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FOREWORD

Geological Fieldwork, 1980 (Paper 1981-1) marks the seventh year of this annual publication which is intended to acquaint the interested public with the preliminary results of field studies by the Geological Division as soon as possible after the field season. Most reports in this publication were written without the benefit of extensive laboratory or office studies and, to speed publication, most of the figures have been draughted by the authors.

To make field data and interpretations more readily available the Division publishes preliminary maps and has begun to emphasize a paper series. For example, a paper will be released soon on sand and gravel deposits in the lower mainland.

As in previous issues, *Geological Fieldwork, 1980* is divided into sections: Metallic Investigations, Coal Investigations, Applied Geology, and Other Investigations. The Other Investigations section consists mainly of reports by graduate students and professors of the University of British Columbia. The reports deal with programs aligned with the objectives of the Geological Division which were funded in part by the Division.

The geographic distribution of reports in the publication is shown on Figure 1 and keyed to the table of contents.

The cover photograph depicts a geologist measuring sections in the northeast coalfield.

Output of this publication was coordinated by W. J. McMillan and production editing and layout by Rosalyn J. Moir with the assistance of Geological Division draughting office under the supervision of J. Armitage.

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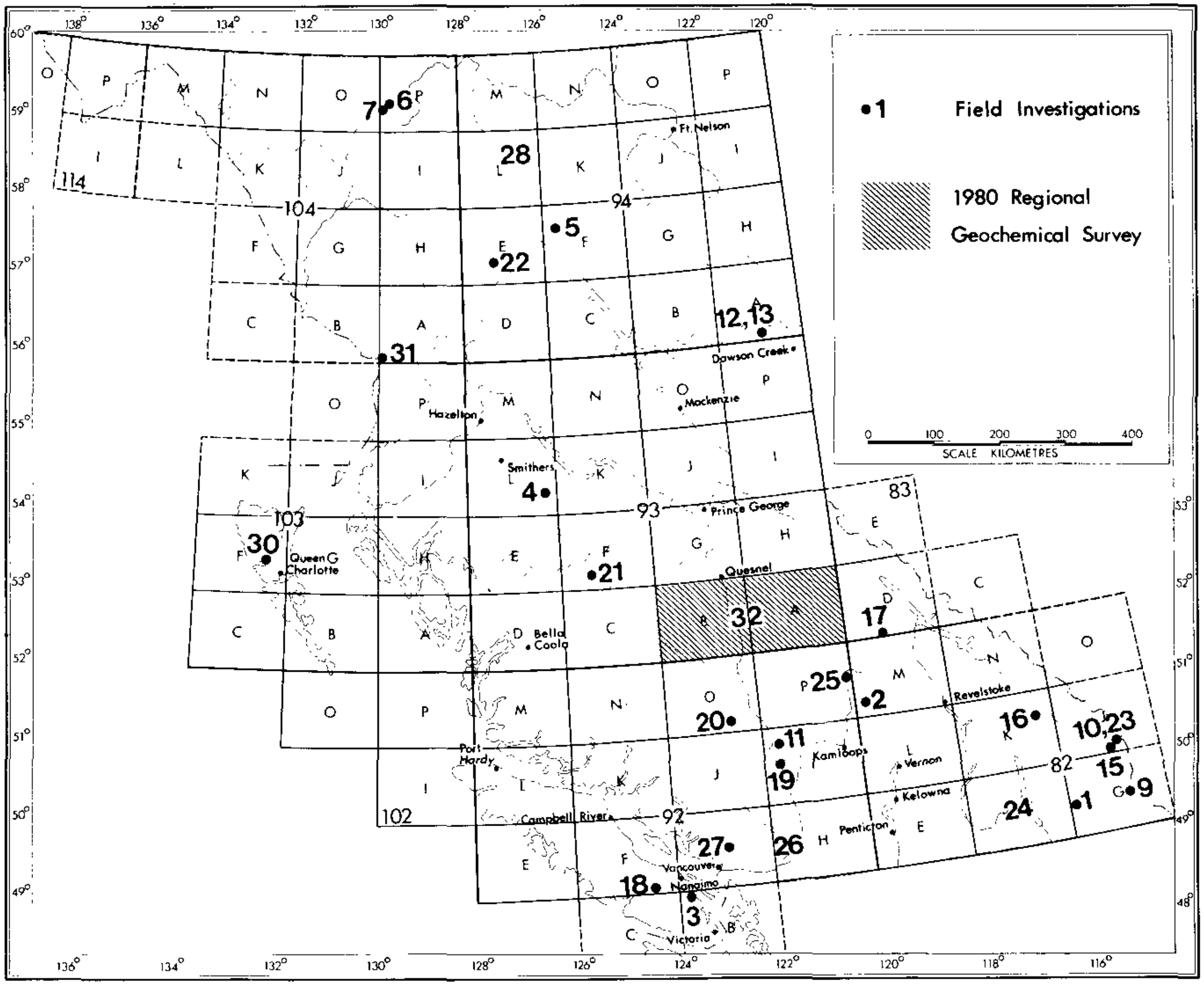

Figure 1. Distribution of programs, Geological Fieldwork, 1980.

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PROJECT GEOLOGY

METALLIC INVESTIGATIONS

SOUTHERN BRITISH COLUMBIA

GEOLOGY OF THE MOYIE LAKE AREA, PURCELL MOUNTAINS, SOUTHEASTERN BRITISH COLUMBIA (82G)

By T. Höy and L. Diakow

INTRODUCTION

Geological mapping of the Moyie Lake area in the southern Purcell Mountains south of Cranbrook was initiated in the 1979 field season and continued in June and July 1980. The area is underlain by Purcell Supergroup rocks of Helikian to Hadrynian age and includes the Midway (MI 82G/SE-128*) and the St. Eugene (MI 82G/SW-25) mines and numerous small silver-lead-zinc vein occurrences. The project is a continuation of a regional study of the Purcell Supergroup in southeastern British Columbia. Two recently published preliminary maps with reports (Höy, 1979 and McMechan, 1979) describe the structure, stratigraphy, and depositional environment of Purcell rocks on the east side of the Rocky Mountain Trench. Results of the 1979–1980 field mapping of the Moyie Lake area will be released shortly, also in the form of a preliminary map.

Previous reconnaissance mapping by Schofield (1915) and Leech (1960) included virtually all the Moyie Lake area; the map by Leech provided an excellent base for the more detailed mapping of this study. The mapping concentrated on stratigraphy of the Aldridge Formation, location of the Lower/Middle Aldridge contact, the controls of vein mineralization, and the relationship of the Moyie fault to Precambrian and younger tectonics.

Discussions with a number of persons, including John Hamilton, Ian McCartney, and Dave Pighin of Cominco Ltd., John Reesor of the Geological Survey of Canada, and Les Tihor and John Wilson of Falconbridge Nickel Mines Limited are gratefully acknowledged. Peter Mustard, Jack Hamilton, and Tom Mueller provided cheerful and able field assistance.

STRATIGRAPHY

The oldest rocks in the map-area, the Aldridge Formation, are exposed on both sides of the Moyie fault in the western part of the area (Fig. 2). The Lower Aldridge comprises rusty weathering siltstone and quartzite, with some interbeds of silty argillite. Well-bedded, grey, graded quartzite layers similar to Middle Aldridge turbidite beds are common near the top of the Lower Aldridge, hence the contact between the

*MI 82G/SE-128 refers to the mineral deposit inventory classification number for this deposit.

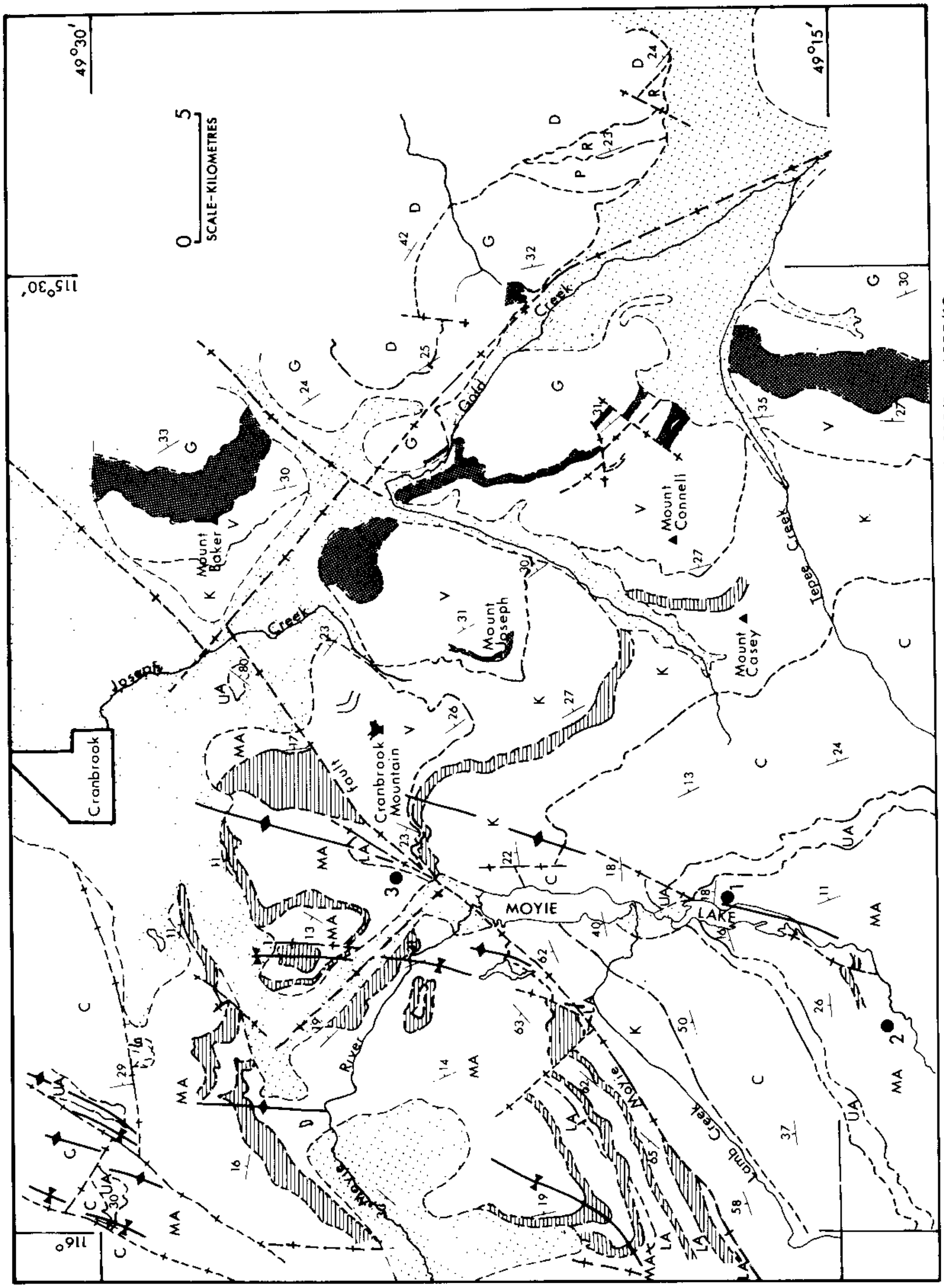

Figure 2. Geology of map-area 82G/5 (Moyie Lake) and parts of 82G/4, 82G/6, and 82G/12.

LEGEND

Pleistocene and Recent - till and alluvial deposits

D Upper Devonian - grey fossiliferous limestone
Middle Devonian - polymictic conglomerate, dolomitic sandstone, dolomite

PROTEROZOIC PURCELL SUPERGROUP

Metagabbro sill

R Roosville - grey-black argillite, green siltstone; dolomitic

P Phillips - maroon argillite, siltstone, quartzite

G Gateway - middle and upper - green, grey and purple siltstone and sandstone with green argillaceous interbeds; - lower - polymictic conglomerate; dolomite, commonly stromatolitic; green and purple siltstone and sandstone

Nicol Creek - green and purple amygdaloidal basalt; tuff; volcaniclastic sandstone

V Van Creek - green and purple argillite and siltstone; minor grey argillaceous limestone

K Kitchener - silty dolomite, dolomitic argillite, grey argillaceous limestone

C Creston - grey, green and minor purple tinged siltstone and quartzite; minor dark argillite and massive grey quartzite

UA Upper Aldridge - dark grey argillite, grey siltstone

MA Middle Aldridge - grey to buff quartz wacke beds, interlayered laminated siltstone and argillite

LA Lower Aldridge - rusty-weathering siltstone and quartzite, minor argillite

SYMBOLS

bedding attitude

geological contact - defined, approximate

fault

● mineral deposit or occurrence
1 - St. Eugene, 2 - Midway, 3 - Vine

anticline   syncline

Lower and Middle Aldridge is somewhat gradational. The boundary chosen indicates the level, where grey quartzite beds begin to predominate over the rusty weathering, irregular bedded siltstone. A complete and continuous Middle Aldridge section is not exposed in the map-area. Approximately 1 500 metres of the lower part of the Middle Aldridge is exposed just north of the Moyie fault (Fig. 2). It comprises thick grey quartz wacke beds with interlayered laminated siltstone layers, intruded by a number of regionally extensive metagabbro sills. In general, quartz wacke beds become thinner, less pure, and volumetrically less important upward in the Middle Aldridge section.

The upper part of the Middle Aldridge comprises a number of distinct cycles of massive, grey quartzite wacke beds at the base that grade upward into an interlayered sequence of quartzite, argillite, and siltstone, capped by siltstone and argillite. The contact with the Upper Aldridge is placed above the last bed of massive grey quartzite.

A number of the diorite sills have been discovered to be reliable markers in the thick Middle Aldridge section. They allow correlation of Middle Aldridge stratigraphy across faults, and will permit a composite thickness estimate for the Middle Aldridge. Locally the 'sills' cut across stratigraphy and provided zones of weakness which localized late fault movements. A prominent sill, approximately 1 200 metres above the Lower/Middle Aldridge contact, thickens dramatically as it approaches the Moyie fault in the northwestern part of the map-area just north of Cranbrook Mountain (Fig. 2).

The Upper Aldridge comprises several hundred metres of laminated dark grey argillite and lighter grey siltstone.

A thick, generally massive grey quartzite commonly marks the base of the overlying Creston Formation. It is overlain by dark argillite containing lenticular green siltstone layers with rare mud cracks, then interlayered grey-green siltstone and dark argillite. The bulk of the Creston Formation overlying the dark argillite comprises grey, green, and minor purple-tinged siltstone and quartzite that contains abundant mud-chip breccias, cross-laminations, and mud cracks. The Kitchener Formation includes generally buff to grey-weathering silty dolomite, dolomitic argillite, and grey limestone. The base of the overlying 'Van Creek Formation' (formally unit 5a of Leech, 1960; McMechan, Höy, and Price, in press) is commonly a conspicuous red-coloured siltstone. In general, the Van Creek Formation comprises interbedded olive green and purple shale and siltstone.

The Nicol Creek Formation (McMechan, Höy and Price, in press) includes the Purcell lavas and intercalated clastic and volcaniclastic rocks that separate the Van Creek Formation from the lithologically similar Gateway Formation. In the Moyie Lake area, the Nicol Creek Formation includes purple and green amygdaloidal basalt flows, tuff beds, volcanic breccias, and purple volcaniclastic sedimentary rocks.

The Gateway Formation unconformably overlies the Nicol Creek Formation. Its base is locally marked by a fluviatile conglomerate. Elsewhere, a stromatolitic dolomite, quartzite, and dolomitic siltstone sequence forms the basal part of the Gateway Formation. The Upper Gateway consists of intercalated sandstone and purple argillite, and a thick monotonous sequence of finely laminated green and purple siltstone. The overlying Phillips Formation consists primarily of thin-bedded maroon and red argillite, siltstone, and sandstone. It is overlain by black argillite in the basal part of the Roosville Formation, which grades upward into green argillite and locally purple argillite in the Upper Roosville.

Numerous sedimentary structures indicate a shallow marine to intertidal environment for the Van Creek, Gateway, Phillips, and Roosville Formations. They include mud-chip breccias, cross-laminations, ripple marks, and mud cracks. Salt crystal casts found in the Middle/Upper Gateway Formation are diagnostic of this formation.

Middle Devonian grey-white and purplish red dolomite and maroon dolomitic sandstone unconformably overly Upper Purcell strata. Locally a fluviatile conglomerate marks the base of the Devonian strata. It crops out on a ridge east of Gold Creek, and in the immediate footwall of the Moyie fault at the north end of Moyie Lake and in a number of localities north of Lamb Creek. The dolomite is overlain by dark grey fossiliferous limestone of Late Devonian age.

STRUCTURE

The Moyie anticline dominates the structure south of the Moyie fault. It is a northeast-plunging, upright anticlinal fold. North of the fault, Lower and Middle Aldridge rocks are folded into moderately tight to open, north to northeast-trending folds that are outlined by the metagabbro sills. In the hangingwall, immediately adjacent to the Moyie fault, folds are tight and locally overturned. The Lower Aldridge is exposed in two overturned anticlinal folds just west of the north end of Moyie Lake and west of Cranbrook Mountain (Fig. 2). Fold structures are more complex in the northwest corner of the map-area, where detailed mapping of the upper part of the Aldridge and lower part of the Creston has outlined a number of tight overturned folds that trend north-northwest and plunge variably to the north and locally to the south.

Late northeast and northwest-trending faults are conspicuous. Complex fold structures and a number of splay faults were recognized in the hangingwall of the Moyie fault. An important north to northeast-trending fault occurs along the western border of the map-area and truncates Lower and Middle Aldridge rocks as well as a large synclinal fold north of Lamb Creek.

MINERALIZATION

The St. Eugene mine on Moyie Lake comprises a northwest-trending silver-lead-zinc vein structure that cuts across Middle Aldridge, Upper Aldridge, and Creston stratigraphy. Total production, until its closure in 1929, amounted to 1.46 million tonnes containing approximately 8 per cent lead, 1 per cent zinc, 125 grams silver per tonne, and 0.5 gram gold per tonne. Between 1936 and 1962, the Midway mine, a small quartz vein deposit in the Middle Aldridge, produced 1 168 tonnes containing 9 042 grams gold and 85 534 grams silver. Vine, a recently discovered lead-zinc-silver showing near the north end of Moyie Lake, is a northeast-trending massive sulphide zone, generally less than 2 metres thick, that cuts across quartzite-wacke beds near the base of the Lower Aldridge. Small silver-lead-zinc veins are common in Middle Aldridge metasedimentary rocks and numerous small copper showings are associated with the metagabbro sills.

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BARRIERE LAKES – ADAMS PLATEAU AREA
(82M/4, 5W; 92P/1E)

By V. A. Preto

INTRODUCTION

Mapping during the 1980 field season was continued in the Barriere Lakes–Adams Plateau area by the writer and D. Forster. Mapping along the Fennell–Eagle Bay contact from Chu Chua Creek to Clearwater was initiated by P. A. Schiarizza and is reported on separately. Work by the writer was concentrated in those portions of the project area between Sinmax Creek and Fadear Creek, northeast of Brennan Creek to the contact of the Baldy batholith, and from Nikwikwaia Creek to the east shore of Adams Lake. Three days were spent in late June with M. J. Orchard of the Geological Survey of Canada sampling carbonates throughout the project area in a further effort to find microfossils; results from this work were disappointing. Although mapping south of Sinmax Creek and east of Forest Lake indicates that folds outlined in 1979 in the Mount Dixon area continue for some distance to the southeast, sparse exposures and dense vegetation preclude accurate mapping of these structures.

'STRATIGRAPHY'

Most of the stratigraphic relationships between mappable units remain undetermined and consequently some aspects of the structural geology remain unresolved and stratigraphic repetitions caused by unrecognized early folds or faults may exist.

Two well-dated fossil localities in map unit 6 (numbers refer to Figure 9, Preto, *et al.,* 1980) and recent dating of zircons from felsic metavolcanic rocks of map unit 7a and quartz feldspar porphyry of map unit 2c in the Birk Creek–Sprague Creek area are beginning to help solve parts of the puzzle. The Eagle Bay Formation is an eugeosynclinal assemblage of high energy, proximal volcanic rocks such as tuff breccias and flows. Rapid lateral facies changes and discontinuity of units in such lithologies are inherent with the origin of the rocks. Use of the word 'stratigraphy' for the Eagle Bay assemblage at this point in time is therefore premature and the legend accompanying Figures 3 and 4 is really a description of mappable rock units, the age of only some of which is known at this time. For the sake of continuity and to minimize confusion most map unit numbers used on Figure 3 are the same as those used on Figure 9 (Preto, *et al.,* 1980).

EAGLE BAY FORMATION – Late Devonian to Early Mississippian (Units 1 and 3 to 12)

A great variety of rock types have been included in the Eagle Bay Formation, and no attempt to subdivide it will be made until more data on the age and stratigraphic relationships of this complex assemblage are obtained.

UNIT 1: Rocks of this unit are generally of higher metamorphic grade but lithologically similar to much of the rest of the Eagle Bay assemblage. The contact between higher and lower grade rocks, though poorly understood, was originally thought to be a structural discontinuity

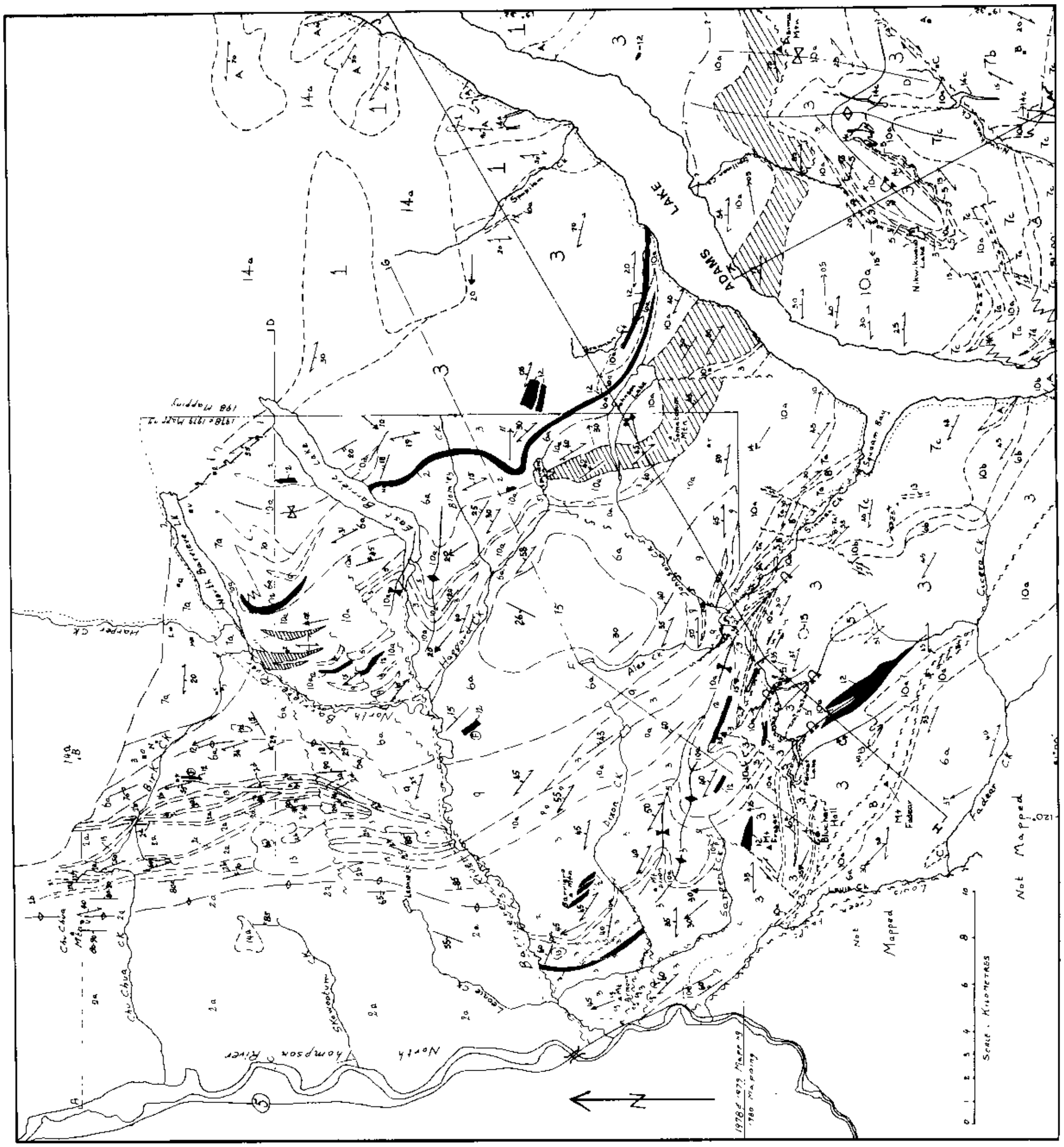

Figure 3. Generalized geological map of the Barriere Lakes–Adams Plateau area.

LEGEND

PLEISTOCENE AND/OR EARLIER

15 — OLIVINE BASALT FLOWS, MINOR INTERBEDDED MUDSTONE

CRETACEOUS

14d — BALDY BATHOLITH BIOTITE QUARTZ MONZONITE GRANITE AND GRANODIORITE

14c — QUARTZ FELDSPAR PORPHYRY DYKES AND SILLS

JURASSIC OR TRIASSIC

13 — DIORITE AND MICRODIORITE

UPPER TRIASSIC ?

C — SHEARED AND POORLY FOLIATED AUGITE PORPHYRY TUFF BRECCIA, SOME INTERBEDDED VOLCANIC SANDSTONE

AGE UNKNOWN

B — SERPENTINITE

LATE DEVONIAN

A — GRANODIORITE ORTHOGNEISS, CUTS ROCKS OF UNITS 1 7a, 7c, AND 10b

LATE DEVONIAN—EARLY MISSISSIPPIAN

EAGLE BAY FORMATION (UNITS 1 AND 3 TO 12)

12 — LIMESTONE DARK TO LIGHT GREY, BANDED TO MASSIVE, MINOR DOLOMITE

11 — TSHINAKIN LIMESTONE MASSIVE, LIGHT GREY TO WHITE, FINELY CRYSTALLINE LIMESTONE AND DOLOMITE

10 — (a) GREENSCHIST DERIVED FROM MAFIC MASSIVE AND PILLOWED (p) FLOWS, BRECCIAS, AND TUFFS
(b) TUFF, PHYLLITE, AND MINOR AMPHIBOLITE, TYPICALLY WITH STRIPED APPEARANCE DUE TO THIN GREY AND GREEN INTERLAYERS. OCCASIONALLY ALTERED TO GARNET EPIDOTE SKARN, LOCALLY WITH APPRECIABLE PYRRHOTITE, PYRITE, AND TRACES OF CHALCOPYRITE AND GALENA. LOCALLY WITH DISTINCTIVE ASBESTIFORM AMPHIBOLE

9 — BRICK RED TO RUSTY COLOURED SIDERITE AND OR ANKERITE-RICH PHYLLITE

LATE DEVONIAN—EARLY MISSISSIPPIAN *(CONTINUED)*

8 — HOMESTAKE SCHIST PLATY, LIGHT RUSTY YELLOW-WEATHERING SERICITE—PYRITE QUARTZ PHYLLITE AND FINE GRAINED SCHIST

7 — (a) INTERMEDIATE TO FELSIC PHYLLITE AND FINE-GRAINED SCHIST DERIVED MOSTLY FROM FELSIC TUFFS AND LITHIC TUFFS, LOCALLY GRADES INTO MINOR, THINLY LAMINATED SERICITE-CHLORITE SCHIST AND PHYLLITE
(b) INTERLAYERED CHERTY TUFF, CHERT, CALC—SILICATE ROCK AND THIN LAYERS OF IMPURE LIMESTONE
(c) GREY TO GREENISH GREY SERICITE AND SERICITE CHLORITE PHYLLITE, DERIVED MOSTLY FROM INTERMEDIATE TUFFS AND POSSIBLY SOME FLOWS, OCCASIONALLY WITH GOOD LAYERS OF VOLCANIC BRECCIA WITH FELSIC AND MAFIC CLASTS
(d) POORLY FOLIATED RHYOLITE

6 — (a) DARK GREY TO BLACK PHYLLITE, INTERBEDDED GRIT, SAND STONE, SILTSTONE, AND ARGILLITE
(b) CALCAREOUS DARK GREY TO BLACK PHYLLITE, WITH THIN LAYERS AND LENSES OF GREY, IMPURE LIMESTONE AND OF WHITE CALCITE, VERY SIMILAR IN LITHOLOGY TO PARTS OF THE SICAMOUS FORMATION

5 — RELATIVELY PURE LIGHT GREY QUARTZITE

4 — PYRITIC CHLORITOID SERICITE QUARTZ SCHIST AND SERICITE QUARTZ SCHIST

3 — INTERLAYERED GRIT, MICACEOUS QUARTZITE, PHYLLITE, CALCAREOUS QUARTZITE, IMPURE LIMESTONE, CALCAREOUS PHYLLITE, AND MINOR GREENSCHIST (cg — CONGLOMERATE ON MOUNT ARMOUR)

1 — AMPHIBOLITE, MICACEOUS QUARTZITE, GARNET BIOTITE SCHIST, IMPURE FINE-GRAINED MARBLE

LATE DEVONIAN

2 — **FENNELL FORMATION**
(a) MASSIVE AND PILLOW BASALT WITH MINOR INTERBEDDED CHERT AND CHERTY ARGILLITE
(b) CHERT AND RIBBON CHERT, LOCALLY BRECCIATED
(c) QUARTZ FELDSPAR PORPHYRY (SPRAGUE CREEK BIRK CREEK AREA)
(d) CONGLOMERATE WITH PEBBLES AND COBBLES OF CHERT, ARGILLITE, QUARTZ FELDSPAR PORPHYRY, AND BASALT

SYMBOLS

BEDDING TOPS KNOWN, OVERTURNED

BEDDING TOPS NOT KNOWN

EARLY SCHISTOSITY INCLINED, HORIZONTAL

PHASE 1 FOLD AXES

PHASE 2 FOLD AXES

INFERRED FAULT

GEOLOGICAL CONTACT

RADIOMETRIC AGE LOCALITY

FOSSIL LOCALITY

MINERAL OCCURRENCE

EARLY AXIAL TRACE
SYNFORM UPRIGHT, OVERTURNED
ANTIFORM UPRIGHT, OVERTURNED

LATE AXIAL TRACE
SYNFORM UPRIGHT, OVERTURNED
ANTIFORM UPRIGHT, OVERTURNED

NOTE: The order of superposition between the Fennell Formation and the Eagle Bay Formation has been established. Units within the Eagle Bay Formation, however, are lithologic units and not lithostratigraphic units. For instance, every unit of greenschist within the Eagle Bay has been designated 10 regardless of its stratigraphic position.

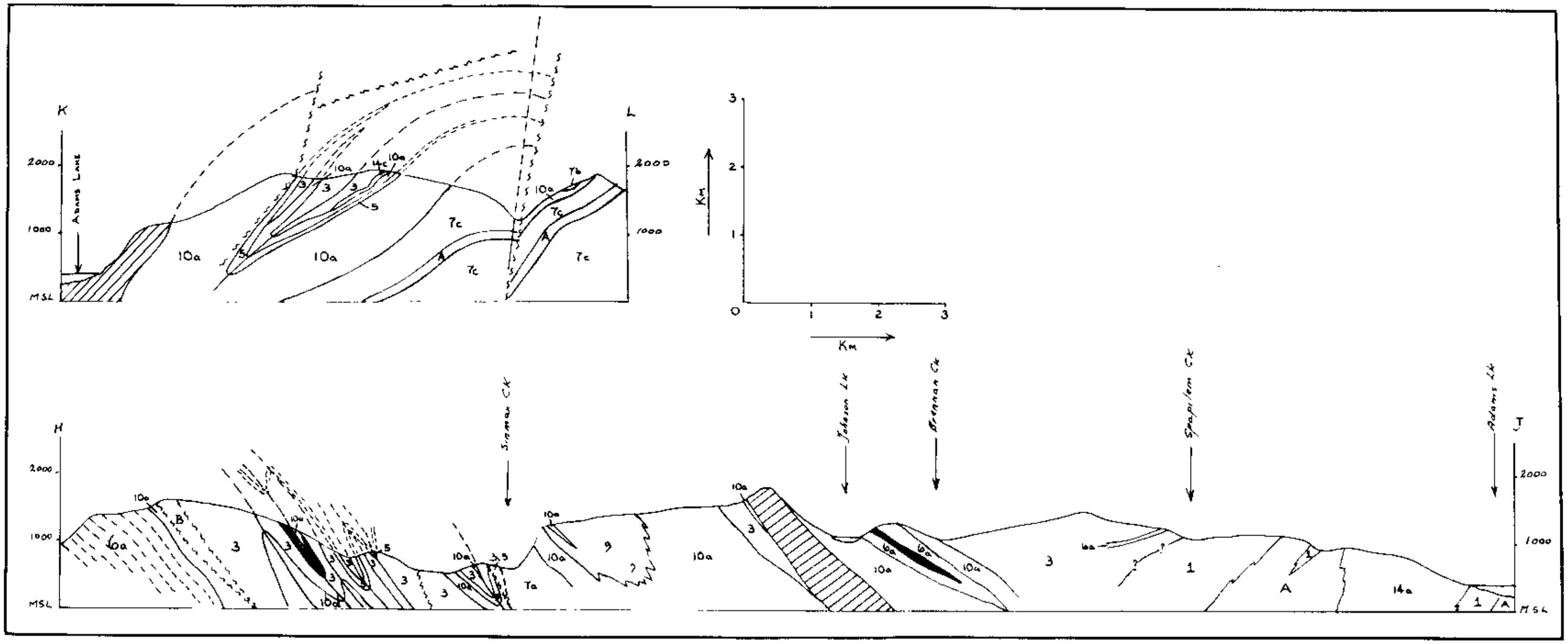

Figure 4. Cross-sections to accompany Figure 3.

(Preto, *et al.*, 1980, p. 28). Exposure is poor but mapping along and in the vicinity of Spapilem Creek suggests that the unit 1 assemblage is a more highly metamorphosed portion of the Eagle Bay. Because rocks of unit 1 are intruded by Late Devonian orthogneiss of unit A (Okulitch, *et al.,* 1975; Okulitch, 1979), they must be of Late Devonian or older age. This age is compatible with Late Devonian ages recently obtained for zircon from map unit 7.

UNITS 3, 4, AND 5: *See* descriptions in Preto, *et al.,* 1980.

UNIT 6a: An extensive unit of interbedded dark grey siltstone, sandstone, and slate, some dark grey to black phyllite and argillite with interbedded grit, some calcareous argillite, and some impure limestone is exposed in the southwest corner of the area. These rocks are separated from the Mount Fadear serpentinite belt and fault zone by a thin but continuous septum of greenschist, with which they are in structural and, apparently, stratigraphic continuity. This sedimentary package has been correlated recently with fossiliferous Upper Triassic strata that crop out east of Vernon (Okulitch, 1979). Structurally and lithologically, however, they more closely resemble rocks of unit 6a that crop out a short distance to the north. At least part of unit 6a is known to be of Early Mississippian age (Preto, *et al.,* 1980, p. 29).

UNIT 6b: A narrow belt of calcareous black phyllite and interbedded dark grey argillaceous limestone with conspicuous lenses of white calcite has been traced from the lower reaches of Bush Creek, a short distance south of the map-area, to approximately 4 kilometres north of South Cicero Creek. This unit structurally underlies, and is apparently conformable with, the very distinctive map unit 10b. Rocks of unit 6b are very similar to parts of the Sicamous Formation exposed along the main road south of Adams Lake, and may well be correlative with it. The Sicamous Formation recently has been assigned to the Upper Triassic Slocan Assemblage (Okulitch, 1979). The correlation is based on lithology because no fossil localities are known within the Sicamous Formation proper.

UNIT 7: Rocks that are similar to and structurally continuous with those of unit 7a at Squaam Bay crop out on the slopes east of Adams Lake. These rocks are generally pyritic and have been derived from felsic tuffs and lithic tuffs as indicated by fragmental members with numerous flattened felsic clasts. Unit 7a is associated with foliated rhyolite (unit 7d) and grades laterally into nondescript, less pyritic, sericite and sericite-chlorite phyllite (unit 7c). Unit 7c is probably also of intermediate volcanic origin as indicated by scattered layers of volcanic breccia with flattened mafic and felsic clasts as much as 50 centimetres in the longest dimension. Fine-grained cherty tuff, calc-silicate rock, thin layers of impure limestone, and minor argillaceous sedimentary rocks (unit 7b) underlie the southeast corner of the map-area. This sequence contains abundant pyrite and pyrrhotite and numerous mineral showings. It dips gently to the north and northwest and is probably relatively thin. It structurally overlies and is apparently conformable with parts of units 7c and 10, but is in fault contact with rocks of units 3 and 10 to the northwest.

UNIT 8: *See* descriptions in Preto, *et al.,* 1980.

UNIT 9: A thin and possibly discontinuous layer of highly foliated, rusty weathering siderite and/or ankerite-rich phyllite is infolded with metavolcanic and metasedimentary rocks of units 3 and 10 on the wooded slopes south of Sinmax Creek opposite Johnson Creek. It is considered to be a distal equivalent of intermediate to acid metavolcanic rocks previously mapped from Johnson Creek to Barriere River.

UNIT 10: Greenschist, clearly derived from massive, fragmental, and, occasionally, pillowed mafic volcanic rocks, is widespread in the map-area and associated with virtually every other rock unit (*see also* Preto, *et al.,* 1980). *Map unit 10b is an easily recognized and traceable unit with* characteristic thin light grey and green layers. It structurally overlies calcareous phyllite of unit 6b and has been traced northwestward from the west shore of Adams Lake at Bush Creek for several kilometres to the south slopes of Sinmax Creek, south of the Homestake mine. Although it is dominantly sharply banded tuff and phyllite, unit 10b also contains some amphibolite. In several places it is altered to garnet-epidote skarn with abundant pyrite, pyrrhotite, and lesser amounts of chalcopyrite and galena. A distinctive asbestiform amphibole is associated with the zones of skarn and sulphide alteration.

UNIT 11: Tshinakin limestone – *see* description in Preto, *et al.,* 1980.

UNIT 12: A large lens of grey, massive to poorly banded limestone and dolomite forms a prominent ridge southeast of Forest Lake. To the southeast it pinches out before it reaches the north branch of Cicero Creek, but to the northwest it splits into two parallel ridges separated by a narrow septum of greenschist. It appears, therefore, to outline the keel of a tight, northerly plunging synform. A short distance to the northwest the same fold is outlined by a quartzite unit near Forest Lake. Although this carbonate has been included in map unit 12, it closely resembles, and is comparable in size, with part of the Tshinakin limestone and dolomite. Unlike the Tshinakin, it is primarily associated with clastic rocks of map unit 3 rather than greenschist of unit 10. If a firm correlation of this carbonate with the Tshinakin could be made, it not only would imply a major stratigraphic repetition either by folding or by faulting but also a major facies change from primarily greenschist in the north to mostly clastic rocks in the south.

DIORITE AND MICRODIORITE – Jurassic or Triassic (Unit 13)

See description in Preto, *et al.,* 1980.

BALDY BATHOLITH – Cretaceous (Unit 14)

See description in Preto, *et al.,* 1980.

OLIVINE BASALT FLOWS, MINOR MUDSTONE – Pleistocene and/or earlier (Unit 15)

See description in Preto, *et al.,* 1980.

ORTHOGNEISS – Late Devonian (Unit A)

Biotite granodiorite and leucogranodiorite orthogneiss cut metamorphic rocks of unit 1 along the west shore of Adams Lake north of Spapilem Creek and in turn is cut by the Cretaceous Baldy batholith. This orthogneiss recently has been correlated with the Mount Fowler pluton to the east from which zircons give a Late Devonian age of 372±6 Ma (Okulitch, *et al.,* 1975; Okulitch, 1979). A similar, and probably related, orthogneiss, occurs as a sill in the southern part of the map-area where it intrudes members of units 7 and

10. A Late Devonian age for this orthogneiss would be possible since zircons from parts of unit 7a have yielded ages of 367 to 379 Ma (R. L. Armstrong, 1980, personal communication).

SERPENTINITE – Age Unknown (Unit B)

Serpentinite (unit B) forms a prominent and well-defined belt from Blucher Hall to Cicero Creek. The serpentinite is massive to brecciated, occasionally contains short fibers of asbestos, and generally forms prominent ridges, the largest of which is Mount Fadear. Three separate bodies, separated by narrow septa of unit 10 greenschist, have been mapped. The generally sheared and brecciated appearance of this rock, as well as the tendency of ultrabasic rocks of this type to follow fault zones, suggests that the serpentinite marks a major southeast-trending fault zone which branches off Louis Creek fault at Blucher Hall.

UPPER TRIASSIC ? (Unit C)

Sheared and poorly foliated augite porphyry tuff breccia and interbedded volcanic sandstone crop out over a limited area near the confluence of Fadear and Louis Creeks. The volcanic rocks form a small area surrounded by sparse exposures of sedimentary rocks of unit 6, but the contact is not exposed. Volcanic rocks with conspicuous augite phenocrysts are rare in the rest of the map-area and it is therefore probable that this unit is a sheared block of younger, possibly Mesozoic, volcanic rocks faulted in from the Intermontane Belt west of the Louis Creek fault.

STRUCTURE

Mapping south of Sinmax Creek and further mapping on the Adams Plateau have generally confirmed the structural pattern previously outlined (Preto, *et al.,* 1980). It has also shown that the Nikwikwaia Lake fold is a larger and more complex structure than originally thought. The relative open folds of the Mount Dixon area continue and become much tighter to the east and southeast of Forest Lake.

Poor stratigraphic control is the biggest obstacle to a fuller understanding of the structure in the map-area. Bedding-cleavage relationships, where observed, indicate a general westerly vergence of folds and the axes of most earliest recognizable folds deforming the bedding plunge to the north or even slightly east of north.

