underlying non-marine conglomerate, form a distinctive lithological unit that Denison Mines' geologists call the Babcock Member.

Marine bivalves were found in the sandstones. Subsequently they were identified as pectinid bivalves, probably Entolium and Camptonectes by Dr. Paul Smith at the University of British Columbia. Further evidence for a marine depositional environment is provided by trace fossils, which are fairly common and easily recognized in cores. These include several distinctive types of marine burrows. The base of the marine sands is marked by a thin layer of very coarse conglomerate that is interpreted to be a marine lag deposit formed during the transgression. The overlying marine sandstones form a coarsening-up sequence, in which several lithofacies are recognized. Detailed core studies suggest that these were deposited in marine shelf and tidally influenced coastal environments.

COAL OCCURRENCES

Between the Monkman and Murray areas, four distinct coal zones* are recognized. The location of these zones is shown on Figure 3.

ZONE 1A: This zone occurs between two marine units in the lower part of the Gates and contains one or two thin coals. The coal is generally less than 1 metre thick; seams thicken to the south and pinch out to the north. Coals in this interval were deposited at the top of a regionally extensive, coarsening-up marine sequence during a short-lived regressive phase.

ZONE 1B: This zone occurs above the next coarsening-up marine unit and represents the beginning of the main phase of non-marine sedi-

*Coal zones: refers to an interval with one or more coal seams.

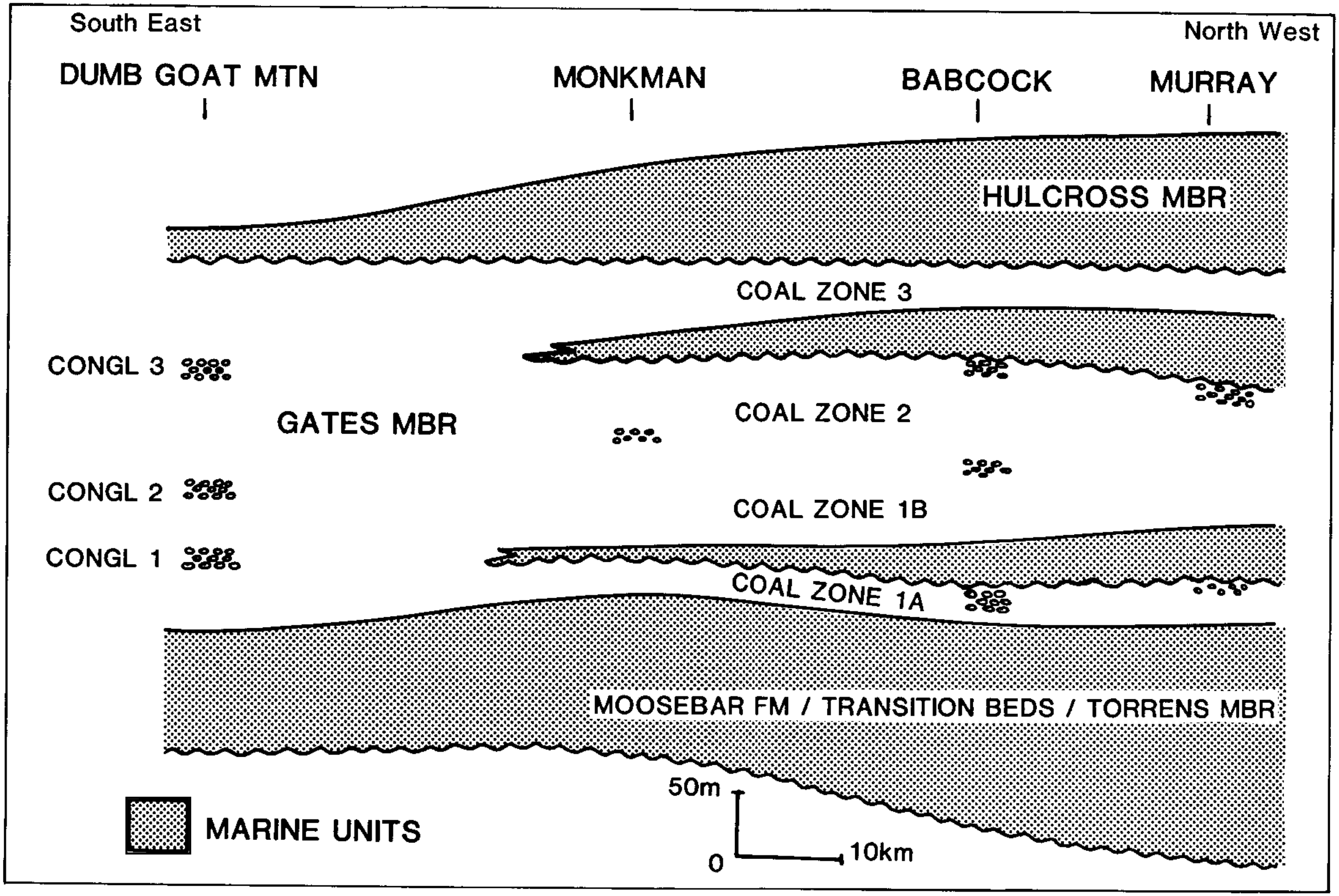

Figure 3. Regional correlation of the Moosebar Formation, Gates and Hulcross Members.

mentation in the Gates. In the Babcock area, up to three closely spaced seams are present in this interval. The thickest of these, seam J, has an average thickness of 6 metres.

ZONE 2: This zone occurs above zone 1B and below the marine unit in the upper part of the Gates. On Babcock, this zone contains four to five seams, each with an average thickness of approximately 2.5 to 3.5 metres. Typically, these coals are developed at the tops of fining-up cycles. On Babcock, two of the seams in this zone, seams E and G, wedge out laterally and are replaced by channel deposits.

ZONE 3: This zone occurs between the Upper Gates marine sands and the Hulcross Member. Coals in it are thin and not economically important. On Babcock there are three seams, A, B, and C, which rarely exceed 0.75 metre in thickness. Seam B, the middle seam, is the thickest and most persistent.

PALEOCURRENTS

Figures 4 to 7 show paleocurrent data, plotted as a series of rose diagrams, for the following intervals:

1) Transition Beds: Measurements in this interval were made on axes of symmetrical wave ripples, and flute and groove marks from thinly bedded sandstones that were deposited in the offshore area as a result of storm activity. The axes of symmetrical wave ripples give an approximate guide to the trend of the paleocoastline, while flute and groove marks indicate the direction of the paleoslope. This data suggests an average east-northeast - west-southwest orientation for the paleocoastline and a north-northwest - south-southeast paleoslope. The flute marks indicate that sediment was derived from the southeast.

2) 'Middle' Gates: Data is from fluvial sandstones and conglomerates in the non-marine part of the Gates between the Torrens Member and the conglomerate in the Upper Gates. Measurements were made of trough crossbedding, planar crossbedding, pebble imbrication, and the alignment of logs from the base of channels. The data indicates an average paleocurrent direction to the north-northeast although the range includes directions between northwest and east-northeast. Part of the spread in paleocurrent directions is from using different kinds of paleocurrect data for differrent types of fluvial systems in this interval.

(3) 'Upper' Gates Conglomerate: This map shows paleocurrent information from the conglomerate below the marine sands in the upper part of the Gates and from conglomerate 3 on Dumb Goat Mountain. Measurements are from pebble imbrication, log orientation, and planar cross-bedding. Conglomerate 3 on Dumb Goat Mountain shows a

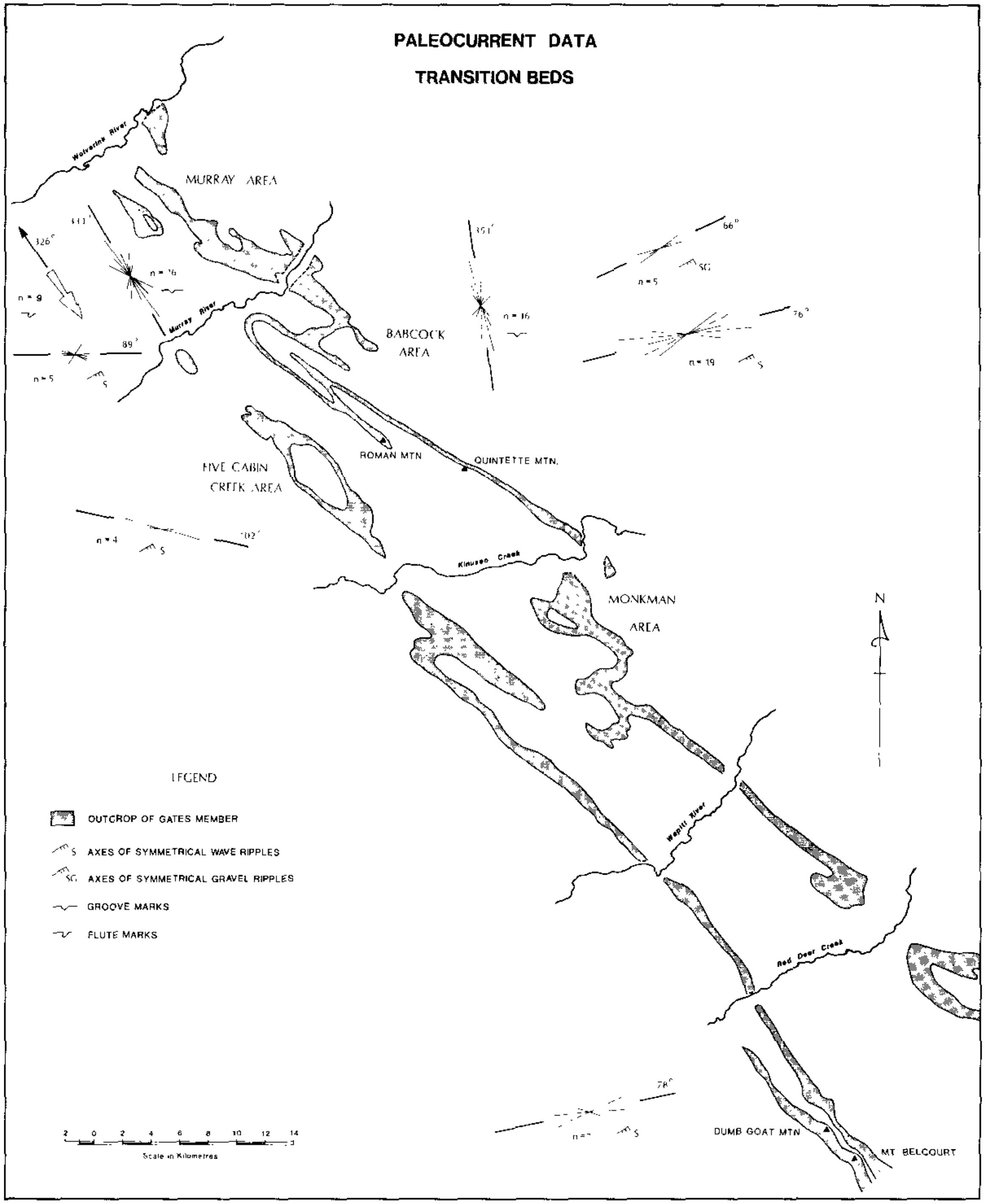

Figure 4. Paleocurrent data - Transition Beds.

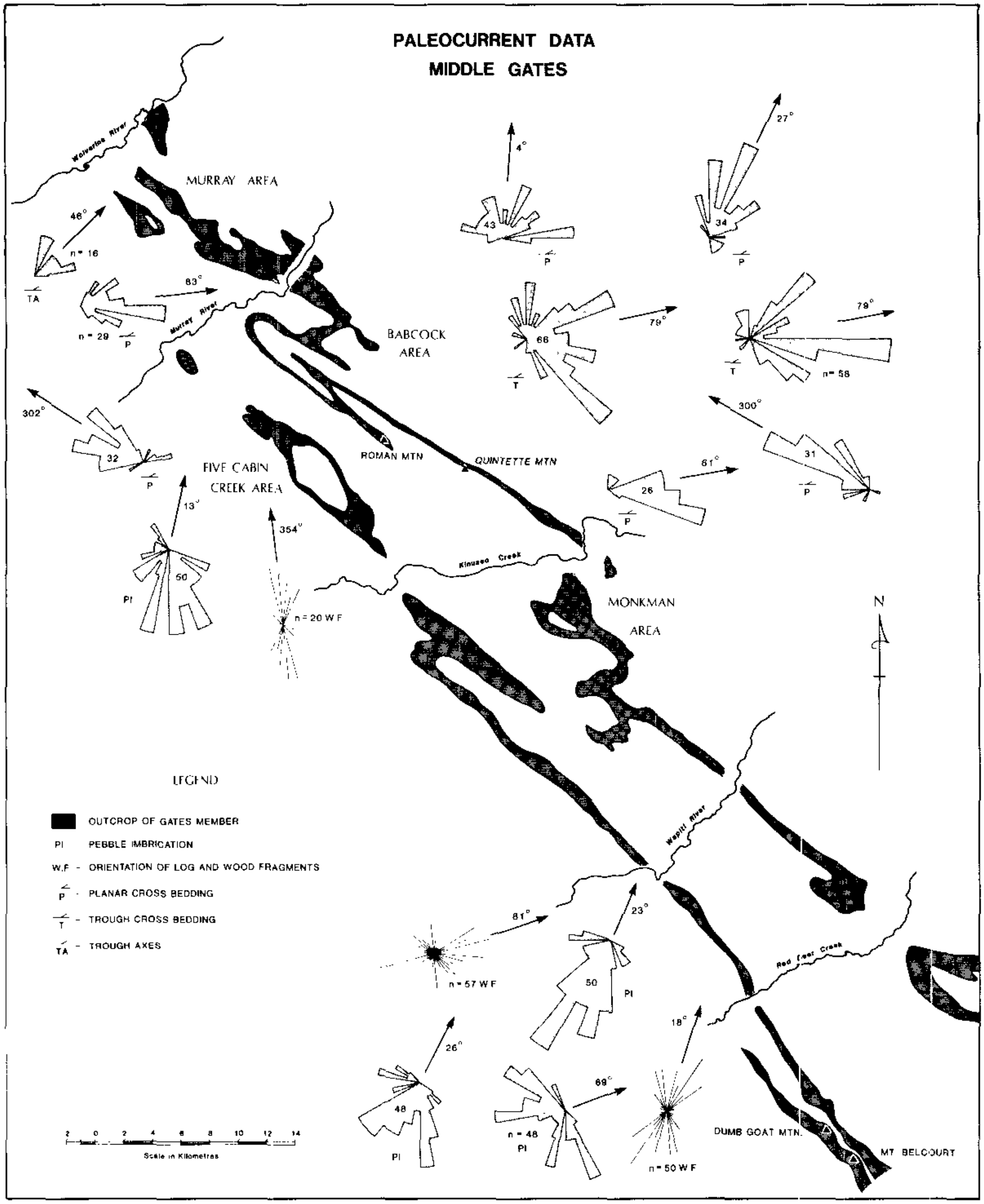

Figure 5. Paleocurrent data - 'Middle' Gates.