EARLY FOLDS

NIKWIKWAIA LAKE FOLD: Although it becomes less clearly defined eastward, Nikwikwaia Lake synform was traced more than 12 kilometres from Spillman Creek to the Nikwikwaia Creek fault. Within this distance the trend of the surface axial trace of the fold changes from northeast to southeast and east, and the axis plunges in various directions. It is apparent that the synform is refolded about northerly trending structures of undetermined plunge. The strong and polyphase deformation indicated by the Nikwikwaia Lake fold is in sharp contrast with the minimal external deformation of the nearby Tshinakin limestone. This thick, competent carbonate is only slightly warped; in no way is its deformation comparable to that of the rocks that structurally underlie it. A great deal of layer-parallel faulting or thrusting must have occurred at or near the lower Tshinakin contact in order to accommodate this discordance. This faulting apparently predated the second period of deformation which deforms the Tshinakin and the strata beneath it in much the same way.

FOREST LAKE – SINMAX CREEK AREA: East and southeast of Forest Lake there are a series of synformal and antiformal west-verging folds that have been outlined with varying degrees of accuracy and reliability. The surface axial traces of these structures trend northwesterly and, in most cases, can be related to traces of comparable folds in the Mount Dixon area to the northwest. Mesoscopic structures and geometric constraints indicate that axial planes dip moderately to the north-northeast. Fold axes also plunge moderately to the north-northeast.

LATE FOLDS

Late-generation mesoscopic structures trend in a number of directions within the map-area. In the southwest, and particularly along the east slopes of Louis Creek, a strong rodding lineation produced by the intersection of later fracture cleavage with the layer-parallel schistosity plunges at moderate angles to the north and northwest. This feature is spatially related to the Louis Creek fault and was probably produced by movement along it.

Along Adams Lake, late-generation mesoscopic folds and associated crenulation lineation trend east-west and plunge gently in either direction.

On the Adams Plateau, the Nikwikwaia Lake synform is refolded about northerly trending axes.

FAULTS

Several early, layer-parallel faults have been postulated either as required by the geometric constraints of fold structures like the Nikwikwaia Lake fold or to account for rotation of structures and truncation of map units. The Mount Fadear serpentinite belt was undoubtedly emplaced along a major northwest-trending fault. If the pelitic sediments southwest of Mount Fadear correlate with similar sediments in the Haggard Creek—North Barriere River area, then this fault caused considerable repetition of the section. Undoubtedly more unrecognized layer-parallel faults exist in this highly deformed region.

Numerous map units are offset by later north to northeasterly trending faults and fractures. On the Adams Plateau, many of these faults are followed by post-tectonic porphyry dykes (unit 14c).

AGE DATING

Recent dating of zircons from felsic metavolcanic rocks of unit 7a that are exposed east of Adams Lake have yielded three dates which range from 367 to 379 Ma and suggest that these rocks are of latest Devonian age (R. L. Armstrong, 1980, personal communication). Similarly, two zircon separates from quartz feldspar porphyry west of North Barriere River have yielded ages of 369 to 380 Ma (R. L. Armstrong, 1980, personal communication). This porphyry (map unit 2c, Preto, *et al.,* 1980) cuts basaltic rocks of the Fennell Formation but also occurs as clasts in intraformational conglomerate that is interbedded with basalt and chert of the eastern facies of the Fennell. The quartz feldspar porphyry was selected for dating because these field relationships suggested that it was roughly of the same age as the Fennell. The zircon dates are in reasonably close agreement with Early Mississippian ages given by conodonts from limestone pods in Eagle Bay rocks of unit 6 (Preto, *et al.,* 1980; M. J. Orchard, 1980, written communication). These data suggest that Eagle Bay rocks in this area are of Late Devonian to Early Mississippian age, rather than

Cambro/Ordovician (Okulitch, 1979). The radiometric dates also confirm field relationships (Preto, *et al.*, 1980) that indicate that the uppermost Fennell Formation correlates with Eagle Bay rocks in the Barriere Mountain—Mount Dixon area.

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BJ PROSPECT, LADYSMITH AREA
(92B/13W)

By G.E.P. Eastwood

The prospect is 5 kilometres southwest of Ladysmith, and is reached by a circuitous system of roads which leaves the Island Highway at the railway overpass north of the town. It is north of Holland Lake, in a limited exposure low on the southwest slope of a ridge.

Mineralization occurs in the northeast contact zone of a small granitic body (Fig. 5) that is either a stock or a large apophysis of Clapp's Ladysmith batholith (*sic*). The rock immediately adjacent to the stock is black amphibolite cut by many small granitic dykes and pegmatitic vein-dykes. It passes northeastward through migmatite to somewhat schistose and recrystallized hornblendic trachyte of the Sicker Group. To the southeast the trachyte is in contact with shonkinite which, like the amphibolite, is cut by many small granitic dykes. The amphibolite and migmatite contain wispy zones, 30 to 60 centimetres wide, of disseminated and seam pyrite accompanied by less chalcopyrite. These zones are exposed in only one place, and only scattered occurrences of sparsely disseminated pyrite were found in the trachyte and shonkinite.

The BJ claim was inadvertently overstaked, and a quarry was opened in the contact zone of the stock to provide rock-facing for dams at each end of Holland Lake. These dams will create a reservoir for Ladysmith.

REFERENCE

Clapp, C. H. (1917): Sooke and Duncan Map-Areas, Vancouver Island, British Columbia, *Geol. Surv., Canada,* Mem. 96, p. 191.

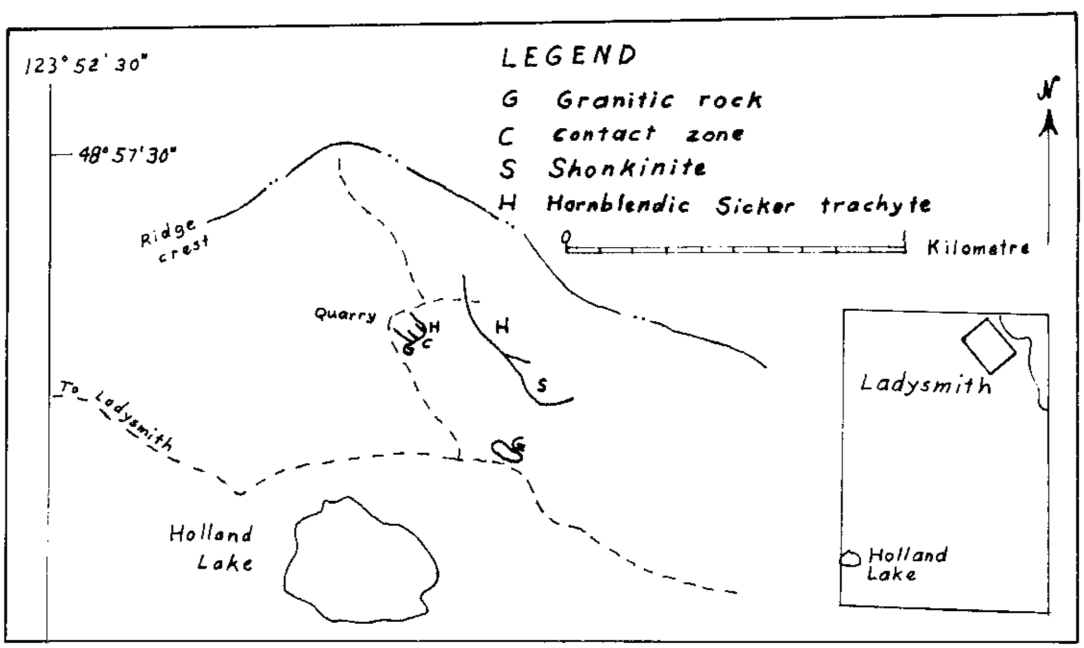


Figure 5. Sketch of the Holland Lake area.

CENTRAL BRITISH COLUMBIA

COMPUTER PROCESSING OF GEOCHEMICAL DATA SHOWING THE PRIMARY DISPERSION OF ELEMENTS NEAR THE EQUITY MINE (SAM GOOSLY) (93L/1W)

By B. N. Church, J. Barakso, and D. Ball

INTRODUCTION

Application of the desk top computer in processing geochemical data is demonstrated using rock analyses from the Goosly area and Equity mine (MI 93L-1), southeast of Houston, British Columbia.

In the course of regional mapping and survey of mineralization, hand specimens were collected from accessible bedrock exposures covering a wide region between Houston, Burns Lake, and Francois Lake, including the Equity mine site. Through the Rock Library System sponsored by the Ministry and separate agreements with interested mining exploration companies, the samples were subsequently analysed for a selection of major and minor elements to establish background levels. Samples were collected, analysed, and the data processed by the authors with the cooperation and assistance of Kennco Explorations, (Western) Limited, Anaconda American Brass Limited, and Placer Development Limited.

GEOLOGICAL SETTING

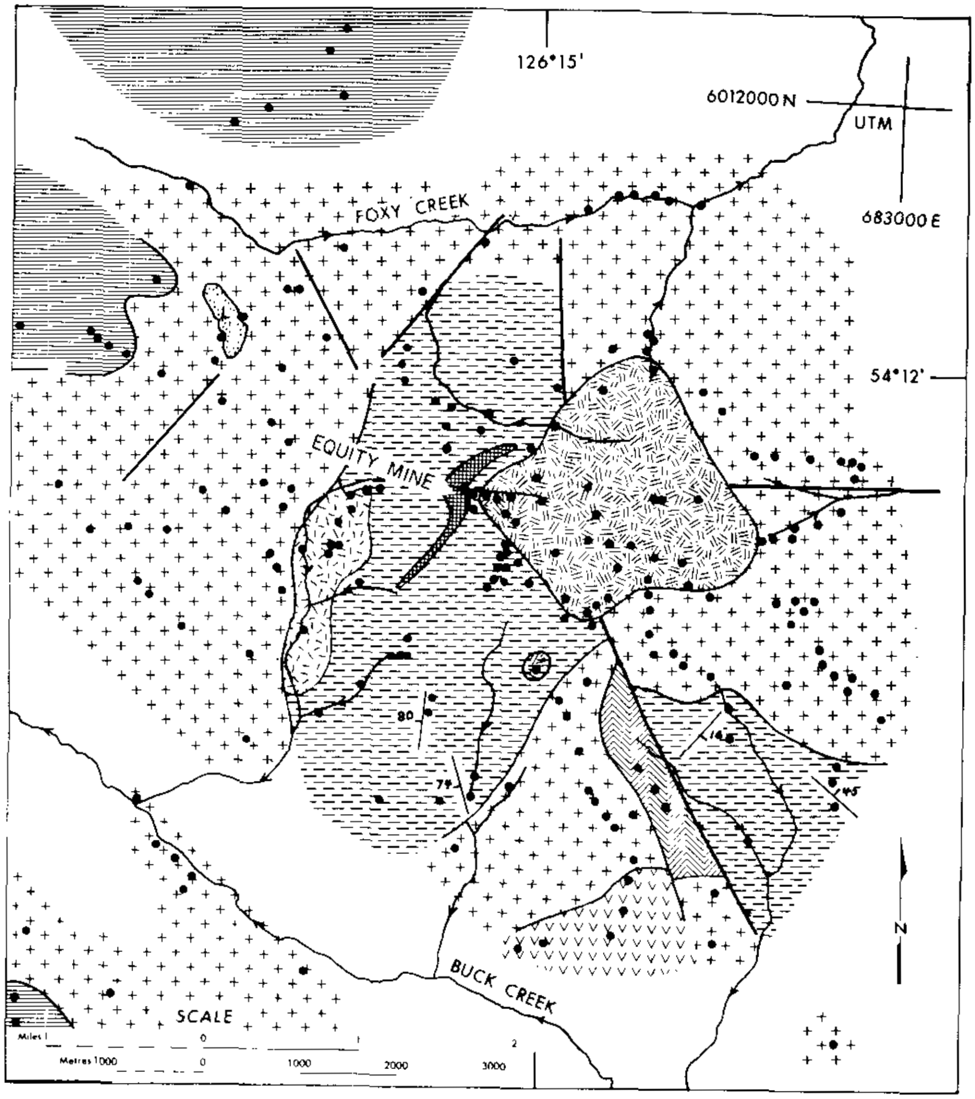
Mineralization was first discovered in the Goosly area in 1967, the geology being described later by Ney, *et al.*, 1972; Wojdak, 1974; Wetherell, 1979; and various reports by the Ministry from 1969 to the present.

The Goosly area is underlain by diverse assemblages of Jurassic to Eocene volcanic and sedimentary rocks cut by a number of small igneous intrusions (Fig. 6).

The principal stratigraphic divisions comprise a basement sequence of deformed Mesozoic metasedimentary rocks and younger, less deformed cover rocks. The basement is poorly exposed and consists mostly of Lower Cretaceous conglomerate and volcaniclastic units assigned to the Skeena Group and some maroon tuff breccia believed to be Sinemurian age (Hazelton Group). The cover rocks are generally well exposed and consist of intermediate and felsic volcanic rocks recognized as the Late Cretaceous Tip Top Hill, Eocene Goosly Lake andesitic lavas and breccias, and Eocene Buck Creek dacitic 'plateau' lavas.

The main intrusions are a syenomonzonite-gabbro stock and a somewhat smaller granitic body described variously as having quartz monzonite, adamellite, or granite composition. These intrusions are younger than the basement strata and may be volcanic necks or feeders to the young volcanic assemblages.

At the Equity mine, erosion has sliced through the cover rocks exposing a zone of disseminated and massive sulphides rich in pyrite, chalcopyrite, and tetrahedrite, some pyrrhotite, and minor sphalerite and magnetite. The main mineralized zone lies immediately west of the syenomonzonite-gabbro intrusion. The



LEGEND

BEDDED ROCKS

EOCENE

BUCK CREEK VOLCANICS

GOOSLY LAKE VOLCANICS

UPPER CRETACEOUS

TIP TOP HILL VOLCANICS

LOWER CRETACEOUS

SKEENA GROUP

JURASSIC

HAZELTON GROUP

IGNEOUS ROCKS

SYENOMONZONITE-GABBRO STOCK

GRANITE STOCK

SYMBOLS

BEDDING

FAULT LINEAMENT

STREAM

STRONG MINERALIZATION

SAMPLE STATION

Figure 6. Geological map and sample locations near the Equity minesite (MI 93L-1), Goosly area (NTS 93L/1W).

aluminous alteration accompanying this mineralization appears to be the same age as the intrusion and is characterized by such minerals as andalusite, pyrophyllite, and scorzalite. A sharp-walled tail-like appendage of the mineralized zone strikes southwest toward the granitic intrusion and penetrates a phyllitic alteration aureole adjacent to this body.

PROCEDURES

The treatment and analysis of rock samples were routine and need not be enlarged on here (Church, *et al.*, 1976), however, some commentary is necessary to explain the geostatistical methods.

The procedure of averaging and contouring geochemical results on a geological base may provide useful insight into element distribution, shedding light on metallogenesis. In the present example a synthesis of scattered results was achieved by the moving average method whereby a grid of averaged values was generated for each element preparatory to contouring. The best results were obtained using a 2-kilometre diameter integrating circular window on a 1-kilometre-sided equilateral triangular grid base. This compact triangular base with equidistant adjacent points was found to give greater control for drawing contours than a square grid.

A computer program designed for a desk top computer that performs the integrating-averaging function is given in Table 1. Input is data on the UTM location of samples, chemical results, coordinates for the starting point for integration, and field limits. Output is a list of averaged values and corresponding UTM coordinates for points in the triangular grid array.

TABLE 1. COMPUTER PROGRAM FOR MOVING AVERAGES FUNCTION
(On a Wang 2200A computer)

```
100 DIM A(15)
110 INPUT "RADIUS OF INTEGRATING CIRCLE",Z
120 T=0:S=0:P=0:INPUT "COORDINATES OF CENTRE OF FIRST CIRCLE",A,B
130 INPUT "EASTING AND NORTHING INTERVALS",G,H
140 Ø=A:Q=B
150 FOR I=1 TO 3: READ A(I): NEXT I
160 IF A(1)=-1 THEN 180: IF SQR((A(1)-Ø)^2+((2(2)-Q*1)^2)>Z THEN 150
170 S=S+1:T=T+LOG(A(3)):GOTO 150
180 IF S=0 THEN 190:Y=EXP(T/S):SELECT PRINT 211(156):PRINT Ø;",";Q,Y
190 Ø=Ø-Z:S=0:T=0
200 IF Ø<A-G THEN 220
210 RESTORE :GOTO 150
220 S=0:T=0:Q=Q-.866 * Z:P=P+0:IF INT(P/2)=P/2 THEN 240
230 Ø=A-.5*Z:GOTO 250
240 Ø-A
250 IF B-Q<=H THEN 210 :END
260 DATA _____, _____, _____, .................... -1, 0, 0
```

Note: The SELECT PRINT 211 (156) statement links the Wang 2200A computer to an IBM Selectric typewriter output.

RESULTS

Many elements were tested but the most interesting results were obtained for silver, copper, arsenic, mercury, barium, and fluorine.

TABLE 2. CORRELATION MATRIX

	Ag	Cu	As	Hg	Ba
Cu	0.47				
As	0.50	0.39			
Hg	0.13	0.18	0.20		
Ba	−0.08	−0.03	−0.25	−0.14	
F	−0.10	−0.05	−0.31	0.01	0.42

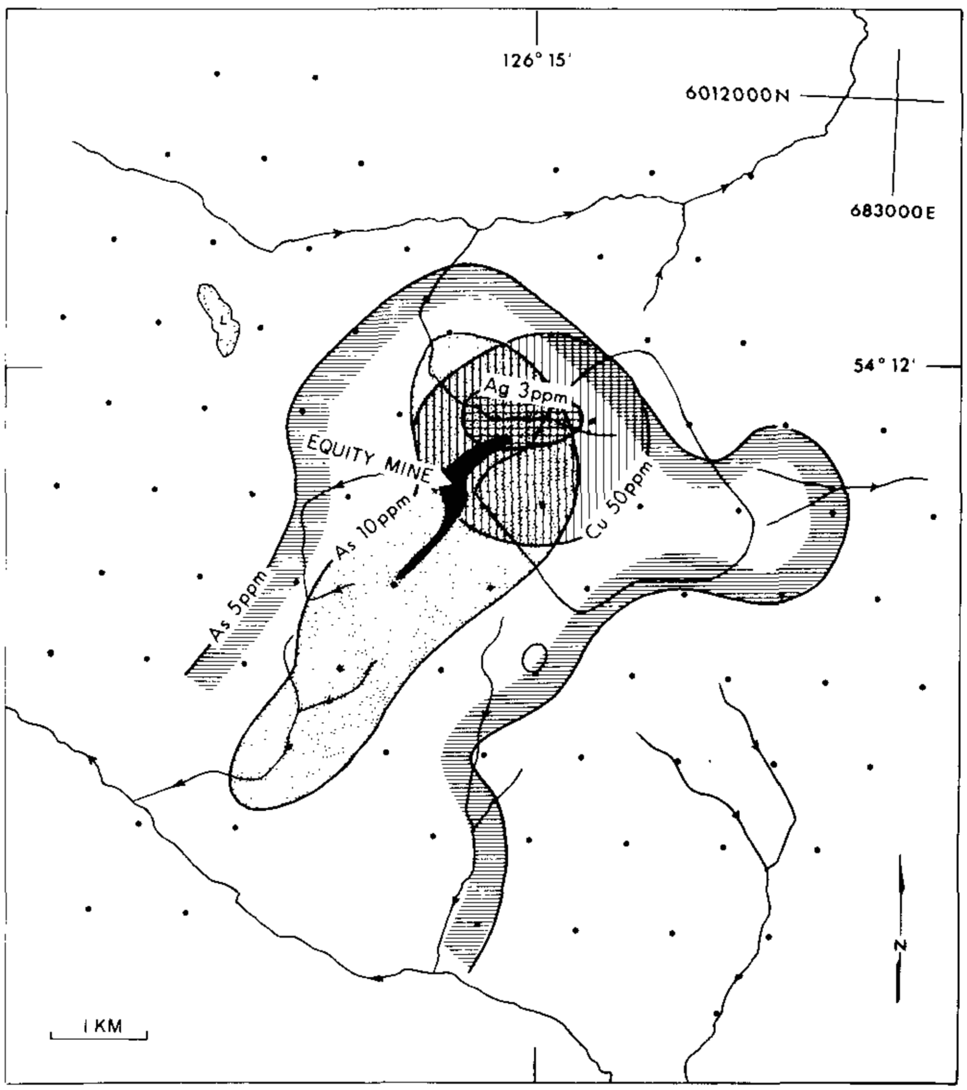


Figure 7. Moving average grid showing lithogeochemical contours for silver, copper, and arsenic in the Goosly area; stipple and hachuring on up-side of contours.

Silver and copper are dispersed in bull's-eye fashion on the contour maps and are centred toward the north end of the Equity ore zone (Fig. 7). Silver greater than 3 ppm is concentrated in a small area of mostly mineralized pre-Tertiary country rock. Copper greater than 50 ppm is coincident but more widely distributed and extensively overlaps the west side of the syenomonzonite-gabbro intrusion. Arsenic above 10 ppm forms an elongated zone that extends beyond the silver-copper bull's eye and covers much of the area peripheral to the main Equity ore zone and the tail offshoot. Arsenic greater than 5 ppm encompasses almost the entire window of the pre-Tertiary rocks that host the ore, the syenomonzonite-gabbro intrusion, and a weak gossan area immediately east of the intrusion. The behaviour of barium and fluorine is antipathetic to the metallic elements (Fig. 8). This is shown by the 1 500-ppm contour for barium and the

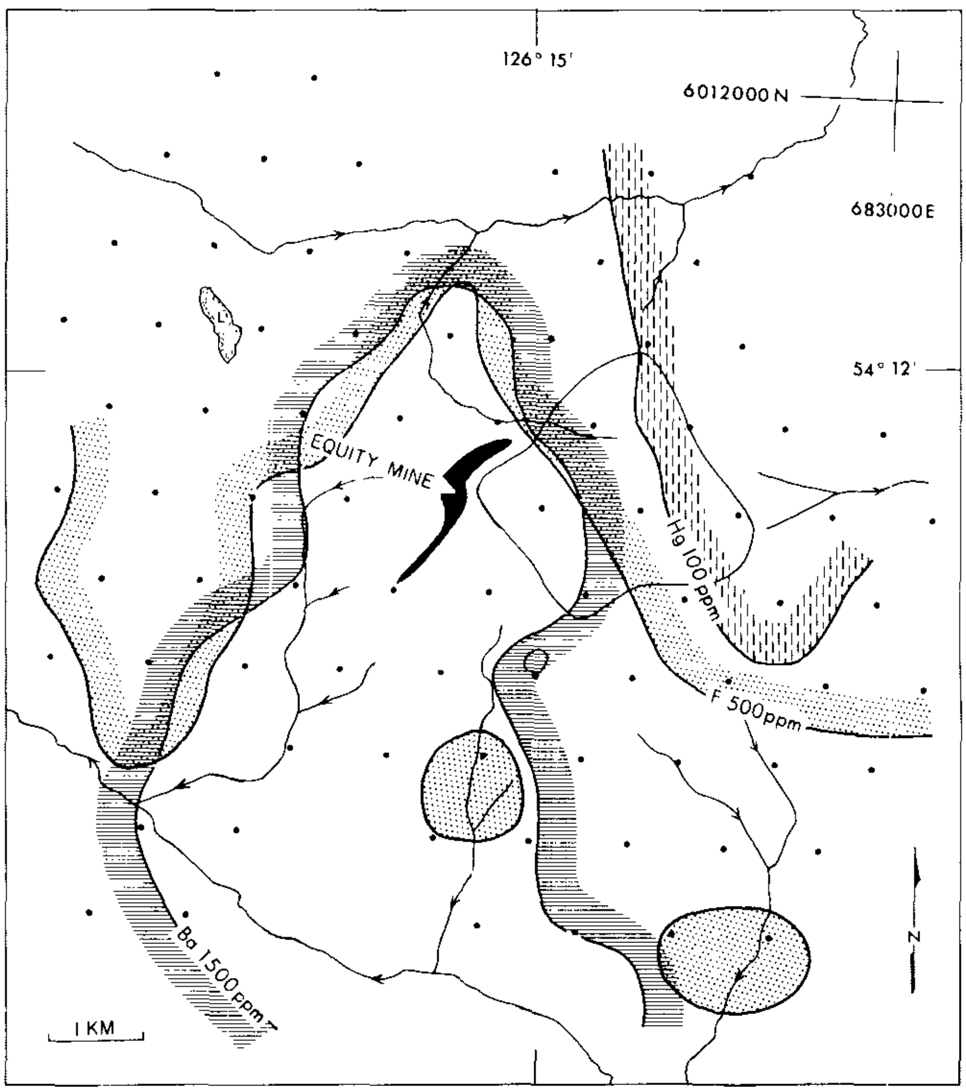


Figure 8. Moving average grid showing lithogeochemical contours for barium, fluorine, and mercury in the Goosly area; stipple and hachuring on up-side of contours.

500-ppm contour of fluorine which are entirely outside the intensely mineralized areas. Mercury is remote from the mineralized zone and is concentrated primarily in the area east of the syenomonzonite intrusion.

The behaviour of the elements is illustrated by the accompanying correlation matrix (Table 2). As might be expected from the above discussion, the element pairs silver-copper, silver-arsenic, and barium-fluorine show fair positive relationships, having coefficients 0.47, 0.50, and 0.42 respectively.

DISCUSSION

Simple computer techniques have assisted in the preparation of contour maps showing the primary dispersion of elements about the Equity ore zone in the Goosly area. Especially useful for this purpose are silver, copper, and arsenic, which seem to display increasing mobility outward from a source area. Converse to the behaviour of these metals, a depletion of barium, fluorine, and mercury is conspicuous in the areas of intense mineralization.

A general transgression of element contours across major geological boundaries suggests overprinting of a younger event on the ore system. This could be a late episode in the main stage of mineralization or simply leakage from a pre-existing orebody. The former is suggested because dyke offshoots from the syenomonzonite intrusion are altered and there is some apparent damming of ore solutions by the dykes.

It can also be pointed out that some of the alteration in the host rocks in the vicinity of the Equity orebody, dated 48.3 Ma by Wetherell (1979), is younger than the main intrusions, whereas the average age of alteration in the host rocks, 54.2 Ma, is essentially the same as the age of the syenomonzonite-gabbro intrusion, 54.3 Ma, as determined by Kennco Explorations, (Western) Limited (1969) (Table 3).

TABLE 3. POTASSIUM–ARGON DATES FROM THE GOOSLY AREA

No.	Unit	Material Analysed	K *per cent*	Ar^{*40} (10^{-5} cc STP/g)	Apparent Age *Ma*
1 x	granite	biotite	6.552	1.624	62.7
2 y	granite	biotite	7.09	1.601	57.2
3 x	syenomonzonite	biotite concentrate	3.087	0.6610	54.3
4 y	syenomonzonite	biotite	7.53	1.475	49.7
5 x	host rock	sericite	5.240	1.165	56.3
6 z	host rock	whole rock	4.795	1.0992	58.1
7 z	host rock	whole rock	3.75	0.7132	48.3

Key to Analyses:

x Collected by B. N. Church for Kennco Explorations, (Western) Limited and dated by Geochron Laboratories Inc., 1969 (not previously reported).

y Collected by B. N. Church and dated by N. C. Carter at the University of British Columbia; reported in *B.C. Ministry of Energy, Mines & Pet. Res.*, Geology, Exploration and Mining, 1972, p. 359.

z Collected by D. G. Wetherell and dated by J. E. Harakal at the University of British Columbia; reported in *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1979, Paper 1980-1, p. 125.

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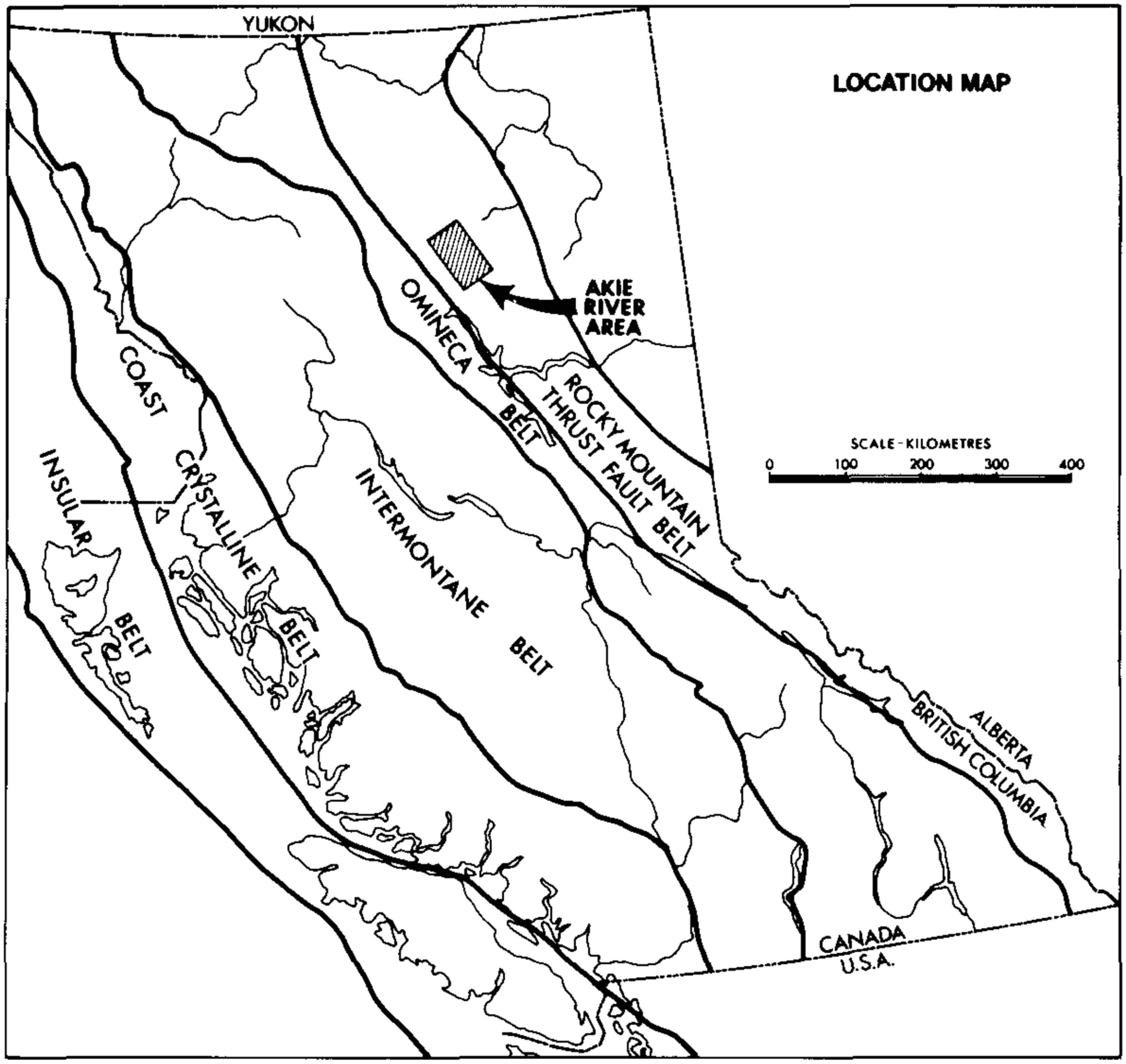

Figure 9. Location and tectonic setting of the Akie River project area, NTS 94F.

NORTHERN BRITISH COLUMBIA

AKIE RIVER PROJECT
(94F)

By D. G. MacIntyre

INTRODUCTION

Regional mapping and detailed stratigraphic studies of host rocks for stratiform barite-lead-zinc deposits were continued in the Akie River area of northeastern British Columbia (Fig. 9). This project, initiated in 1979, was accelerated in 1980 in response to intense exploration activity generated by the announcement of the discovery of a major deposit (+30 million tonnes, 10 per cent lead and zinc, 46.65 grams per tonne silver) at Cyprus Anvil's Cirque property (MI 94F-8). The 1980 fieldwork involved two 2-man helicopter-supported field crews doing 1:50 000-scale mapping and measurement of stratigraphic sections, mainly from strategically located fly camps. A rectangular area, approximately 50 kilometres long and 25 kilometres wide extending from Kwadacha Wilderness Park to the Akie River, has now been mapped. Coverage will be extended to both the north and south during the 1981 field season.

Geologic data is currently being compiled on a 1:50 000-scale orthophoto base* and will be released as a preliminary map as soon as possible. This report deals mainly with the stratigraphic setting of mineral deposits in the area and possible facies relationships between these deposits and their host rocks. A model is presented for these facies relationships as deduced from fieldwork completed during the 1979 and 1980 field seasons. Detailed petrographic, geochemical, and paleontological studies of the Devonian host rocks are currently in progress and will help to refine this model as data becomes available. In addition, Kevin Heather, a fourth year student at the University of British Columbia, has started a thesis study on the Ordovician stratigraphy of the map-area based on his fieldwork during the 1980 field season.

TECTONIC SETTING

The Akie River area is part of the Rocky Mountain Thrust and Fold Belt of northeastern British Columbia (Fig. 9). This part of the thrust and fold belt consists of fault-bounded northwest-trending synclinoria of Early Paleozoic basinal facies rocks of the Kechika Trough separated by anticlinoria of Cambrian and older rocks. During Early Paleozoic time, prior to the postulated 400-kilometre right lateral offset along the transverse Rocky Mountain Trench fault system (Templeman-Kluit and Blusson, 1977), the Kechika Trough was bounded by the MacDonald platform and craton to the northeast and the Pelly—Cassiar platform to the southwest. The Kechika Trough is a southeasterly extension of the larger Selwyn Basin in the Yukon.

GENERAL GEOLOGY

The geology of the Driftpile Creek—Akie River barite-lead-zinc district is shown on Figure 10. A previous report (MacIntyre, 1980) has already described the geology and mineral occurrences of the district. This,

*Available through Surveys and Mapping Branch, Ministry of Environment, Victoria (Project 80-030-T-O, Ware).

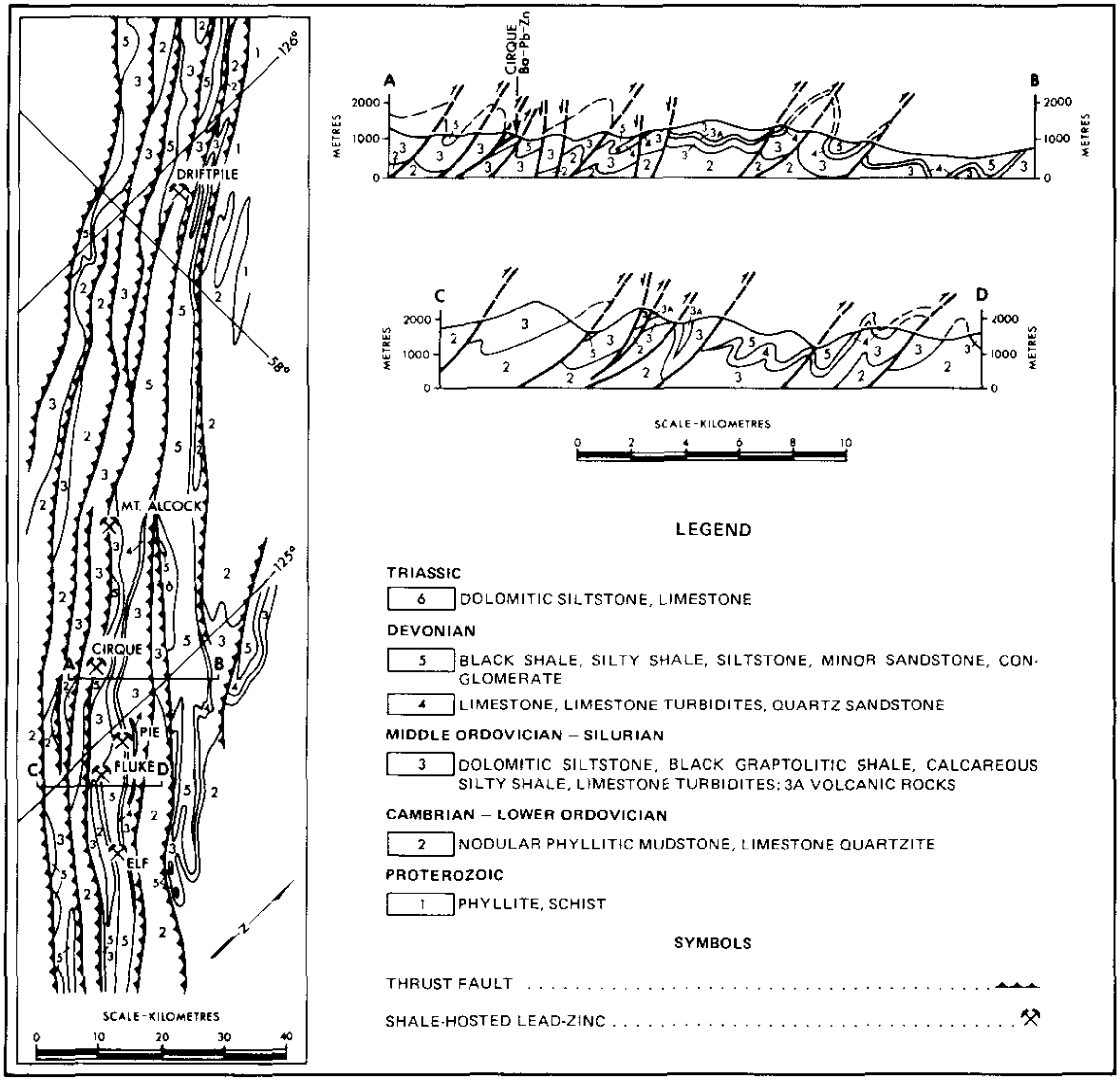

Figure 10. General geology, Driftpile–Akie River barite-lead-zinc district.

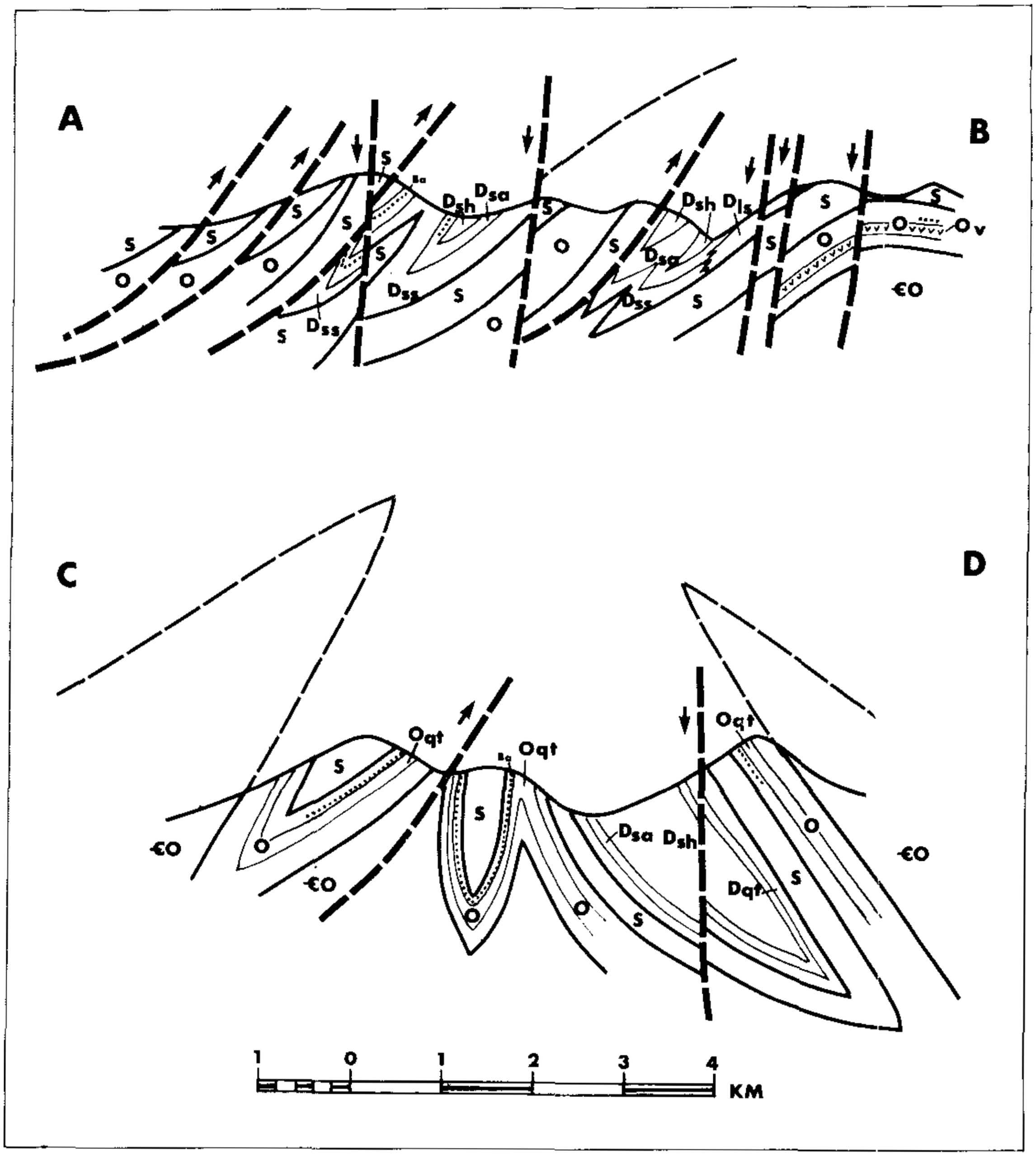

Figure 11. Structural sections across the eastern (A–B) and western (C–D) shale belts, Akie River area. *See* Figure 12 for location of sections and Table 1 for explanation of sedimentary facies designations. **Note:** vertical scale 1.5 x horizontal scale.

report deals mainly with the Ordovician, Silurian, and Devonian stratigraphy of the Akie River area (94F/6, 7, 10, 11) and the stratigraphic and structural setting of the bedded barite-sulphide deposits that occur within these rocks.

STRUCTURE

The Early Paleozoic rocks of the Akie River area are preserved within a series of parallel northwest-trending synclinoria that are bounded by southwest-dipping thrust faults. These structures are the products of northeast-directed compression during the Columbian and later orogenies. The westernmost synclinoria are composed of tight, overturned, asymmetric fold structures with southeast-dipping axial surfaces. Imbricate thrust faults typically occur along axial surfaces resulting in stacking of thrust plates and overriding of younger strata by older rocks (Fig. 11).