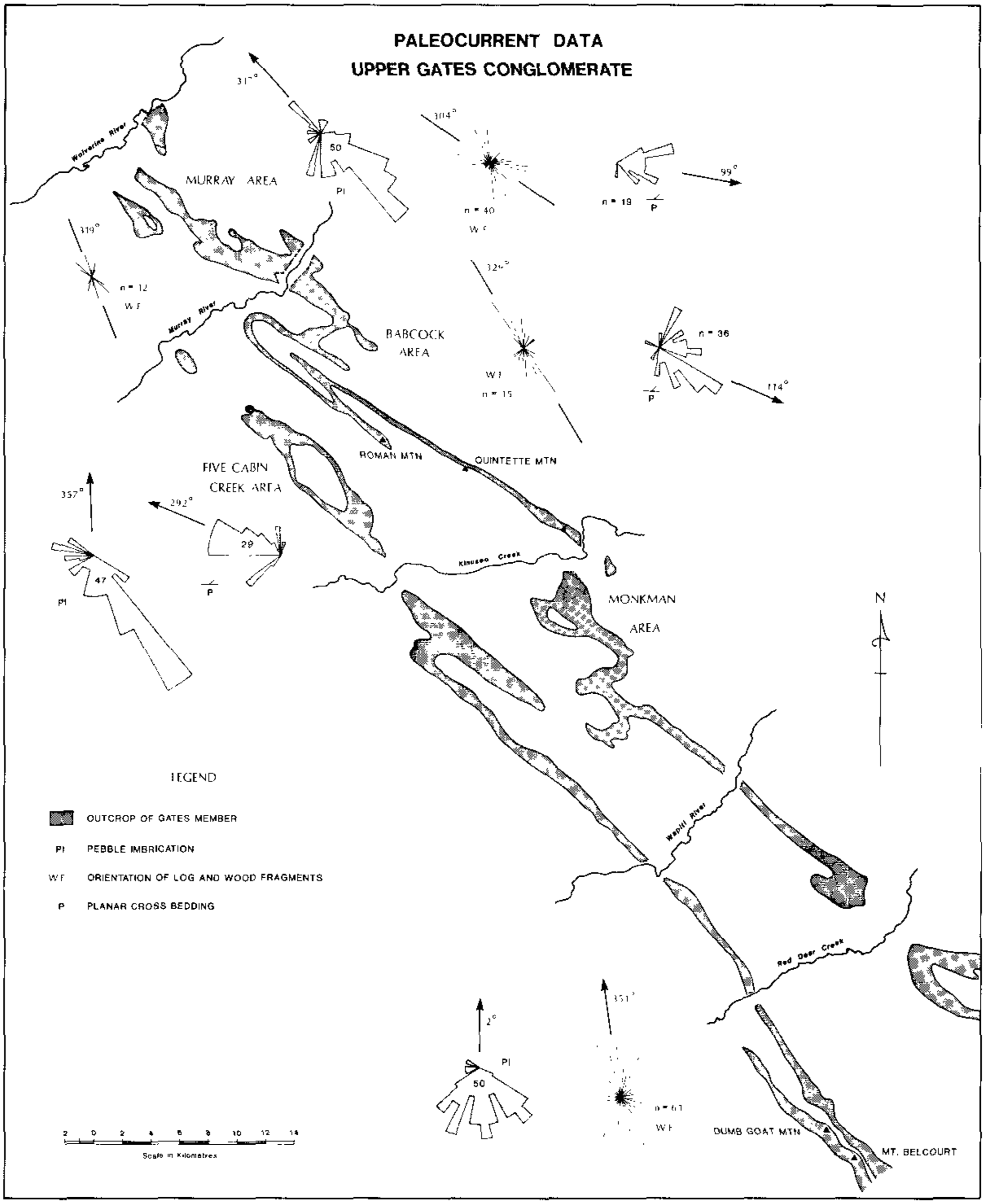

Figure 6. Paleocurrent data - 'Upper' Gates conglomerate.

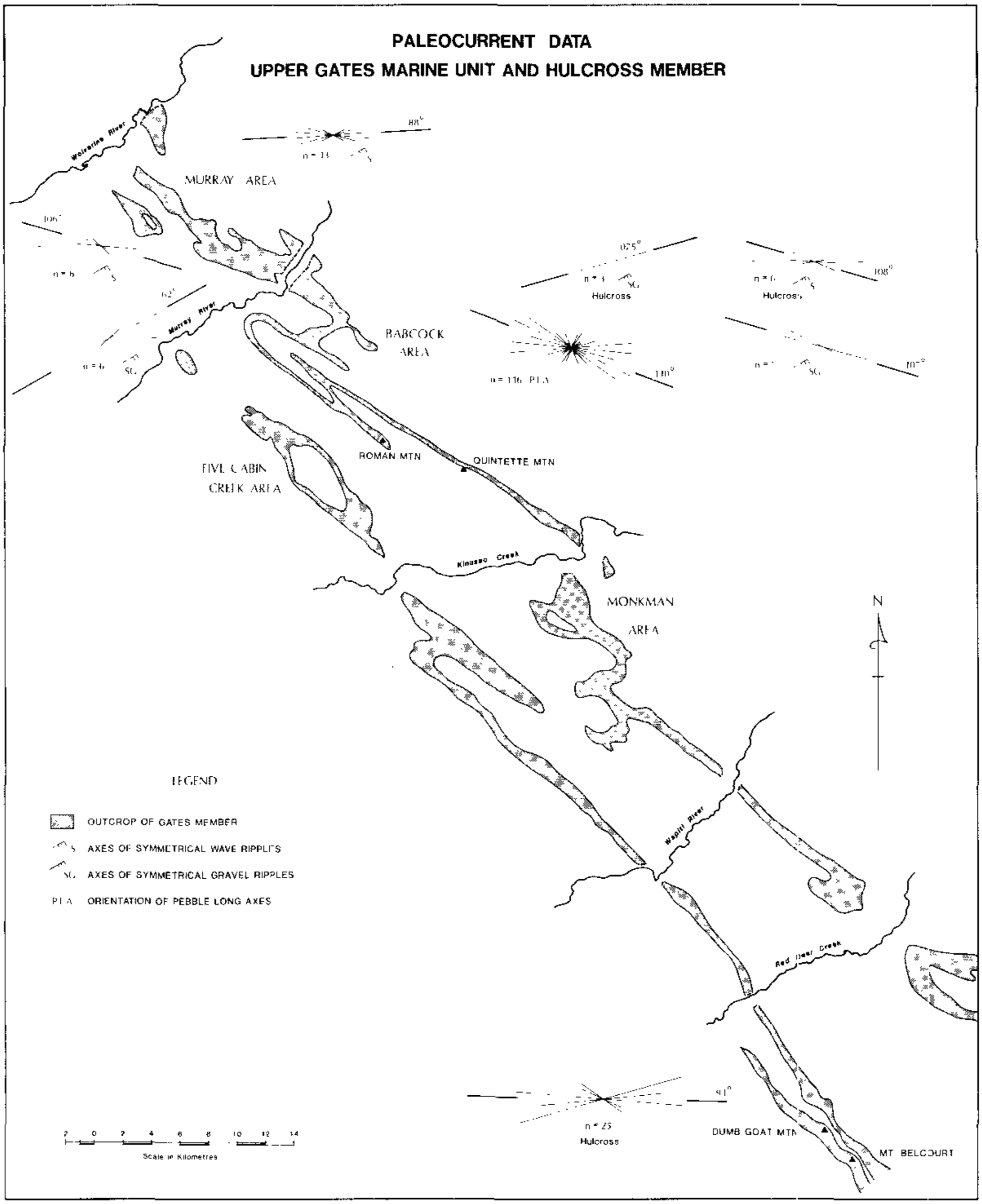

Figure 7. Paleocurrent data - 'Upper' Gates marine unit and Hulcross Member.

paleocurrent direction to the north, while further to the north the average direction is to the northwest. Planar cross-bedding from sandstones near the top of the conglomerate suggest currents in the opposite direction, toward the east-southeast. This is interpreted to represent deposition associated with the start of the marine destructive phase at the onset of marine transgression which occurs at the top of the unit.

(4) Marine Units of the 'Upper' Gates/Hulcross: Paleocurrent measurements from these intervals were made on the axes of symmetrical wave ripples from thinly bedded marine sandstones and conglomerates. The conglomerates occur at the base of the Upper Gates and Hulcross marine transgressions and are believed to be the result of marine processes. In addition, measurements were made on the long axis orientation of large pebbles in the 'lag' deposit at the base of the Upper Gates transgression on Babcock.

In the Babcock and Murray areas this data indicate an average east-west trend for the paleocoastline. On Babcock, the data suggest an east-southeast - west-northwest orientation for the Upper Gates paleocoastline.

DISCUSSION

(1) Gates Nomenclature

The last comprehensive description of Lower Cretaceous stratigraphy in the Foothills was that by Stott (1968). Since then, much new information has become available as a result of drilling by coal companies. Consequently, there is a need for a review of the stratigraphic nomenclature. Some of the problems with regard to the Gates nomenclature are as follows:

(a) The type section of the Gates (McLearn, 1923) is in the Peace River Canyon, east of Hudson Hope. The Gates there is predominantly marine and very different in character from the Gates further to the south along the length of the coalfield.

(b) The Gates in the Peace River area has formation status, but in the Pine Pass and the Foothills to the south, it is given only member status within the Commotion Formation.

(c) The Torrens Member is a name frequently used for a thick, relatively continuous marine sand in the lower part of the Gates. This unit, however, has not been formally described and there is some ambiguity in deciding which marine sand it refers to. For example, in the regional correlation section (Figure 3), does the Torrens Member refer to the sand above or below coal zone 1A, or both?

The following suggestions may be of value in a future revision of the nomenclature:

(a) The Gates is a sufficiently important interval for it to be given formation status along the length of the coalfield.

(b) Several marine units within the Gates can be recognized and correlated over a fairly large area. (Trace fossils are particularly useful in identifying these marine units). These units increase in number to the north and are replaced by non-marine sediments to the south. It is proposed that these marine units be given member status within the Gates Formation. The marine unit in the Upper Gates is particularly well developed in the Babcock area is referred to as the Babcock Member by Denison geologists. This unit is probably equivalent to part of the Notikewan Member in the subsurface to the east.

(2) Paleocurrents

Many of the published paleogeographic maps of the Lower Cretaceous show the main fluvial systems trending to the east or northeast, at right angles to the tectonic strike. These are frequently hypothetical directions and they differ from measured paleocurrent directions presented in this paper and those of Leckie (1981) for the Gates north of the Wolverine River. Both studies show a more northerly component for the fluvial paleocurrents and a paleocoastline oriented approximately east-west.

Measured paleocurrent data indicates, therefore, that the main drainage patterns in the Gates were longitudinal, subparallel to the tectonic strike. In the present day Himalayan molasse basin, the direction of flow of the major rivers is longitudinal, subparallel to the tectonic strike. It is not surprising, therefore, that similar drainage patterns are found in the Gates, which formed in a similar tectonic setting.

3) Conglomerates, Tectonics, and Marine Transgressions

The interdependence of sedimentation and tectonics in molasse basins has been described in some detail by Miall (1978). In the Gates, three major conglomerates are recognized at consistent stratigraphic levels throughout the area. These are interpreted as indicating three separate phases of tectonic activity in the source area.

In the Gates, deposition of conglomerates 1 and 3 was followed by marine transgressions. It is postulated that these transgressions resulted from isostatic adjustment and increased subsidence in the foredeep basin following periods of increased tectonic activity. Other factors such as sediment supply and eustatic sea level changes can also cause a marine transgression. The relative importance of these in the Gates has yet to be fully evaluated.

ACKNOWLEDGMENTS

This study was supported by grants from Union Oil and the B.C. Ministry of Energy, Mines and Petroleum Resources. I wish to thank Denison Mines, Petro Canada, Ranger Oil, and Crows Nest Resources for supplying data and assistance in the field. Dr. R.M. Bustin and Dr. J.W. Murray reviewed the paper and made useful criticisms.

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GEOLOGY OF THE McDAME TUNGSTEN SKARN PROSPECT

(104P/5)

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INTRODUCTION

The McDame tungsten skarn prospect (MDI No. 104P/004) lies approximately 6 kilometres north of Cassiar in northern British Columbia (Figure 1). Road access is available from Cassiar via the Cassiar Asbestos mine road and a four-wheel-drive track. The property, consisting of 10 claims and 109 units, is presently under option to Shell Canada Resources Ltd. Two main zones of economic interest have been identified: the A zone, on which the Kuhn tungsten-molybdenum skarn showing occurs, and the B zone, which includes the Dead Goat tungsten skarn and the Contact lead-silver vein occurrences (Figure 1).