The intensity of deformation and degree of supracrustal shortening and thickening appear to decrease eastward across the Akie River area. The predominant structural style of the eastern shale belt (Fig. 11) is one of large-scale folding within a synclinorium that is being overridden from the southwest and northeast by anticlinoria of older strata. Axial surfaces of folds generally dip away from the core of the synclinorium.

Post-orogenic normal faults are also common. The downthrown block is typically to the west with displacements varying from less than 10 to greater than 200 metres. The faults offset earlier thrust faults in the eastern shale belts.

STRATIGRAPHY

Location of stratigraphic sections and the distribution of Devonian rocks in the Akie River area are shown on Figure 12. Stratigraphic sections are illustrated on Figure 13 and Table 1 (pages 46 and 47) summarizes the various sedimentary facies delineated during the current mapping project.

ORDOVICIAN

In the Akie River area phyllitic nodular mudstones and siltstones of the Cambrian to Lower Ordovician Kechika Formation (Cecile and Norford, 1979; Taylor, 1979; Taylor, *et al.*, 1979) are unconformably overlain by a succession of Early Ordovician to Late Devonian basinal facies limestone, siltstone, shale, and minor volcanic rocks. These rocks exhibit facies variations across the map-area which suggest that the basin to platform transition to the east was very abrupt with a relatively steep basinward slope. Within the Kechika Trough three major transgressive depositional cycles, each beginning with shallow water carbonate and associated turbidites and grading up-section into progressively deeper water black shales, occur in the stratigraphic record. These depositional cycles, which are separated by unconformities, conveniently divide the stratigraphy into well-defined formations (Figs. 14 and 15). Cecile and Norford (1979) proposed that the Ordovician and Silurian cycles are correlative with the Road River Formation. More recently Thompson (personal communication) has suggested elevating the Road River to group status with inclusion of the Devonian part of the section in this group.

The stratigraphy of the Ordovician and Silurian parts of the Road River 'Formation' in the Ware (94F) map-area have been described by Taylor, *et al.* (1979) and Cecile and Norford (1979). In the Akie River area, the base of the Road River 'Formation' includes cream, beige, and reddish brown-weathering, laminated, and calcareous siltstone and shale (O_{ss}) with limestone turbidite (O_{lt}) interbeds. The latter are probably derived from the Skoki limestone (O_{ls}) which occurs east of the project area (Cecile and Norford, 1979). These rocks grade up-section into black shales and minor cherts (O_{sh}) which contain Middle Ordovician graptolite assemblages. The shales are incompetent relative to underlying and overlying strata and are intensely sheared and folded with pervasive cleavage. Upon weathering these rocks decompose to a black carbonaceous mud.

Discontinuous volcanic horizons (O_v) occur near the base of the Ordovician black shale unit in the western shale belt. The best exposures occur in the vicinity of the Pie prospect where a greenish grey-weathering, massive microdioritic flow, up to 50 metres thick, overlies graptolitic black shale and chert and is overlain by interbedded shale and orange to brown-weathering, carbonate-rich vitric, crystal, and lapilli tuff. These rocks are probably the product of periodic volcanic activity along a deep-seated rift zone. Minor nodular barite was noted in highly altered tuffs at section 15 (Fig. 13).

Close to the Skoki limestone (O_{ls}) shale-out, along the eastern margin of the shale basin, a sequence of quartzose proximal turbidites (O_{qt}) occurs in the upper black shale unit of the Ordovician section. This turbidite unit is 150 metres thick near the southern limit of the easternmost shale belt and thins gradually to the north, east, and west. The massive grey-weathering quartz sandstone and siltstone beds that are characteristic of this unit are separated by thin black shale interbeds with late Middle to early Upper Ordovician graptolite assemblages (Cecile and Norford, 1979). This unit therefore lies stratigraphically above the Middle Ordovician volcanic unit. At the Sika showing, an extensive barite bed, up to 1 metre thick, overlies the quartzose turbidite unit (sections 31, 32, and 35, Fig. 13).

SILURIAN

Road River shales are unconformably overlain by as much as 800 metres of orange to brown-weathering siltstone (S_{sl}) and minor limestone (S_{ls}) of Silurian age. This unit is relatively competent and resistant and typically caps peaks and ridges throughout the project area, particuarly where it has been thrust over younger, less resistant rocks.

Platy, thin laminar-bedded and blocky, thick flaser-bedded dolomitic siltstone with minor grey and orange-weathering limestone and dolostone interbeds dominate the Silurian succession. Generally, these rocks are strongly bioturbated. Spiral feeding trails, siliceous sponge spicules, sponge imprints, and poorly preserved graptolites are also common. Cecile and Norford (1979) suggest an early Middle Silurian (Wenlockian) age based on sponge and graptolite taxa from the dolomitic siltstone part of the succession.

In the Akie River area the base of the Silurian section is marked by a 10 to 20-metre-thick unit of grey, blocky weathering massive limestone (S_{ls}) or dolostone (S_{ds}) or by limestone turbidites (S_{lt}). Up-section these rocks grade into a unit of interbedded black chert and grey laminated to crosslaminated limestone (S_{sa}) which is locally overlain by dark grey-weathering silty shale and siltstone turbidites (S_{ss}) containing Early Silurian (Llandovery) graptolites (Cecile and Norford, 1979). The thick dolomitic siltstone unit (S_{sl}) unconformably overlies these basal rocks, and, in places, has been deposited directly on Middle Ordovician black shale.

In the eastern shale belt, a distinctive unit of orange-grey-weathering dolomitic quartz sandstone and siltstone turbidite overlies the basal limestone turbidite (S_{lt}) unit of the Silurian section. Thin beds of grey barite were noted in this unit at section 35 (Fig. 13).

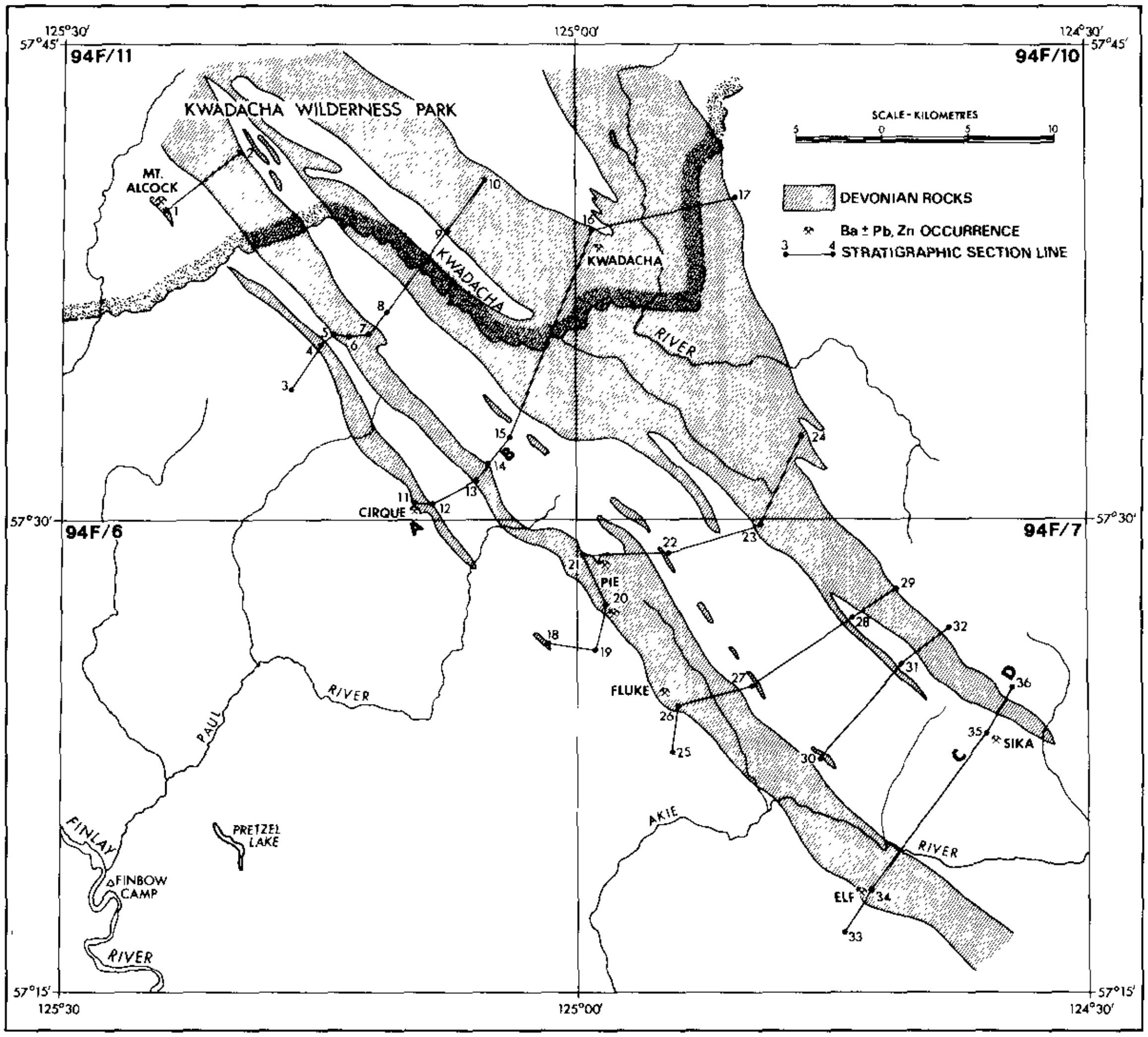

Figure 12. Location of stratigraphic sections and distribution of Devonian rocks in Akie River project area.

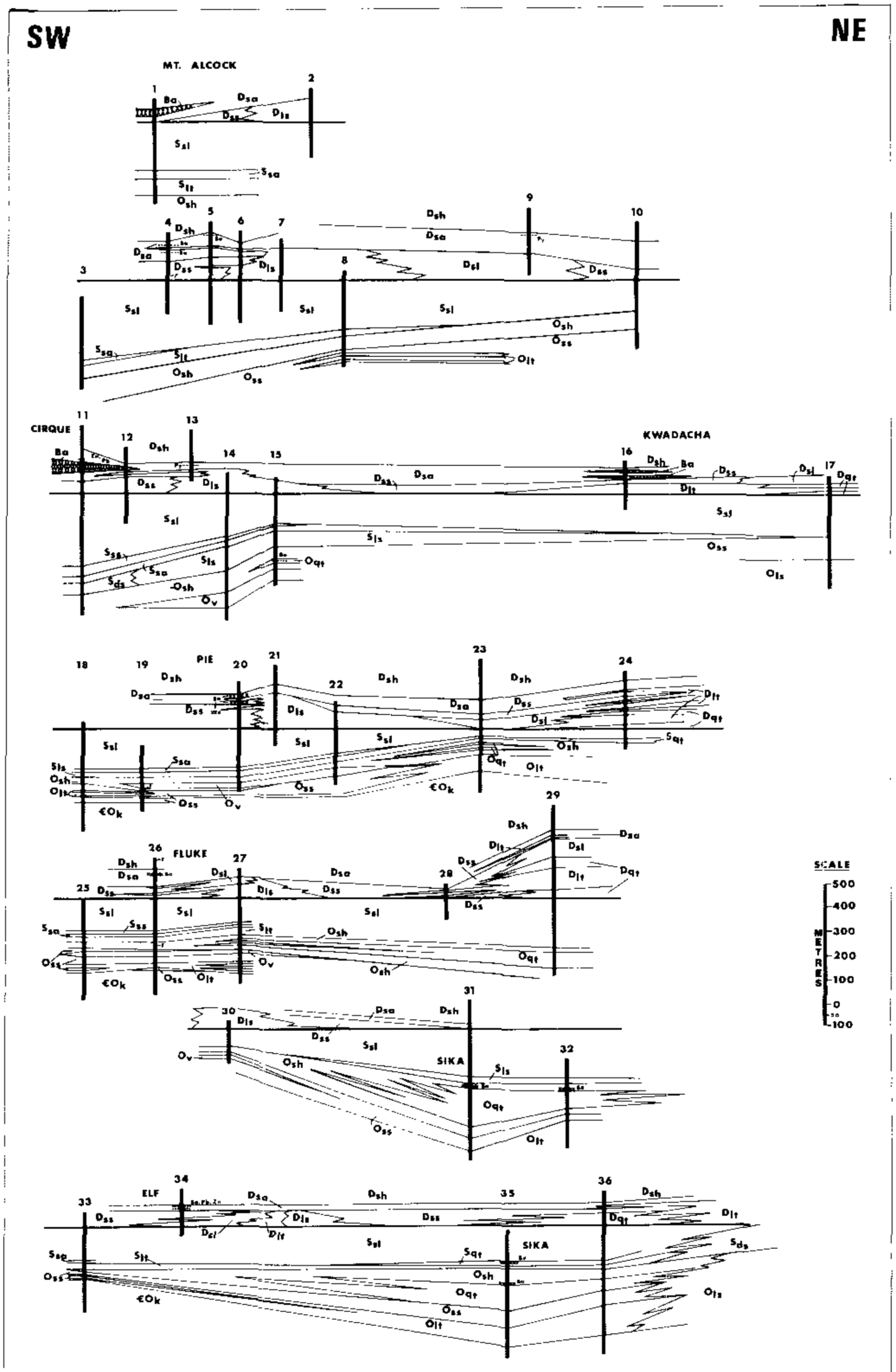

Figure 13. Stratigraphic sections, Akie River area. Note that the thicknesses of sedimentary facies are only approximate in most cases. Sections positioned by location of traverse, with no correction made for supracrustal shortening due to faulting and folding.

The stratigraphy of the Silurian section suggests early deposition of shallow water limestone and dolostone and their associated turbidite facies was followed by a marine transgression and deposition of progressively deeper water clastic rocks. This cycle was terminated by a period of uplift in Middle Silurian time that resulted in extensive erosion of the carbonate platform to the east and concomitant deposition of dolomitic siltstone turbidites in the Kechika Trough. During the marine transgression minor amounts of barite were deposited.

DEVONIAN

The Silurian siltstone unit is unconformably to disconformably overlain by Devonian shale, siltstone, and limestone. With the exception of limestone and the more siliceous shale facies, these rocks are recessive and poorly exposed. In many areas erosion has completely removed the Devonian succession. The most complete Devonian sections occur in overturned synclinoria where they have been preserved beneath overriding thrust plates of older, more resistant strata. Under such a stress regime the incompetent Devonian rocks tend to coalesce into tight isoclinal folds and develop a pervasive axial plane cleavage. These features mask original stratigraphic thicknesses and make recognition of lateral and vertical facies changes difficult. Despite the structural complexity of the Devonian section, an attempt has been made to divide the succession into sedimentary facies and these are described in Table 1.

The distribution of sedimentary facies in the Akie River area suggests that in Early Devonian time the shale basin consisted of two parallel troughs separated by a chain of shallow water carbonate reefs (Fig. 15). The reefs, which are typically composed of an upper and lower unit of medium to thick-bedded limestone containing coral, shell, and crinoid detritus separated by an intermediate unit of shaly thin-bedded argillaceous limestone, appear to have grown on the uplifted edges of tilted fault blocks. The limestone facies (D_{ls}) is thickest along this edge, grading abruptly to the west into a sequence of limestone turbidites, reef front breccias, and pelagic black shale (D_{lt}). The black shales contain Lower Devonian (Pragian) graptolite assemblages. The limestone turbidites grade laterally and vertically into dark grey argillaceous siltstone and sandstone (D_{sl}) containing shell and coral detritus and blue-grey-weathering laminated silty shale (D_{ss}) with orange-weathering calcarenite interbeds that are interpreted to be distal turbidites. These proximal to distal turbidites define several submarine fans within the western shale belt which probably emanated from submarine canyons incised into a steep westward dipping slope. The crest of this slope was probably marked by a northwest-trending fault scarp or hinge zone that was periodically reactivated during Early to Middle Devonian time thus triggering debris flows into the shale basin. Secondary rifts, parallel to the main trend, also occur within the main basin of deposition. These were probably related to development of small-scale graben and horst structures which created second and third order basins within the deepest part of the Kechika Trough.

In contrast to the rapid shale-out observed on the west side of the carbonate reef, on the east the limestone facies thins gradually and grades into a progressively deeper water shale facies. This suggests a gentle paleoslope on the east side of the carbonate reef during Early to Middle Devonian time.

Proximal turbidite facies also occur in the basal part of the Devonian section on the east side of the eastern shale belt. This suggests the west-facing slope of the eastern shale belt, which may have been located immediately adjacent to the main carbonate platform, was also steep. However, in contrast to the western shale belt, the turbidites in this area are predominantly quartz siltstones, sandstones, and conglomerates (D_{qt}) with interbedded limestone debris flows (D_{lt}) and graptolitic black shales. The composition of these rocks indicate a build-up of shallow water quartz sands along the platform margin during Early Devonian time. Much of this detritus may have been derived from erosion of older (Cambrian ?) quartz-rich rocks exposed east of the carbonate platform. The proportion of quartz relative to the carbonate detritus in the Lower Devonian section increases to the northwest. The quartz-rich rocks of the eastern shale belt may correlate in part with the upper part of the Muncho McConnell Formation (Wokkpash Formation of Taylor and MacKenzie, 1970; unit 6 of Thompson, 1976).

The apparent influx of coarse clastic debris into the shale basin during the latter part of the Early Devonian suggests a possible episode of uplift or marine regression that resulted in exposure and erosion of the carbonate reef. A similar hiatus is recognized in the carbonate platform to the east where the Muncho McConnell Formation and older cratonic rocks were exposed prior to deposition of dolomites of the Stone Formation (Morrow, 1978; Taylor and MacKenzie, 1970).

Lower to Middle Devonian turbidites and shallow water carbonate reefs are conformably overlain by a distinctive unit of rhythmically bedded siliceous rocks (D_{sa}). This unit is resistant, typically blocky to slabby weathering, and consists of medium to thin beds of banded black chert to siliceous argillite and siliceous laminated silty shale to siltstone separated by recessive intervals of carbonaceous black siliceous shale. Soft sediment slump structures are common within these rocks. The siliceous facies varies from 20 to 150 metres in thickness and is host to the major bedded barite and massive sulphide deposits of the Driftpile Creek–Akie River district. The siliceous character of the unit may be due to exhalative activity associated with interbasin rifting during the early stages of a major marine transgression during the Middle to Late Devonian (Fig. 15).

Where the siliceous facies transgresses the carbonate reef-shale basin transition zone, it includes thin interbeds of dark grey, fetid limestone and debris flows which locally contain two-hole crinoid plates and coral fragments. Two-hole crinoids also occur near the top of the upper thick-bedded limestone unit of the carbonate reef suggesting that these two facies are in part correlative and probably early Middle Devonian in age (Morrow, 1978). Roberts (personal communication) reports the occurrence of the earliest Upper Devonian ammonoid *ponticeres* from the top of the siliceous facies at the Cirque property. These rocks are probably in part time-equivalents of the Stone Formation of the carbonate platform.

The siliceous facies and its contained barite deposits are conformably overlain by blue-grey-weathering fissile black shale of probable Late Devonian age. The basal part of this unit, which may exceed 500 metres in thickness in the core of synclinoria of the eastern shale belt, is typically rusty brown weathering and locally contains disseminated pyrite and thin pyrite laminae. Nodular barite also occurs sporadically within the basal part of the black shale unit. These rocks probably correlate in part with Besa River shales (Kidd, 1963; Pelzer, 1966) of the eastern carbonate platform and represent a major marine transgression during Late Devonian to Mississippian time.

STRATIFORM BARITE/SULPHIDE DEPOSITS

The timing of stratiform barite-lead-zinc mineralization in the Kechika Trough coincides with the beginning of a major marine transgression in the Middle to Late Devonian. This metallogenic event is represented in the stratigraphic record by a very siliceous and carbonaceous sequence of shale, argillite, and chert which typically contains laminae of nodular barite and pyrite. Locally, the nodular barite grades into beds of massive laminated barite which may or may not have an associated sulphide facies.

The most significant barite-sulphide deposits, Cirque (MI 94F-8), Mount Alcock, and Elf, are restricted to the western shale belt (Fig. 12). This shale belt may represent muds deposited in the deepest part of the Kechika Trough (Fig. 15), in a more reducing environment that favoured sulphide deposition. Such deposition may have occurred in one or more euxinic, third order basins within the trough. Roberts (1977) has

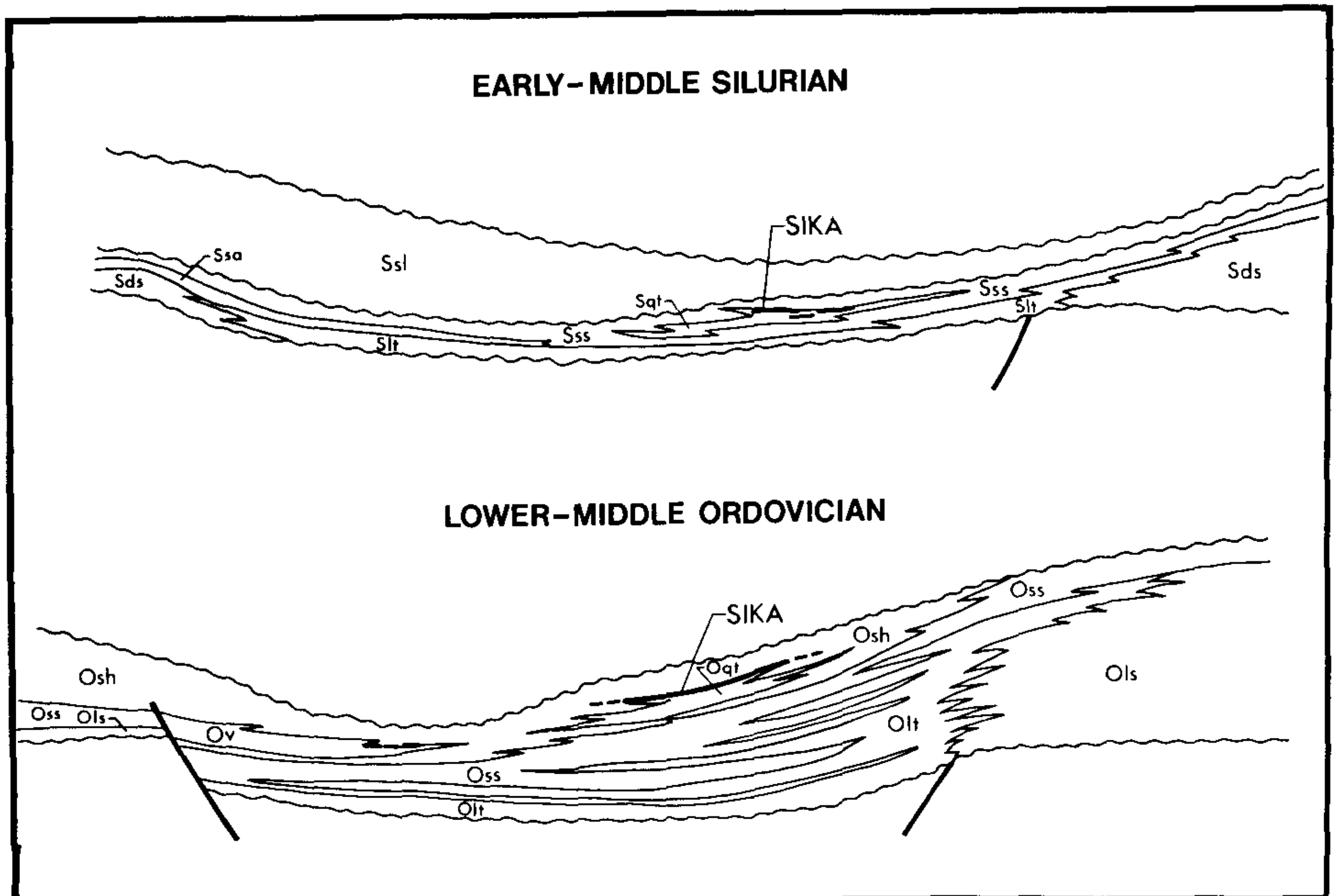

Figure 14. Idealized sections across Akie River shale basin showing possible facies relationships during Ordovician and Silurian time.

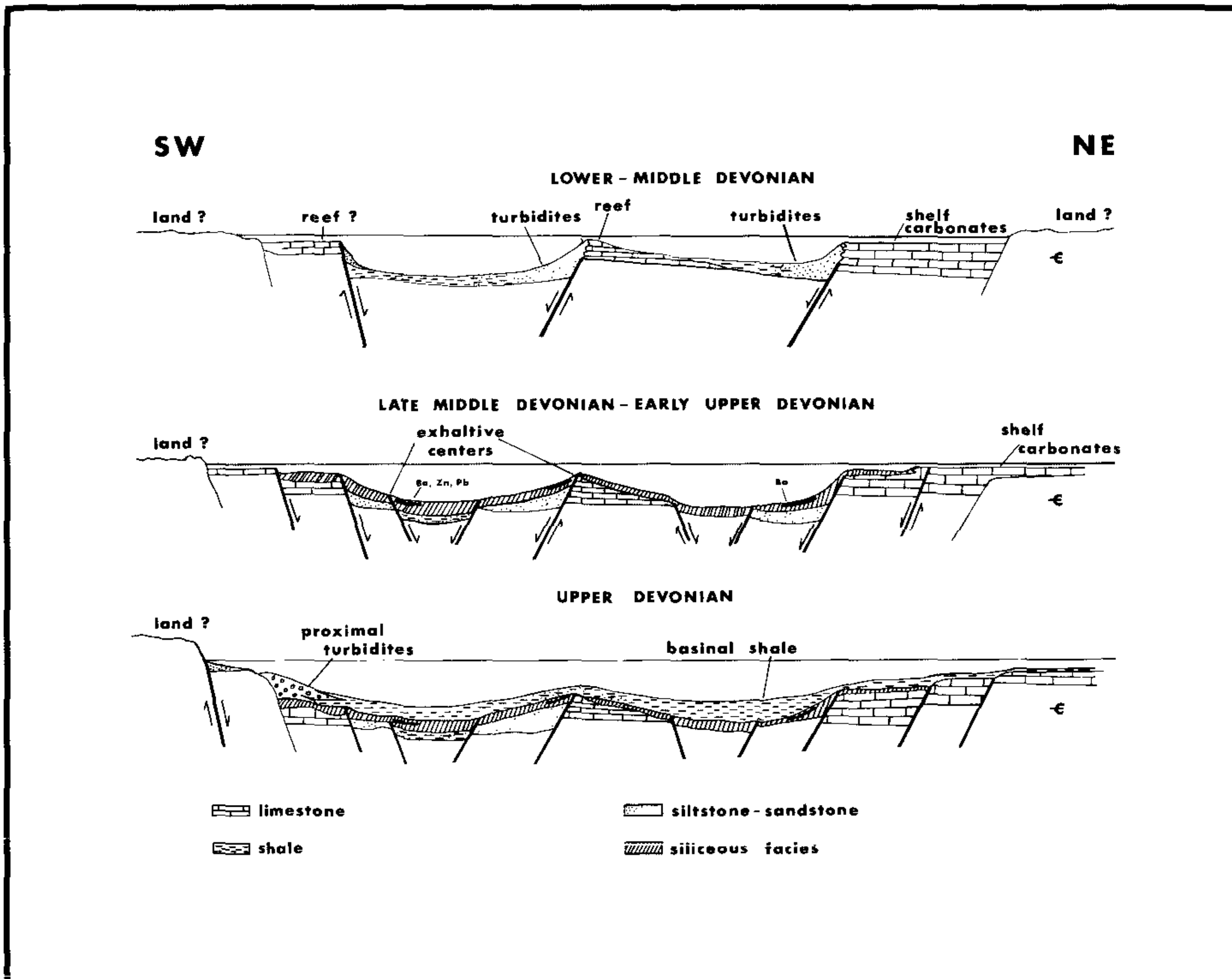

Figure 15. Idealized sections across Akie River shale basin showing sedimentary environments during Early, Middle, and Late Devonian time.

cited anomalous thickening of the siliceous facies as evidence for such a basin at Cirque property. Furthermore, local breccias occur within the mineralized interval at Cirque and may have originated as debris flows that were triggered by movement along nearby synsedimentary faults. The deposit itself, which contains in excess of 30 million tonnes of 10 per cent lead and zinc and 46.65 grams per tonne silver, thickens considerably down dip and to the northwest. The massive bedded barite grades vertically and laterally into laminated massive sulphide toward the northwest, suggesting a feeder vent (Roberts, 1980) in this direction. A similar situation is suggested for the Mount Alcock deposit.

The only major bedded barite occurrence of Devonian age in the eastern shale belt is the Kwadacha deposit (section 16, Fig. 13). It is located immediately north of the southern boundary of Kwadacha Wilderness Park (Fig. 12) and occurs in siliceous argillites and shales overlying Lower Devonian limestone turbidites. The baritic interval, which is up to 30 metres thick, is divisible into a lower unit of interbedded barite and siliceous shale (10 to 15 metres), a middle unit of shale with minor limestone (5 to 10 metres), and an upper unit of medium-bedded grey rusty weathering laminated barite (5 to 10 metres). The limestone contains abundant two-hole crinoid plates, suggesting an early Middle Devonian age. The upper bedded barite unit is overlain by recessive, rusty weathering black shales which locally contain laminae of nodular barite. To date, sulphides have not been found associated with the Kwadacha barite deposit.

DISCUSSION

The stratigraphic setting of shale-hosted barite-sulphide deposits in the Akie River district is strikingly similar to that of Devonian deposits in both the MacMillan Pass area of the Yukon (Carne, 1979) and in West Germany. The deposits, which are clearly syngenetic, typically occur within a siliceous, carbonaceous black argillite or shale facies underlain by or interfingered with proximal to distal turbidites and overlain by deeper water, basinal black shales. This indicates that mineralization coincided with the early stages of a major marine transgression (crustal downwarping ?) which may also have been accompanied by rifting and exhalative activity within the shale basin.

A synsedimentary graben structure and a stockwork feeder zone have been defined at MacMillan Pass (Carne, 1979) but are still unrecognized in the Akie River area. However, in the Akie River area the mineral deposits appear to be associated with northwest-trending interbasin rifts. This rift system was the locus of periodic volcanic and hydrothermal activity from Middle Ordovician to Late Devonian time.

The massive barite-sulphide deposits are wedge to lens-shape and generally lack pelitic interbeds. These features are consistent with Sato's (1972) model of rapid accumulation of dense metalliferous brines in a sea floor depression adjacent to an exhalative vent. A period of alternating pelitic sedimentation and syngenetic to early diagenetic pyrite crystallization accompanied and followed the main episode of barite precipitation and was apparently restricted to the same basin of deposition. It is suggested that the source fluids for both types of mineralization emanated from vents located along the rift zones bounding third order basins. These metalliferous fluids were probably derived by dewatering of underlying shales. Elevated heat flow along the deep-seated rifts may have been the driving mechanism for fluid circulation.

ACKNOWLEDGMENTS

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Roberts, Rob Carne, Charlie Jefferson, Dan Kilby, Mike Cecile, Bob Thompson, Gordon Taylor, and Hugh Gabrielse provided a useful and informative introduction to the area. Kevin Heather, Mike Fournier, and John Mawdsley ably assisted in the field.

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TABLE 1

FACIES DESCRIPTIONS

UPPER DEVONIAN

D_{sh} – Blue grey weathering, fissile black shale. Locally silty and laminated. Rusty brown weathering with minor pyrite and nodular barite near base of unit. Recessive unit.

MIDDLE–UPPER DEVONIAN

D_{sa} – Light bluish grey to dark greenish grey, blocky weathering, rhythmically bedded laminated siliceous argillite, banded chert, siliceous shale, laminated silliceous silty shale, and siltstone. Contains bedded and nodular barite and laminated massive pyrite beds with varying amounts of galena and sphalerite. Thin black fetid limestone and fossiliferous limestone debris flows and turbidites common where unit transgresses shale-carbonate transition zone. Resistant unit.

LOWER–MIDDLE DEVONIAN

D_{ss} – Dark grey weathering, thin-bedded laminated to cross-laminated black silty shale turbidites with minor dark grey argillaceous siltstone and thin orange weathering calcarenite interbeds. Recessive unit.

D_{sl} – Dark grey blocky weathering, thin to medium-bedded laminated and cross-laminated siltstone and sandstone turbidites with thin argillaceous limestone and orange weathering, calcarenite interbeds. Moderately resistant unit.

D_{qt} – Medium grey blocky weathering, medium to thick-bedded quartz siltstone, sandstone, and pebble conglomerate proximal turbidites. Interbedded argillaceous limestone turbidites and graptolitic black shale. Resistant unit.

D_{lt} – Light grey, blocky weathering, medium to thick-bedded limestone turbidites and debris flows. Minor interbedded quartz, siltstone, and graptolitic black shale. Resistant unit.

D_{ls} – Light grey blocky weathering, medium to thick-bedded dark grey argillaceous limestone. Fossiliferous. Resistant unit.

SILURIAN

S_{sl} – Brown to orange, platy to blocky weathering, massive, thick-bedded to thin flaser-bedded dolomitic siltstone. Minor grey laminated limestone and/or dolostone interbeds. Worm burrows and feeding trails common. Resistant unit.

S_{ss} – Dark grey, platy weathering silty shale and siltstone turbidites. Recessive unit.

S_{sa} – Interbedded black chert and grey weathering limestone and/or dolostone turbidites. Slump structures and cherty bands common in limestone. Resistant unit.

TABLE 1 – *Continued*

S_{lt} – Grey, platy weathering, thin-bedded laminated to cross-laminated limestone and dolostone turbidite. Minor shaly interbeds. Resistant unit.

S_{qt} – Orangy grey blocky weathering, massive, thick to medium-bedded dolomitic quartz sandstone and siltstone turbidites. Resistant unit.

S_{ls}/S_{ds} – *Grey to orangy grey, blocky weathering, massive, thick to medium-bedded limestone and/or* dolostone. Resistant unit.

MIDDLE ORDOVICIAN

O_{sh} – Dark to bluish grey weathering black shale. Contains Middle Ordovician graptolite assemblages. Very recessive unit.

O_{qt} – Grey blocky weathering, massive, medium to thick-bedded quartz siltstone, sandstone, and conglomerate, proximal turbidites. Thin black shale interbeds common. Very resistant unit.

O_{v} – Orange weathering, crystal, lithic, and lapilli tuff with black shale interbeds. Greenish grey blocky weathering microdioritic flows locally underlie tuff horizon. Resistant unit.

LOWER TO MIDDLE ORDOVICIAN

O_{ss} – Light brown to cream weathering, laminated silty shale and dark grey argillaceous siltstone with thin iron oxide streaks. Locally calcareous. Thin cream platy weathering laminated limestone interbeds common. Recessive unit.

O_{lt} – Light grey to yellowish weathering, medium to thin-bedded, laminated to cross-laminated limestone turbidites. Minor dark grey silty shale interbeds.

O_{ls} – *Grey, blocky weathering, medium to thick-bedded massive limestone. Fossiliferous. Resistant* unit.

LITHOGEOCHEMICAL STUDY OF THE 'CASSIAR MOLY' DEPOSIT CASSIAR MAP–AREA (104P)

By A. Panteleyev

INTRODUCTION

Recent regional mapping in Cassiar map-area (*see* Geological Fieldwork 1978 and 1979, Papers 1979-1 and 1980-1) has focussed on a number of areas with significant molybdenum mineralization. The main prospects include the Storie Mo (Casmo) project of Shell Canada Resources Limited, the 'Cassiar Moly' prospect (MI 104P-35) of Cassiar Resources Limited, and the Lamb Mountain (STAR or WINDY) molybdenum-tungsten prospect (MI 104P-3) of Union Carbide Exploration Corporation Limited. All these deposits are associated with Upper Cretaceous rocks of the so-called Troutline Creek quartz monzonite or Cassiar Stock, a coarse-grained porphyritic pluton emplaced along the eastern margin of the late Lower Cretaceous Cassiar batholith (Panteleyev, 1980).

Cassiar Moly deposit was selected for closer examination during 1980 in order to investigate the lithogeochemical expression of this large, diffuse mineralized zone. The prospect offers an opportunity to sample mineralized rocks that are well exposed in an area with much topographic relief. Figure 16 outlines the 10-kilometre-square area investigated and shows locations of 52 samples collected over a vertical range of 860 metres. The samples are currently being analysed for a number of elements including molybdenum, tin, tungsten, and fluorine.

EXPLORATION HISTORY

Molybdenite showings are on the flanks of a 2 185-metre peak approximately 9.5 kilometres south of Cassiar townsite. The showings were discovered in 1966 and acquired by Value Line Minerals Limited, of Calgary, as the RUSTY, ELOISE, X, and other claim groups (MI 104P-35). Starting in 1967 the company explored the prospect for three consecutive summers. Their main effort was spent in driving a 1 023 (1 067 ?)-metre adit northwestward to intersect favourable rock types and to pass beneath small high-grade showings west of the peak (Fig. 17). In addition, some geological mapping, prospecting, and limited diamond drilling were done. Drill results are poorly documented and available information is fragmental. It is said (C. J. Brown and other sources, 1980, personal communication) that four drill holes totalling 532 metres were completed from underground and two surface diamond-drill holes totalling 457 metres were put down east of the adit. Samples from the underground workings show molybdenite concentrated in narrow fractured zones, some with spectacular grades. One sample contained 4.17 per cent MoS_2 over 1 metre and another had 1.64 per cent MoS_2 over 3 metres. However, over-all molybdenite grade is low, for example, 0.026 per cent MoS_2 across 100 metres in the crosscut (*see* Assessment Reports 1700 and 7206).

The property was relocated in 1977 by W. Elsner as the ANGEL group and subsequently acquired by Cassiar Resources Limited. Cassiar considered the possibility of ore at depth and, in 1980, remapped the property. Accessible portions of the mineralized zone were tested with three angle holes drilled westerly for a total depth of 1 370 metres.

GEOLOGY

'Cassiar Moly' deposit is in the south-central part of the Troutline Creek quartz monzonite stock more than 2 kilometres from the nearest intrusive contact with Paleozoic metasedimentary rocks. The claim area is dominated by a large northward trending rusty zone of closely jointed and fractured rocks that are associated with small, finer grained intrusive rocks.

Rocks in the study area consist, in essence, of two granitic types: (1) the regional coarse-grained rocks and their local textural variants (Fig. 16, map units 1, 1A, and 1B), and (2) small bodies of equigranular alaskite and quartz monzonite porphyry as well as some related aplite and pegmatite segregations.

Map unit 1 is regional in extent and is a megacrystic hornblende biotite quartz monzonite or granite porphyry. It contains perthitic K-feldspar phenocrysts up to 4 centimetres in length as well as somewhat smaller phenocrysts of quartz, plagioclase, and biotite. The matrix is a fine to medium-grained mosaic of quartz-plagioclase-orthoclase-biotite and rare hornblende. Over-all colour is pink though there are local variations to grey.

The main textural variant (map unit 1A) of the megacrystic porphyry is a rock of similar composition and colour but with smaller phenocrysts. It ranges from very coarse-grained porphyry with K-feldspar phenocrysts to 2 centimetres in a medium-grained matrix, to coarse-grained porphyry with both K-feldspar and albite phenocrysts to 1 centimetre in a finer grained matrix. It can also be medium grained, equigranular, or porphyritic with medium-grained feldspars and biotite set in a finer grained matrix.

The other textural variant (map unit 1B) is similar to map unit 1A. It can be distinguished by its grey matrix that is caused by abundant fine-grained biotite. The biotite is bimodal and present both as grains to 5 millimetres in size and as fine, disseminated flakes dispersed throughout the matrix. In addition, this grey porphyry contains a greater than average number of inclusions. The inclusions are commonly spherical bodies a few centimetres to 50 centimetres in size although larger, tabular zones are present southwest of drill hole 3. The inclusions consist of fine-grained biotite quartz diorite to quartz monzonite and are thought to be granitized roof zone metasedimentary rocks.

Rapakivi texture, mantling of K-feldspar phenocrysts by albite, is common in all coarse porphyritic rocks in the map-area. This texture is characteristic of map units 1A and 1B.

Map unit 2 is a heterogeneous assemblage of mainly fine-grained leucocratic rocks but also includes coarse quartz feldspar porphyry, minor aplite, some pegmatite pods, and lenses or screens of megacrystic porphyry. The rocks form northeasterly to northward trending, steeply dipping dykes that crosscut the coarser rocks of units 1, 1A, and 1B. The dominant rock type of unit 2 is a fine-grained equigranular to granophyric alaskite that grades into buff to pink, fine to medium-grained porphyritic quartz monzonite. Contained within the finer grained zones are 'blind' lensoid bodies of coarse-grained quartz-eye feldspar porphyry, some of which have albite as the dominant feldspar phenocryst. In addition, a few quartz feldspar porphyry dykes up to 5 metres in width cut the megacrystics textural variants. These small dykes commonly have thin pegmatite selvages and, in one locality, pods of greisen occur along the contact.

Contacts between map units 1, 1A, and 1B as shown on Figure 16 are arbitrary. Distinctions are based on differences in grain size, texture, fabric, and colour. Mapping shows that changes are gradational and related to topography. That is, the coarse porphyries occur as subhorizontal zones and the textural variants are exposed on ridge crests at the highest elevations.

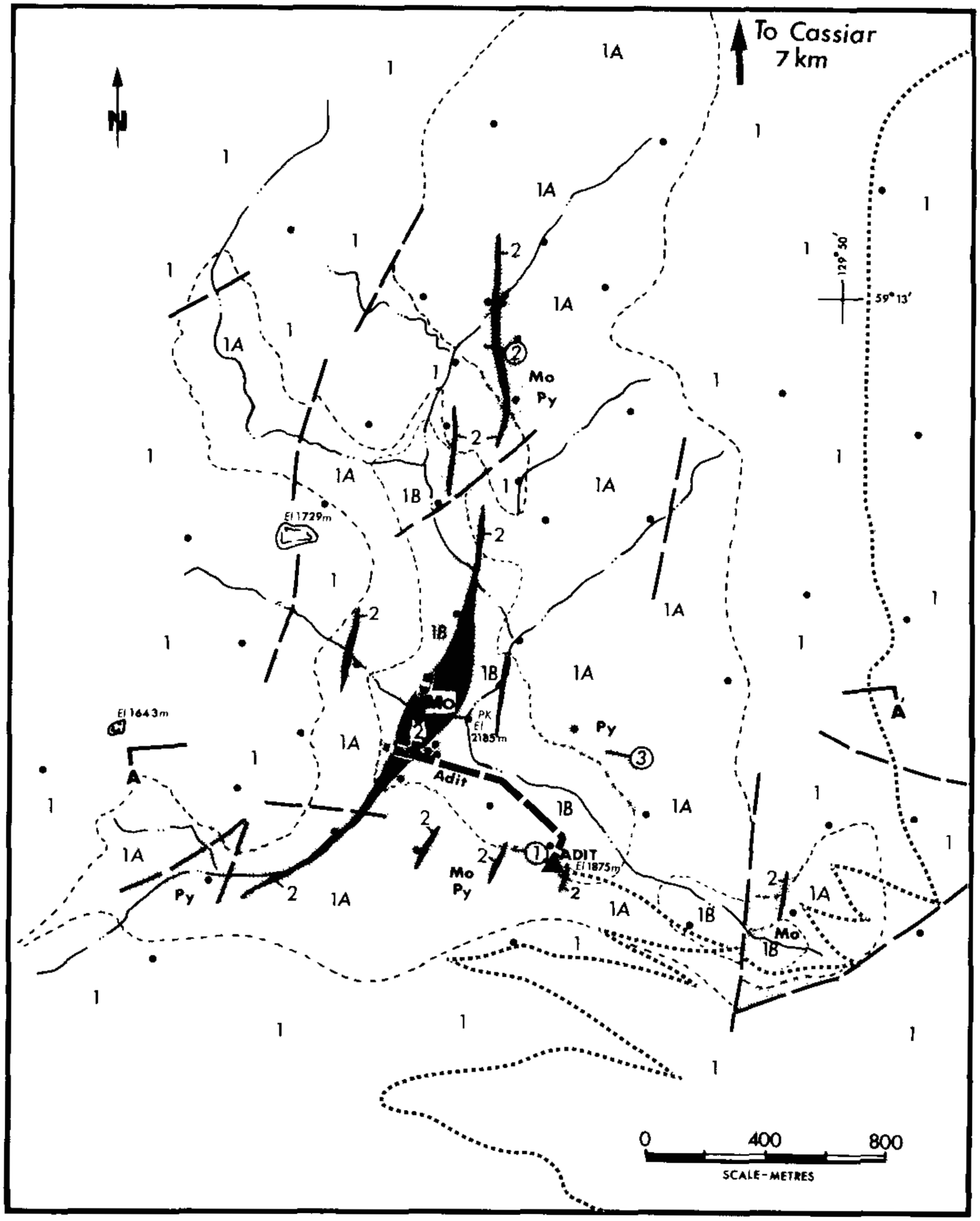

Figure 16. Geology of the 'Cassiar Moly' deposit (MI 104P-35).

LEGEND

CASSIAR STOCK (TROUTLINE CREEK QUARTZ MONZONITE) 73±2.5 Ma

2 — **MINOR INTRUSIONS, SEGREGATIONS**: FINE TO MEDIUM–GRAINED, EQUIGRANULAR, BUFF TO PINK QUARTZ MONZONITE; IN PART PINK QUARTZ MONZONITE PORPHYRY, K–FELDSPAR MANTLING RARE TO ABSENT; INCLUDES SOME QUARTZ–EYE PORPHYRY, APLITE, AND RARE PEGMATITE, MAFIC–RICH SEGREGATIONS, GREY QUARTZ MONZONITE INCLUSIONS AND MINOR XENOLITHS WITH SULPHIDE AND CALC–SILICATE MINERALS

1 — **REGIONAL UNIT**: MEGACRYSTIC HORNBLENDE BIOTITE QUARTZ MONZONITE PORPHYRY; PINK, VERY COARSE GRAINED

TEXTURAL VARIANTS OF UNIT 1

1A — BIOTITE QUARTZ MONZONITE PORPHYRY AND PORPHYRITIC QUARTZ MONZONITE; MEDIUM TO COARSE GRAINED, PINK AND GREY, K–FELDSPAR PHENOCRYSTS ABUNDANT, MANY MANTLED BY ALBITE

1B — QUARTZ MONZONITE PORPHYRY; GREY, SOME FINE–GRAINED BIOTITE IN MATRIX, K–FELDSPAR VARIES IN ABUNDANCE, ALBITE MANTLING COMMON TO RARE IN K–FELDSPAR–ALBITE PORPHYRY, GREY FINE–GRAINED INCLUSIONS COMMON

SYMBOLS

RIDGE CREST . . . .

ACCESS ROADS . . . .

1980 DIAMOND–DRILL SITE 1

INTRUSIVE CONTACT, GRADATIONAL . . . .

INTRUSIVE CONTACT, DISTINCT . . . .

FAULT/FRACTURE ZONE . . . .

ROCK GEOCHEMISTRY SAMPLE SITE . . . .

MINERALIZED ZONE INDICATING MAIN SULPHIDE MINERALS . . Mo

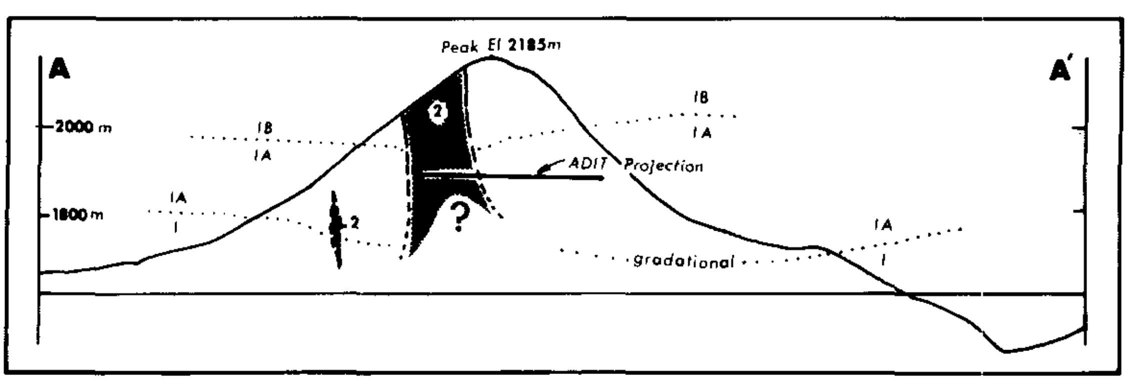

Figure 17. 'Cassiar Moly' deposit, cross-section A—A', looking northward.

Clearly the fine-grained leucocratic to porphyritic rocks of map unit 2 crosscut the coarser porphyries; in detail their contact relations are enigmatic. Frequently it appears that rocks of unit 2 are intergradational with rocks of map unit 1 and its variants, especially at the terminations of the dyke-like bodies. In such settings there appears to be a zone of mutual interaction between the alaskitic rocks and the coarse porphyries. At outcrop scale this interaction is expressed as mixed coarse-fine lithologies. The mixed zones contain small aplite dykes, simple pegmatite pods, and rare, zoned spherical segregations up to 1 metre in diameter with quartz-orthoclase pegmatite cores and biotite-rich, molybdenite-bearing, layered rinds. Away from the dyke terminations the contact between both large and small dykes and coarse country rocks is sharp or consists of aphanitic to aplitic alaskite, fine-grained equigranular quartz monzonite, or porphyritic quartz monzonite in a layered zone up to 1 metre in width. However, it is unlikely that the rocks of unit 2 are actually chilled against the coarser rocks. Instead, the contact zone appears to be one of mutual quenching of two, crystal-bearing magma mushes that contain pockets of volatile-rich residual fluids.

Jointing is well developed throughout the map-area. Joint-bounded blocks in the coarse megacrystic porphyry tend to be large and rectilinear but those in the textural variants and map unit 2 are more slab like. The grey porphyry of map unit 1B, for example, has closely spaced, curvilinear slab-jointing. Faults tend to follow the two main joint sets; they dip steeply and trend 010 and 040 degrees.

Traces of molybdenite and minor pyrite are found in fractured and fine-grained rocks and dykes of map unit 2 as well as in isolated areas along the ridge southeast of the peak. Within this broad zone of diffuse mineralization, molybdenite is present mainly as small rosettes and flakes in the fine, granular rocks and in fractures and joints within quartz feldspar porphyries and their adjoining megacrystic porphyries. One of the main controls of mineralization is increased fracture density and the best mineralization occurs where closely spaced fracture sets intersect. The fractures in this case are joints and minor fault zones with argillic alteration (so-called 'shears') that parallel the main steeply dipping 010 and 040-degree joint sets. Two other joint sets containing pyrite and some molybdenite trend northwesterly and northeasterly with 45 to 60-degree northward dips. These intersecting flatter joint sets give rise to rusty stain on many of the outcrop faces.

Locally 'high grade' pods with spectacular coarse molybdenite crystals up to 4 centimetres in size are found in or near rocks of map unit 2. These zones are small in size and erratically distributed. They consist either of quartz-rich layered pegmatite a few metres to a maximum of 12 metres in size and much smaller bodies of spherical, zoned pegmatite with biotite-rich rinds or, rarely, quartz-sericite-rutile-molybdenite greisen. One pegmatite locality west of the peak contains layered pyrrhotite-bearing calc-silicate rock that is presumably derived from calcareous xenoliths.

Quartz veins are not common and no breccia of consequence has been recognized. Some fractures have vuggy crystalline quartz linings with or without molybdenite and/or pyrite. Many of the massive quartz veins contain molybdenite and less commonly K-feldspar, magnetite, and traces of fluorite. Rock alteration is unobtrusive and that which occurs in generally argillic-type related to fracture zones and faults.

A MODEL FOR 'CASSIAR MOLY' DEPOSIT

The 'Cassiar Moly' prospect is not like the typical Cordilleran stockwork or porphyry-type molybdenum deposits. Nonetheless, it is becoming increasingly evident from ongoing work both there and at the nearby Storie molybdenum deposit, that this style of deposit has economic merit and importance. This type of molybdenum environment can be called the 'dry,' fracture-related, alaskite-pegmatite type.

These deposits occur in shallow settings in the roof zone or in cupolas of small batholithic intrusions, in this case the Troutline Creek quartz monzonite (Panteleyev, 1980). Evidence for high level emplacement includes the following:

(1) Large-scale subhorizontal textural and possibly compositional layering (that is, flat-lying contacts of major map units 1, 1A, and 1B).
(2) Abundant inclusions and xenoliths of granitized metasedimentary and calc-silicate rocks; a large marble-skarn roof pendant was mapped 4.6 kilometres to the northwest (Panteleyev, 1980).
(3) Abundance of: porphyritic, Rapakivi, and granophyric textures, miarolytic cavities, and sheeted, curvilinear joints.

It appears that magma was emplaced in a single episode, then underwent normal fractional crystallization. The extensive development of Rapakivi texture with albite mantling perthite phenocrysts reflects solidus-solvus shifts caused by changes in water pressure within the cupola zone during crystallization. These disequilibrium conditions may have occurred as a result of emplacement of the steep dyke-like bodies of map unit 2. The dykes represent residual melts of near minimum granite melt composition that were segregated and quenched by influx into zones of dilation. Consequently, contacts are intergradational with the megacrystic country rocks and there are crosscutting finer grained alaskitic rocks. There is no evidence of any other more forceful pressure release, such as venting or piercement of the subhorizontal layers in the cupola zone by younger intrusions.

Quenching of residual fluids to produce alaskites resulted in synchronous deposition of disseminated rosettes and flakes of molybdenite in the fine-grained rocks. Elsewhere, concentration by diffusion of volatiles from interstitial fluids produced local pockets of vapour saturation that resulted in crystallization of pegmatite, greisen pods, and also weak mineralization in early formed fractures, joints, and faults. The amount of volatiles evolved was relatively small and too limited to cause brecciation, hydrofracturing, extensive quartz vein stockworks, quartz flooding, or widespread rock alteration. The impact of meteoric water also was too limited in the granitic mass to cause any significant late-stage argillic or phyllic alteration.

In summary, the potential of this type of geological setting and style of molybdenum mineralization might be underestimated because this type of mineralization could be an expression of leakage from a zone of volatile concentration at depth. If such volatile entrapment exists, the potential for significant volumes of mineralization is enhanced. Hopefully this and other lithogeochemical studies will help to discriminate between potentially productive versus barren intrusions.

Useful comparisons between the setting of the Cassiar molybdenum deposits might be made with similar molybdenum deposits at Questa, New Mexico (Carpenter, 1968), Newfoundland (Whalen, 1980), and in the Grenville province (Vokes, 1963).

ACKNOWLEDGMENTS

It is a pleasure to acknowledge the cooperation and hospitality of Cassiar Resources Limited, especially C. J. Brown. Don Travers assisted the writer in the field.

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CASSIAR GOLD DEPOSITS
McDAME MAP–AREA
(104P/4, 5)

By L. J. Diakow and A. Panteleyev

INTRODUCTION

A mapping program at scale 1:10 000 encompassing approximately 120 square kilometres was initiated in 1980 in the area containing all the significant lode gold deposits east and southeast of Cassiar townsite. **Mapping**, centred on McDame Lake near Highway 37, covers the area from Quartzrock (Quartz) Creek adjacent to the Cassiar road on the north to Table (Tabletop) Mountain and the headwaters of Pooley Creek on the south. The area is between longitude 120 degrees 35 minutes and 129 degrees 46 minutes and latitude 59 degrees 7 minutes and 59 degrees 17 minutes (Fig. 18).

The main purpose of this mapping is to document stratigraphy, structure, and the distribution of quartz veins in the region. Geological mapping will be extended somewhat and selected areas studied in more detail during the 1981 field season.

HISTORY

Activity related to gold in Cassiar area has been ongoing since the discovery of placer gold in McDame Creek in 1874. In total some 70,000 ounces of placer gold was recovered, mainly between 1874 and 1895, although small-scale placer mining continues to date. Free gold in quartz veins was discovered on Troutline (Trout) Creek by F. F. Callison in 1934 which led to the discovery of many more veins during the next three years. During 1937 The Consolidated Mining and Smelting Company of Canada, Limited did extensive work including diamond drilling in the area. With rare exceptions, all the veins that are of interest today had been located and tested by 1939.

High-grade portions of some of the veins have been exploited by small-scale mining. In 1934, 1 ton of ore containing 4 ounces of gold from the discovery vein was shipped by air by Callison. In 1939, A. W. Boulton recovered 114 ounces of gold and 20 ounces silver from 130 tons of ore from the Erickson Creek (Jennie) vein. During each following decade a few tens of tons to a maximum of 100 tons of ore was mined from one or more of the five or six main deposits. In total, there are five abandoned millsites in the map-area, none larger than 12 tons per day capacity, and the remains of a 200-ton-per-day crusher site are at Snow (Snowy) Creek.

Boulton's venture remained the single biggest mining effort in the area until late in 1978 when Erickson Gold Mining Corp. (Nu-Energy Development Corporation and The Agnes & Jennie Mining Co. Ltd.) began milling ore. Full production began on January 18, 1979, and to the end of that year the company milled 28 296 tonnes with average recovery of almost 20.9 grams per tonne of gold and 20.5 grams per tonne of silver per tonne of ore (590 900 grams gold and 581 522 grams silver). Mining and milling continued in 1980 and the mill capacity is expected to be increased to 150 tonnes per day in 1981. Also in 1980, on the 18th of September, Cusac Industries Limited began milling a small stockpile of high-grade ore in their 30-tonne-per-day mill. The source vein is one of the rare new discoveries in the area. In addition, Plaza

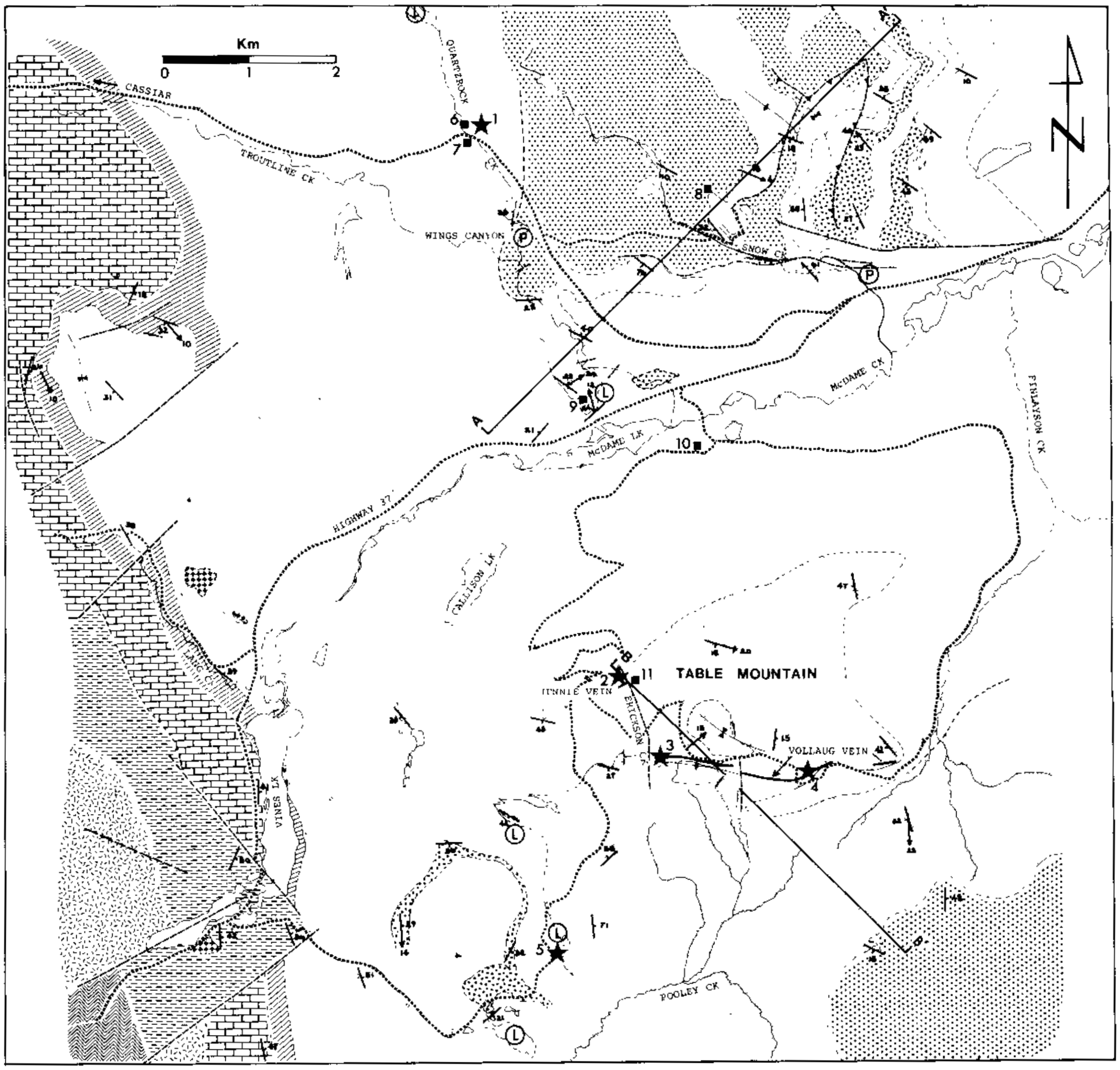

Figure 18. Geology of the McDame map-area.

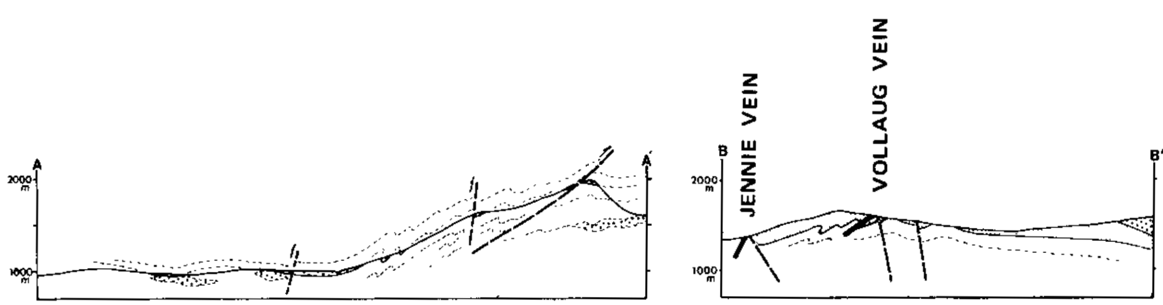

Figure 19. McDame map-area, cross-sections; for location *see* Figure 18.

LEGEND

SYLVESTER GROUP (MISSISSIPPIAN TO ? PERMIAN)

4 BASALT: WIDESPREAD PILLOWS, SOME BRECCIA, TUFF, AND MINOR ARGILLITE; IN SOUTHEAST, ABUNDANT BRECCIA, TUFF, AND SMALL LIME-STONE PODS

3 SILTSTONE, ARGILLITE, GREYWACKE, PEBBLE CONGLOMERATE, QUARTZ ARENITE, CALCAR-EOUS SILTSTONE, LIMESTONE

2 GREENSTONE–CHERT ASSEMBLAGE: MASSIVE PALE TO DARK GREEN ANDESITE FLOWS, TUFF, IN PART FINE-GRAINED DYKES AND SILLS, SOME CHERT, INCLUDES PORPHYRITIC FELD-SPATHIC ANDESITE FLOWS (AND ? SILLS)

2A CHERT, TUFFACEOUS CHERT, INCLUDES SOME ARGILLITE; IN NORTHEAST WELL-LAYERED CHERT–PHYLLITE, TUFFACEOUS CHERT, RIB-BONNED CHERT, AND ARGILLITE

1 ARGILLITE, SILTSTONE, CHERT, QUARTZITE, LIMESTONE, PEBBLE CONGLOMERATE, TUFF; INCLUDES NUMEROUS DIABASE AND ANDESITE SILLS

1A DIORITE: SMALL PLUGS AND SILLS IN UNIT 1 AND OLDER ROCKS

INTRUSIVE ROCKS

TROUTLINE CREEK QUARTZ MONZONITE (CASSIAR STOCK), UPPER CRETACEOUS

QUARTZ MONZONITE PORPHYRY

BEDDED ROCKS

SANDPILE AND McDAME GROUPS (ORDOVICIAN AND DEVONIAN

LIMESTONE, DOLOMITE

KECHIKA GROUP (CAMBRIAN AND ORDOVICIAN)

SHALE, ARGILLITE

ATAN GROUP (LOWER CAMBRIAN)

CALC–SILICATE HORNFELS, HORNFELS

SYMBOLS

ACTIVE PROPERTIES ....

ABANDONED MILL SITES ....

MAJOR PLACER WORKINGS .... (P)

BEDDING 15

FOLIATION 42

MAJOR FOLD AXIS ....

MINOR FOLD AXIS 23

FAULT – NORMAL, THRUST ....

QUARTZ–CARBONATE ALTERATION (LISTWANITE) . (L)

ROAD ....

★ OPERATING PROPERTIES

1	UNITED HEARNE RESOURCES LTD.	104 P / 012
2	ERICKSON GOLD MINING CORP.	104 P / 029
3	TABLE MOUNTAIN MINES LIMITED	104 P / 019
4	PLAZA RESOURCES CORP.	
5	CUSAC INDUSTRIES LTD.	

■ FORMER MILL SITES

6	CORNUCOPIA (HANNA, BENROY)	104 P/012
7	GLEN HOPE (QUARTZROCK CREEK)	104 P/010
8	SNOW CREEK	104 P/014
9	TROUTLINE CREEK GOLD MINES	VARIOUS
10	NORA (DAVIS)	104 P/018
11	ERICKSON CREEK (BOULTON)	104 P/029

Resources Corporation began stripping and stockpiling ore in anticipation of future milling; engineering studies leading to production were proceeding for United Hearne Resources Limited; and advanced exploration work was being done by Table Mountain Mines Limited, Esso Resources Canada Limited, Newcoast Silver Mines Limited, and others (*see* Fig. 18 for locations).

GEOLOGIC SETTING

Host rocks for the gold-bearing quartz veins are Sylvester Group volcanic and sedimentary rocks of Mississippian to Permian age (Monger, 1980, personal communication) that form the core of the McDame synclinorium (Gabrielse, 1963). These rocks are mainly a greenstone-chert-argillite assemblage that is believed to be an allochthonous oceanic terrane thrust onto the carbonate and clastic rocks of the Cassiar platform (Monger, 1977).

LITHOLOGIES

The map-area is divisible into two major units: a lower sedimentary-volcanic assemblage consisting of fine-grained clastic rocks, andesitic fine-grained volcanic rocks, and diabasic or porphyritic intrusions, and an upper part composed primarily of massive and pillowed basalt.

In more detail, the basal unit (map unit 1) overlies McDame Group and consists of approximately 150 metres of mainly argillite, siltstone, and their calcareous equivalents, as well as some chert, quartzite, limestone, pebble conglomerate, and tuff. North of Lang Creek, diabase to medium-grained porphyritic andesite sills 5 to 15 metres in thickness are well exposed and intrude siliceous (cherty) tuffs near the top of this succession. We suspect that similar and considerably thicker sills are present throughout much of the map-area. This unit is also intruded by small bodies of medium-grained diorite (map unit 1A).

The overlying unit (map unit 2) is made up of fine-grained volcanic rocks of andesitic and possibly slightly *more acidic composition. They are interbedded with varying amounts of chert and medium-grained diabasic* to porphyritic feldspathic volcanic rocks that are probably sills. The fine-grained volcanic rocks form massive outcrops along Highway 37 and the walls of McDame Valley. These rocks are dark grey-green to brown and orange weathering but are pale grey-green when freshly broken. In the western and central parts of the map-area, little can be deciphered from the highly fractured and jointed but otherwise homogeneous outcrops. It appears that there are thick, massive units of both flows and tuffs that are of similar composition and texture. In detail, there is rare chert, and tuffaceous chert interbeds or lenses can be found as well as rare zones of flow breccia. Generally, flow breccia occurs as local, small zones with sparse, small clasts. One exception occurs on Table Mountain at the top of this map unit where excellent flow breccia developed with large, closely packed clasts.

Thin, reticulate chlorite veinlets that impart a webbed appearance to the rock are a common feature in the fine-grained volcanic rocks. Where the chlorite veinlets are abundant and well developed, the rock can have a brecciated appearance with angular 'fragments' surrounded by linear or interconnected, braided zones of chlorite veining.

To the south and west, in the vicinity of Cusac Industries' millsite, the fine-grained volcanic unit contains abundant interbedded chert and tuffaceous chert. These form chalky weathering pale, green to grey and brown massive outcrops that can be traced throughout the immediate area. They constitute continuous, mappable units, even though their contacts are somewhat arbitrary (map unit 2A).

In the northeastern part of the map-area north and east of Snow (Snowy) Creek and along Highway 37, volcanic rocks in the fine-grained volcanic map unit are similar to those seen elsewhere but contain considerably more, thinly bedded chert, tuffaceous chert, tuff, argillite, and impure quartzite. The rocks are very well bedded with interlayered thin-bedded to ribbon chert and phyllitic sedimentary rocks in tuff-argillite and tuff flow units that are in the order of 50 to 150 metres in thickness.

Note that although all the siliceous rocks in this volcanic unit and throughout the map-area are fine grained to microcrystalline, they range from thin to thick-bedded to massive layers. Consistently they appear to be chert or tuffaceous chert not rhyolite or any other acidic pyroclastic or flow rocks.

Bedded fine to coarse-grained clastic rocks (map unit 3) lie stratigraphically above the fine-grained volcanic-sedimentary unit and cap Table Mountain. These consist mainly of siltstone, argillite, greywacke, quartz pebble conglomerate, and quartz arenite. The coarser clastic rocks have abundant fluvial structures, including cyclical graded beds, crosslaminations, ripple marks, and flute casts. Much of the upper part of the succession is calcareous and it contains brown-weathering limestone beds to 1.5 metres in thickness. This map unit (3) appears to have been deposited as turbidites in a shallow, localized basin or trough. The succession appears to fine upwards and to the south and east.

Two kilometres east and southeast of Table Mountain the clastic rocks are overlain by a thick sequence of coarse tuffs and breccias (part of map unit 4). These are the only abundant coarse pyroclastic rocks known in the map-area. This unit also includes sparse pods of crystalline limestone to 5 metres in thickness.

A thick sequence of massive and pillowed basalt (map unit 4) underlies the entire north-central part of the map-area as well as a zone extending southward along Quartzrock and Troutline Creeks. Locally, the sequence contains basaltic tuff and argillite units. The tuffs may be iron rich with abundant magnetite and ferruginous chert and mudstone. Map unit 4 forms the upper part of the Sylvester Group in the map-area.

FOLDING

Two major folding events can be recognized and a third, older event is suspected. Phase 1 ? (F_1) folds, seen only in the northeast, have flat to gently plunging, northwesterly trending axes (Fig. 19). The folds are asymmetrical recumbent structures that probably formed during northeasterly directed thrust faulting. Phase 2 (F_2) is characterized by mesoscopic minor folds and moderately appressed recumbent folds with inclined axes that trend at 55 degrees azimuth. A weak foliation parallels the shallow northwest dip of the axial plane in some folded siltstone beds. Southeasterly plunging phase 3 (F_3) minor folds with well-developed axial plane cleavage are widespread. Axes of these upright folds trend at 150 degrees azimuth parallel to the trend of the McDame synclinorium. Crenulation lineations parallel to the F_3 fold axis occur locally.

A northeast-southwest-trending joint set is well defined in the area. The joints appear to be related to the youngest period of folding (F_3). Northeasterly compression resulted in a shear couple with strongly developed shear joints trending at 070 to 085 degrees as well as 015 degrees. In addition, a northwesterly trending cleavage developed along with northeasterly trending tension gashes. The tension gashes occur in zones trending at 050 degrees but individual gash veins within these zones trend at 040 degrees. The joint density is highest in the greenstone units and lower in the thinly bedded sedimentary rocks. A more detailed study of the jointing in restricted parts of the area was reported by Gabrielse (1963).

FAULTING

Thrust faults as well as steep normal transverse faults with considerable lateral offset are seen in the map-area. Thrust faulting is evident on the ridge north of Snow Creek where there is stacking of phyllite-basalt units. On Table Mountain a series of northerly trending, steeply dipping faults offsets the volcanic-sedimentary contact as well as sections of the Vollaug vein.

The major Erickson Creek fault has considerable oblique slip movement. It truncates the Vollaug vein in the west as well as cutting off the massive andesite flow unit southwest of the Silver Standard camp. Steeply dipping, polished, slickensided fault planes were found at the west end of the Vollaug vein and in Erickson Creek adjacent to the minesite. The displacement on this fault is not known, but it might be considerable. If the Jennie vein is a faulted extension of the Vollaug vein, the throw is about 575 metres.

East of the Erickson Creek fault, sections of the Vollaug vein are offset by small high-angle faults. Other faults are suggested by the displacement of the volcanic-sedimentary contact, localized overturned bedding, and skewed bedding attitudes.

South of Vines Lake, the McDame Formation, which normally underlies Sylvester rocks, is absent. Instead, there is a thick section of Kechika argillite. In addition, south of the fault the contact of the major granite body is displaced to the west about 1 kilometre. This implies that major northeasterly trending faults underlie the northwest flank of Table Mountain and McDame Valley.

LODE GOLD DEPOSITS

As a generalization, apart from its age, the Cassiar lode gold district is very similar in its geological setting to the Archean greenstone gold camps of Eastern Canada (Boyle, 1979; Roberts, 1980).

An excellent historical record and description of the placer and lode gold deposits was documented by Mandy (1931, 1935, and 1937). He recognized the three northeast to east-northeasterly trending greenstone-hosted vein systems that contain many of the well-mineralized veins. The three vein systems are subparallel fracture zones hundreds of metres in width and about 3 kilometres apart. The most southerly is along the south shore of McDame Lake. The middle system is the most extensive with a strike length of about 8 kilometres. It trends from the headwaters of Snow Creek through the junction of Troutline and Quartzrock Creeks and continues to the southwest. The northernmost system starts east of the Cassiar road by Quartzrock Creek bridge and passes southwest toward Troutline Creek. In addition to the three northeasterly trending belts, some of the largest and most continuous veins in the region are ribboned relatively flat-lying structures at or near the greenstone-argillite contact or are steeper massive veins in greenstone and cherty tuff. The most important of these are the Vollaug, Jennie, and Cusac Industries' veins in the vicinity of Table Mountain and on its south slopes toward Pooley Creek.

In the mineralized belts the majority of quartz veins in greenstone dip steeply; dominant trends are 075 and 010 degrees. These veins are a few centimetres to over 5 metres in width and are related to well-developed shear joints and faults. The better veins are commonly 10 to 30 metres apart, about 0.5 metre in width, up to a hundred metres in length, and several tens of metres in a vertical range. Northeasterly trending veins tend to be smaller and fill *en echelon* tension gashes. Many other veins with random orientations are found in faults, fracture zones, bedding planes, and along greenstone-argillite contacts. In the Wings Canyon area of Quartzrock Creek, for example, closely spaced veins resemble saddle reef structures or follow folded bedding contacts. In this highly faulted and altered locality up to 50 per cent of the canyon wall consists of quartz veins.

Veins at the contacts of greenstone with argillite are of secondary importance to those in greenstone. However, this is the setting of some of the largest and most continuous veins in the area, such as the Vollaug and other veins on Table Mountain. The contact in many areas appears to be a plane of décollément (possibly a major thrust fault). Argillite beds along the contact are crumpled and locally contain large boudins of dyke material. Quartz veins along this contact are highly fractured, ribboned, sinewy structures consisting of bone white quartz, minor carbonate, and laminae of graphite. Other more massive white quartz veins occupy crests of folds along the greenstone-sediment contact. Although many quartz veins follow the contact closely, a number clearly crosscut it.

In more detail, veins that are in greenstone are fairly regular in attitude and width although some pinch and swell, split, interconnect, and curve. Vein quartz is typically massive, coarsely crystalline, milky white to cream in colour and contains cream-coloured carbonate grains and veinlets. Local zones display multiple fracturing and healing by several generations of progressively finer grained quartz. These rehealed sections appear to contain some of the better gold-bearing oreshoots. At the extremities of the quartz vein belts, as well as at higher elevations, the veins contain vugs lined with white milky quartz, chlorite, epidote, and coarsely crystalline calcite. Veins of this type are barren.

The veins generally contain few metallic minerals but where these are present they are usually associated with free gold. On average, gold-bearing shoots contain 2 to 3 per cent metallic minerals consisting of pyrite, tetrahedrite, chalcopyrite, and local arsenopyrite, sphalerite, and galena. Near surface, the veins contain limonite, malachite, and azurite; occasionally they carry spectacular free gold in cellular boxworks resulting from leaching of sulphide minerals. Locally black tourmaline and white mica are present in the veins.

Alteration envelopes are pronounced around quartz veins in greenstone but are less obvious in argillite and chert. In greenstone even hairline fractures can have altered margins up to a few centimetres in width. The strong veins have bleached, buff to cream alteration zones up to 10 metres in width. The alteration zones consist of distinctive pale carbonate, quartz, mica, and coarse euhedral pyrite crystals; locally, coarsely crystalline arsenopyrite is developed. Margins of the altered zones are remarkably sharp.

One intriguing highly altered rock type found in the map-area (shown on Fig. 18) and reported from other greenstone gold camps (Karvinen, 1980), is quartz-carbonate rock containing green mica (mariposite). While it is not immediately associated with gold-bearing quartz veins in McDame map-area, it might be important as a regional indicator of favourable terrane. In at least two localities quartz veins are developed in narrow shear zones containing serpentinized volcanic rocks.

The mariposite-bearing rock was referred to as Listwanite by S. F. Leaming (1978) after a term coined by A. Holmes in 1928. The term has found widespread local usage and refers to 'a schistose rock of yellowish green colour composed of various combinations of quartz, dolomite, magnesite, talc, and limonite -- commonly called quartz-carbonate rock with distinctive features due to addition of mariposite.' In McDame map-area it forms large pods as well as smaller bodies that appear to have been emplaced along fault zones and at fault intersections. Karvinen (1980) argued convincingly that these rocks are metasomatized ultrabasic rocks. In Cassiar area, a specimen from Pooley Creek contained 70 ppm cobalt, 1100 ppm nickel, and 2300 ppm chromium, consistent with an ultrabasic origin. However, a similar rock in the same area contains crinoid columnals and a drill hole cored in similar rock nearby was also said to contain fossils

(W. D. Groves, 1980, personal communication). Therefore the origin of the Listwanite and its significance to exploration for gold veins is uncertain.

CONCLUSIONS

- In McDame map-area most quartz veins occur in volcanic flow rocks (greenstone) though some major veins occur at contacts between greenstone and argillite.
- Groups of quartz veins form well-defined east-northeasterly trending belts. These crosscut the major lithologic units.
- Quartz veins appear to be related to structures formed during large and small-scale folding. Lithologic control of veins is secondary.
- 'Exhalites' (chemical precipitates produced by seafloor hotsprings and volcanic vents) are present in the map-area in the form of widespread chert, minor ferruginous tuff, jasper, pyritic dolomite lenses, and rare rhodonite pods. None of these have any obvious association with quartz veining or mineralization.
- No rhyolite or other acidic volcanic rocks were recognized.
- Quartz carbonate alteration accompanies mineralized quartz veins.

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STRUCTURAL MATERIAL INVESTIGATION

SAND AND GRAVEL INVENTORY

By N. M. Hunter and Z. D. Hora

During the past year the Resource Data and Analysis Section has been making an inventory of sand and gravel deposits in the interior of British Columbia. The purpose of the study is two-fold: first, to locate areas with potential reserves of construction aggregate where demand exists or is expected, and second, to identify all factors influencing the continuous supply of granular material to local markets. The survey covered corridors along established major and important secondary transportation routes and areas surrounding larger population centres.

Prior to the field season, available relevant information was obtained from surficial geology and soils/landform maps and transferred to 1:50 000-scale base maps. Major sources of this information were the Resource Analysis Branch, British Columbia Ministry of Environment and the Terrain Sciences Division, Geological Survey of Canada. Interpretation of aerial photographs was done to fill gaps in the available mapping as well as to plot locations of sand and gravel pits.

In the field, natural and man-made exposures of granular deposits were visited to describe mode of deposition and general texture, to estimate the reserves, and to assess obstacles to development. In addition, the pits were identified as active or inactive and their status of ownership was determined. In this regard, the information supplied by the district offices of the Ministry of Energy, Mines and Petroleum Resources and the Ministry of Transportation and Highways was very helpful.

Fieldwork was carried out by Marilynn Hunter (party chief) and Katrine Foellmer (assistant) under supervision of Z. D. Hora.

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

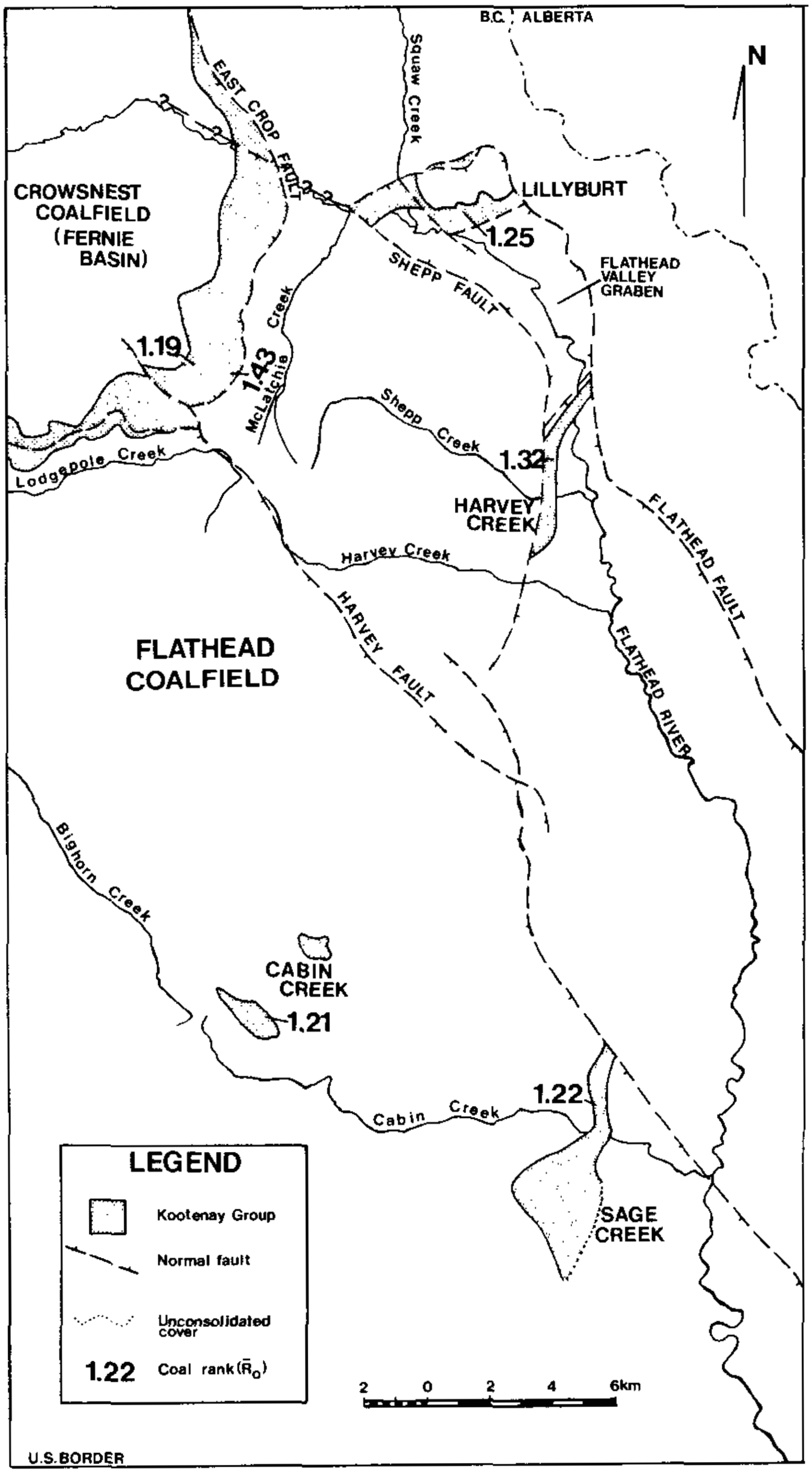

Figure 20. The Flathead region showing Kootenay Group outcrops in Flathead Coalfield and the southeast corner of Crowsnest Coalfield, major normal faults, and coal rank ($\bar{R}_o$) on representative coal seams. Modified after Price (1961, 1965) and Pearson and Grieve (1979).