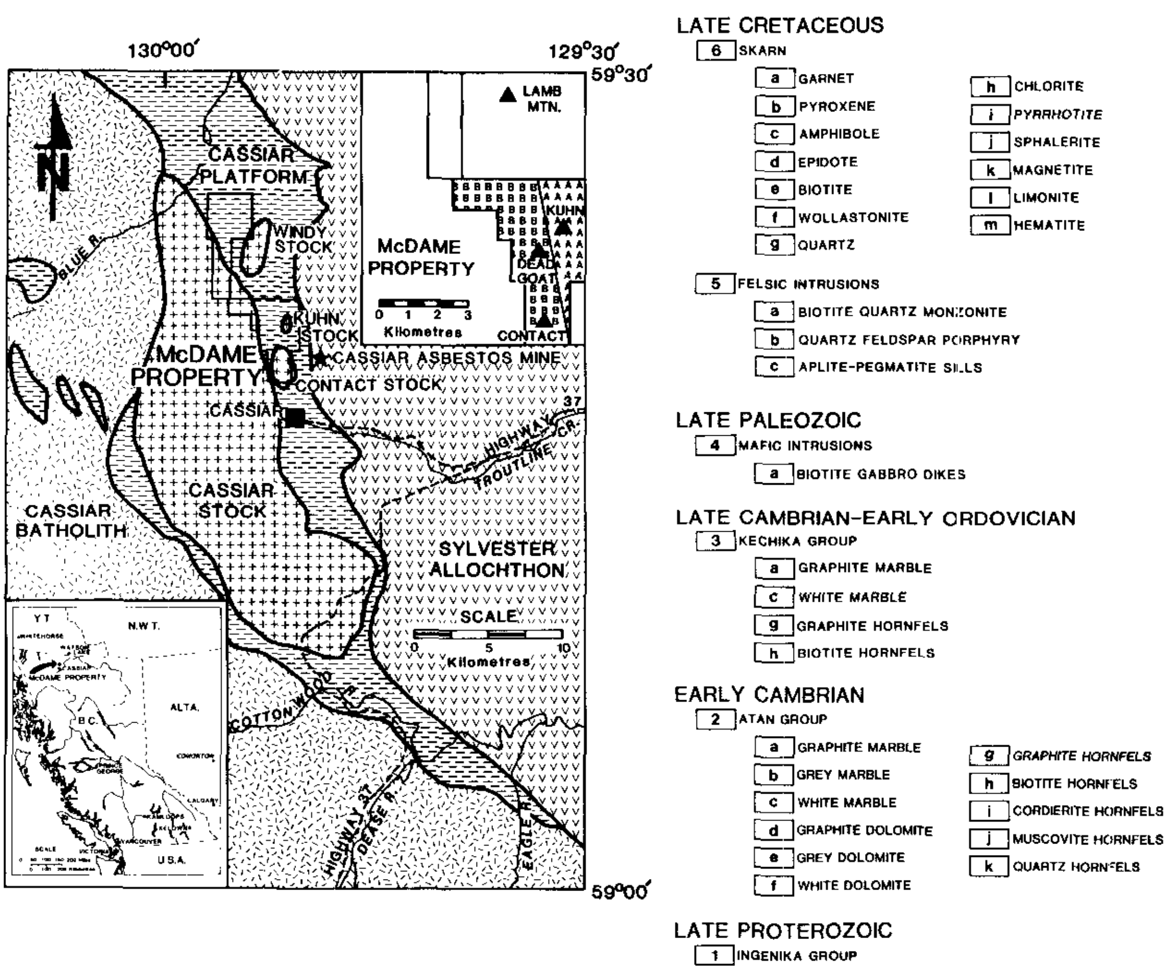

Figure 1. Regional geology of the Cassiar area (modified from Panteleyev, 1978, 1979) and setting of the McDame property.

TABLE 1. REGIONAL CORRELATION OF GEOLOGICAL UNITS

TECTONIC ELEMENT, AGE AND GROUP	GABRIELSE 1963	PANTELEYEV 1979	MANSY 1978	FRITZ 1980	THIS REPORT
					Unit 6 - skarn
Contact					
Cassiar Complex Late Cretaceous Cassiar Intrusions	quartz monzonite, granodiorite, granite, porphyry, aplite, pegmatite	porphyritic biotite quartz monzonite Unit A - coarse grained Unit B - mantled Unit C - quartz feldspar porphyry Unit D - medium grained			Unit 5 a) biotite quartz monzonite b) quartz feldspar porphyry c) aplite-pegmatite sills
Intrusive Contact					
Middle Mesozoic					Unit 4 a) lamprophyre dikes
Intrusive Contact					
Sylvester Allochthon Devonian- Permian Sylvester Group	greenstones, sediments	Unit E - diorite also greenstones			
Fault Contact					
Cassiar Platform Cambrian-Ordovician Kechika Group	Upper - black shale, slate, minor limestone Lower - limestone phyllite, minor conglomerate (330-820 m Upper and Lower)	shale, slate		siltstone, shale	Unit 3 a-graphite marble b-white marble g-graphite hornfels n-biotite hornfels (>520 m)
Conformable Contact					
Cassiar Platform Lower Cambrian Atan Group	Upper - limestone, dolomite, minor shale	Upper - dolomite, marble, limestone, minor slate	quartzite, siltstone, shale, limestone	Rosella Formation limestone, minor dolomite, shale, basal sandstone (693 m)	Unit 2 a-graphite marble b-grey marble c-white marble d-graphite dolomite e-grey dolomite f-white dolomite (<140 m)
	Lower - quartzite, argillite, slate, shale, siltstone, conglomerate (980 m Upper and Lower)	Lower - hornfels, argillite, quartzite		Boya Formation quartzite, siltstone, shale (400 m)	g-graphite hornfels h-biotite hornfels i-cordierite hornfels j-muscovite hornfels k-quartz hornfels (<380 m)
Conformable Contact					
Cassiar Platform Hadrynian-Cambrian Ingenika Group	Good Hope Group limestone, dolomite, quartzite sandstone siltstone, argillite, shale, slate, limestone (>1310 m)	Good Hope Group Upper - marble, limestone Lower - hornfels, quartzite, phyllite, schist, skarn	Stelkuz Formation shale, siltstone, sandstone (293 m) limestone, dolostone (125 m) redbed limestone, dolostone, slate (86 m) slate, minor limestone (529 m)	siltstone, minor quartzite, shale	Unit 1 i-cordierite hornfels (<400 m) marble, dolomite (100 m) hornfels, marble, skarn (>200 m)

Early prospecting in the Cassiar area concentrated on gold placer and asbestos vein deposits. The Contact vein was explored in 1954 by the Harvest Queen Mill and Elevator Company (McDougall, 1954). Fort Reliance Minerals later attempted to high-grade the vein (Minister of Mines, B.C., Ann. Rept., 1962) and in 1961 discovered the Lamb Mountain (MDI No. 104P/003) tungsten-molybdenum skarn showing north of the McDame property A zone (Cook, et al., 1979). Prospector B. Kuhn restaked the Lamb Mountain prospect in 1977 for Union Carbide and subsequently discovered similar mineralization on strike to the south (the Kuhn and Dead Goat showings on the McDame property).

REGIONAL GEOLOGY

The geology of the Cassiar area has been mapped on a regional scale by Gabrielse (1963) and Panteleyev (1978, 1979). Three major lithotectonic elements have been identified (Figure 1):

(1) Cassiar platform, a miogeoclinal continental terrace wedge developed along the eastern margin of the North American craton in Late Proterozoic to Early Paleozoic times (Monger, et al., 1979).

(2) Sylvester allochthon, an oceanic basin assemblage tectonically emplaced in Middle Mesozoic times (Monger, et al., 1979).

(3) Cassiar complex, a Late Mesozoic plutonic complex, probably related to anatexis of continental crust (Tempelman-Kluit, 1979).

Gabrielse (1963) showed that the Cassiar complex lies in the core of a northwest-trending anticlinorium flanked on the east by the Cassiar platform, which forms the southeast-plunging McDame synclinorium. The Sylvester allochthon now occupies the core of the synclinorium (Figure 1).

PROPERTY GEOLOGY

Rocks on the McDame property have been subdivided into six main units (Table 1). Lower Hadrynian to Lower Ordovician Ingenika, Atan and Kechika Group metasedimentary rocks (Units 1 to 3 respectively) are crosscut by minor Mesozoic mafic intrusions (Unit 4) and Late Mesozoic felsic intrusions (Unit 5). Skarn (Unit 6) occurs along favourable stratigraphic horizons in the metasedimentary rocks near the felsic intrusions.