COAL INVESTIGATIONS

FLATHEAD COALFIELD
(82G)

By D. A. Grieve

INTRODUCTION

Flathead Coalfield lies in the drainage of the Flathead River, approximately 35 to 55 kilometres southeast of Fernie, in the vicinity of the United States–Alberta–British Columbia boundary intersection (Fig. 20). It is southeast and east of the Crowsnest Coalfield (Fernie Basin) and is separated from it spatially and structurally. The coalfield consists of the Lillyburt, Harvey Creek, Sage Creek, and Cabin Creek properties, all of which are separate structural and/or erosional remnants of coal-bearing Kootenay Group strata. All are accessible from Fernie by a system of forestry access roads which originates at Morrissey.

Lillyburt, Harvey Creek, and Cabin Creek properties are currently held under coal licence by Crows Nest Resources Limited, while the Sage Creek property is licensed by Sage Creek Coal Limited.

PREVIOUS WORK

Outcrops of coal-bearing strata were examined in the first decade of the century in response to the successes of new coal mines at Coal Creek and Michel in the Crowsnest Coalfield. Dowling (1914) described occurrences of coal at the Lillyburt, Harvey Creek, and Sage Creek properties. MacKenzie (1916) mapped the Sage Creek property, especially exposures near Cabin Creek. Price (1961, 1965) conducted regional and detailed mapping in the Flathead map-area.

In the past decade considerable assessment of coal resources on all four properties has been carried out by exploration companies. Work has included geological mapping, trenching, diamond and rotary drilling, and adit development.

REGIONAL GEOLOGY

The Flathead region lies in the Front Ranges of the Rocky Mountains. It is underlain mainly by clastic and carbonate sedimentary rocks ranging in age from Precambrian to Late Cretaceous. Small Upper Cretaceous syenitic intrusions are also found in the region. Tertiary sedimentary rocks are exposed in the Flathead Valley, and many of the major valleys contain considerable thicknesses of unconsolidated Quaternary cover.

The study area has been influenced by two major structural events: the earlier corresponded to uplift of the Rocky Mountains with concomitant development of thrust faults and folds; the later characterized by normal (gravity) movement on listric surfaces. Faults formed in the later event include the west-dipping Flathead fault and a series of splay faults (Price, 1965) that includes the Harvey and Shepp faults (Fig. 20).

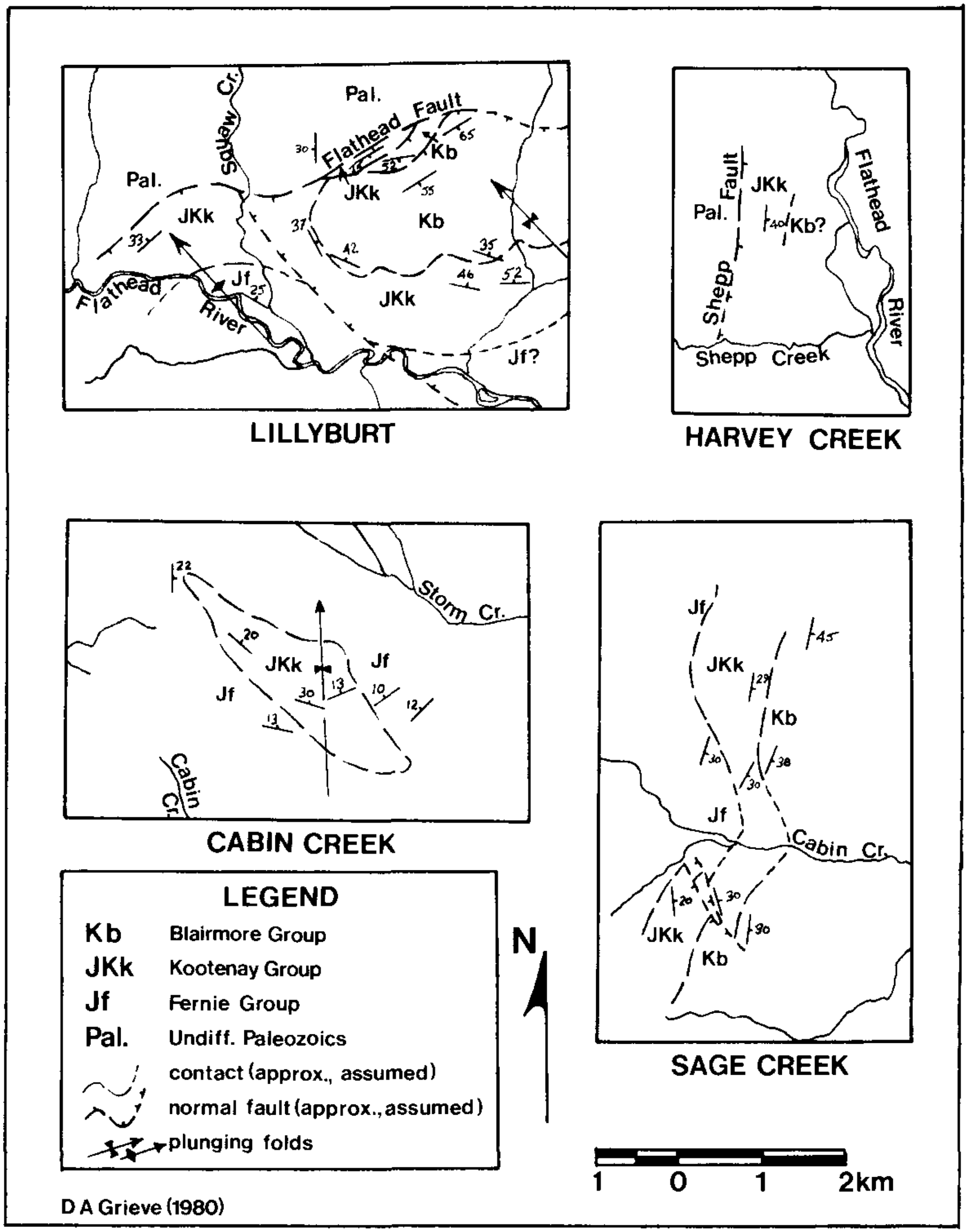

Figure 21. Geology of portions of the four properties that comprise the Flathead Coalfield.

The Flathead graben is bounded on the west by the east-dipping Shepp fault and on the east by the west-dipping Flathead fault (Fig. 20). Movement in the graben has been highly asymmetrical, with much more offset on the Flathead fault. All four coal properties lie within the Lewis thrust sheet, and are considered to be in approximately the same relative position to each other and the Crowsnest Coalfield as they were at the time of their deposition. In support of this, Price (1965) stated that Mesozoic stratigraphy on the Lillyburt property is very similar to that in the Crowsnest Coalfield, but considerably different to that exposed east of the trace of the Lewis thrust in southern Alberta.

FIELD AND LABORATORY WORK

Six days were devoted to reconnaissance geological mapping of the Flathead Coalfield properties (Fig. 21). Topographic maps (1:50 000) were used, in conjunction with compass and altimeter. Outcrop coal samples were collected for determination of rank.

Coal ranks were determined by the vitrinite-reflectance-in-oil method by D. E. Pearson, project geologist with the Ministry.

Reflectance and geological data from the Crowsnest Coalfield are reproduced from previous reports (Pearson and Grieve, 1979, in press).

GEOLOGY OF THE FLATHEAD COALFIELD PROPERTIES

LILLYBURT

This property, located at 1 550 metres elevation adjacent to the confluence of Squaw Creek and Flathead River, is underlain by Mesozoic sedimentary rocks of the Fernie, Kootenay, and Blairmore Groups (Fig. 21). It comprises a northwest-plunging anticline-syncline pair, probably separated by a northeast-dipping normal fault. The deposit lies within the Flathead Valley graben, although the Shepp fault is not exposed here. However, it is clearly bounded on the north and east, by the Flathead fault, which has brought Paleozoic and Precambrian rocks into contact with the Mesozoic strata. Normal movement at this site was in the order of 1 200 metres (Price, 1965).

Bethune (*in* Price, 1965) calculated a total Kootenay Group thickness of 490 metres on the property. However, Fernie Group grey beds were observed at one location adjacent to the Flathead River (Fig. 21) so this probably represents some Fernie Group and perhaps some Blairmore Group strata. Two or more Kootenay Group coal seams are exposed on old trench and adit sites, and probably represent C and D seams in today's terminology. In all, four seams, ranging from 2 to 5 metres in thickness, were reported by Dowling (1914). Sandstones and shales comprise the other Kootenay Group rocks exposed. Neither the basal sandstone nor the Elk Formation are exposed. A prominent pebble to cobble conglomerate marks the contact between Kootenay and Blairmore Groups. Red and green shales, conglomerate, sandstone, and nodular limestone comprise the Blairmore Group.

HARVEY CREEK

This property occurs at 1 500 metres elevation in a low relief area, in the Flathead Valley. Very little bedrock is exposed (Fig. 20). The strata observed dip eastward within the Flathead Valley graben. The property is bounded by the Shepp fault and Paleozoic carbonate rocks are exposed to the west (Fig. 21). A thick coal zone that crops out in two road cuts is apparently the 12-metre seam described by Dowling (1914). Dowling also reported five other minor seams, ranging from 1 to 3 metres in thickness. Blairmore conglomerate forms a small north-south-trending ridge along the east side of the property.

CABIN CREEK

The two ridges above Storm Creek, near the headwaters of Cabin Creek, are underlain by Kootenay Group strata (Fig. 20). The more southerly ridge, which has maximum elevation of 2 200 metres, was mapped (Fig. 21). The contact between the basal sandstone of the Kootenay Group and the underlying Fernie Group outlines an open north-south-trending syncline in the ridge but probably it has no regional significance. Two coal seams of approximately 5 and 10-metre thickness are preserved within the 100-metre-thick erosional remnant of Kootenay Group strata. Two prominent sandstone bodies occur and, together with the basal sandstone, sandwich the two coal seams.

SAGE CREEK

The Sage Creek property straddles the lower part of Cabin Creek, at roughly 1 500 and 1 700 metres elevation and is cut off to the north by the Harvey fault. It comprises an east-dipping sequence of Fernie, Kootenay, and Blairmore Group rocks that are offset by small-scale southwest-dipping normal faults. Both the basal sandstone of the Kootenay Group and the basal conglomerate of the Blairmore Group are well exposed. The coal-bearing portion of the Kootenay Group comprises 328 metres (MacKenzie, 1916) of coal, shale, sandstone, and minor conglomerate. Immediately north and south of Cabin Creek there are three major coal seams (5, 4, and 2 seams), with thicknesses ranging from approximately 8 to 15 metres. The Blairmore Group consists of conglomerate, sandstone, and red and green shales. No Elk Formation strata are exposed.

This portion of the Sage Creek property is referred to as the North and South Hills in current production plans. Continuation of Kootenay Group strata southward beneath unconsolidated cover of the Flathead Valley may provide significant additional reserves.

COAL RANK

Figure 20 includes coal rank data (vitrinite reflectance in oil) from one seam at each of the four Flathead properties, as well as data from the highest and lowest exposed West Ridge seams on the Lodgepole property in Crowsnest Coalfield.

In the Crowsnest Coalfield, Pearson and Grieve (1979, in press) studied the relative timing of coalification in southeastern British Columbia with respect to thrust and later normal faulting. Apparently coalification largely postdated thrust faulting, but predated normal faulting. On the basis of this model, rank differences suggest approximately 1 260 metres of total normal movement has been calculated to have taken place on the East Crop fault 12 kilometres north of the Flathead River in the Crowsnest Coalfield. This quantity is very close to the 1 230-metre net normal movement suggested by Price (1965) for the Flathead fault adjacent to the Lillyburt property. The interpretation is corroborated by the rank on the highest seam at Lillyburt ($\overline{R}_o$ = 1.25) which is within the range of ranks of the coal seams exposed at the southeast corner of Crowsnest Coalfield ($\overline{R}_o$ from 1.43 to 1.19) (Fig. 20). At Harvey Creek the rank of the exposed seam, which is in the middle portion of the succession, is in the same range ($\overline{R}_o$ = 1.32). This is unexpected considering the large 6 000-metre displacement which Price (1965) has calculated on the Flathead fault in this area. Two possible explanations are proposed: either movement on the Flathead fault increases southward, although that on the Shepp Creek fault changes little along its length; or, the Harvey Creek property has experienced relatively high heat flow associated with emplacement of a small syenitic intrusion about a kilometre from the property (*see* Price, 1961, 1965).

Rank values of the lowest seams at the Sage Creek and Cabin Creek properties are nearly identical ($\bar{R}_o$ = 1.22 and 1.21 respectively), slightly lower than at the other Flathead properties. This may reflect relatively greater normal movement southwest of the Harvey fault and a system of northwest-trending faults that splay off from the Flathead fault (Fig. 20). Sage Creek property in particular is bounded on the north by this fault system.

Vitrinite reflectance suggests that all the seams in the Flathead Coalfield consist of medium-volatile bituminous coals.

ACKNOWLEDGMENTS

D. E. Pearson, project geologist with the British Columbia Ministry of Energy, Mines and Petroleum Resources, carried out reflectance determinations and provided much useful discussion.

Blair Krueger provided cheerful and capable field assistance.

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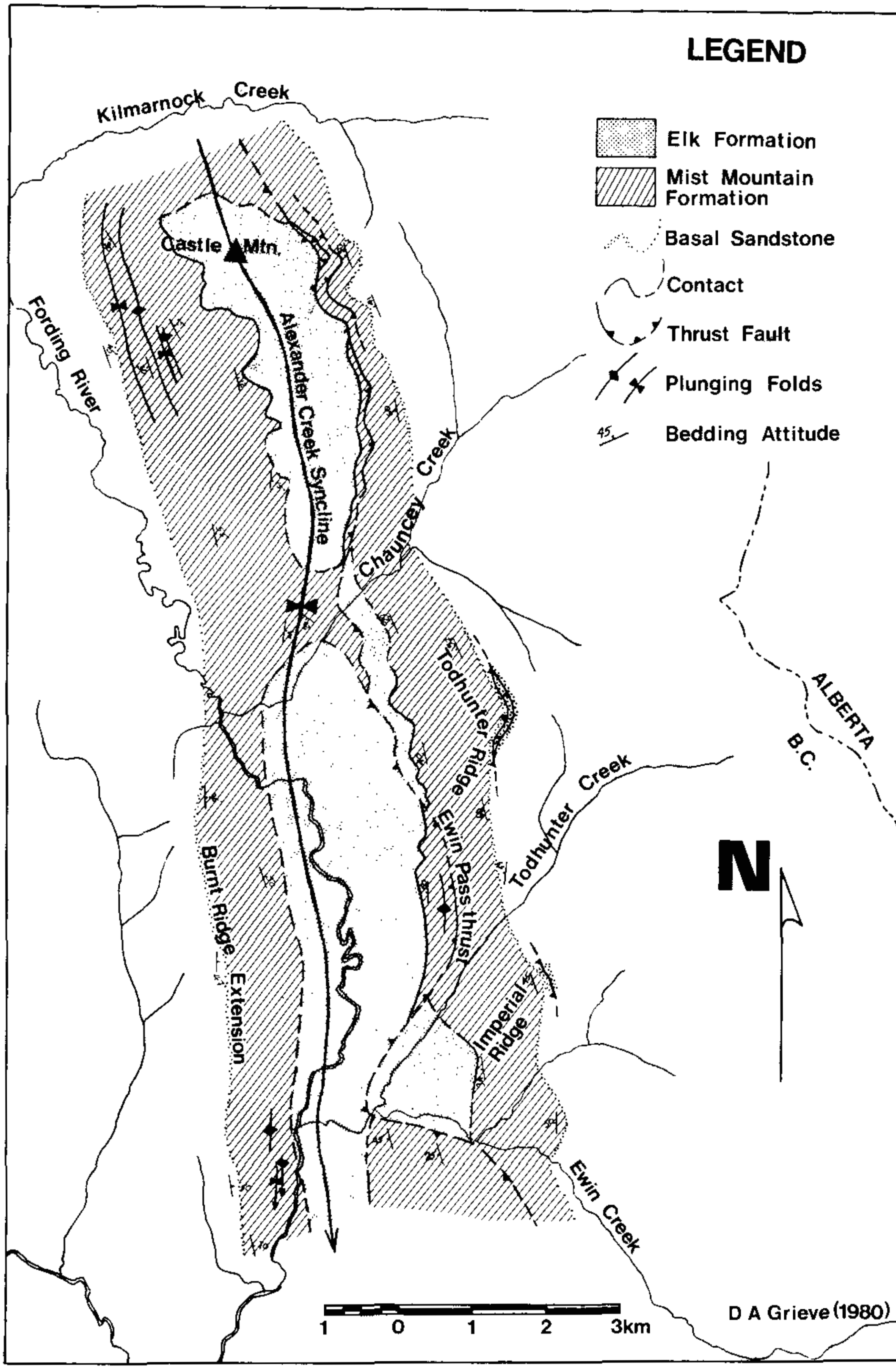

Figure 22. Geology of the Fording River area in the Elk Valley Coalfield.

ELK VALLEY COALFIELD
(82J/2)

By D. A. Grieve

INTRODUCTION

The central part of the Elk Valley Coalfield has been investigated as a continuation of studies of the structure and coal resources of the coalfield (Pearson and Grieve, 1980a, 1980b). The study area is 10 kilometres east and northeast of Elkford, and straddles Fording Coal Limited's mine road in the Fording Valley (Fig. 22). The area studied is bounded on the north by Kilmarnock Creek, on the south by Ewin Creek; elevations range from 1 530 metres to 2 500 metres.

Coal properties in the study area belong to Kaiser Resources Ltd., Crows Nest Resources Limited, and Fording Coal Limited, and Fording's open-pit operations lie north of Kilmarnock Creek.

FIELD AND LABORATORY WORK

Fording's mine road and secondary forestry and exploration roads were used to gain access to most of the study area. A helicopter was used to reach the highest parts of ridges.

Mapping was done on British Columbia government air photographs BC78153-110 to 118, enlarged to approximately 1:15 000 scale. A stratigraphic section of coal-bearing strata was measured on Imperial Ridge, using chain and compass. Outcrops and trenches were sampled for coal rank and maceral studies.

Vitrinite reflectance in oil of selected samples was determined in Victoria by D. E. Pearson, project geologist with this Ministry.

STRATIGRAPHY

Sedimentary rocks of the Jurassic-Cretaceous Kootenay Group comprise the Elk Valley Coalfield. Basal sandstone of the Morrissey Formation overlies passage beds of the Fernie Group and outlines the study area (Fig. 22). The coal-bearing Mist Mountain Formation of the Kootenay Group is 640 metres in thickness on Imperial Ridge, and includes nine major coal seams, ranging in thickness from 3.1 metres to 10.5 metres. Other strata in the coal-bearing section include shale, siltstone, and sandstone.

The Elk Formation, at the top of the Kootenay Group succession, is well exposed and includes an estimated 250 metres to 300 metres of shale, siltstone, sandstone, minor conglomerate, thin coal seams (up to 1 metre), and lenses of 'Elk coal.' The last is a brittle coal rich in alginite, and is commonly referred to as 'needle coal.' The contact between the underlying Mist Mountain and the Elk Formations does not represent a consistent stratigraphic horizon. It was generally mapped at the lowest stratigraphic occurrence of Elk coal and at correlated horizons. On the west-facing slope of Todhunter Ridge, a prominent conglomeratic unit occurs immediately above the lowest Elk coal and forms a mappable 'contact' over a distance of 3 kilometres.

Conglomerate of the overlying Blairmore Group crops out 3 kilometres south of the study area, in the core of the Alexander Creek syncline.

STRUCTURE

The north-south-trending Alexander Creek syncline, known locally as the Fording River syncline, is the dominant structure in the study area (Fig. 22). It generally plunges south in the map-area and reaches a culmination immediately to the north and a depression to the south (Pearson and Grieve, 1980a). Dips on both limbs are steep, especially in lower parts of the section. Both limbs are complicated by minor folding which, in at least one case (north of Todhunter Creek), is directly related to movement on thrust faults.

The east limb is considerably faulted. The major fault zone, the Ewin Pass or Fording thrust, transects the study area and has been mapped throughout the southern half of the coalfield. South of Ewin Creek, it places coal-bearing Mist Mountain strata adjacent to Elk Formation on the west end of Imperial Ridge (Fig. 22). The fault cuts rapidly up-section at this point, and throughout the rest of the study area it lies either within the upper coal-bearing section or in the Elk Formation.

COAL RANK

Rank distribution of coal in the Elk Valley Coalfield has already been described (Pearson and Grieve, 1980a, 1980b). For this study rank determinations made so far include values from samples taken on the south side of Ewin Creek. It appears that coal in the lower part of the section at Ewin Creek is lower in rank than that from the base of the Imperial Ridge section ($\overline{R}_o$ = 1.11 compared with $\overline{R}_o$ = 1.34, or high volatile compared with medium volatile). This is consistent with a similar rank difference across the Ewin Pass thrust at Ewin Pass, and substantiates the hypothesis that some portions of the Ewin Pass thrust experienced late-stage, post-coalification normal movement.

Several other new rank determinations confirmed data presented in previous reports.

ACKNOWLEDGMENTS

D. E. Pearson carried out vitrinite reflectance determinations and generated useful discussions.

Blair Krueger is thanked for his assistance in the field.

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FURTHER STUDIES OF THE HAT CREEK COAL DEPOSIT (92I/12, 13E)

By B. N. Church

INTRODUCTION

Additional information has been gathered on the effects of combustion metamorphism in the vicinity of the No. 1 coal reserve and the paleodepositional environment of the Hat Creek coal deposit.

COMBUSTION METAMORPHISM

A general description of prehistoric combustion in the Hat Creek coal deposit has been provided by Church (1975, p. G 110; 1979; 1980). Further information is added by a suite of chemically and mineralogically analysed samples (Table 1, page 76).

The best exposure of the burned zone is in 'A' trench which was excavated for bulk sampling in 1977. This is an east-west slot measuring 274 metres in length, 90 metres in width, and 24 metres in depth cut into the No. 1 coal reserve.

Bright red, brown, and yellowish soils and burned shaly residue are exposed along much of the trench. They are silica-saturated, aluminous rocks with markedly variable water content (analyses numbers 8, 9, and 10). The material is characterized by high cristobalite or tridymite content and variable amounts of clay minerals including kaolinite and illite and subordinate glass, hematite, mullite, corundum, plagioclase, and pseudobrookite (?).

Baked fossil logs are conspicuous within the burned shales. These have been transformed from siderite, calcite, and dolomite (analysis number 1) to mixtures of carbonates, hematite, and magnetite (analyses numbers 2 and 3) or, in some cases, to almost pure hematite (analysis number 4).

Light grey clay-like material forming a number of thin beds in the coal and patches near baked fossil logs may be ash residue of burned coal. It has exotic compositions (analyses numbers 11 and 12) with unusually high concentrations of phosphorus, strontium, and barium attributable to the presence of woodhouseite-hinsdalite± goyazite or gorceixite group minerals and barite.

Cap rock above the baked shales on the south wall of 'A' trench was subjected to intense heating during combustion of the underlying coal. On the upper bench of the trench, grey, vesicular 'slag' mixed with undigested fragments of reddish brown shale is exposed; on the whole they resemble rootless lava flows. Locally, expulsion of hot gases from the burning coal had a blow torch effect along joints and cracks and fused their walls to form peculiar hornito or chimney-like structures (Rogers, 1917, p. 5). The first structure of this type in the Hat Creek area was observed by MacKay (1925, p. A320) on the upper slope south of Dry Lake gulch; he called it a 'volcanic dyke.'

SAMPLE NO.	ALNUS SP	PINACEAE	OSMUNDA SPP	LAEVIGATOSPORITES SP	PTEROCARYA SP	PODOCARPUS SP	LIQUIDAMBAR SP	TSUGA SP	JUGLANS SP	BACULATISPORITES SP	CICATRICOSISPORITES SP	PLEURICELLAESPORITES SP	PISTILLIPOLLENITES SP	GLYPTOSTROBUS-TAXODIUM	SPHAGNUM SPP	BETULA SP	CYCADOPITES SP	TYPHA-SPARGANIUM	ERICACEAE	CARYA SP	ULMUS-ZELKOVA	?PROTEACEAE	cf. PARAALNIPOLLENITES SP	cf. RHAMNACEAE	CASTANEA SP	ENGELHARDTIA SP	LYCOPODIUM SP	GOTHANIPOLLIS SP	TILIA SPP	NYSSA SP	SEQUOIAPOLLENITES SP	QUERCUS SP	FAGUS SP	ILEX SP	TYPHA SP
MEDICINE CREEK FORMATION																																		
DDH-25-2026	*	*	*		*																														
DDH-35-356	*	*		*		*	*	*	*		*	*	*	*																				
DDH-40-511	*	*		*	*			*	*					*	*	*		*	*	*	*													
DDH-61-595																									*				*					
DDH-63-757	*	*	*										*		*						*					*			*					*			
DDH-70-1113	*	*		*	*			*						*	*	*		*		*												*		
DDH-48-497	*	*	*	*	*			*						*						*				*	*	*					*			
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DDH-72-645	*	*	*	*	*				*							*	*			*	*						*		*		*			
HAT CREEK COAL FORMATION																																		
DDH-37A-1535	*	*	*	*																*														
DDH-57-1337	*		*	*	*				*	*				*						*									*		*			
DDH-73-472	*	*							*	*				*		*																		
DDH-73-484	*	*		*	*	*						*		*						*														
DDH-73-671	*	*	*	*		*		*		*				*						*	*										*			
DDH-74-1426	*		*	*					*				*		*				*						*	*	*			*		*		*
HAT-223	*		*	*	*					*				*																				
DDH-57-1151	*		*		*				*			*		*		*	*			*														
DDH-73-1182	*	*							*					*						*					*			*			*	*	*	*	
DDH-57-1305	*	*		*	*				*	*				*		*				*	*				*						*		*		
DDH-74-487	*	*		*			*			*						*				*	*						*								*
DDH-74-945	*	*		*															*	*															
DDH-74-1230	*	*		*	*		*			*				*						*	*				*	*			*			*		*	
DDH-74-1861	*			*	*		*							*						*	*											*			
DDH-74-2018	*		*																	*														
DDH-57-1428	*			*	*				*			*		*								?				*	*	*				*			
DDH-68-1160	*	*		*															*								*									
DDH-52-355				*										*																				
DDH-57-740	*			*	*					*				*	*			*							*		*	*	*						
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DDH-43-1300	*	*		*				*								*		*		*	*	?	*													

TAXON

Figure 23. Microflora content of core samples from the Hat Creek section.

Unlike normal lava or slag, the fused rocks are aluminous and their compositions are akin to argillites or shales (analyses numbers 5 and 6). The mineral composition is often variable but commonly consists of abundant cordierite, cristobalite, hematite, clinopyroxene, and calcic plagioclase. Petrified logs in the fused cap rock were transformed into dark grey, vesicular rock composed mainly of specularite and magnetite with minor amounts of tridymite, cristobalite, plagioclase, corundum, and cordierite.

PALYNOLOGY RESULTS

Preliminary results from a palynology study by W. S. Hopkins (1977, personal communication) on drill core, supplied to the Institute of Sedimentary and Petroleum Geology in Calgary, mostly agree with a more recent, comprehensive investigation also undertaken by Hopkins (1980). Initial examination of core samples from the principal sedimentary formations showed 35 taxa of which angiosperm pollen was most abundant, followed by fern spores and gymnosperms (Figs. 23 and 24). Other than a few minor fluctuations, perhaps due to climactic changes, the taxa are remarkedly constant throughout, with no definite biostratigraphic subdivisions.

The Hat Creek flora grew in a warm to subtropical lowland environment in a purely continental setting. Alder swamps flourished and may have been surrounded at a distance by pine-covered highlands. The Hat Creek Coal Formation is approximately 425 metres thick; consequently, it is estimated that between 1.66 and 2.5 million years were required to accumulate the coal measures. The complete sedimentary cycle, including an undetermined thickness of Coldwater beds below and approximately 300 metres of strata of the Medicine Creek Formation above, may represent an additional million years of deposition.

The age of the coal measures from fossil evidence is not completely defined. According to Hopkins, *Ilex, Tilia, Juglans,* and *Carya* point to a post-Middle Paleocene age. The presence of *Gothanipollis* narrows this to Eocene or perhaps Oligocene, while *Pistillipollenites* suggest Late Paleocene to Middle Eocene. A potassium-argon date on biotite from rhyolite overlying the sedimentary rocks gives a Middle Eocene age of 51.2 Ma (Church, *et al.*, 1979, p. 1883). The combined data give an Eocene age for the coal measures and suggest that they are of Early to Middle Eocene age.

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TABLE 1. CHEMICAL ANALYSES OF SAMPLES FROM BOCANNE ZONE, NO. 1 COAL RESERVE AREA, HAT CREEK

	1	2	3	4	5	6	7	8	9	10	11	12
SiO_2	0.60	2.72	1.57	0.39	14.21	24.96	45.76	61.15	52.83	52.50	16.73	18.22
TiO_2	<0.05	<0.05	<0.05	<0.05	1.21	0.91	0.839	1.39	1.02	0.895	2.76	0.319
Al_2O_3	0.11	0.37	0.32	0.08	18.03	15.00	25.2	27.69	21.72	31.2	25.41	27.40
Fe_2O_3	0.90	24.57	85.98	>95.00	63.03	47.28	13.7	4.81	2.55	2.22	11.24	1.27
FeO	16.51	0.09	0.10	0.07	0.66	0.11	0.35	0.29	0.07	0.10	0.17	0.14
MnO	0.25	0.20	0.64	0.15	0.23	0.48	0.194	0.01	0.03	0.021	0.05	0.016
MgO	5.89	2.31	5.50	0.07	0.84	3.11	1.92	1.15	0.47	0.81	0.65	0.17
CaO	28.68	41.12	2.12	0.30	0.97	7.84	8.48	0.61	0.98	0.94	8.02	5.55
Na_2O	<0.01	0.05	0.03	0.34	0.088	0.28	0.49	0.76	0.35	0.758	0.10	0.166
K_2O	<0.02	<0.02	0.02	<0.02	0.18	0.22	0.514	1.29	0.97	1.211	0.24	0.139
$+H_2O$	3.81	0.37	1.51	0.29	0.21	0.19	0.50	0.02	7.87	0.0	1.14	12.14
$-H_2O$	0.71	0.11	0.53	0.35	0.03	1.03	0.29	0.02	8.13	8.60	6.54	10.04
CO_2	>40.00	29.06	0.55	0.26	<0.07	<0.07	0.30	<0.07	0.26	0.07	1.14	2.05
P_2O_5	N.D.	N.D.	0.30	0.32	N.D.	N.D.	0.39	0.20	0.22	0.55	11.50	12.9
S	0.56	0.01	0.01	0.10	<0.005	<0.005	0.02	<0.02	0.03	0.04	0.47	1.26
SrO	0.008	0.005	0.005	0.001	0.01	0.03	0.021	0.02	0.01	0.065	2.09	3.60
BaO	0.014	0.01	0.02	0.01	0.02	0.07	0.048	0.07	0.06	0.046	2.37	2.23
		100.99	99.21		99.72	101.51	99.02	99.48	97.57	100.03		

Key to Analyses

1 Petrified wood from coal in bulk sample trench 'A,' composed of calcite, siderite, and some ferroan dolomite.
2 Petrified wood from bocanne zone in trench 'A,' composed of calcite with minor amounts of quartz, hematite, and magnetite.
3 Outer shell of petrified wood in bocanne zone, composed of hematite, magnetite, and a trace of calcite.
4 Petrified wood in bocanne zone replaced almost entirely by hematite.
5 Heavy vesicular slag from bocanne zone composed mostly of hematite and magnetite with minor amounts of tridymite, cristobalite, corundum, plagioclase, and a trace of cordierite.
6 Vesicular slag mottled grey and orange from bocanne zone, composed of plagioclase, hematite, and clinopyroxene.
7 Chimney of fused rock in bocanne zone south wall of Dry Lake gulch, composed of calcic plagioclase, hematite, cristobalite, cordierite, and tridymite (Table 1, no. 12, Church, 1975, G 106).
8 Cream-coloured, very hard-baked phase of bocanne rock in trench 'A,' composed of cristobalite (high) ±tridymite with subordinate amounts of mullite, corundum, hematite, plagioclase, quartz, and pseudobrookite (?).
9 Baked shale-like residue from bocanne zone, composed of amorphous material (possibly glass), quartz, cristobalite, and very minor amounts of illite and feldspar.
10 Light brown to cream-coloured phase of bocanne rock on south wall of Dry Lake gulch, composed mostly of kaolinite and quartz (Table 1, no. 2, Church, 1975, p. G 106).
11 Clay-like material by remains of baked petrified log in bocanne zone, composed mostly of amorphous material with minor amounts of woodhouseite-hinsdalite±a *goyazite group mineral or gorceixite, hematite, barite, illite, plagioclase, and maghemite* (?).
12 Light grey to cream-coloured band passing from bocanne to fresh coal in trench 'A,' composed mostly of amorphous material with some woodhouseite-hinsdalite±goyazite minerals or gorceixite, barite, illite, tridymite (?), cristobalite (?), and a trace amount of plagioclase (?).

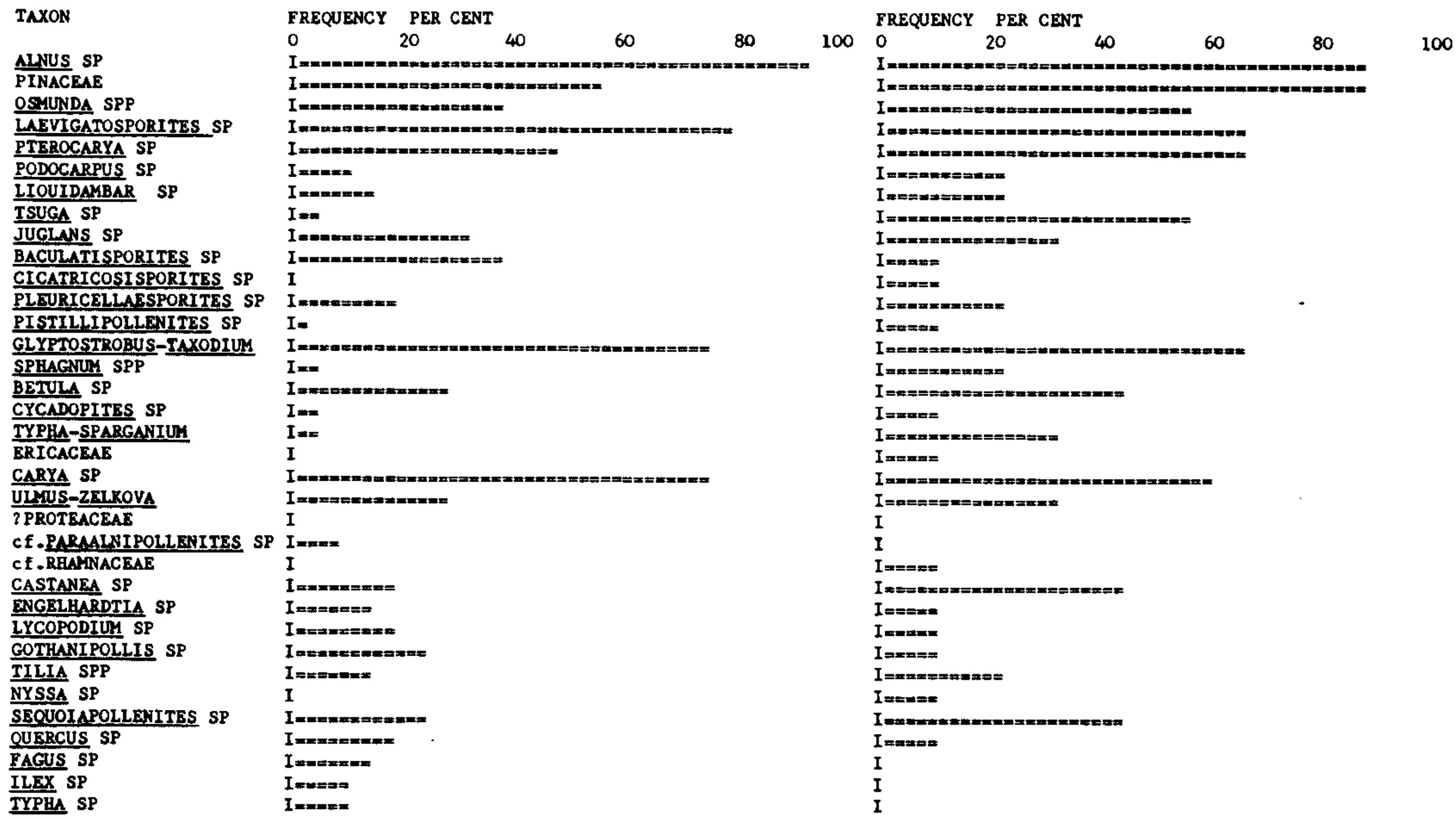

Figure 24. Frequency of spore and pollen taxon in Eocene beds at Hat Creek.

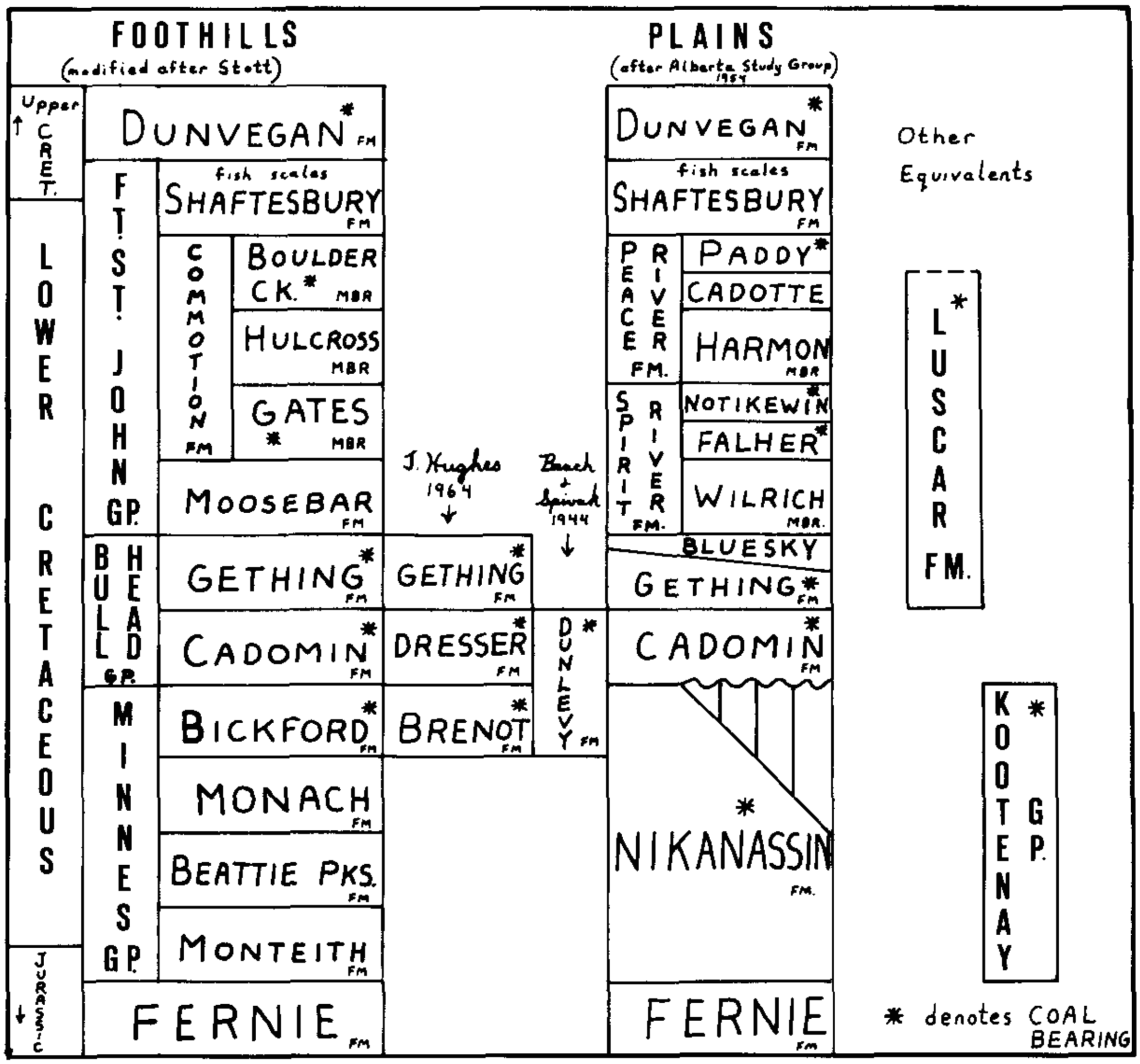

Figure 25. Table of formations, northeastern British Columbia.

CORRELATION OF THE LOWER CRETACEOUS STRATIGRAPHY OF NORTHEASTERN BRITISH COLUMBIA FROM FOOTHILLS TO PLAINS

By R. H. Karst

INTRODUCTION

The Lower Cretaceous of northeastern British Columbia consists of clastic sedimentary rocks having an accumulative thickness exceeding 3 000 metres in the Foothills and thinning northeastward in a wedge-like manner in the western Canadian sedimentary basin. These rocks are composed of detritus shed from an uplifted western source and provide an early record of the Laramide orogeny (responsible for the present Rocky Mountains). Most of the sedimentary sequence **prior** to the Cretaceous was more shelf like in character off the flank of an eastern source area, the Canadian craton. These pre-Cretaceous sedimentary rocks (quartzites, carbonates, cherts, and shales) were uplifted and eroded and their detritus transported eastward in Cretaceous time.

The table of formations that comprise the Lower Cretaceous of northeastern British Columbia is shown on Figure 25. Formation names marked with an asterisk are coal bearing and therefore at least in part non-*marine. The other formations are marine. It is apparent from the table that repeated marine transgressions* and regressions characterized Early Cretaceous time in this region, imparting a marine/nonmarine cyclicity to the sedimentary sequence. The marine influence is attributed to a Cretaceous boreal sea that periodically transgressed southeastward into Alberta. The alternating marine/continental character of the sedimentary pile created a geological environment favourable for the occurrence of both coal and hydrocarbons. The continental sedimentary units are generally fluvial-deltaic assemblages with associated coal seams and coarse clastic rocks. The marine units are predominantly silty shales and provide good cap rock for hydrocarbon entrapment.

The petroleum and coal industries have been very active in northeastern British Columbia during the last seven years. Both have been drilling Lower Cretaceous rock formations. The major Lower Cretaceous gas play in recent years has been the Elmworth-Deep Basin which trends northwest and is located in the Plains region near the British Columbia—Alberta border, south of Dawson Creek. Coal companies, on the other hand, have been actively exploring Lower Cretaceous rocks in the Foothills Belt where the formations are exposed at surface and are accessible for mining purposes. The target formations in both areas are nearly identical and information derived from one would most certainly help the exploration efforts in the other.

The purpose of this report is to compare the Lower Cretaceous rocks of the Foothills and Plains. Although some of the formation names are different, it is apparent that many of the lithologic units are essentially the same. This study was conducted from a broad, regional perspective and is more concerned with stratigraphic relationships between formations than their detailed sedimentologic descriptions. Most of the data on the stratigraphy under the Plains are derived from subsurface geophysical logs, supplemented in some cases by bit-cutting descriptions. Any sedimentologic descriptions given in this report are general in nature and were obtained from coal exploration drill cores and surface outcrops in the Foothills Belt.

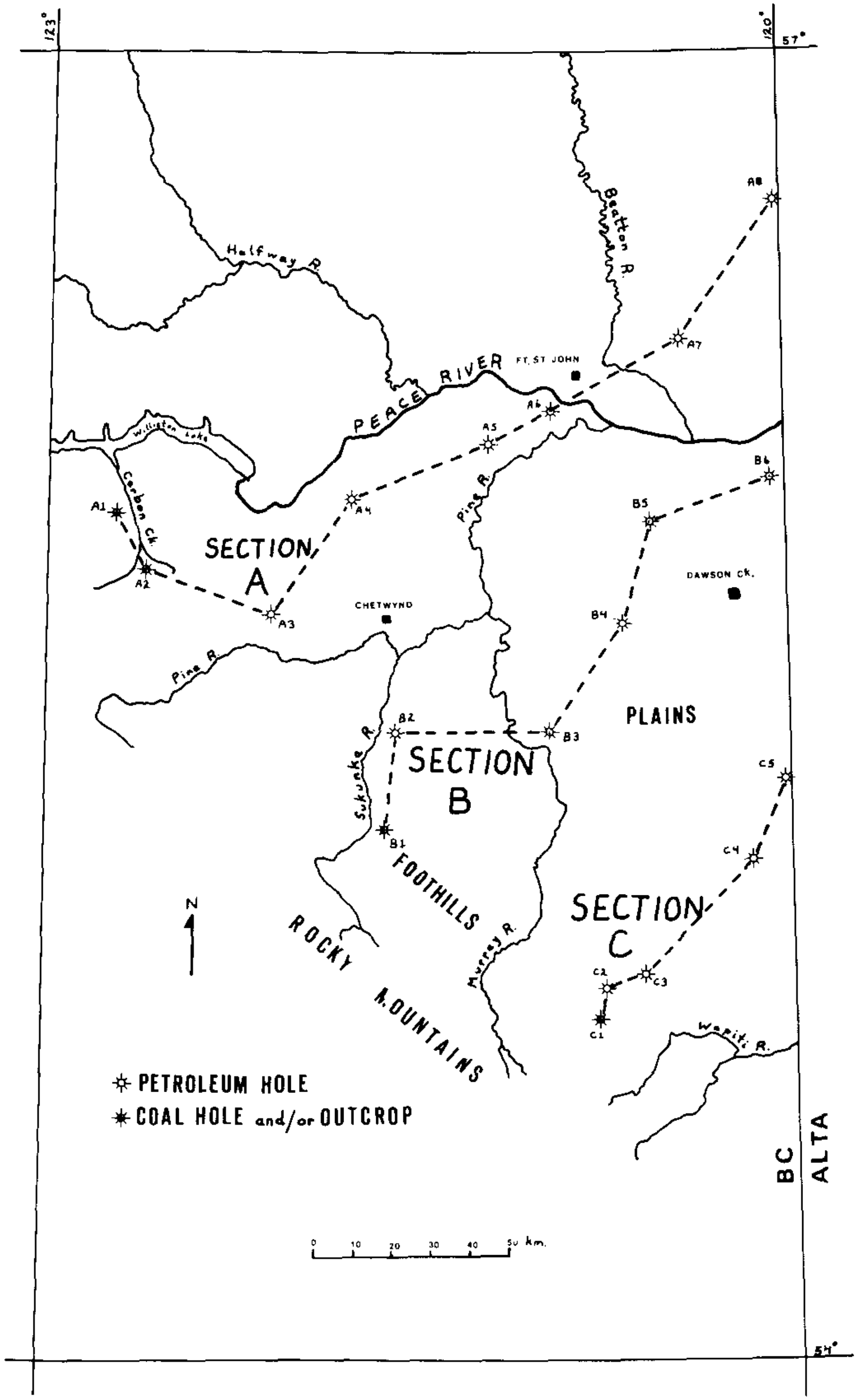

Figure 26. Map showing location of stratigraphic sections.

STRATIGRAPHIC SECTIONS

Three northeasterly stratigraphic sections A, B, and C, perpendicular to regional strike, have been constructed. The datum used is the Bluesky horizon at the top of the Gething Formation. These sections link the Lower Cretaceous surface rocks of the Foothills with their deep subsurface counterparts under the Plains (Fig. 26). The following review of formations lists formational names in the Foothills Belt in capital letters with the corresponding subsurface equivalents in brackets. The formations are listed from top to bottom, in the same order they would be encountered in a typical drill hole.

STRATIGRAPHIC REVIEW

BOULDER CREEK MEMBER (Paddy Member and Cadotte Member)

The Boulder Creek member is correlative with the Paddy and Cadotte members under the Plains. The upper contact with the overlying Shaftesbury shales is abrupt and marked by the first influx of sand and carbonaceous sediment. There is sometimes a thin conglomerate unit (less than 10 metres in thickness) near the top of the member. Where absent, this conglomerate is replaced by a dark, carbonaceous, silty mudstone containing small rounded chert pebbles. The upper or 'Paddy' part of the Boulder Creek member is continental and contains coal seams (Alberta Study Group, 1954). These seams are generally thin but at least one coal company has conducted a drill program with these coals in mind. The basal or 'Cadotte' portion of the Boulder Creek member consists of a thick, sandstone-conglomerate unit that coarsens upward and is easily recognizable on geophysical logs and from core descriptions.

The unit represents a classic prograding delta sequence which culminates with conglomerate overlain by coal measures above (Paddy member). At some localities the Cadotte has two or more of these coarsening upward cycles separated by local thin marine transgressions. Sandstones near the base of the Cadotte grade downward into prodelta silts and clays of the Hulcross member.

The Paddy is coal bearing well out into the Plains (section C). Northward, coal in the member is progressively further west on each section (Figs. 27, 28, and 29). The Cadotte is continuous over the entire area and is an important source of natural gas in the Dawson Creek area. In general, the Cadotte is thick where the Paddy is thin so except for the extreme eastern portions where there is significant thinning, the thickness of the Boulder Creek member as a whole is relatively constant.

HULCROSS MEMBER (Harmon Formation)

The Hulcross is a marine mudstone which weathers rusty brown and often displays laminae of very fine-grained sand. Ripple marks in some sand laminae suggest that the water depth was not great. In some areas the Hulcross is identical in sedimentary character to the Shaftesbury shales. The Hulcross (Harmon) thins in both easterly and southerly directions (Figs. 27, 28, and 29) until it pinches out completely in west-central Alberta (within the Luscar Formation; *see* Fig. 26).

GATES MEMBER (Notikewin Formation and Falher Formation)

The Gates member in the Foothills Belt is equivalent to the Notikewin and Falher Formations under the Plains. The contact with the overlying Hulcross is abrupt and defined by the first influx of sand and carbonaceous sediment. There is often a thin, coarse conglomerate (less than 2 metres in thickness) at the top of the formation. This is followed by a sequence of thin sandstones, carbonaceous shales, and thin coals

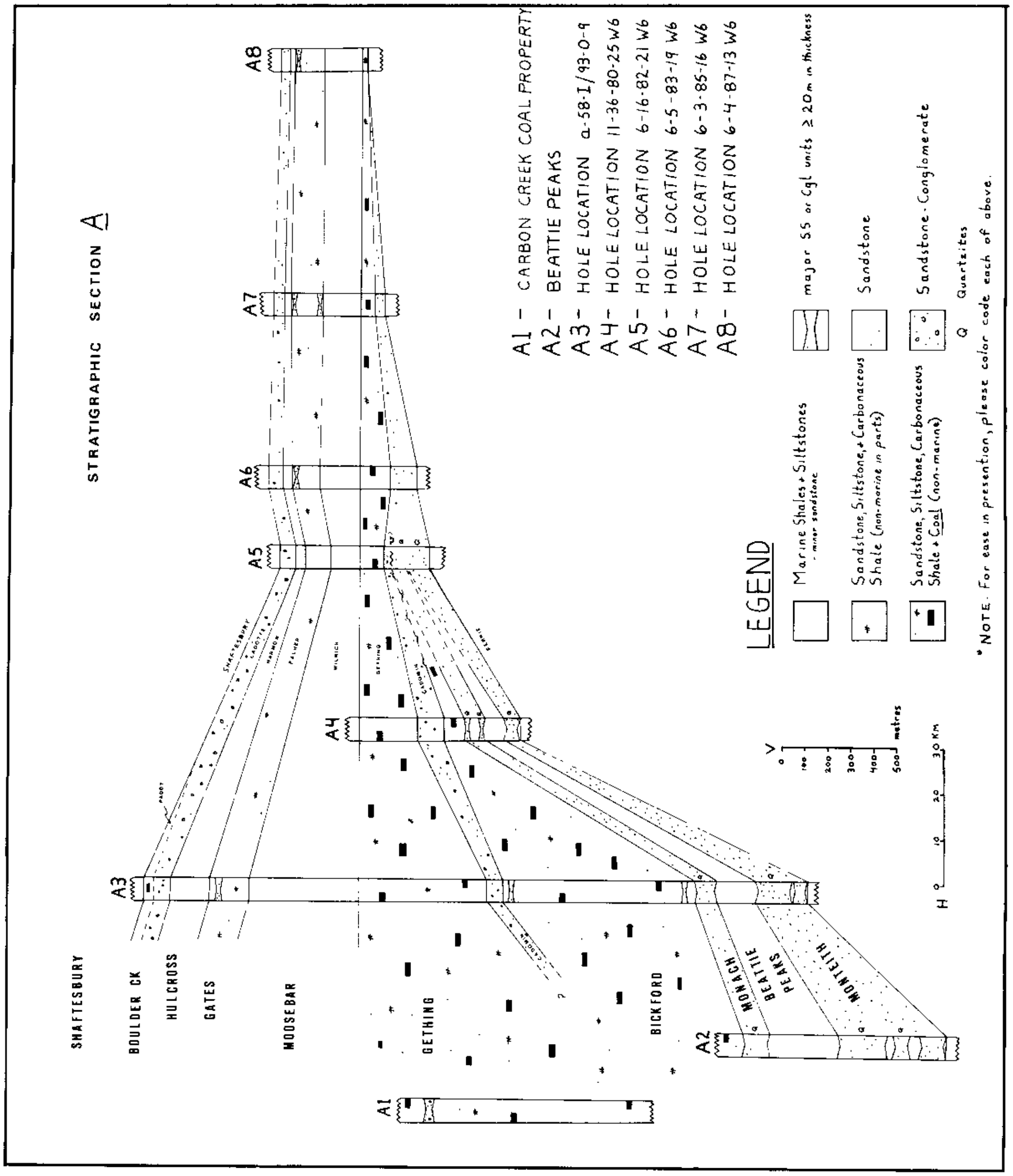

Figure 27. Stratigraphic section A.

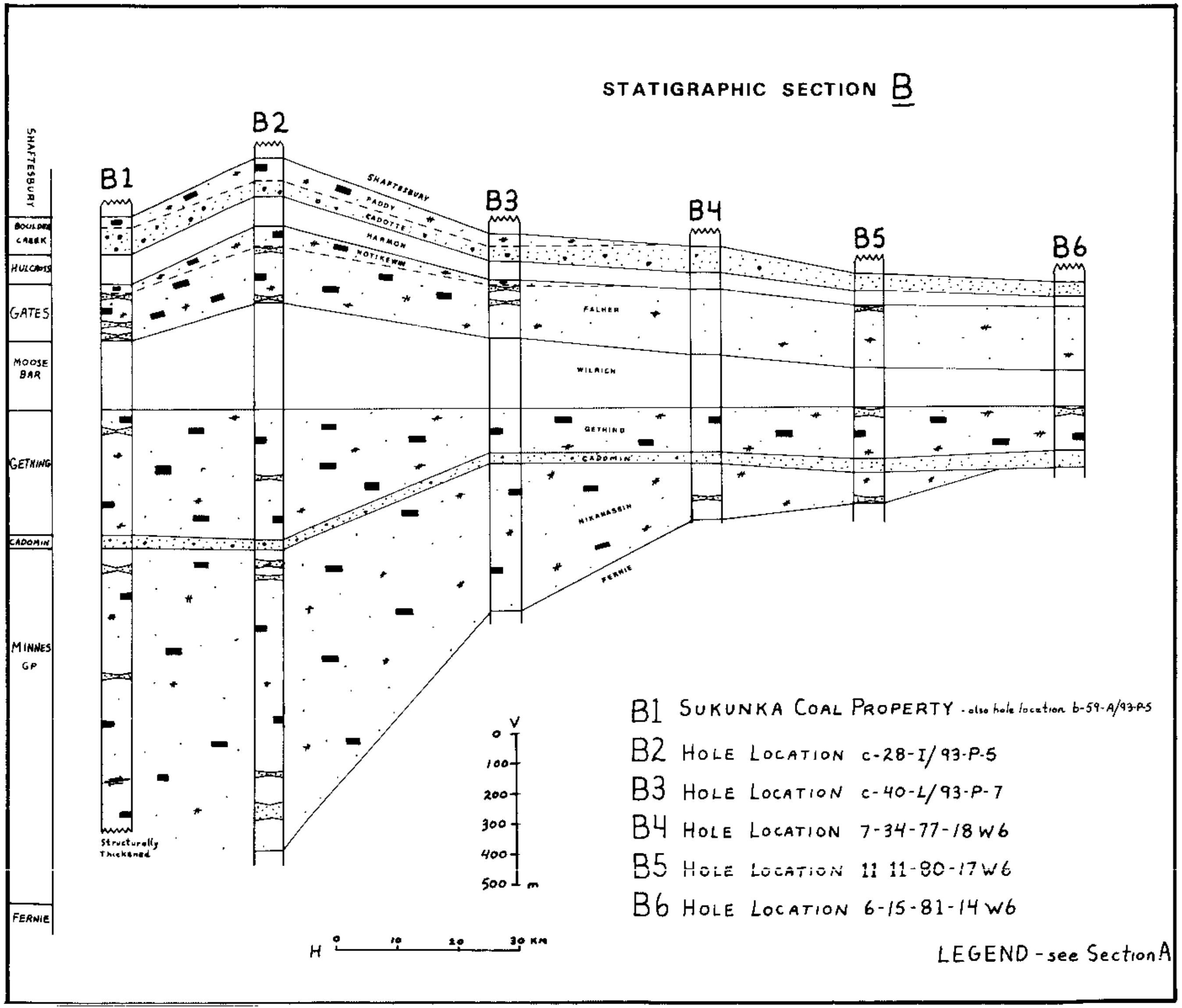

Figure 28. Stratigraphic section B.

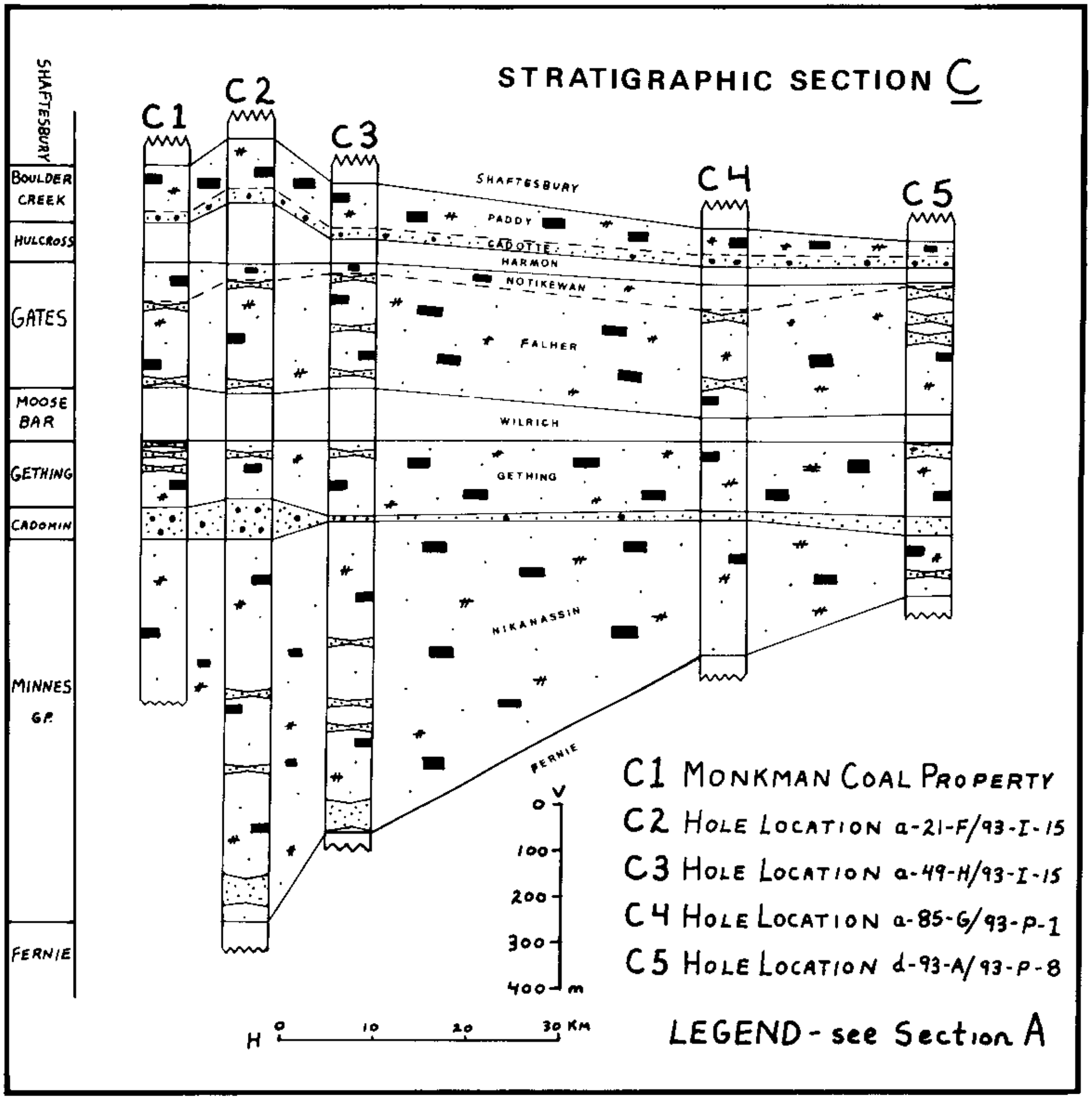

Figure 29. Stratigraphic section C.

which comprise the Notikewin. These thin, often high sulphur coals are not the important coal-bearing seams in the Gates member. Rather it is in the Falher Formation, which is marked by multiple, thick sandstone-conglomerate units and multiple, thick coal seams, that the coal is economically significant. The coarse sandstone-conglomerate units often coarsen upward, suggesting another prograding delta. There is some debate whether the thick sandstone-conglomerate units, which are the main producers in the Elmworth-Deep Basin gas field, represent prograding distributary mouth bars or prograding beaches (Armstrong and McLean, 1979). This author favours the interpretation that the large, sheet-like sandstone-conglomerates (that is, Falher A and B) represent beaches. The sand-gravel mixture is transported by the distributary channels and deposited as distributary mouth bars, then reworked by wave action and redistributed by long-shore drift to beaches adjacent to the delta front. These delta front beaches appear to have migrated back and forth over the lower delta plain in response to several minor marine transgressions, burying the peat swamps under sand and ensuring their preservation. The lowermost coarsening upward cycle at the base of the Gates member is continuous over most of the length of the Peace River Coalfield and has been named the 'Torrens member' by several coal companies. This thick sand unit grades down into silts and clays of the underlying Moosebar Formation.

The Gates member maintains a relatively constant thickness in each stratigraphic section; however, a definite thinning trend is evident in more northerly sections (*see* Figs. 27, 28, and 29). The coal-bearing character of the formation also diminishes northward until the Gates is essentially marine in section A. The coal measures also pinch out northward where the Gates becomes essentially marine (section A, Fig. 27). As would be expected, the large sandstone-conglomerate units decrease in frequency and grain size as the coals disappear. This suggests that exploration for gas in the Falher should be concentrated in areas where the Falher is coal bearing.

MOOSEBAR FORMATION (Wilrich Formation)

The Upper Moosebar (Wilrich Formation) is a closely interbedded sequence of very fine-grained sandstone, siltstone, and mudstone. Locally the sandstone layers have erosional bases and grade up into siltstone and mudstone over a distance of 10 to 20 centimetres. Zones of strong bioturbation are common and occasional small-scale slump structures are evident. The Upper Moosebar is commonly interpreted to be either intertital or prodelta. The author favours the prodelta viewpoint.

The Moosebar grades downward into dark grey mudstones that are much darker than the shales from the higher marine formations. Near the base of the Moosebar the mudstone becomes glauconitic. A multiple series of thin bentonite layers with microscopic volcanic textures are also common within the basal portion of the Moosebar (Duff and Gilchrist, in preparation). These ash layers are often noticeable on the gamma logs as local 'hot spots'; most are 2 to 3 centimetres in thickness but some reach 20 to 30 centimetres. They represent a distal explosive volcanic event not unlike the present Mount St. Helens eruption which had multiple releases of ash over a short time interval.

The Moosebar (Wilrich Formation) also thins in both east and south directions. However, the Moosebar is more persistent than the Hulcross and the marine horizon has been recognized as far south as Cadomin, Alberta, before pinching out within the Luscar Formation (Stott, 1974).

GETHING FORMATION (Bluesky Formation and Gething Formation)

The Moosebar Formation ends abruptly against sandstone at the top of the Gething Formation. This material is commonly conglomeratic and invariably glauconitic at the top of the Gething. In northwestern

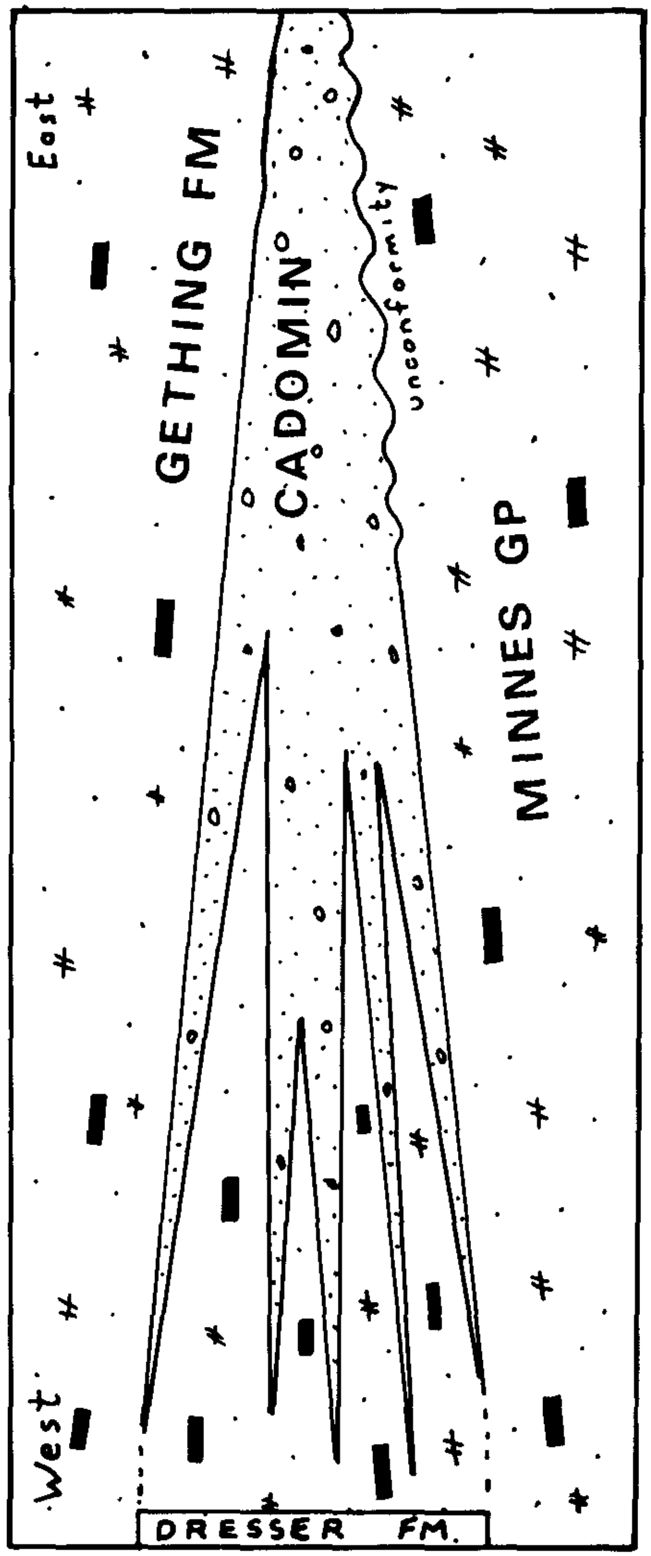

Figure 30. East-west facies relationship of the Cadomin Formation.

Alberta this upper unit has formation status (Bluesky Formation) but in northeastern British Columbia it is so variable in thickness (0.1 metre to 25 metres) that it is referred to as a stratigraphic horizon. When thick, the Bluesky is a very coarse conglomerate having well-rounded quartzite phenoclasts up to 15 centimetres across in a sandstone matrix. When thin (less than 1 metre in thickness), the Bluesky is characteristically a locally carbonaceous, silty mudstone, having small, black, polished chert pebbles that are less than 2 centimetres in diameter. The Bluesky is an important oil and gas producer in the Fort St. John area and probably represents a beach facies, created by the rapidly transgressing Clearwater Sea. A coarsening upward character is noted in some localities.

The Bluesky is a transitional unit and there is some debate whether it should be placed within the Moosebar or the Gething Formations. In this report the Bluesky has been placed in the Gething Formation because of its coarse clastic character and because it is easy to recognize on geophysical logs. Therefore, it is a convenient way to define the top of the Gething.

The Gething is largely a sequence of continental coal measures consisting of coal, carbonaceous mudstone, fine-grained sandstone, and abundant siltstone. Generally sedimentary cycles of the fining upward type, like these, suggest a strong fluvial environment. Most of the good Gething coals are located in the upper part of the formation where it is associated with several thin, marine sedimentary tongues (Duff and Gilchrist, in preparation). These marine tongues are usually mudstone containing the marine pelecypod *Entolium irenense.*

Both sections A and B show a thinning trend for the Gething in a northeastern direction. In section C, however, the Gething Formation has relatively constant thickness. In that section, the Gething has several unusually thick sandstone-conglomerate units that approach 20 metres in thickness. Recently, a gas strike was made in one of these units along the Deep Basin trend (Oilweek, 1980).

CADOMIN FORMATION (Cadomin Formation)

The type Cadomin was defined near the Alberta town bearing that name more than 50 years ago. As described by MacKay (1929), the Cadomin consisted of massive conglomerate 'composed of flattened and well-rounded pebbles of black, white, and green chert, white and grey quartzites, and quartz, which range in diameter from ¼ to 3 inches.' A major disconformity was recognized at the base of the formation. Subsequently, the Cadomin has been traced over much of central and northern Alberta and northeastern British Columbia. In the study area, the Cadomin in the subsurface under the Plains resembles that in the type section. At surface to the west, however, the formation apparently 'fingers-out' into multiple conglomeratic sandstone units separated by appreciable thicknesses of coal measures (Fig. 30).

The contact between the Gething and Cadomin Formations is gradational. Arbitrarily, it is placed at the top of the first thick sandstone-conglomerate unit in a succession of sandstone-conglomerate units in which the coarse units are thicker than the intervening coal measures. This problem could be avoided by adopting the stratigraphic term Dresser Formation for the Foothills Belt northwest of the Sukunka River. Hughes (1964) describes the Dresser Formation as multiple 5 to 15-metre beds of medium-grained sandstone, grits, and local conglomerate separated by coal measures of similar thickness.

Although there is a major unconformity at the Cadomin's base in the subsurface to the east where there is an obvious truncation of Nikinassin rocks (Figs. 27, 28, and 29), there is no field evidence of a major unconformity in the Foothills to the west (Fig. 29).

MINNES GROUP (Nikinassin Formation)

In northeastern British Columbia the Cadomin is underlain by a significant succession of coal measures. This fact was first recognized by highes in 1964 and he proposed that these continental rocks be called the Brenot Formation. Earlier workers such as Beach and Spivak (1944) did not distinguish the Cadomin Formation in the Peace River area but refer to a thick succession of sandstones and carbonaceous shale that is nonmarine in parts, overlying the marine shales of the Fernie Formation. This unit, which has beds of coal and conspicuous conglomerate at the top, was called the Dunlevy Formation. Stratigraphically it was placed below the Gething (Fig. 25). More recent work by Stott has emphasized the marine portion of these rocks which underlie the upper coal-bearing member. This upper coal-bearing member was left unnamed by Stott (1968) but is subsequently referred to as the Bickford Formation in his open file maps for northeastern British Columbia.

These coal measures, which lie below the Cadomin Formation, are the dominant lithostratigraphic unit of the Minnes Group. In the subsurface this nonmarine unit is referred to as the Nikinassin and extends well out into the Plains, especially in sections B and C. Sandstones within the Nikinassin are important gas producers in some areas (for example, Grizzly Valley). Coal seams are locally frequent but generally thin (less than 2 metres in thickness).

Underlying the upper coal-bearing unit are marine formations of the Monach, Beattie Peaks, and Monteith Formations respectively. First described by Mathews (1947) from what is now their type locality of Beattie Peaks, these units do not persist eastward in the subsurface; consequently they were never adopted by the petroleum industry. These formations are also increasingly difficult to recognize in the Foothills Belt south of the Burnt River. In the Pine Pass-Williston Lake area, however, they are prominent, easily distinguished, and marine. The Monach Formation consists of fine-grained, very thin-bedded sandstone with coarse-grained to conglomeratic quartzose sandstone interbeds near the top of the unit. Characteristically white, sugar-like, coarse-grained 'quartzite' (quartzose sandstone) caps the unit. At times the 'quartzite' displays large pelecypod burrows and large wood casts on the upper bedding surface. The contact with the overlying Bickford coal measures is abrupt and, at several localities, subtly irregular, suggesting that the base of the Bickford Formation is an unconformity.

The Beattie Peaks Formation is a recessive unit of interbedded shale and very fine-grained argillaceous sandstone. Dark-coloured worm tracks are common on some bedding surfaces. At several localities there were lenticular sandstone beds, less than 1 metre in thickness, with erosional bases and occasional pebbles and broken belemnite fragments near the bottom. These lenses appear to be graded and may have been deposited from turbidity currents.

The Monteith Formation is predominantly a fine grained to very fine-grained sandstone unit with thick intervals of very fine-grained, 'milky-grey' quartzites. The unit is very resistant but contains occasional recessive shale interbeds. The Monteith Formation is generally finer grained than the Monach (especially the quartzites) and the two can usually be distinguished on that basis. The base of the Monteith Formation is drawn at the bottom of the last major sandstone before the dark grey, Fernie-type shale interbeds become the dominant lithology.

SUMMARY

The Lower Cretaceous sedimentary sequence exposed at surface in the Foothills Belt of northeastern British Columbia continues into the subsurface of the Plains with only occasional changes in sedimentary character. The sedimentary changes that do occur are useful indicators of regional paleoenvironments. Both coal and petroleum exploration could benefit from the examination of open file geologic information from both areas. The coal companies would receive continuous stratigraphic information from top to bottom of the Lower Cretaceous sedimentary pile at certain localities. This would help unravel their sedimentary sequences in structurally complicated areas or areas where surface outcrop is sparse. The petroleum companies would have access to abundant diamond-drill core from the same formations they are actively exploring. The relative close-spaced aspect of this drilling would provide a three-dimensional view of porous intervals that are necessary for determining reservoir geometry. The British Columbia Ministry of Energy, Mines and Petroleum Resources through its Charlie Lake core storage facility and the open files in Victoria offers this geologic information to those concerned.

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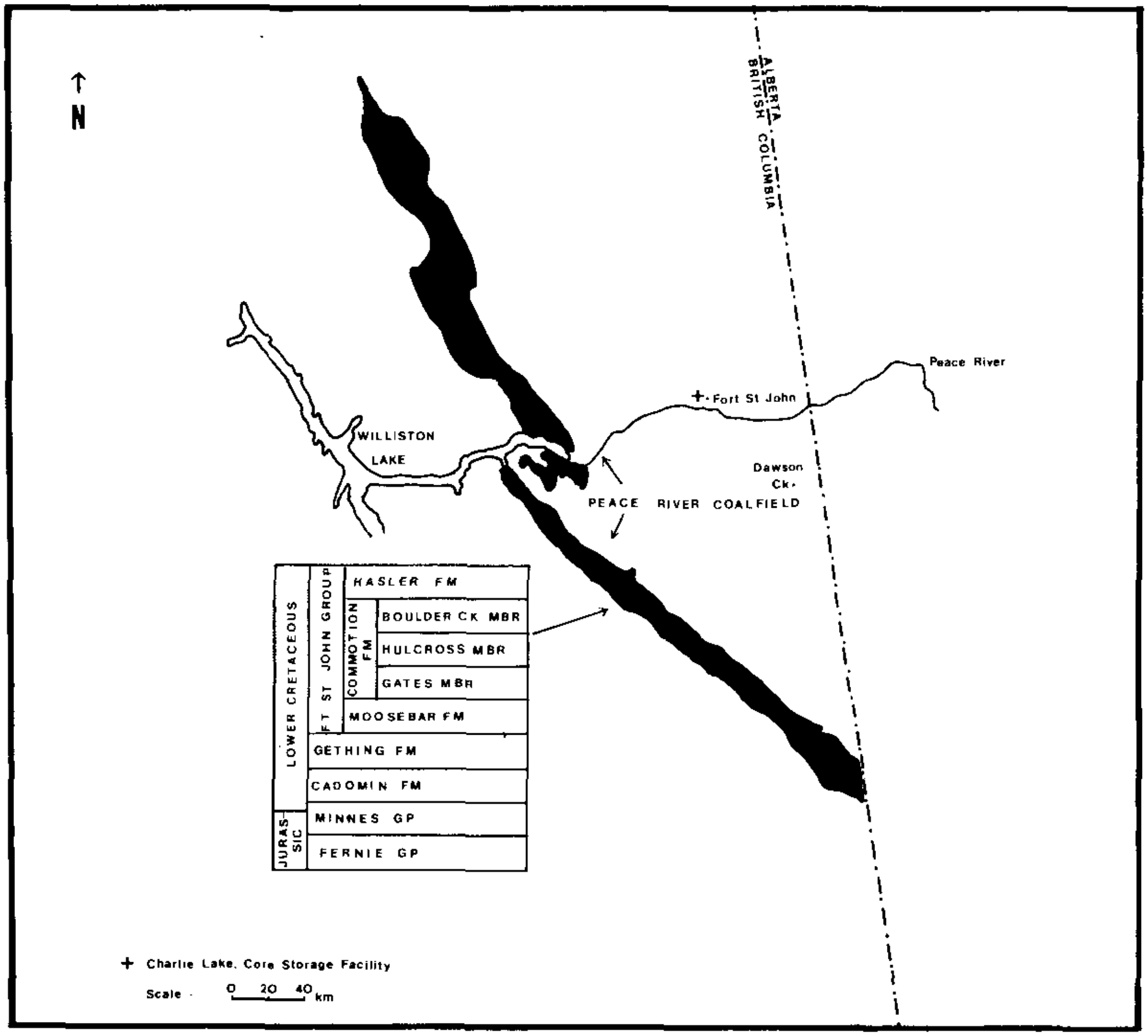

Figure 31. The Peace River Coalfield and location of the Charlie Lake storage facility.

CORE STORAGE IN NORTHEASTERN BRITISH COLUMBIA

By G. V. White

A core recovery program in the Peace River Coalfield commenced in May 1976. Responsibility for recovery, transport, and storage of diamond-drill core in northeastern British Columbia was assigned to the Applied Geology Section of the Ministry of Energy, Mines and Petroleum Resources. The main priority of the core recovery program was to collect and transport core that was left in the field to a central core depot located at Charlie Lake.

Coal exploration companies have extensively drilled the Cretaceous sedimentary rocks of northeastern British Columbia (Fig. 31) attempting to intersect economically significant coal seams. After drilling, however, the diamond-drill core was often improperly stored and much was destroyed by the weather. This was especially true if the company had decided to abandon the coal property.

Steps were taken to preserve the core because drilling is expensive and lost core was virtually irreplaceable. By collecting and storing it at a central location, a permanent core library has been assembled. The value of the stored and catalogued core becomes increasingly significant as more coal properties are drilled and more stratigraphic information is compiled. A single exploration company has information on their own coal property; information on each of the coal properties within the Peace River Coalfield is gathered at the Charlie Lake storage facility. This facility is now enabling detailed studies on the entire coalfield. Examples of research being conducted include environmental interpretations, coal rank studies, coal quality investigations, and stratigraphic correlation projects.

Since the core storage program was initiated, considerable interest has resulted. Industry, universities, and governments have all made use of the facilities at Charlie Lake, which include a well-lighted, heated room and five examination tables. Examination fees are currently twenty dollars ($20.00) per day and fifty cents ($ 0.50) for every core box examined.

Recent changes to the *Coal Act* reclassified all 1973 and older core as open file and any interested person or company may now examine this core. According to the Act, by 1983 all core and relevant files more than three years old will also be reclassified as open file. Presently, core drilled after 1973 cannot be examined without written permission from the company who initiated the drilling.

The storage program has ensured the preservation of core from the coal properties of northeastern British Columbia. In the past, a significant amount of diamond-drill core was destroyed by the weather and improper storage. Now there is more than 135 000 metres of core in storage at Charlie Lake. Used as a library, the core provides information and the opportunity for research into Cretaceous sedimentation in the Peace River Coalfield.

APPLIED GEOLOGY

SUMMARY STATEMENT

By E. W. Grove

GENERAL REVIEW

Emphasis on the various roles of the Applied Geology Section staff changed somewhat during 1980. All seven offices maintained operations with regard to mineral exploration, mining, prospectors' assistance, and technical assistance to the industry and public. The Mineral Exploration Incentive Program initiated in 1978 was dropped in April, but new mineral land-use studies more than compensated with increased time demands.

DISTRICT GEOLOGISTS

The number of assistance grants to *bona fide* prospectors increased from 141 in 1979 to 150 in 1980. Of *these, only 17 were novices partnered with experienced grantees. Only a very few of the grantees were* unable to complete their programs, and most spent far more than the required time in the field. The number of new mineral finds, samples submitted, claims staked, and, more importantly, the number of option commitments also reached new levels.

The Fourth Annual Mineral Exploration Course for Prospectors was again held in May, but the location was changed from Selkirk College in Castlegar to David Thompson University Centre in Nelson. Field courses in geochemistry and geophysics remained similar to previous years, but at the demand of previous graduates the geology content was increased. The geology portion was staffed by the district geologists, under the supervision of A. F. Shepherd, the geochemistry session by Stan Hoffman (BP Minerals Limited), and geophysics by Jules Lajoie (Cominco Ltd.). W. S. Read acted as over-all coordinator.

Winter basic geology and prospecting courses were held at more than 20 different centres during the year. The reduction from previous years was due to increased demands for other services.

MINERAL EXPLORATION INCENTIVE PROGRAM

The Mineral Exploration Incentive Program, instituted in 1978 to help a faltering exploration industry, was dropped on March 31, 1980. Applications during 1978 resulted in contractual agreements with 46 exploration companies and individuals. All programs were completed by February 15, 1980 and all payments made before March 31, 1980.

Payments to the 46 contractors totalled $290 077 and were responsible for the initiation and completion of $3 655 298 worth of mineral exploration. In addition, 255 persons were employed on these projects, with a total of 12 097 man days involved. A breakdown of the work produced shows that it involved more than

$700 000 in diamond-core drilling, the establishment of 300 kilometres of control grid lines and 58 kilometres of B.C.L.S. control survey stations, $51 700 worth of geologic mapping, more than 50 kilometres of detailed geophysical surveys, the analysis of more than 10 500 rock, silt, and soil samples, and the purchase of more than $46 000 in remote helicopter services.

All projects required the submission of assessment reports which can be viewed by the public after the confidentiality period expires.

In addition to the obvious economic spin-off from 46 projects, some of the 1979/1980 projects will be ongoing. These include:

(1) Banwan Gold Mines Ltd. (Porcher Island),
(2) Consolidated Cinola Mines Ltd. (Queen Charlotte Island),
(3) Dimac Resource Corporation (Clearwater),
(4) Granges Exploration Aktiebolag (Capoose Lake),
(5) Hallmac Mines Ltd. (Sandon),
(6) Penresh Explorations Ltd. (Golden), and
(7) Scottie Gold Mines Ltd. (Stewart).

GEOTHERMAL INVESTIGATIONS

Involvement in geothermal investigations in 1980 was continued by E. W. Grove and B. N. Church as members of several steering committees on Meager Creek development. In addition, previous geological studies by Church on the sedimentary and volcanic basins of central British Columbia were used as the basis for the development of concepts for exploration for hot water systems for use of small communities and industries.

CORE STORAGE

Coal core from the northeast coalfield has been stored at the Charlie Lake facility since 1976. The current Regulations require that core designated as essential be shipped to Charlie Lake for storage. The core and accompanying maps and logs are treated as confidential under the limits of the Regulations.