The stratigraphy forms the upright and steeply east-dipping western limb of the McDame synclinorium. Minor folding was observed but the main foliation, lineation, and fracture directions correspond respectively with the axial plane, fold axis, and a-c joints of the McDame synclinorium. Only one fault with an apparent left-hand strike offset of about 120 metres was mapped in the A zone (Figure 2).

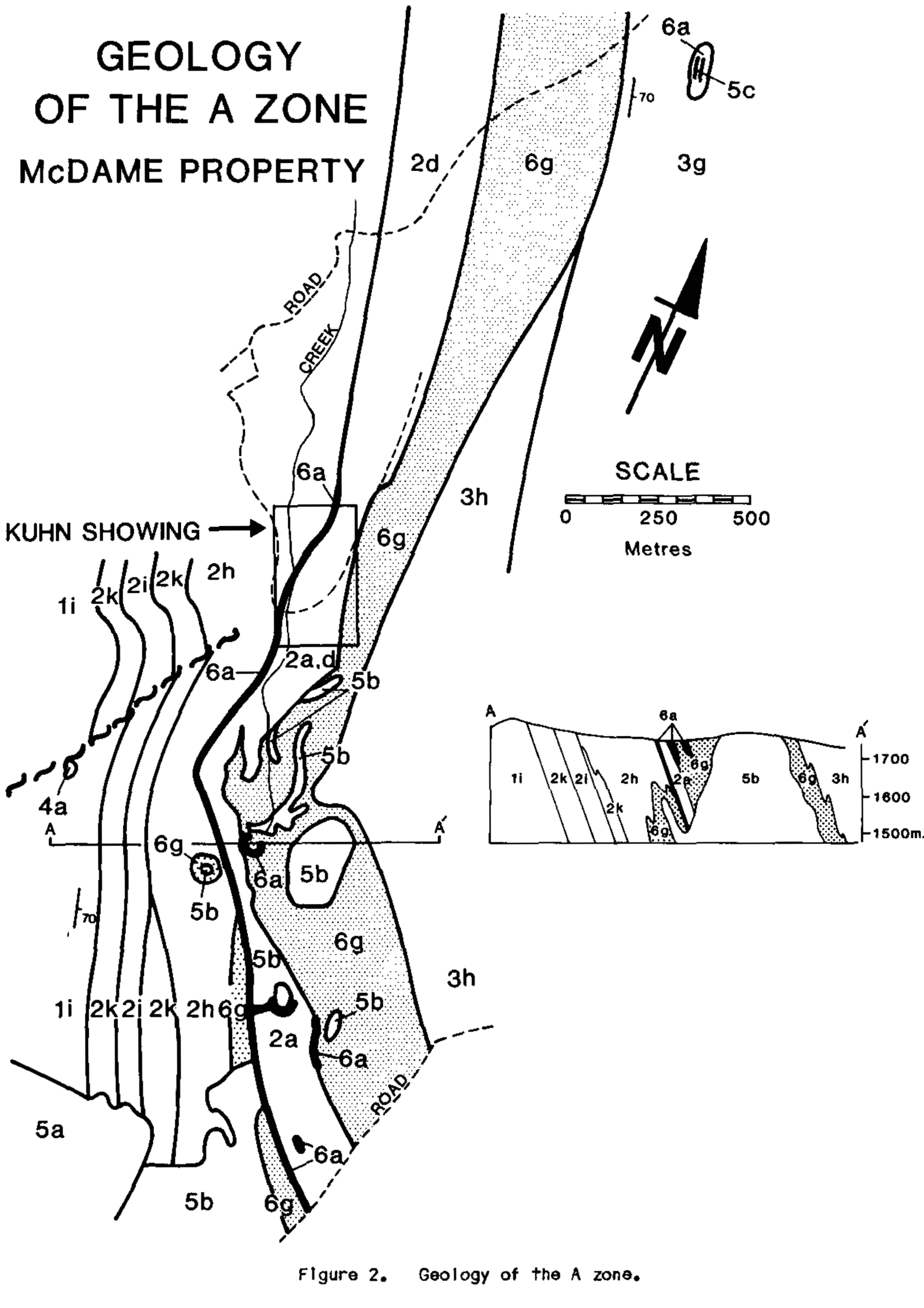

Figure 2. Geology of the A zone.

INGENIKA GROUP

Ingenika Group rocks underlie the B zone and contain the Dead Goat and Contact showings (Figure 1). These rocks represent the westernmost exposures of stratified rocks on the McDame property and are divided into three metasedimentary units. From west to east these are:

(1) interbanded biotite hornfels, white marble, and garnet-pyroxene skarn; these form the country rocks in contact with felsic intrusive rocks of the Cassiar stock to the west.

(2) banded graphite marble and massive grey marble that make up a carbonate band which contains rare patches of zebra-textured graphitic dolomite and pods of concentrically banded structures up to 20 centimetres across (stromatoporoids ?).

(3) spotted cordierite hornfels (Unit 1i, Figure 2) that forms a thick unit with minor biotite and muscovite hornfels bands and rare white marble bands.

These three rock bands correlate respectively with the redbed, carbonate, and clastic layers in the upper part of the Stelkuz Formation mapped by Mansy (Mansy, et al., 1978; Mansy, 1979) elsewhere in the Cassiar Mountains (Table 1).

ATAN GROUP

Atan Group rocks underlie the western part of the A zone and contain the Kuhn showing (Figure 1). The strata are conformable with the Ingenika Group and consist of two metasedimentary units. From west to east these are:

(1) interbanded hornfels that form a thick band which includes the following lithologies:

> Banded biotite hornfels, Unit 2h, is rusty weathering, brown, and very fine grained, with minor cordierite, quartz, or muscovite hornfels layers.
>
> Spotted cordierite hornfels, Unit 2i, is rusty weathering, brown to grey, foliated, very fine grained, and porphyroblastic, with minor biotite or quartz hornfels; disseminated pyrrhotite is common.
>
> Foliated muscovite hornfels, Unit 2j, is bleached weathering, tan, and aphanitic, and generally forms partings in quartz hornfels.
>
> Massive quartz hornfels, Unit 2k, is rusty weathering, white, and very fine grained, with moderate muscovite hornfels bands and minor cordierite or biotite hornfels bands; quartz-tourmaline veins and pods are common.

(2) interbanded marble and dolomite form a carbonate band which includes the following lithologies:

Banded graphite marble, Unit 2a, is grey weathering, black to white, and medium grained, with moderate grey or white marble bands and rare hornfels bands.

Massive grey marble, Unit 2b, is grey weathering and medium grained and is almost pure calcite.

Massive white marble, Unit 2c, is grey weathering and coarse grained and occurs as bleached fracture envelopes or bands within the other marbles.

Zebra graphite dolomite, Unit 2d, is tan weathering, black to white, fine grained and sucrosic, with moderate grey or white dolomite bands, minor marble or hornfels bands, and rare dolomite breccias or nodular pods; the breccias contain concentrically layered structures (stromatoporoids ?) and the pods contain elongate ovoid structures up to 5 centimetres long (Archeocyathids ?); well-developed zebra texture is characteristic of this rock.

Mottled grey dolomite, Unit 2e, is tan weathering, fine grained, and sucrosic and is almost pure dolomite.

Massive white dolomite, Unit 2f, is tan weathering, fine grained, and sucrosic and occurs as bleached fracture envelopes or bands within the other dolomite.

Banded graphite hornfels, Unit 2g, is grey weathering, black, and aphanitic and forms rare bands within marble or dolomite; disseminated pyrrhotite is common.

The two metasedimentary units of the Atan Group are lithologically similar to clastic and carbonate sedimentary rocks of the Boya and Rosella Formations as mapped by Fritz (1978, 1980) elsewhere in the Cassiar Mountains (Table 1).

KECHIKA GROUP

Kechika Group rocks underlie the eastern part of the A zone (Figure 1). The rocks are conformable with the Atan Group and consist of banded hornfels, with minor marble, including the following lithologies:

Banded graphitic hornfels, Unit 3g, is similar to Unit 2g.

Banded biotite hornfels, Unit 3h, is similar to Unit 2h.

Banded graphitic marble, Unit 3a, is similar to Unit 2a.

Massive white marble, Unit 3c, is similar to Unit 2c.

These rocks are lithologically comparable with clastic and carbonate rocks of the Kechika Group as mapped by Gabrielse (1963) and Panteleyev (1978, 1979, 1980) near Cassiar (Table 1).

MAFIC INTRUSIONS

Mafic intrusions occur as dykes cutting the older stratified rocks (Figure 2):

> Massive lamprophyre dykes, Unit 4a, are green, very fine grained, and subophitic to porphyritic with biotite; chilled margins; in places, there is a strong foliation.

Fractures in the lamprophyre occasionally contain skarn surrounded by bleached envelopes, suggesting that the mafic intrusions are older than skarn. They are probably of Middle Mesozoic age.

FELSIC INTRUSIONS

Felsic intrusions occur as four discrete stocks on the McDame property (Figure 1) and contain three different lithologies:

> Biotite quartz monzonite, Unit 5a, is pink, coarse grained, and porphyritic with K-feldspar mantled by Na-feldspar (rapakivi texture). This unit is typical of the Cassiar and Contact stocks.
>
> Quartz feldspar porphyry, Unit 5b, is grey, fine grained, and strongly jointed; biotite and hornblende are accessory minerals in the Kuhn stock and quartz-muscovite patches occur in the Windy stock.
>
> Aplite and pegmatite sills, Unit 5c, are white, fine to coarse grained, and equigranular; they cut both the sedimentary and other plutonic rocks.

Units 5a and 5b and lithologically comparable with Panteleyev's (1978) Units B and C respectively as mapped in the Cassiar area (Table 1).

SKARN

Skarn forms several bands on the McDame property (Figure 2) and is classified into six main facies:

(1) Massive calc-silicate skarn occurs as semi-continuous zones up to 10 metres thick along the western contacts of the carbonate bands in the Ingenika and Atan Groups. This skarn type also forms lenses along the eastern contacts of the two carbonate bands and within the carbonates themselves. The following lithologies were observed:

Massive garnet skarn, Unit 6a, is red to brown and coarse grained, with a faint banding occasionally apparent from variations in grain size and mineralogy. This unit is the most common massive calc-silicate skarn on the property.

Massive pyroxene skarn, Unit 6b, is green to white and coarse grained; it generally occurs in the A zone as narrow bands in garnet skarn or as bands separating garnet skarn from country rocks.

Massive amphibole skarn, Unit 6c, is white and very coarse grained and occurs as small pods in dolomite near quartz feldspar porphyry dykes in the A zone.

Massive epidote skarn, Unit 6d, is green and medium grained and forms rare bands associated with garnet skarn and quartz skarn in the A zone.

Spotted biotite skarn, Unit 6e, is variable in colour and grain size; it occurs as rare bands in the A zone between Atan Group marble and hornfels where garnet skarn is absent.

Banded wollastonite skarn, Unit 6f, is white and very coarse grained; it is found only in one outcrop of Kechika graphite hornfels and white marble at the north end of the A zone.

(2) Banded calc-silicate skarn forms two major bands on the McDame property:

Banded quartz skarn, Unit 6g, is light coloured and aphanitic to fine grained; textures in this unit reflect original features. Quartz skarn in Kechika Group hornfels forms narrow, bleached quartz and calc-silicate-rich envelopes on bedding plane and a-c joint fractures. Where fracture density is high, the original rock can be bleached throughout; near the Kuhn stock, the quartz skarn forms a distinct alteration halo and the Kechika Group rocks are generally brecciated, with banded quartz skarn to biotite hornfels fragments enclosed in a siliceous matrix containing disseminated sulphides; two other minor quartz skarn zones occur in Atan Group hornfels in the southern part of the A zone and are associated with quartz feldspar porphyry dykes. Banded calc-silicate skarn within the Ingenika Group in the B zone discrete fine-grained calc-silicate bands with bleached quartz-rich envelopes and remnant biotite hornfels and white marble bands.

(3) Vein sulphide skarn fills fractures in Atan Group dolomites in the A zone north of the Kuhn showing and includes: vein chlorite skarn, and Unit 6h which is green and fine grained, with disseminated and vein pyrrhotite and pyrite.

(4) Massive sulphide skarn forms pods and veins up to 1 metre thick in massive garnet or pyroxene skarn. The following units are defined:

Massive pyrrhotite skarn, Unit 6i, that is bronze and coarse grained, with minor disseminated chalcopyrite; this is the most common type of massive sulphide skarn.

Massive sphalerite skarn, Unit 6j, which is black and coarse grained and commonly intergrown with pyrrhotite; sphalerite is most common south of the Kuhn and Dead Goat showings in the A and B zones.

(5) Vein oxide skarn forms a unique set of fracture fillings in Atan Group dolomites north of the Kuhn showing in the A zone and includes banded magnetite skarn, Unit 6k, which is black to green and fine grained and commonly contains sulphide and calc-silicate minerals. This facies locally forms bands between dolomite and massive garnet or pyroxene skarn.

(6) Gossan oxide skarn is simply the weathering product of massive and vein sulphide and oxide skarns and consists of the following:

Goethite skarn, Unit 6i, is yellow to brown, fine grained, and earthy.

Hematite skarn, Unit 6m, is red to brown, fine grained, and earthy.

MINERALIZATION

Mineralogy and texture vary in both the A and B zones. At the Kuhn showing, scheelite, powellite, and molybdenite, associated with minor pyrrhotite, pyrite, calcite, quartz, and fluorite, form coarse-grained disseminations and veins in massive garnet and pyroxene skarn. North of the Kuhn showing, powellite and scheelite occur as fine-grained disseminations and veins within vein chlorite and magnetite skarn. South of the Kuhn showing, significant disseminated scheelite is found with massive pyrrhotite skarn, but only minor scheelite is found in the more sphalerite-rich skarn toward the south end of the A zone. A similar change in mineralogy occurs in the B zone. Significant disseminated scheelite occurs in massive garnet, pyroxene, and pyrrhotite skarns at the Dead Goat showing, but only minor scheelite is found with massive pyrrhotite and sphalerite skarns toward the south end of the B zone.