There is now more than 135 000 metres of core from northeast exploration programs in storage. Considerable use has been made of this core by industry as well as university and government geologists and engineers. Examination rates for the use of the core and facilities are twenty dollars ($20.00) per party per day and fifty cents ($ 0.50) per core box examined. The facilities are open all year, except on holidays and weekends.

MINERAL LAND–USE STUDIES

Field and office studies related to mineral land use have become an increasingly large aspect of the work performed by the Applied Geology Section. These studies include field examination of sites for ecological reserves, recreation areas, wilderness proposals, and parks. In addition, numerous requests for mineral and placer reserves from various levels of government and Crown corporations form a steady stream through all offices, and all require field and office examination.

Another aspect of mineral land use that requires considerable input is Crown land priorization. It is a committee process, involving various ministries and public groups, which examine large tracts of land or subregional districts for best resource use. The South Moresby, Spruce Lake, Clinton Subregional Plan, and the Libby Pondage Area studies are examples where input from the Applied Geology Section and other personnel of the Geological Division attempt to prevent alienation of mineral resources.

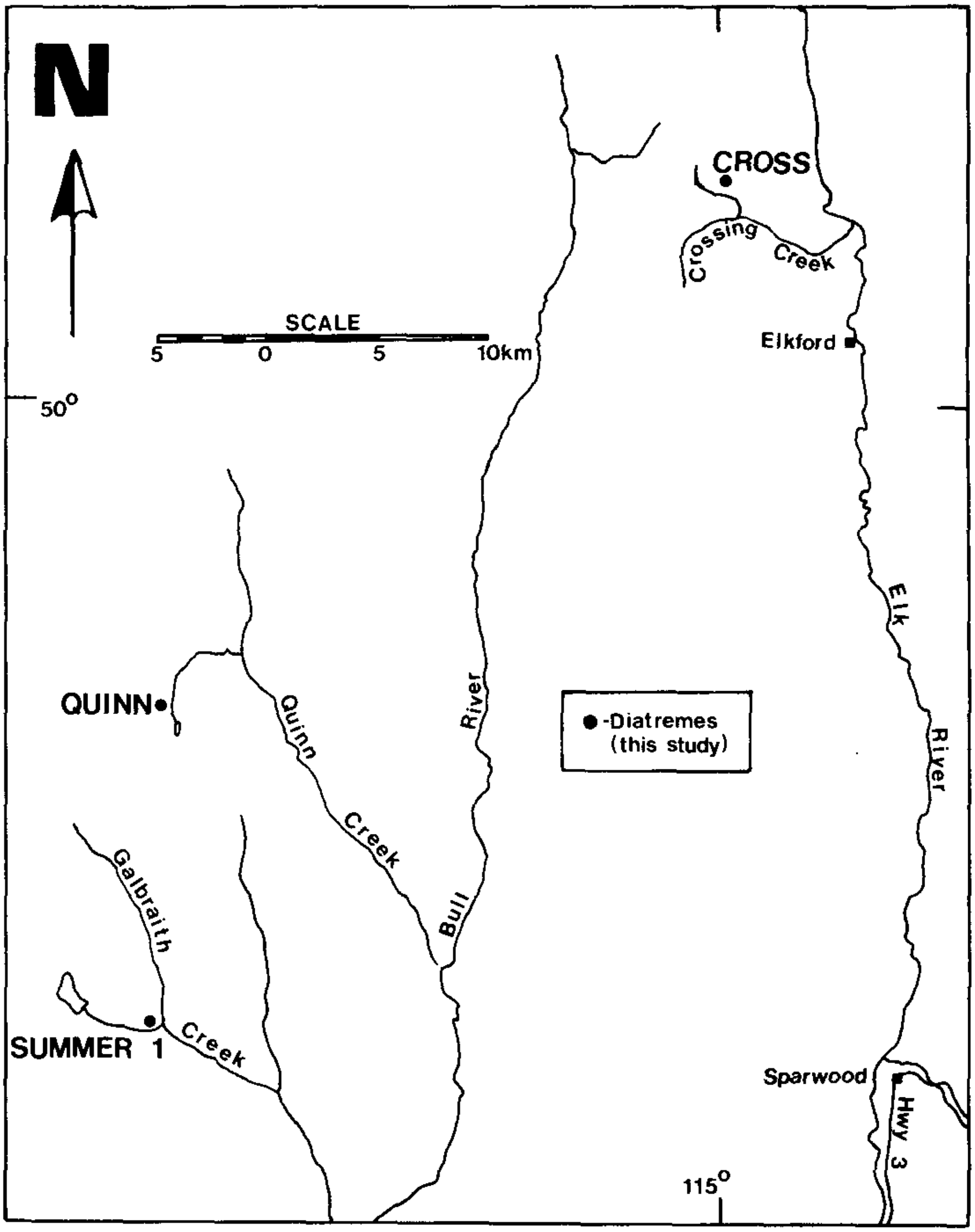

Figure 32. Location of three diatremes (Cross, Quinn, and Summer 1) discussed in this study, NTS 82G and 82J.

MINERAL PROPERTY EXAMINATIONS

SOUTHEAST BRITISH COLUMBIA

DIATREME BRECCIAS IN THE SOUTHERN ROCKY MOUNTAINS (82 G and J)

By D. A. Grieve

INTRODUCTION

Intrusive breccias in southeastern British Columbia are a relatively recent discovery. Hovdebo (1957) described the Crossing Creek diatreme (Fig. 32) found during work with a California Standard field party under the supervision of G.G.L. Henderson. The ultrabasic nature of the intrusion was not recognized at that time. G. B. Leech noted the locations of several diatreme breccias in the west half of map sheet 82J (Leech, 1964, 1965) and included their locations on his open file map of the area (Leech, 1979). A Cominco Ltd. exploration party became interested in the Crossing Creek intrusion in 1976. After tentative identification of the rock as a kimberlite, an ambitious exploration program was launched, which succeeded in discovering approximately 40 other diatremes (Roberts, *et al.*, 1980). Subsequent exploration by Cominco and others has turned up other similar intrusions.

The intrusions are dispersed sporadically along a north-south zone roughly 90 kilometres long and 20 kilometres wide. They are clustered in the drainages of the Bull River in the south and the White and Palliser Rivers in the north (Roberts, *et al.*, 1980). An exception is the Crossing Creek diatreme, which is in the drainage system of the Elk River, approximately 20 kilometres east of the centreline of the zone containing the other intrusions. Most of the diatremes are in rugged topography with limited or poor access, a factor which has contributed to their elusiveness.

REGIONAL SETTING

The diatremes are within the northwest-southeast-trending main and western ranges of the southern Rocky Mountains. This part of the Rockies is characterized by southwest-dipping thrust faults and associated folding and overfolding. The region is underlain by predominantly Cambrian through Permian carbonate and clastic sedimentary rocks. According to Roberts, *et al.* (1980) all except the Crossing Creek diatreme were intruded into Middle Devonian and older strata. The Crossing Creek diatreme lies within Permian rocks.

Other igneous rocks in the same zone include: the 'Bull River amygdaloid' (Leech, 1979), an intermediate or basic volcanic rock of unknown age; the 'White River diabasic sill complex, with associated breccia (diatremic) dykes' (Leech, 1979); and small intrusions of quartz monzonite, monzonite, and granodiorite (Leech, 1960). Alkalic igneous rocks are found outside the zone; these include the Ice River complex in Yoho National Park, and the alkalic Crowsnest volcanic and associated Howell Creek intrusive rocks, from the Crowsnest and Flathead regions respectively. The Ice River complex is Devonian and has been dated at

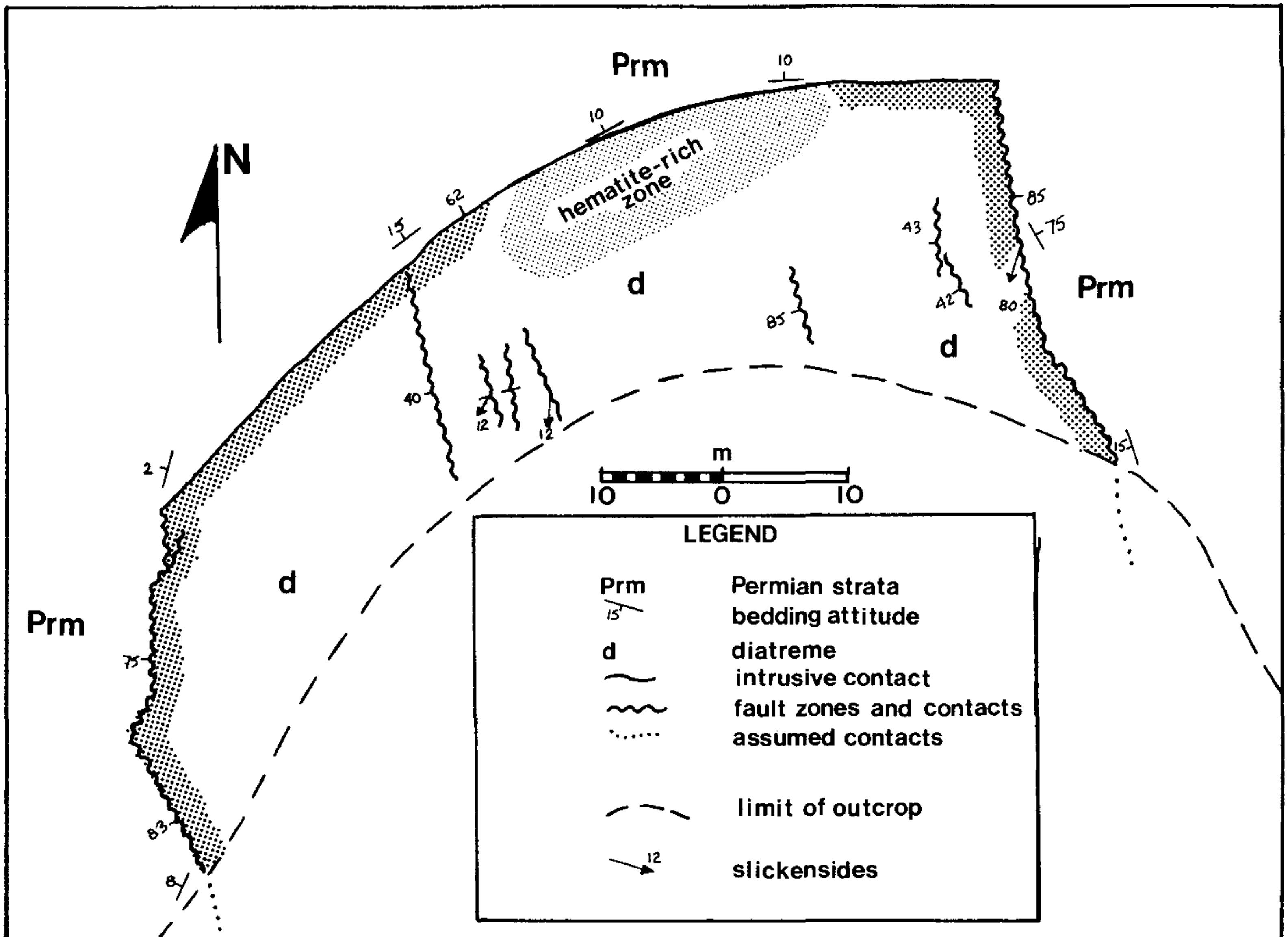

Figure 33. Geologic map of the Cross diatreme, NTS 82J (Prm = Permian Rocky Mountain Group).

between 327 and 390 Ma, while the Crowsnest and Howell Creek are of Late Cretaceous age (Currie, 1976; Gordy and Edwards, 1962).

The nearest known kimberlitic diatremes occur in north-central Montana (Hearn, 1968) and in the boundary area of Wyoming and Colorado (McCallum and Mabarak, 1976).

FIELD AND LABORATORY WORK

Diatremes at Crossing Creek, Quinn Creek, and Summer Creek were examined (Fig. 32) and geological mapping of the Crossing Creek exposure was carried out (Fig. 33). All three were sampled for petrography, geochemistry, X-ray diffraction, and age dating. Follow-up laboratory work has so far included minor thin-section analysis and X-ray diffraction and spectrographic analysis of a garnet crystal (at the British Columbia Ministry of Energy, Mines and Petroleum Resources laboratory in Victoria). A potassium-argon age date on phlogopite samples from Crossing Creek has been obtained from the Department of Geological Sciences at the University of British Columbia.

CROSSING CREEK (CROSS) DIATREME

The Cross diatreme is located at 2 200 metres elevation on the steep south-facing slope on the north side of the Crossing Creek valley, 8 kilometres northwest of Elkford (Fig. 32). It may be reached via the Crossing Creek road and an old access road or by helicopter. A helicopter landing pad has been constructed at the exposure.

The outcrop of the Cross diatreme is approximately 70 metres by 60 metres (Fig. 33). The trace of the diatreme downward into Crossing Creek has been mapped by Cominco geologists (Pighin, 1980, personal communication), although below the exposure described here only highly weathered material can be found.

The shape of the intrusion is pipe like, and steep-dipping contacts with the host limestones, cherts, and black shales of the Permian Rocky Mountain Group are well exposed (Fig. 33). Strata adjacent to the western and northern contacts are nearly flat lying and undisturbed, whereas the eastern contact is marked by a vertical zone of highly contorted and sheared strata (Fig. 33). Numerous slickensided shear zones occur within the exposure; most are subparallel to the contacts. These zones often mark the contact between different lithologies within the intrusion. No thermal metamorphic effects are evident adjacent to the contacts.

Based on field observation, the outcrop is composed of at least three distinct lithologies. The spatial relationship of these lithologies was not mapped in detail, with the exception of the hematite-rich zone in the upper portion of the outcrop (Fig. 33). This latter zone is characterized by visible phlogopite, altered olivine, hematite, and calcite, in a dark bluish green calcareous groundmass. Xenoliths are generally small (up to 5 centimetres), well rounded to subangular, and include limestone, argillite, and serpentinized ultrabasic material.

A second lithology occurs at the western portion of the outcrop and in sheared zones. It consists of xenoliths up to 2 metres in diameter and hematite pods up to 2 centimetres in diameter, in a pale green friable and earthy groundmass; apparently it represents severe weathering of intrusive material. Xenoliths consist of sedimentary and ultrabasic material, including limestone, chert, argillite, serpentinized ultrabasic material, relatively fresh peridotite, and ultrabasic breccia. The last is identical to portions of the diatreme. Xenoliths tend to weather out of the groundmass, and generally have rounded and polished surfaces.

A third gross lithology, found generally in the central portions of the outcrop, includes massive dark green calcareous groundmass with phenocrysts (<5 millimetres) of phlogopite, altered olivine, calcite, green chrome diopside, and rare red-brown garnet. Rounded xenoliths of sedimentary and ultrabasic material (up to 15 centimetres in diameter) are identical in composition to those described previously. A variation of this lithology is a rock which has a massive black groundmass with 1 to 2-millimetre phenocrysts in which xenoliths are less than 1 centimetre in diameter.

Fibrous calcite is common within shear zones, where it coats fractures.

A thin section of a sample from the hematite-rich zone shows a fine groundmass of carbonate, serpentine, phlogopite, hematite, and other opaques, with xenocrysts and/or phenocrysts of carbonate, phlogopite, serpentine, hematite, and rare pyroxene. Xenoliths include: serpentinized ultrabasic rocks with relict mosaic textures; material identical to surrounding groundmass; carbonate rock; and altered garnet-bearing ultrabasic rocks (peridotite ?) with garnet, serpentine, chlorite, phlogopite, spinel, and opaques. Reaction rims occur with many of the xenoliths and are composed of combinations of serpentine, carbonate, chlorite, and mica. In certain portions of the section, hematite appears to have replaced the entire groundmass assemblage. Microveins of serpentine and carbonate are also present.

A garnet crystal was determined, by X-ray diffraction, to be of composition: pyrope (65 per cent); almandine (15 per cent); and grossular and uvarovite (20 per cent). Chrome content of the same crystal was determined as greater than 2 per cent by semiquantitative spectrographic analysis.

A spurious age of 595±15 Ma was obtained by potassium-argon method on a phlogopite concentrate. This age apparently reflects the gas-assimilating capabilities of phlogopite, and the gas-rich nature of kimberlite magma (McCallum and Mabarak, 1976), which have resulted in anomalously high argon contents.

QUINN CREEK (QUINN) DIATREME

The Quinn diatreme is located at 2 030 metres elevation on the east-facing slope near the head of a small tributary of Quinn Creek, 60 kilometres northeast of Cranbrook (Fig. 32). The diatreme is clearly visible from a trail which follows the east side of the tributary.

The diatreme is exposed over an elevation change of at least 70 metres. It is pipe like in nature and cuts the country rock. Host carbonates of the Ordovician-Silurian Beaverfoot-Brisco Formation (Leech, 1960) dip shallowly to the northwest, whereas the intrusive contact plunges steeply to the southwest. As was the case with the Cross diatreme, there is no evidence of thermal metamorphism along the contact.

The Quinn diatreme is a pale grey-green breccia, with generally small (up to 5-centimetre) clasts. Xenoliths are generally well rounded and consist of limestone, argillite, quartzite, granitic intrusive rocks, and, rarely, altered ultrabasic rocks. Phenocrysts or xenocrysts of olivine and spinel up to 5 millimetres were also noted. The matrix is calcareous, and calcite veining is common throughout.

The relatively coarse diatreme breccia is cut by a pale green, fine breccia dyke, with sharp sinuous contacts. The dyke averages 1 or 2 metres in width and can be traced over much of the exposure. It is calcareous and contains well-rounded fragments of argillite, carbonate, and quartzite.

A thin section of the coarser breccia includes rounded to angular quartz and feldspar grains, devitrified fine to vesicular volcanic fragments, carbonate, argillaceous material, and serpentine, set in a fine carbonatized groundmass. A section of the fine breccia dyke contains subrounded grains of altered plagioclase (composition approximately An_{60}), carbonate, and serpentine, with only a small amount of highly altered fine-grained matrix.

SUMMER CREEK (SUMMER 1) DIATREME

The Summer 1 diatreme is one of two small intrusive bodies found adjacent to Galbraith Creek logging road, at the intersection of Galbraith and Summer Creeks, 40 kilometres northeast of Cranbrook (Fig. 32). It is at approximately 1 340 metres elevation and is readily identifiable because it weathers red brown and forms a 50-metre-high resistant knoll. Limestone outcrops on top of the knoll imply that the cap of the intrusion is preserved. Host rocks were mapped as Upper Cambrian McKay Group by Leech (1960) and include thin-bedded and argillaceous limestones.

The Summer 1 diatreme does not obviously crosscut the host strata, but a distinct foliation within the intrusion parallel to one exposure of the contact dips steeply southeast, compared with a 30-degree northeast dip on the limestone.

The diatreme is a breccia throughout. The coarsest fragments are angular limestone clasts up to 70 centimetres in length adjacent to the contact. Other portions of the intrusion consist of coarse or fine breccia with subangular to well-rounded fragments in a medium grey calcareous matrix. Xenoliths are of limestone, quartzite, argillite, granitic rocks, and rhyolite. Coarsely crystalline quartz and serpentine, believed to be xenocrysts, were also noted.

Petrographic analysis of one sample showed a completely carbonatized groundmass with patches of serpentine. Xenoliths include very fine-grained carbonatized volcanic fragments, carbonate, and serpentine-carbonate intergrowths.

Float samples from across Galbraith Creek, less than 250 metres east of the outcrop of the diatreme, contain distinctive green chrome diopside.

The smaller Summer 2 diatreme, located 1 kilometre to the west, is characterized by an abundance of phenocrysts and xenocrysts of altered chrome diopside and spinel, quartz, and calcite.

An intrusive hornblende porphyry crops out locally between the two diatremes.

DISCUSSION

The Cross, Quinn, and Summer 1 diatremes have certain features in common that may be typical of some or all the diatremes in the southern Rocky Mountains. All are apparently pipe-like intrusions discordant to bedding. All have fragmental and breccia textures, with well-rounded to subangular fragments. Xenoliths in all cases include sedimentary rocks typical of the host and nearby Paleozoic rocks. None produced thermal metamorphic effects on the host rocks. All appear to have been carbonatized and serpentinized during intrusion.

The contrasts are fewer, at least in terms of field observation, but are definitely significant. The large quantity of ultrabasic xenoliths in the Cross diatreme is anomalous, along with the presence of phlogopite and chrome-rich pyrope-almandine garnet.

Another contrast is the apparently younger age of the Cross diatreme. Roberts, *et al.* (1980) state that a Middle Devonian conglomerate contains clasts of the intrusions and, based on the age of host rocks, postulate a pre-Middle Devonian age for all the diatremes except the Cross. As the Cross cuts Permian rocks, it must be at least 100 Ma younger than the others. Interestingly, kimberlites near the Wyoming-Colorado state line are believed to be of very Late Silurian or Early Devonian age (McCallum and Mabarak, 1976).

Cominco geologists have identified the Cross intrusion as a kimberlite (Roberts, *et al.*, 1980). The presence of pyrope-almandine garnet, chrome diopside, olivine, phlogopite, and calcite, minerals which typically occur in kimberlites along with the occurrence of xenoliths of garnet-bearing ultrabasic rocks tends to support this identification. Further petrography and geochemical analyses are needed to confirm this interpretation. The Cominco staff believes that the other diatremes are limburgites, not kimberlites (Pighin, 1980, personal communication). Limburgites have olivine or pyroxene in an ultrabasic and alkaline groundmass.

The lack of thermal effects along their contacts suggests the diatremes were intruded 'cold.' Partially solid conditions are evidenced by the rounded and polished xenoliths. The forcefulness of the Cross intrusion is suggested by the contorted bedding in sedimentary rocks adjacent to the eastern contact (Fig. 33).

An upper mantle source for the Cross diatreme is suggested due to the presence of garnet-bearing ultrabasic xenoliths and the occurrence of chrome-rich pyrope-almandine garnet and chrome-bearing diopside (*see*, for example, McCallum and Mabarak, 1976). A deep origin for other diatremes cannot be ruled out, especially given the presence of chrome diopside, olivine, and ultramafic nodules (Pighin, 1980, personal communication). Kimberlitic affinities cannot therefore be precluded.

Taken as a group, the diatremes of southeastern British Columbia reflect a tectonic control with a north-south orientation and therefore were intruded in zones of weakness not directly related to the tectonic control of the Rocky Mountains. It is interesting to note that diatremes in Colorado and Wyoming are also aligned in a rough north-south pattern (McCallum and Mabarak, 1976). An ancient north-south-trending, deep fault system in cratonic basement rocks underlying the Paleozoic platform-continental margin assemblage may account for the spatial orientation of the diatremes.

Further conclusions on classification and derivation of the diatreme breccias of the southern Rocky Mountains must await petrographic and geochemical analyses. The study will be extended to other properties in the future.

ACKNOWLEDGMENTS

G. G. Addie of the Ministry was involved in the field investigations and will be a coworker in further studies. Cominco geologist, D. Pighin provided helpful advice and enlightening discussion. E. W. Grove suggested the project and has given much advice and support.

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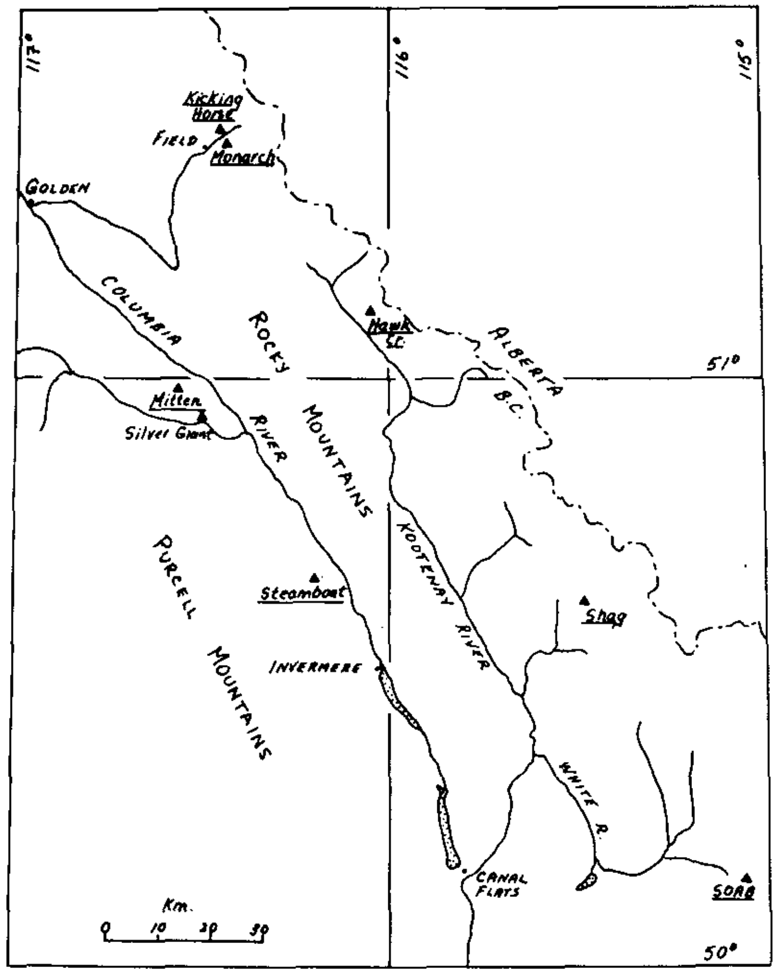

Figure 34. Location of Paleozoic lead-zinc deposits in southeastern British Columbia.

	Kootenay Arc	Steamboat Mtn Jubilee Mountain	Western Shale facies	Monarch-Kicking Horse Shag
UЄ		McKay	McKay	Bison Creek Lyell
		Jubilee	Chancellor	Sullivan Waterfowl Arctomys Pika Eldon Stephen Cathedral
MЄ	Nelway			
LЄ	Laib Reno Quartzite Range	Eager Cranbrook		Mt Whyte Gog

Figure 35. Correlation of Middle Cambrian stratigraphy, southeastern British Columbia.

LEAD–ZINC SHOWINGS IN CARBONATE ROCKS
SOUTHERN ROCKY MOUNTAINS
(82)

By D. A. Grieve and Trygve Höy

INTRODUCTION

Carbonate rocks of the southern Rocky Mountains are often overlooked as potential host rocks for economic base metal deposits. However, numerous lead-zinc deposits and showings have been discovered over the years, the most significant of which is the Monarch – Kicking Horse (MI 82N-19, 20) at Field. Among the more recently discovered are the Shag (MI 82J/NW-2) and SOAB (MI 82J/SW-13) prospects, both of which were found as a result of reconnaissance geochemical exploration programs in the 1970's. These, and a number of other prospects, were visited in August 1980, in order to gain a general understanding of the type, distribution, and characteristics of Paleozoic lead-zinc deposits and to assess the potential for further exploration and discoveries.

The showings are within the foreland fold-and-thrust belt of the Cordillera and occur not only in the Rocky Mountains but also in the Rocky Mountain Trench. Although the structural style varies within the study area, northeast-directed thrust faults and associated folds and overfolds with northwest-southeast axes dominate.

The deposits, with the exception of the Hawk Creek showing (MI 82N-21), are in Middle to Upper Cambrian and Devonian platformal carbonates. The Monarch – Kicking Horse deposits occur in a thick succession of massive to thin-bedded limestone and dolomite of the Middle Cambrian Cathedral Formation. The Shag group was reported to be in the Cathedral Formation (Bending, 1978); however, it now appears that the host carbonate is part of the overlying Pika and Eldon Formations (Bending, 1980, personal communication). Steamboat (MI 82K/NE-65) and Mitten occur in carbonate of the Middle to Upper Cambrian Jubilee Formation within and along the western margin of the Rocky Mountain Trench. Hawk Creek is a vein deposit in limestone and shale of the Cambro-Ordovician Goodsir Group, and the SOAB prospect is in dolomite of the Palliser Formation.

Characteristically the Middle Cambrian deposits are in close proximity to carbonate bank margins. They have many features characteristic of the so-called Mississippi Valley-type deposits (Sangster, 1970). Monarch – Kicking Horse and Shag are in Middle Cambrian platformal carbonates just east of a transition to basinal shale and limestone of the Chancellor Group (Cook, 1970; Aitken, 1971). Deposits in the platformal Jubilee Formation are on an ancestral high, the Windermere, that was periodically emergent in Early Paleozoic time (Reesor, 1973).

DESCRIPTIONS OF DEPOSITS

MONARCH – KICKING HORSE (MI 82N-19, 20)

The Monarch – Kicking Horse deposits that occur in the steep cliffs on either side of the Kicking Horse River just east of the town of Field (Fig. 34) were described by Ney (1957) and Westervelt (1979). Their regional stratigraphic and tectonic setting was outlined by Cook (1970). Production from both deposits, from 1888 until their final closure in 1952, totalled 0.82 million tonnes containing 5.63 per cent lead, 8.85 per cent zinc, and 31 grams per tonne silver.

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The deposits comprise a number of separate and discrete mineralized zones within massive to brecciated dolomite that forms a 60-metre stratigraphic interval in the lower 125 metres of the Cathedral Formation (Fig. 35). The dolomite zone cuts sharply into underlying well-bedded limestone and dolomite and is overlain by well-bedded carbonate rock. The brecciated dolomite that hosts the orebodies consists either of a stockwork of white dolomite 'veins' in grey dolomite or of light grey dolomite fragments in dark grey dolomite. Dolomite alteration zones immediately underlying the orebodies have original bedding preserved. The dolomite zones and orebodies trend northerly, parallel to both late normal faults, and to the abrupt carbonate platform-basinal shale transition zone described earlier.

The orebodies occur as narrow elongate runs in brecciated dolomite. They die out gradually along trend into barren, unmineralized dolomite but have sharp lateral boundaries. Sulphides, consisting of amber-coloured sphalerite, galena, minor pyrite, and trace chalcopyrite, are disseminated in the dolomite matrix of breccias and form irregular veinlets cutting both matrix and fragments. Coarse sphalerite and galena commonly rim dark dolomite fragments; spar dolomite is interstitial.

Dolomitization and the development of breccia and associated cavities cannot be directly related to any late fault structures. Faults cutting the deposits are not conspicuous and one of the two supposed boundary 'faults,' the Stephen-Dennis fault (Allan, 1914), is dominantly a stratigraphic, not a structural break (Cook, 1970). The location of the Monarch – Kicking Horse deposits in dolomitized breccia adjacent to a platformal bank margin suggests rather a regional stratigraphic control of mineralization.

SHAG (MI 82J/NW-2)

A number of small lead-zinc showings were discovered by C. Graf in 1977 in limestone and dolomite in the heavily wooded drainage of Shag Creek 35 kilometres east of Radium (Fig. 34). Work by Rio Tinto Canadian Exploration Limited has included geological mapping, prospecting, soil sampling, and diamond drilling.

The showings occur in a thick, massive to well-bedded limestone-dolostone unit originally correlated with the Middle Cambrian Cathedral Formation (Bending, 1978) but may be in the overlying Middle Cambrian Pika or Eldon Formations (Fig. 35; Bending, 1980, personal communication).

Most of the showings consist of concentrations of galena and pale yellow to orange-coloured sphalerite in granular or brecciated dolostone overlain by dark laminated limestone. The sulphide concentrations appear to be restricted to two horizons, although a number of megascopically similar horizons occur in the succession. The dolostone at the 'BM,' the largest of the showings, consists of a number of cyclical beds. Each is a few centimetres thick, and each consists of an erosional basal surface overlain by massive or irregularly laminated dark dolomite capped by a coarse fragmental breccia or fenestral dolomite. This succession of cyclical beds is capped by dark, well-layered limestone.

Coarse crystallized sphalerite, minor galena, and trace amounts of pyrite occur either within sparry dolomite or dark argillaceous limestone that is interstitial to breccia fragments or as disseminated grains through more massive dolomite.

A second, similar horizon hosts scattered sulphide occurrences over a wide area. The mode of mineralization is generally similar, although locally galena and minor sphalerite occur in crosscutting calcite veins and shears.

The finely disseminated nature of some of the sulphide minerals and their restriction to specific horizons suggests a syngenetic to early diagenetic origin. The host rock is an intertidal dolostone that was repeatly emergent and hence subjected to erosion, solution, and local brecciation. Dark argillaceous limestone between dolomite fragments probably represents concentrations of less soluble residue, and interstitial sparry dolomite represents early diagenetic cavity filling. The favourable horizons developed just prior to or during the marine transgression that caused deposition of the overlying subtidal laminated limestone. As at Monarch – Kicking Horse, the deposits are proximal to a platform-basin transition zone.

STEAMBOAT (MI 82K/NE-65)

The Steamboat property is on Steamboat Mountain, 12 kilometres northwest of Radium (Fig. 34). It is accessible by logging roads which branch off a secondary road on the west side of the Columbia River. Work by the owner, Cominco Ltd., includes drilling and geophysical and geochemical surveys in 1975 and 1976.

Host rocks are massive dolomites of the Jubilee Formation (Fig. 35) on the overturned eastern limb of a southwest-dipping syncline (Reesor, 1973). Sparse mineralization occurs along a strike length of approximately 300 metres and to a depth in excess of 100 metres (Webber, 1977). Galena, sphalerite, pyrite, and minor copper sulphides are associated with silicified dolomite and dolomite breccia with quartz and barite veins and pods. Dolomite breccia is generally of a coarse to fine chaotic or 'crackle' variety, but may also appear clastic (Webber, 1977). Fragments of light or dark-coloured dolomite lie in a matrix of fine to coarsely crystalline dolomite, barite, or quartz.

Galena and sphalerite occur as disseminations, irregular clusters, or stringers of generally fine crystals. They occur in dolomite fragments, in barite, in quartz, or in the breccia matrix. Malachite and azurite were observed locally.

Mineralization is considered to be of the vein-replacement type in 'late' fractures and fracture breccia.

MITTEN

The Mitten prospect is located on Lead Mountain, 17 kilometres northwest of Spillimacheen, and is reached by a 9-kilometre road north from the Silver Giant mine (Fig. 34). Discovery of the property dates to the turn of the century, but early work, that includes two adits and numerous surface cuts, did not prove up an economic orebody. Further drifting and diamond drilling were carried out in the mid-1950's. Work by Cominco in 1976 included surface and underground mapping and soil geochemistry.

The host rock was mapped as Middle Cambrian Jubilee Formation by Reesor (1973), but Cominco geogists believe it to be a dolomitized equivalent of the Cambro-Ordovician McKay Group (Fig. 35). Underlying Lower Cambrian quartzite, grit, and conglomerate of the Cranbrook Formation is also exposed on the property. Both units dip steeply (55 to 65 degrees) to the southwest.

Mineralization on surface occurs in an area of roughly 50 square metres. A 60-metre-wide mineralized zone was intersected in three drifts and in diamond-drill holes (*Minister of Mines, B.C.,* Ann. Rept., 1955). Galena, sphalerite, and pyrite, in decreasing order of abundance, are associated with centimetre-scale sparry medium-grained dolomite pods and veinlets.

Galena is finely crystalline. It lines cavities that were later filled by spar dolomite, occurs as irregular patches and stringers in the sparry dolomite pods, and forms stringers, veinlets, and disseminated clusters in both dolomite host rock and spar dolomite. Sphalerite is fine to medium grained. It is mainly associated with the spar dolomite as enclosed clusters or as cavity linings but also occurs as stringers in the dolomite. Minor pyrite is disseminated in the spar dolomite.

The shape of the spar dolomite pods and the rimming texture formed by galena and sphalerite suggests filling of open spaces. The origin of the cavities is not known; they may represent spaces in an original reefal limestone or they may be related to later dolomitization and brecciation. Remobilization of sulphides into stringers and veinlets is common.

Sampling of the deposit over a 5 by 35-metre zone yielded an average grade of 3.75 per cent lead (*Minister of Mines, B.C.*, Ann. Rept., 1954, p. 149). Assays of five grab samples collected during this study are given below. Lead varies from approximately 2 to 5 per cent, zinc <1 per cent to 2 per cent; the silver and gold content are low.

Sample No.	Au	Ag	Pb	Zn
	ppm	*ppm*	*per cent*	*per cent*
Lead Mountain 1A	<1	5.8	5.52	0.58
Lead Mountain 1B	<1	5.0	4.50	0.71
Lead Mountain 3A	<1	2.6	4.48	0.29
Lead Mountain 3B	<1	5.0	2.40	1.38
Lead Mountain 3C	<1	4.6	2.21	1.94

HAWK CREEK (MI 82N-21)

The showing is located on the north side of Hawk Creek in Kootenay National Park, about 50 kilometres northeast of Radium (Fig. 34). Trenching and drilling in 1942 by Base Metals Mining Corporation Ltd. constitute the only major physical work done on the property. Host rocks are strongly cleaved, thin-bedded argillaceous limestones and argillites of the Cambro-Ordovician Goodsir Group. A prominent, steep, northwest-trending shear zone appears to control the distribution of the vein and replacement mineralization. The shear zone and associated mineralization cuts sharply across bedding in the sedimentary rocks.

Mineralization comprises an irregular cylindrical zone roughly 15 metres in width and 75 metres in length (Henderson, 1953). Amber-coloured sphalerite, the dominant sulphide, forms massive fine-grained pods, disseminations, and stringers. Coarser grained dark brown sphalerite occurs as disseminated clusters in sparry calcite veins and stringers. Galena, which is less abundant, occurs as fine-grained disseminations and stringers associated with both sphalerite, calcite, and minor pyrite.

A 2-metre-wide high-grade zone assayed 30.6 per cent zinc, 43 per cent lead, 50 grams per tonne silver, and 1.56 grams per tonne gold (Richmond, 1930).

SOAB (MI 82J/SW-13), BOIVIN, ALPINE

On the SOAB mineral claims stratabound lead-zinc showings occur in platformal carbonates of the Devonian Palliser Formation. The claims are located near the headwaters of Bull River, 50 kilometres east of Canal Flats (Fig. 34). They were discovered in 1972 by Silver Standard Mines Limited during follow-up of a regional stream sediment anomaly. The Alpine and Boivin showings were discovered in 1977 and 1978. Limited drilling of the SOAB and Alpine and blasting and sampling of Boivin has evaluated these occurrences. The geology of the property has been described by Gibson (1979) and is the basis of his M.Sc. thesis in progress at the University of British Columbia.

Mineralization is restricted to a unit within the Lower Morro member of the Palliser Formation. The unit is in the lower, overturned limb of an eastward-verging asymmetrical anticlinal fold that is thrust against Mississippian carbonates to the east. Overlying Cambrian-Ordovician strata to the west are also assumed to be in thrust-faulted contact with the Devonian package (Gibson, 1979).

A distinctive carbonate rock termed 'zebra facies,' that is characterized by fenestral (and geopetal) spar dolomite crescents in a fine-grained granular dolomite matrix, hosts the mineralization. It is interpreted to be of supratidal algal origin (Gibson, 1979) and is underlain and overlain by massive, subtidal limestone. Pale yellow to almost clear sphalerite is disseminated through the granular dolomite and is concentrated along the periphery of spar dolomite patches and within the spar dolomite. The mineralization is confined to a number of discrete zones generally less than 1 metre thick and a few metres in length. The Boivin showing, for example, measures approximately 12 metres in length and 2 metres in width and contains up to 20 per cent zinc (Gibson, 1979).

SUMMARY

The location of Middle Cambrian deposits in platformal carbonates adjacent to a bank margin is considered an important stratigraphic control. Associated brecciation and dolomitization in the Monarch – Kicking Horse and Mitten deposits does not appear to be structurally controlled; rather, it may be related to early karsting or cave development. Mineralization at Shag also appears to be stratigraphically controlled, not related to late structures. Its local disseminated nature in dark intertidal dolomite suggests an early, perhaps diagenetic, emplacement. Mineralization at Hawk Creek, and perhaps at Steamboat, may be structurally controlled.

The disseminated nature of sphalerite in the SOAB and its restriction to a specific carbonate unit within a thick succession of carbonates suggest an early syngenetic to diagenetic origin. Zinc-lead mineralization in Devonian rocks in southeastern British Columbia are scarce by comparison with the northeast Cordillera. Perhaps this reflects levels of exposure. The bank margin environment and shale basin facies that hosts northeast sulphide accumulations is not exposed in southeastern British Columbia; only the platformal environment, which would presumably lie to the east of the shale basin, is exposed.

ACKNOWLEDGMENTS

Parks Canada personnel are thanked for permission to collect rock samples within park boundaries. Permission of exploration companies to examine properties is greatly appreciated. Discussion with Gordon Gibson and Colin Godwin regarding the SOAB occurrence was most informative.

J. Hamilton provided cheerful field assistance.

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CENTRAL BRITISH COLUMBIA

FURTHER POTENTIAL CARBONATITE LOCALITIES (83D/6E)

By G.P.E. White

Carbonatite-like rocks were examined at Paradise Lake, at Howard Creek, at the Verity showing (MI 83D-5), and at Gum Creek, all northeast of Blue River and accessible by truck or helicopter.

Paradise Lake, accessible by helicopter, is located east of Lempriere at an elevation of 2 132 metres. Outcrops of carbonate rocks occur within high-grade metasedimentary rocks on the north face of the mountain immediately south of Paradise Lake (elevation 2 936 metres), along the ridge to the west of this 2 936-metre peak, and on both sides of the ridge. The largest exposure measuring over 100 metres along the dip occurs on a dip slope close to the col of this west ridge.

Howard Creek flows easterly into Canoe River. An outcrop of carbonatite-like rock was examined in the northwest region of the headwaters of Howard Creek on a south-facing slope. The locality is well above timberline, at around 2 300 metres elevation, and is visible from a helicopter. Other carbonates have been reported near a glacier in this area but these were not observed.

The Verity showing, which was originally staked for its vermiculite content, has received considerable attention and a stratigraphic thickness of 50 metres of carbonate rock has been reported. In the summer months, Verity is accessible by truck.

Carbonatite-like rocks have also been uncovered along the British Columbia Hydro and Power Authority right-of-way just south of Gum Creek which flows west into the North Thompson River, north of Blue River. This showing is also accessible by truck in the summer season.

At higher elevations, as might be expected, no residually weathered red soils are formed. Where residual soils are present, Three Valley Gap, Mud Lake, Gum Creek, and, to a lesser extent, at the Verity showing, they are often colour banded. The bands are distinct and 1 to 4 centimetres wide in shades of reddish brown, green, and buff. This weathering phenomenon suggests a form of banding in the fresh carbonatite but none is evident either in core or in outcrop.