CONCLUSIONS

On a regional scale (Figure 1) metamorphism, metasomatism, and mineralization in the Cassiar area are all spatially related to felsic intrusions. These intrusive rocks are acidic, porphyritic, and jointed. They represent high-level, late differentiates of granitic magma. On property scale, skarn and ore minerals are concentrated along favourable stratigraphic horizons (Figure 2). The country rocks are interbedded clastic and carbonate beds typical of continental shelf sedimentary rocks in a cratonic environment.

Mineralized zones containing tungsten-molybdenum, tungsten-copper, and tungsten-zinc occur within massive calc-silicate and sulphide skarn along major marble-hornfels contacts in the Ingenika and Atan Groups. Banded calc-silicate skarn forms several zones, normally barren of mineralization, in hornfels of the Ingenika, Atan, and Kechika Groups adjacent to the Cassiar and Kuhn stocks. Minor amounts of tungsten mineralization are contained in vein sulphide and oxide skarns that fill fractures within Atan Group dolomites.

Detailed study of these skarn deposits is in progress. However, field mapping indicates the following to be significant exploration parameters:

(1) Favourable country rocks are composed of interbedded carbonate and clastic sedimentary rocks that contain major elements such as silica and calcium that are necessary for skarn formation. Bleached hornfels zones are a potential source of iron, zinc, and sulphur and bleached marble and dolomite are potential sources of sulphur.

(2) Favourable intrusive rocks are felsic stocks of anatectic origin. These are capable of supplying lithophile and atmophile elements such as tungsten, molybdenum, fluorite, oxygen, and sulphur to the mineralizing fluids (Godwin, et al., 1980).

(3) Extensive skarn development in hornfels (for example quartz skarn) indicates proximity to favourable intrusive rocks whereas skarn between marble and hornfels (for example, garnet skarn) defines favourable stratigraphic horizons.

(4) Minor tungsten-zinc mineralization within massive skarn (for example, pyrrhotite skarn) may mark the distal end of a zoned hydrothermal system which contains proximal tungsten-molybdenum mineralization.

ACKNOWLEDGMENTS

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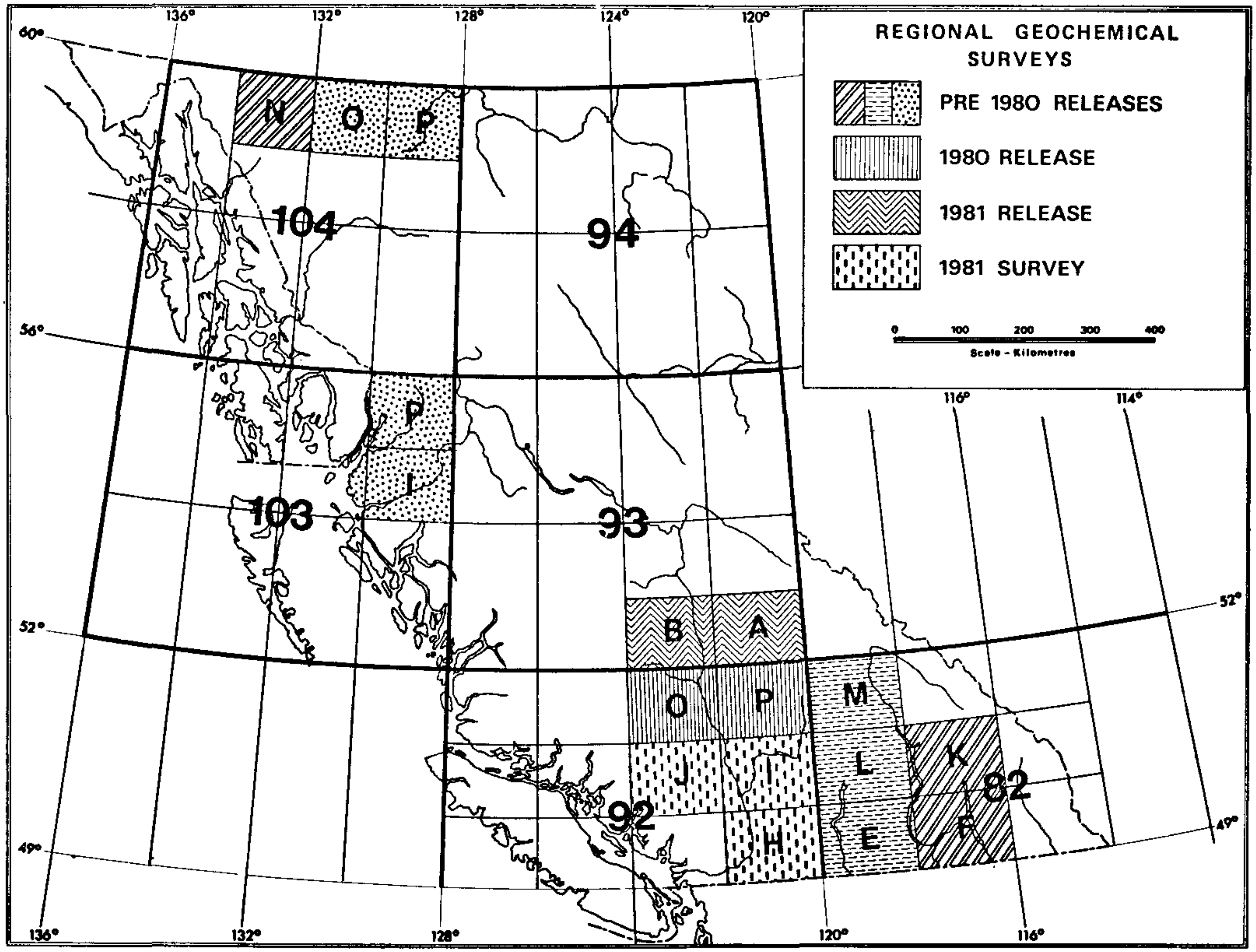

Figure 1. Index map - regional geochemical surveys.

REGIONAL GEOCHEMICAL SURVEY
HOPE, ASHCROFT, AND PEMBERTON MAP-AREAS
(92 H, I, and J)

By W.J. McMillan

The British Columbia Ministry of Energy, Mines and Petroleum Resources conducted a regional geochemical survey of map-areas 92H, 92I, and 92J during the 1981 field season. It is anticipated that analytical work will be completed and the data compiled in late May of 1982. Results of the survey will be released in June or July, depending on snow conditions, in the form of sample location maps and data sheets similar to those of previous surveys.

Stream sediment and stream water samples were collected in a truck-supported ground phase where possible and with helicopter support in more remote locations. Sample density was similar to that for previous surveys, about 1 per 15 square kilometres.

The sampling crew and equipment for the program were provided by ROOI Enterprises Ltd. Helicopter support was from Quasar Aviation Ltd. Ministry supervision was supplied by W.J. McMillan and W.M. Johnson.

Sample preparation was done by Kamloops Research & Assay Laboratory Ltd. The stream sediments were analysed for all other elements by Chemex Laboratories Ltd. Stream waters were analysed by Bondar-Clegg and Company Ltd.

The stream sediments were analysed for zinc, copper, lead, nickel, cobalt, silver, manganese, iron, arsenic, molybdenum, tungsten, mercury, uranium, and antimony. Stream waters were analysed for uranium, fluorine, and pH. Data processing was performed by the Geological Survey of Canada data processing group.

Figure 1 shows map areas covered by previous surveys and those covered by this survey. Results of the 1980 program in areas 93A and 93B were released May 26, 1981.