Attempts will be made in the near future to make element comparisons from chemical analyses of these carbonate rocks to obtain zircon age dates and to try to correlate some of the units that crop out above timberline. If one or all of these carbonates are true carbonatites, the mode of emplacement will be studied. For example, at Three Valley Gap evidence suggests that carbonatite has intersected early fenite while at Verity fenite appears to cut carbonatite.

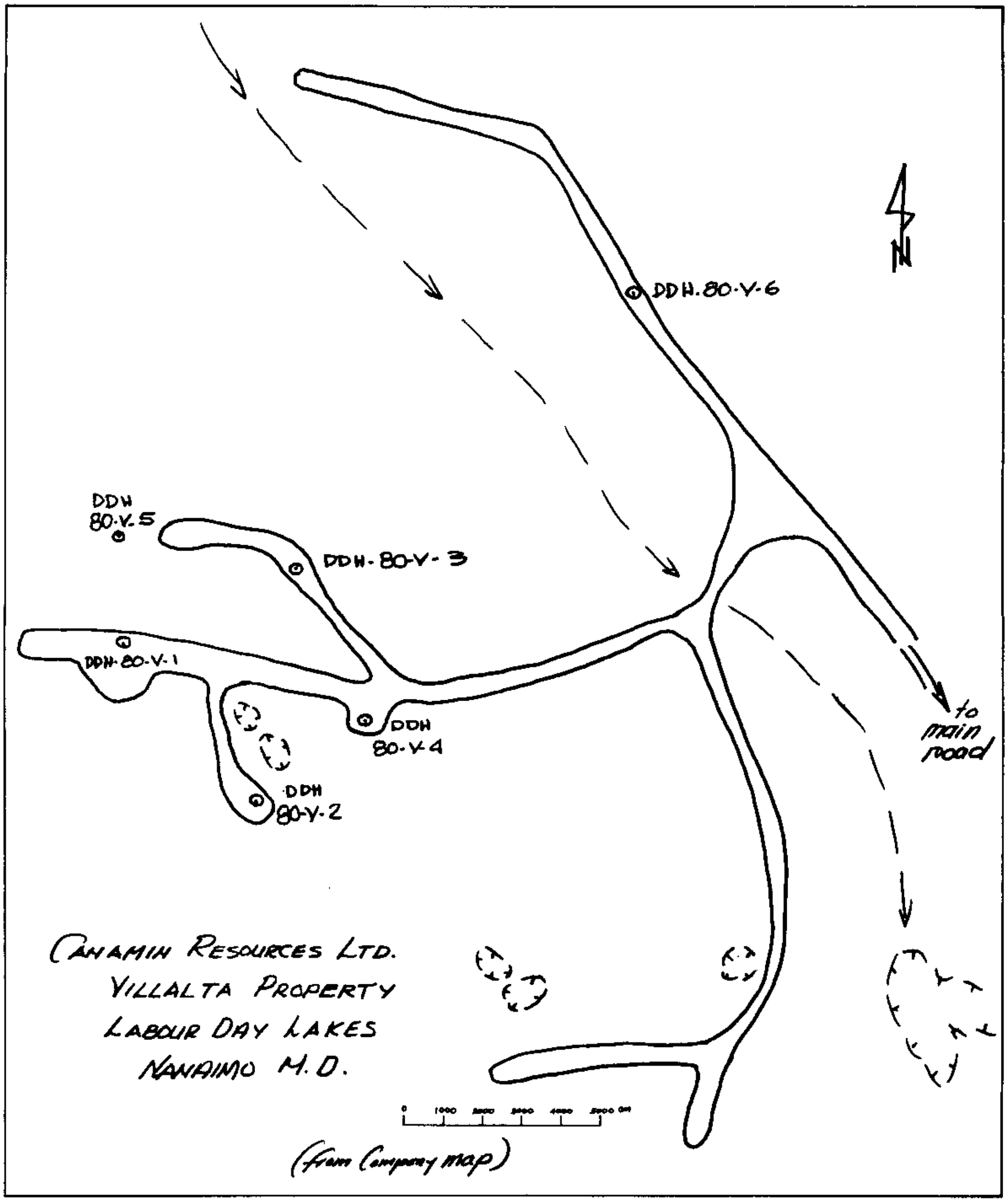

Figure 36. Villalta property (MI 92F-384).

VILLALTA PROPERTY
(92F/1W)

By E. W. Grove

The Villalta property (MI 92F-384), owned by Canamin Resources Ltd., is located 40 kilometres west of Nanaimo and 4 kilometres southwest of Labour Day Lake. Access is from Nanaimo over mostly paved logging road.

The presence of mineralization was discovered by Efrem and Lucia Specogna while engaged in a prospectors' assistance project during 1976. Reconnaissance stream silt sampling followed by float examination led *to the discovery of three new and significant mineral deposits in this one area.*

Work in 1980 included trenching, extensive sampling, geological mapping, and drilling. Six core holes totalling approximately 399 metres were drilled on the mineralized zone shown on Figure 36.

Because of the Specognas' work in the Nanaimo Lakes area, the geology of the area has been reviewed and revised. Only preliminary results will be given here.

Good exposures of crinoidal limestone and marble with thinly banded grey chert can be easily traced along the length of the east side of the valley. These members of probable Sicker Group are variable in thickness and the chert is particularly lenticular. They overlie deformed basaltic volcanic and sedimentary rocks of undetermined age and are in turn gradational to or unconformably overlain by remnants of a formerly more extensive rhyolite tuff unit. The limestones have well-developed karst topography characterized by crater-like sinkholes, dolines, and small caverns. The Sicker sedimentary units dip gently eastward and are unconformably overlain by undulating or gently dipping Nanaimo Group sandstone, siltstone, and conglomerate. It is very obvious from studies of the conglomerates that the area was extensively eroded in pre-Nanaimo times, resulting in deep major and subsidiary valleys. Many of major valleys have now been exhumed so that old hanging valleys filled with thick sedimentary rocks are exposed along the present-day walls.

The first mineralization discovered was hematite forming bouldery soil and extending down along the walls of the sinkholes into the dolines. Further prospecting showed that the massive to powdery hematite is extensive and is related to the unconformity. Rock cuts made during the recent logging operation confirmed the relationship of the hematite to the top of the Sicker sedimentary rocks.

Core drilling by Canamin during 1980 showed that the hematite mineralization extends into the hillside at a low angle for at least 110 metres and is over 30 metres wide. Drilled thickness of the mineralized horizon varies to 14 metres. Studies of the core suggest that the hematite represents the weathered product of an irregular thick, massive sulphide unit comprising primary magnetite, marcasite, and minor arsenopyrite. Silicate and other secondary minerals include siderite, calcite, quartz, serpentine, goethite, and some ilvaite. The ilvaite appears to be related to a contact skarn developed along the contacts of narrow pre-Nanaimo hornblende diorite dykes that cut the sulphide lens.

Granitic plutons adjacent to this mineralized zone were at first thought to be the normal steep-sided intrusive rocks as suggested by older mapping. A detailed look at this feldspar porphyry showed that it is in fact a shallow-dipping 50-metre-thick sill that cuts acutely across parts of the Nanaimo Group at a very low angle and overlies the mineral deposit. Extensive talus shed by the sill line the valley walls must have given the impression that there was a relatively extensive, typical Tertiary pluton. Other work by the writer on Vancouver Island has shown that these sills are more extensive than is generally known.

The potential of this new type of deposit lies in its gold and silver content. Other similar deposits at the same stratigraphic horizon has been identified on Vancouver Island but their potential has not been recognized.

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A TENNANTITE OCCURRENCE
McGILLIVRAY CREEK–LYTTON/LILLOOET AREA
(92I/5E)

By G.P.E. White

This showing is located on the Alice (Lot 1073) claim, latitude 50 degrees 29 minutes, longitude 121 degrees 42 minutes, on the north side of McGillivray Creek east of the Lytton/Lillooet highway. The area is accessible by a four-wheel-drive vehicle or on foot.

A series of basalt to rhyolite flows and flow breccias are in sinuous contact with diorite and quartz diorite of the Mount Lytton batholith (Fig. 37).

Within the volcanic sequence, conformable siliceous dolomite breccia and siliceous limestone crop out along the crest of a south to east-facing hill.

Tennantite, with what appears to be secondary chalcocite veinlets, occurs as ribbon-like, 1 to 2-centimetre bands and discontinuous blebs that are concordant with the host dolomitic beds. Generally, the tennantite is within 30 centimetres of the dolomite-volcanic rock contact.

The volcanic rocks strike 130 degrees and dip 50 degrees northeast but tight drag folds and faults occur in the carbonates. The principal fault direction is 020 degrees with steep dips.

A quartz feldspar porphyry and a feldspar porphyry intrude all rocks in the area. However, local transportation and partial rotation of quartz feldspar porphyry blocks in limestone suggest more than one period of structural movement.

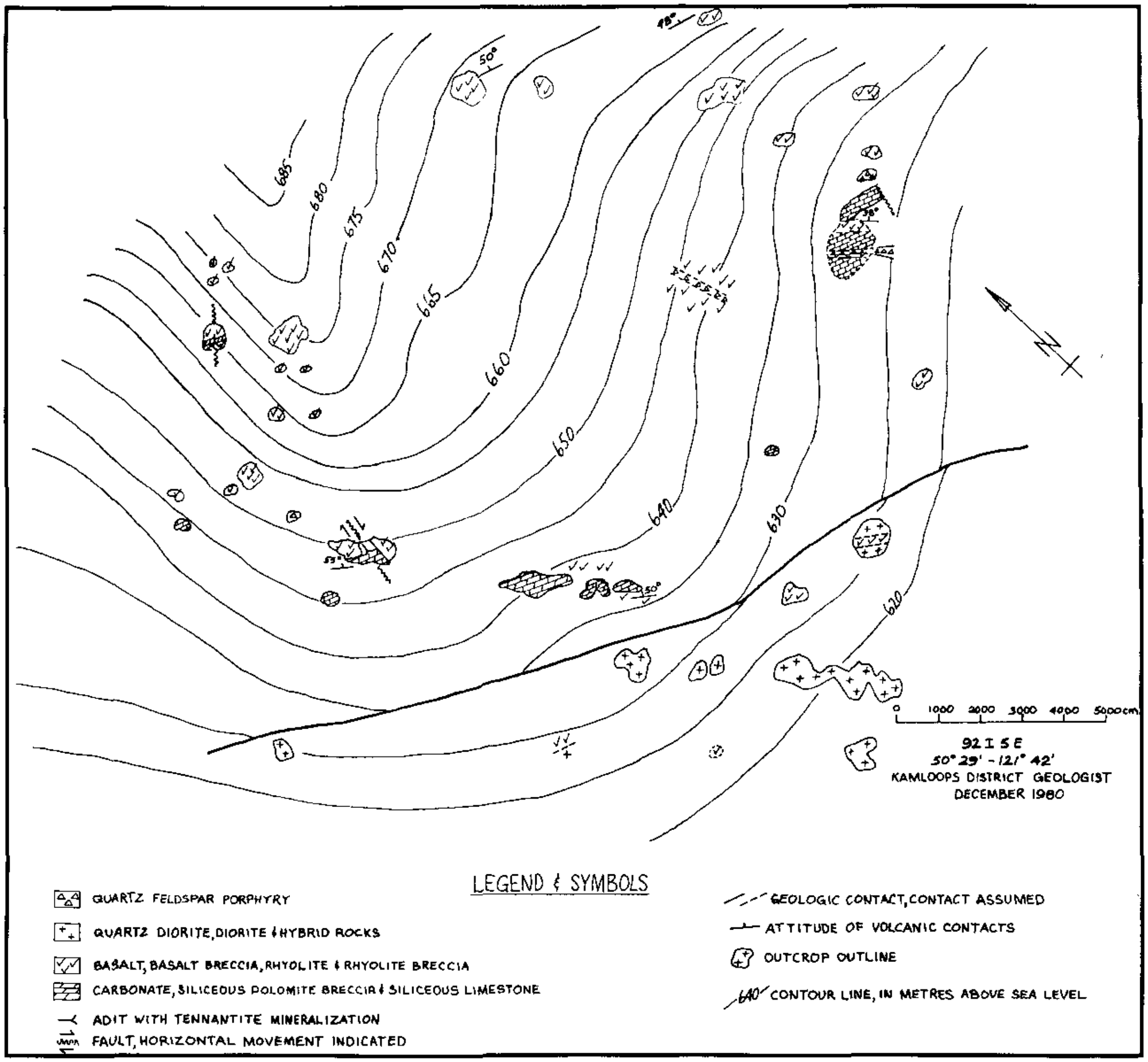

Figure 37. Geology of the Alice claim.

POISON MOUNTAIN PROSPECT
(92O/2W)

By E. W. Grove

INTRODUCTION

The Poison Mountain prospect, consisting of 262 units, lies approximately 84 kilometres north-northwest of Lillooet and 37 kilometres west of Big Bar. Road access is now via the Lillooet–Bralorne road, from Moha.

The discovery of placer gold was recorded on Poisonmount (Poison Mountain) Creek, near the headwaters of Churn Creek in 1932 (Richmond, 1933). These placer deposits lie between Buck and Poison Mountains and are northerly from the main mineralized zones which are found on the southerly slope of Poison Mountain, along the drainage of Copper Creek. It was also noted in Richmond's report that gold-bearing quartz veins cutting 'birds-eye porphyry' were found during the reconnaissance survey of Poison Mountain.

Assessment of the lode mineral potential started in 1935. Spotty work on the Copper Creek mineralization continued to 1970 when a major diamond-drill core program was undertaken by Canadian Superior Exploration Limited. No work was done on the property from 1972 to 1978. In 1979, Long Lac Mineral Exploration Ltd. drilled about 1 023 metres in five core holes which, when reviewed, indicated potentially economic values of copper, molybdenum, gold, and silver.

In 1980, Long Lac expanded its program to include 184 percussion holes totalling about 14 000 metres and 29 core holes totalling about 7 200 metres, as well as further geological studies. In addition, about 35 kilometres of the Lillooet road was upgraded and maintained to provide better access for service vehicles. Long Lac also operated a 20-man camp during the 1980 field season. The project manager was John Hogan and project geologist, Robert Brown.

GEOLOGY

The regional geology is not well enough known to detail the relationships between the Poison Mountain 'window' and the surrounding thick sedimentary sequence currently known as Relay Mountain Group of Jura-Cretaceous (?) age (Seraphim and Rainboth, 1976). The relatively isolated, steep-dipping, northwesterly trending sedimentary units at Poison and Buck Mountains include feldspathic sandstones, boulder conglomerates, and thin-bedded intercalated siltstones. At Poison Mountain, the members are largely sandstone/siltstone that have been intruded by two main types of granitic plutons. The oldest intrusion, a hornblende biotite granodiorite, extends northwesterly across the lower slope of Poison Mountain from Copper Creek to Fenton Creek. This pluton and the sedimentary country rocks are cut by a number of steep northerly trending hornblende biotite, porphyry dykes. These dykes are the birds-eye porphyry of MacKenzie (1920) and the Main, North, and East porphyry of Seraphim and Rainboth (1976). The presence of somewhat rounded inclusions of altered hornblende granodiorite in several of the porphyry dykes clearly demonstrates the sequence of intrusion. As noted by Seraphim and Rainboth (1976) and Pegg (1980), alteration associated with these various intrusive rocks is mainly formation of biotite hornfels in an

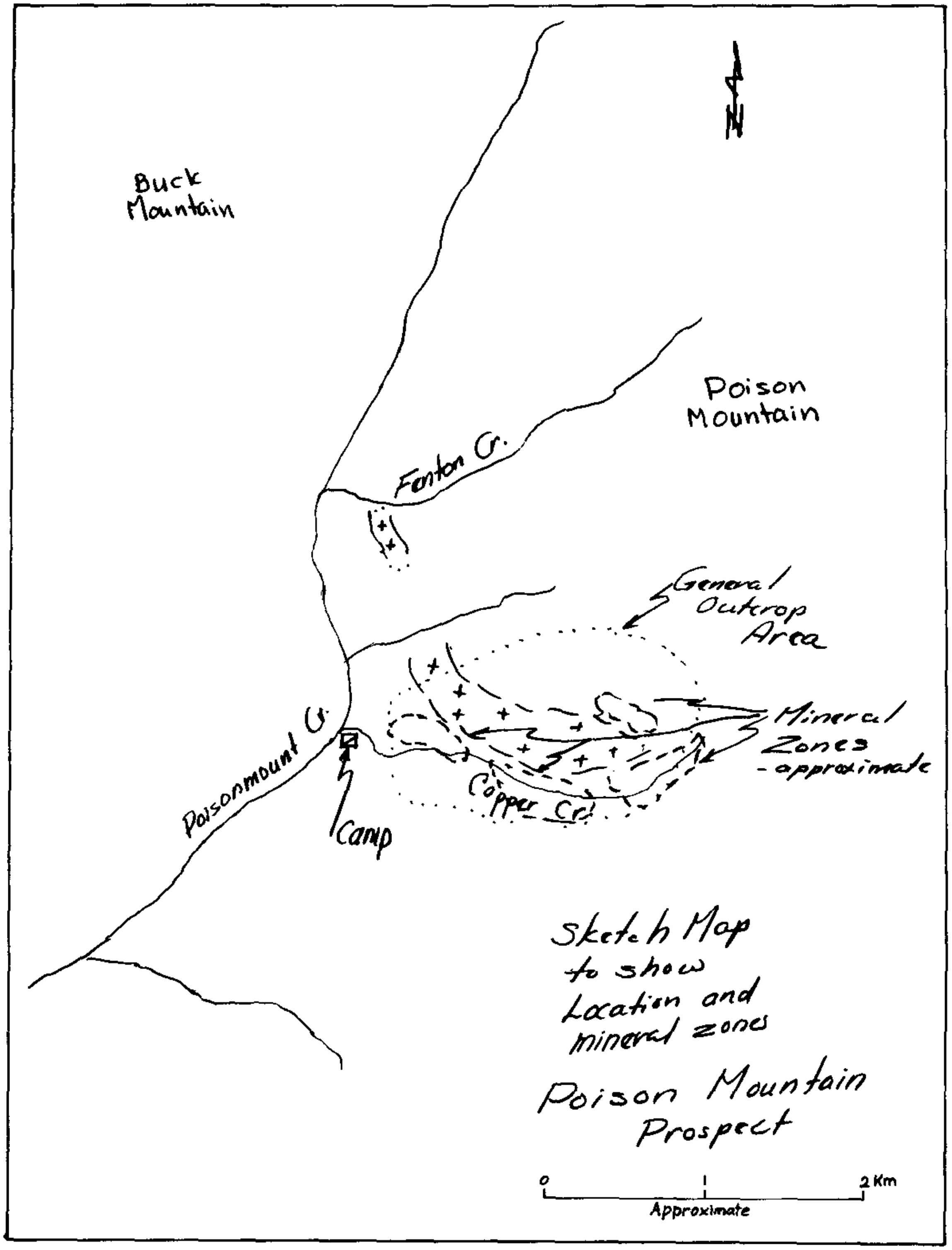

Figure 38. Sketch map of the Poison Mountain prospect.

almost complete aureole around the plutonic zone. Petrographic studies indicate that both plutonic phases were initially hornblendic but subsequently were pervasively biotitized. Rock ages are yet to be determined.

As indicated (Fig. 38), the sedimentary country rocks dip steeply and trend northwesterly across the property. One relatively thin boulder conglomerate member was traced from Fenton Creek toward Copper Creek, where it is cut off by the intrusive rocks and confirms the relatively simple country rock structure. The elongate granodiorite pluton generally sharply crosscuts the sedimentary rocks with an arcuate northwesterly trend. The north-trending porphyry dykes show irregular contact relationships with both the older granodiorite and the country rocks.

Less apparent structures, such as faults, are expressed as sharp lineaments. The northeasterly set of fractures or faults which cut across the Copper Creek area may be particularly important in that they appear to control zones of deep surficial weathering (kaolinization, etc.) that are now expressed by gullies. The relative importance of westerly, northwesterly, and northerly fractures remains to be determined.

Mineralization related to quartz veins in the porphyries (MacKenzie, 1920) included pyrite and native gold. Richmond (1933) also reported gold-bearing quartz but did not examine Poison Mountain because of snow. Exploration work since 1935 has shown the presence of pyrite, chalcopyrite, molybdenite, bornite, azurite, malachite, native copper, and cuprite, along with vein quartz, calcite, and gypsum with secondary sericite, chlorite, biotite, serpentine, kaolin, and hematite. The results of the work up to 1972 indicated a copper-molybdenum deposit of major size but subeconomic grade. The 1979 work confirmed this but also indicated a significant gold and silver content which increases the economic potential of the deposit.

Detailed drilling in 1979 and 1980 has shown that the copper-molybdenum, gold-silver-bearing mineralization is crudely confined to the hornfels/granodiorite contact. To date, four zones of above-average-grade mineralization have been outlined in which a crude parallel relationship between copper and gold content is apparent. Significant gold values have also been outlined in portions of the so-called 'barren' granodiorite, in which sulphide minerals are sparse.

Detailed mineral and trace element studies on the country and intrusive rocks currently underway may shed some light on the geochemical nature of this major gold-copper-molybdenum-silver deposit.

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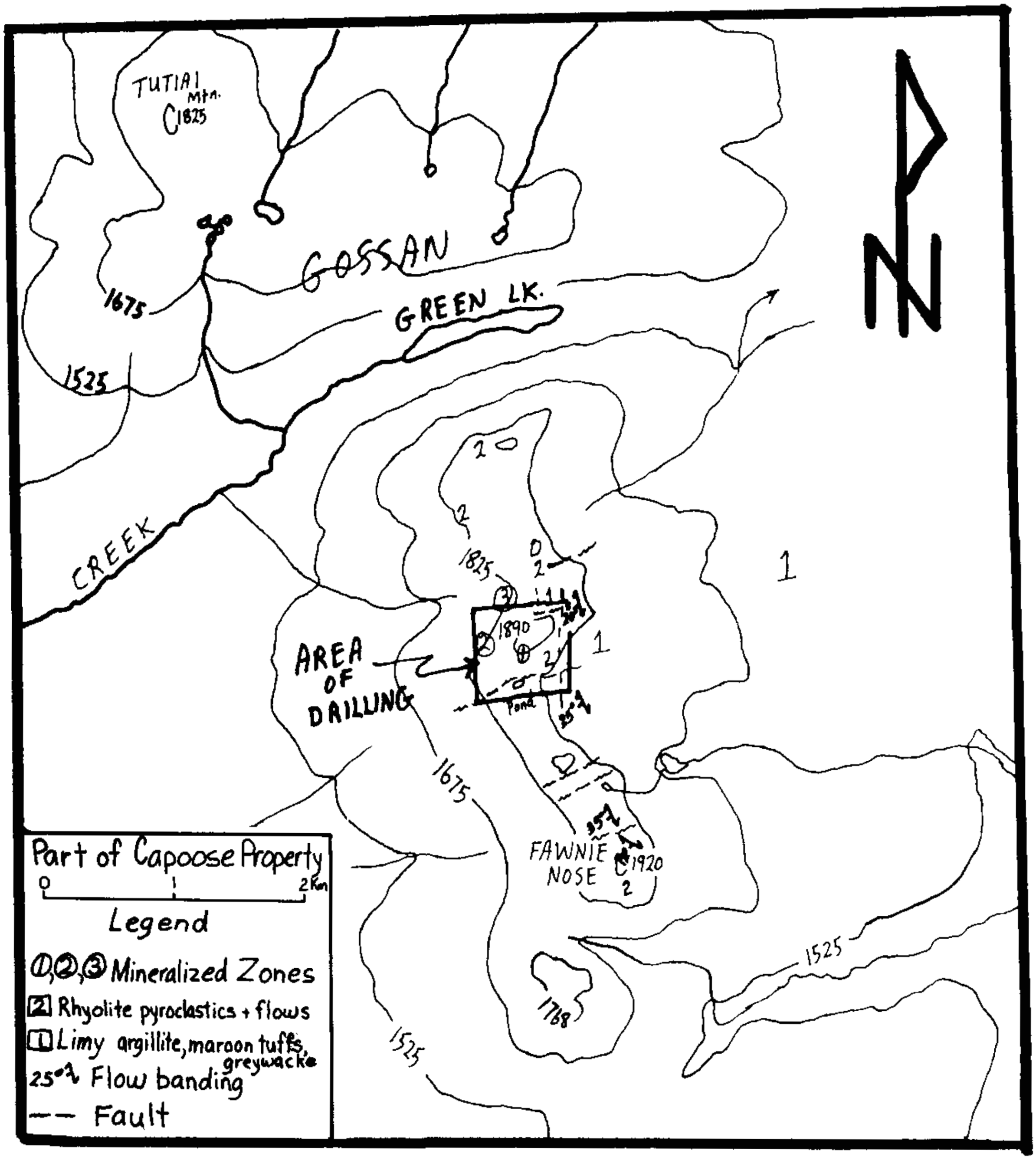

Figure 39. Sketch map of the Capoose property.

WEST–CENTRAL AND NORTHWEST BRITISH COLUMBIA

CAPOOSE PRECIOUS AND BASE METAL PROSPECT (93F/6)

By T. G. Schroeter

The Capoose precious and base metal prospect is situated a few kilometres north of Fawnie Nose, approximately 110 kilometres southeast of Burns Lake (Fig. 39). Access is by four-wheel-drive road off the main Kluskus logging road south of Vanderhoof or by helicopter.

During the 1980 season, Granges Exploration Aktiebolag completed approximately 3 962 metres of diamond drilling in 21 holes.

LOCAL GEOLOGY

The Fawnie Range in the vicinity of the Capoose property consists of a conformable sequence of interbedded greywacke, shales and pyroclastic rocks, and flows of rhyolitic and andesitic composition that unconformably overlie andesitic rocks of the Takla Group (Fig. 39). Tipper (1963) postulates that intermittent late Middle Jurassic volcanism took place in an unstable basin that was undergoing rapid changes. Finer sedimentary rocks were accumlating in a northwestery trending sedimentary trough bounded on the north and northeast by a landmass in which Topley Intrusions were beginning to be exposed. The pile of of Hazelton Group (or younger) rocks is estimated to be greater than 460 metres (Tipper, 1963, p. 32) in stratigraphic thickness. The east side of the Capoose property, a topographic low, is underlain by interbedded greywacke, maroon tuffs, and limy argillites of probable Late Jurassic (English Callovian) age (Upper Hazelton Group ?). Fossils found in limy argillite of this sequence have been identified by H. Frebold (Tipper, 1963, p. 29) as follows:

No. 4 GSC Locality 20116 – 2.4 kilometres from the north end of Fawnie Nose
Belemnites sp. indet.
'Rhynchonella' sp. indet.

Limestone blocks in argillite occur immediately below the contact with rhyolite. Unfortunately only a broad Jurassic or Cretaceous age can be inferred.

An acidic unit consisting of rhyolitic pyroclastic and flow rocks, with an attitude of 170 degrees/20 degrees west, unconformably overlies the limy argillite unit. Phenocrysts of highly embayed quartz are set in a cryptocrystalline groundmass of quartz and feldspar. Flow banding in the rhyolite averages 135 degrees/15 degrees west and there is a strong vertical jointing at 090 degrees parallel to the major structural zones. Local 'balling' or pisolitic formation in the rhyolite has produced beds with 'balls' up to 30 centimetres in diameter. Pisolites are actually nuclei growth phenomena and exhibit rare spherulitic radiating textures, indicative of rolling during or after growth. This unit has been garnetized to varying degrees (*see* Alteration and Texture).

ALTERATION AND TEXTURE

Amber-brown garnets are an ubiquitous feature in the rhyolitic and hornfelsed rocks. Some are fresh but others are totally altered or replaced by a mixture of quartz±sericite±opaques. Some garnets are highly poikilitic; they show no evidence of rolling during growth. Garnets occur as disseminations, fracture fillings, vein fillings in quartz, and replacement nuclei. Many garnets have been fractured and healed by sulphides (mainly pyrite).

The matrix of the rhyolite has been highly sericitized.

The predominant texture observed is one of nucleation and/or dispersion exhibited by pseudomorphs after garnet and dispersion rims of quartz and/or sericite are common. The textures suggest that crystallization took place rapidly under strong chemical or energy gradients. Dendritic growth textures are also exhibited. It is thus postulated that sulphide replacement of garnets was controlled by diffusion because the composition of the garnets differed appreciably from that of the groundmass (quartz and feldspar). The skeletal texture of garnets implies difficulty in nucleation.

Thus the process of garnetization is suggested to have been:

Growth → nucleation → dispersion → replacement and/or healing by sulphides.

Globular to botryoidal and fracture-filling hematite is common in rhyolite.

Epidote and chlorite are common alteration products in the andesitic rocks.

STRUCTURE

East-west faults are the predominant structures in the area. Fault traces are marked by small linear depressions on Fawnie Range and fault gouge has also been identified in several drill holes. Broad warping of thin bands in the argillite unit occur.

MINERALIZATION

Three zones of precious ('bulk silver') and base metal mineralization have been preliminarily identified:

- Zone 1 – area of most previous diamond drilling has defined a steep west-facing zone in garnetized rhyolite.
- Zone 2 – area to the west of Zone 1.
- Zone 3 – area to the north-northwest of Zone 1; characterized by more massive sphalerite, pyrrhotite, and chalcopyrite in rhyolite and hornfels.

ZONE 1

Galena, pyrite, pyrrhotite, chalcopyrite, arsenopyrite, and sphalerite occur as disseminations (especially galena), replace garnets (nuclei and attendant dispersion halos), and occur as fracture and/or vein fillings *both in fine-grained rhyolite tuffs, breccias, and flows and in hornfelsed argillite.* Tetrahedrite, pyrargyrite, electrum, native gold, and cubanite mineralization has been reported and precious metals also occur within galena and sphalerite. Pyrite is ubiquitous and may have formed throughout the mineralizing event. Garnet replacement and mineralization are closely related. Belemnites in limy argillites underlying the rhyolite unit have been locally replaced by pyrite and a sample of one collected previously by the author assayed 0.03 per cent molybdenum and 0.03 per cent tungsten (Schroeter, 1980, p. 123).

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TOODOGGONE RIVER
(94E)

By T. G. Schroeter

INTRODUCTION

The Toodoggone River area is situated approximately 300 kilometres north of Smithers. Geographically, it is one of the most isolated areas in the province, being several hundred kilometres from the nearest settlement and without road access. The 'Omineca mining road' from Germansen Landing terminates at Moosevale Flats, approximately 65 kilometres south of the Toodoggone area. Access at the present time is by fixed-wing aircraft, floatplane, or helicopter and nearly all the traffic has come from Smithers. The Sturdee airstrip, completed to a useable length of over 1 620 metres, was the centre of activity during the past year. A Hercules aircraft supplying the Baker mine and several other charter aircraft used the gravel strip, which will soon be equipped with landing lights. The area discussed in this report is a northwesterly trending belt 80 kilometres in length, 35 kilometres in width, and approximately centred on the Baker mine (Fig. 40).

Early mining exploration dates back to the early 1930's when placer claims near the junction of Belle Creek and the Toodoggone River were worked. Lead-zinc showings near the head of Thutade Lake were covered by several small blocks of claims. Exploration was minimal until the late 1960's when numerous companies explored the area for large tonnage, low-grade copper and molybdenum porphyries. Of the numerous claims staked, the most significant to date are the Chappelle claims which cover the Baker mine which is currently being readied for production by Du Pont of Canada Exploration Limited. With the notable exceptions of the Baker (formerly Chappelle) gold-silver prospect and the Lawyers gold-silver prospect, the 1970's saw little exploration. Minor work was carried out on the McClair Creek, the Shas, the Kemess, and the Fin (formerly Pine) prospects, to name a few. 1980 heralded the beginning of a new era for this rich gold-silver 'province.' At present, approximately 2 600 active claim units exist within the Toodoggone area, about 2 000 of which were staked during the past year (Fig. 40).

REGIONAL GEOLOGY

The Toodoggone area lies within the eastern margin of the Intermontane Belt. The oldest rock exposed are wedges of crystalline limestone more than 150 metres thick that have been correlated with the Asitka Group of Permian age. The next oldest rocks consist of andesitic flows and pyroclastic rocks including augite-tremolite andesite porphyries and crystal and lapilli tuffs that belong to the Takla Group of Late Triassic age. The Omineca intrusions of Jurassic and Cretaceous age (potassium-argon age of 186 to 200 Ma obtained by the Geological Survey of Canada) range in composition from granodiorite to quartz monzonite. Some syenomonzonite bodies and quartz feldspar porphyry dykes may be feeders to the Toodoggone rocks which unconformably overlie the Takla Group. The 'Toodoggone' volcanic rocks (named informally by Carter, 1971) are complexly intercalated volcanic and volcanic-sedimentary rocks of Early and Middle Jurassic age, 500 metres or more in thickness, along the west flank of a northwesterly trending belt of 'basement' rocks at least 90 kilometres in length by 15 kilometres in width (*Geological Survey of Canada*, Open File 306, replaced by Open Files 483 and 606). A potassium-argon age of 186±6 Ma was obtained by

Carter (1971) for a hornblende separate from a sample collected from a volcanic sequence 14 kilometres southeast of Drybrough Peak. Four principal subdivisions of 'Toodoggone' rocks have been recognized:

(1) *Lower volcanic division* – dominantly pyroclastic assemblage including purple agglomerate and grey to grey to purple dacitic tuffs.

(2) *Middle volcanic division* – an acidic assemblage including rhyolites, dacites, 'orange' crystal to lithic tuffs, and quartz feldspar porphyries; includes welded tuff. The 'orange' colour of the tuffs resulted from oxidation of the fine-grained matrix while the rock was still hot. A coeval period of explosive volcanism included the formation of 'laharic' units and intrusion of syenomonzonite bodies and dykes. This event was accompanied by explosive brecciation along zones of weakness, predominantly large-scale faults and attendant splays, followed by silicification and deposition of precious and base metals to varying degrees in the breccias. Rounded fragments of Omineca intrusive rocks are rare components in Toodoggone tuffs.

(3) *Upper volcanic-intrusive division* – grey to green to maroon crystal tuffs and quartz-eye feldspar porphyries.

(4) *Upper volcanic-sedimentary division* – lacustrine sedimentary rocks (sometimes varved), stream bed deposits, and possible local fanglomerate deposits and interbedded tuff beds.

Many Toodoggone rocks have a matrix clouded with fine hematite dust implying a subaerial origin, however, some varieties may have accumulated in shallow water. The host rock for mineralization (division 2) is an orange to chocolate brown-coloured crystal tuff with varying minor amounts of lithic and vitric ash. Broken crystals of plagioclase and quartz are set in a fine-grained 'hematized' matrix of quartz and feldspar. The exact chemical composition(s) and rock name(s) await chemical analyses. Carter (1971) determined the composition of a suite of rocks collected from the Toodoggone area to range from latites to dacite (less than 30 weight per cent quartz); fused beads gave refractive indices between 1.505 and 1.535. Apatite may be a common accessory mineral.

To the west, Upper Cretaceous to Tertiary pebble conglomerates and sandstones of the Lower Tango Creek Formation of the Sustut Group (Eisbacher, 1971) unconformably overlie both Takla Group volcanic rocks and Toodoggone volcanic rocks.

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. The entire area has been subjected to repeated and extensive normal block faulting from Jurassic to Tertiary time. It is postulated that a northwesterly trending line of volcanic centres along a gold-silver-rich 'province' marks major structural breaks, some extending for 60 kilometres or more (for example, McClair Creek system, Lawyers system). Prominent gossans are often associated with structural zones but many contain only pyrite; sulphides occur as disseminations and fracture fillings in Toodoggone and Takla Group rocks. Thrusting of Asitka Group limestones over Takla Group rocks probably occurred during Middle Jurassic time.

Today Toodoggone rocks display broad open folds with dips less than 25 degrees. The Sustut Group sedimentary rocks have relatively flat dips and do not appear to have any major structural disruptions.

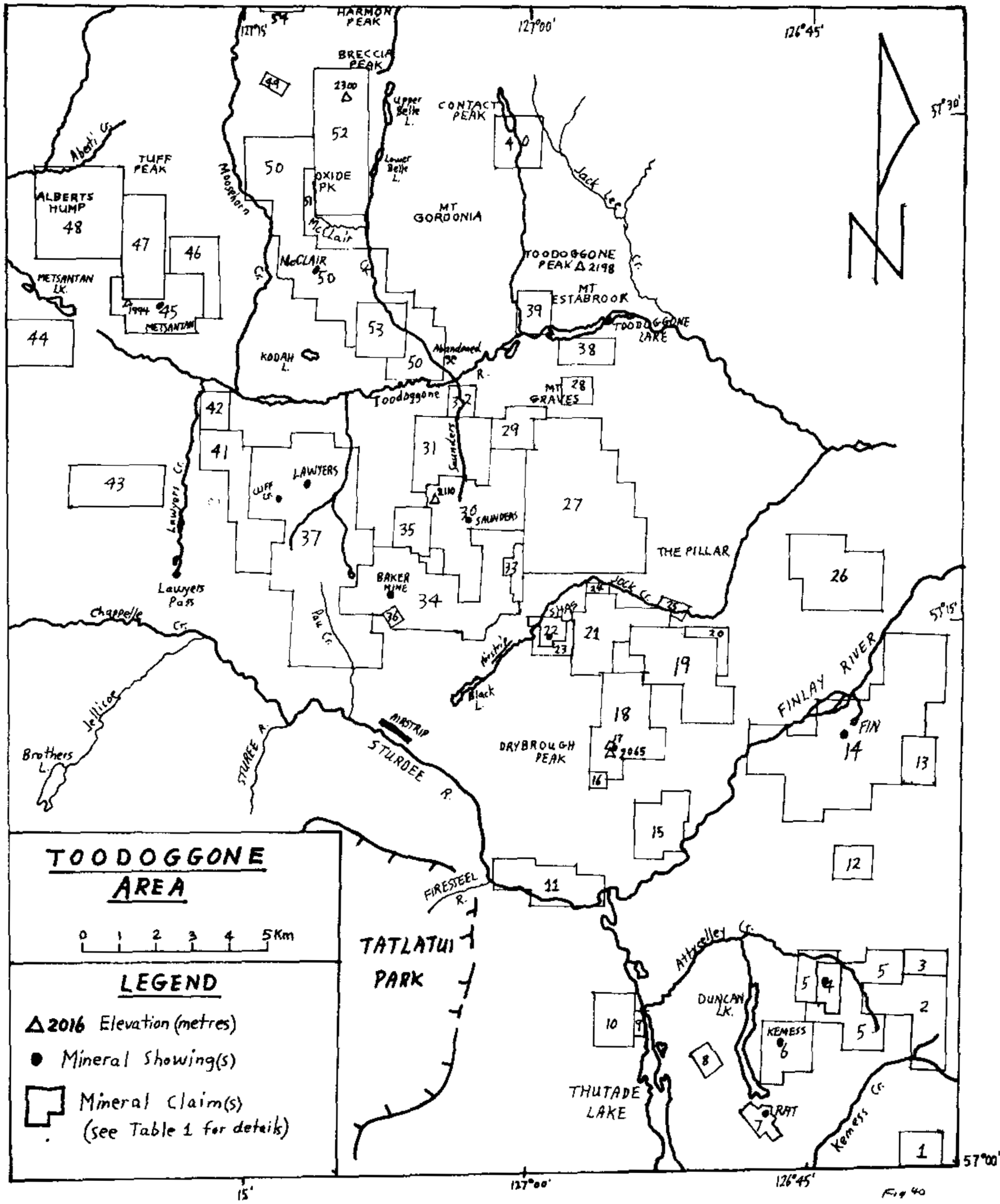

Figure 40. General map of the Toodoggone River area.

TABLE 1. TOODOGGONE RIVER AREA, MINERAL PROPERTIES

No.	Claim Name	MDI 94E	Operator
1	Aura	------	SEREM Ltd.
2	Mess 1-3	------	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	------	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	Rio Tinto
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	------	Lacana Mining
21	Jock 1-5	8, 39	SEREM Ltd.
22	Shas	50, 45	International Shasta
23	Silver Reef	45, 50	C Kowall
24	Pili	------	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	SEREM Ltd.
28	To No 2	------	Du Pont Expl.
29	GWP	7	Great Western Pet.
30	Golden Neighbour 1-4, Camp, Camp Fr., Jolly Roger, Artful Dodger	37	Lacana Mining
31	Saunders	17, 40	Taiga Cons.
32	Canyon No. 1	------	Lacana Mining
33	Fagan No. 1	------	Lacana Mining
34	Chappelle	26, 27	Du Pont Expl.
35	Pel	------	Du Pont Expl.
36	Crown granted claims	------	O. MacDonald
37	New Lawyers 1-4, Law 1-3, Breeze, Road I-III, Perry 1-2, Mason 1-2, GTW 1-3 Plus Fractions	------	SEREM Ltd.
38	Duke 1-2	------	SEREM Ltd.
39	To No. 1	------	Du Pont Expl.
40	Mul 1-2	------	Du Pont Expl.
41	Silver Pond, Silver Creek, Silver Butte, Silver Peak, Silver Grizzly	------	C. Kowall
42	Kodah	------	SEREM Ltd.
43	Lass 1-4	------	Du Pont Expl.
44	Edo 1-4	------	Du Pont Expl.
45	Metsantan 1-5	------	Lacana Mining
46	Ant 1-3	------	Du Pont Expl.
47	Mets 1-2	------	Taiga Cons.
48	Al 1-6	------	Texasgulf
49	Har	53	SEREM Ltd.
50	Scree 1-3, Moose 1-3, JM, JD, JB, JS, JR, McClair Creek 1-5, plus Fractions	31, 32, 1	Texasgulf
52	Poo, On, Lou, Oxide	------	SEREM Ltd.
53	Belle 1-2	------	Taiga Cons.
54	Moose 1-4	------	S. Young

MINERALIZATION

The Toodoggone area is host to many polymetallic mineral prospects and four main types are recognized:

(1) *'Porphyry'* copper±molybdenum±silver±gold – mainly associated with Omineca Intrusions. Chalcopyrite and pyrite, with or without molybdenite, occur in fractures, as disseminations, or in quartz veins within both intrusive and the host volcanic rocks (mainly Takla Group andesitic rocks). Secondary chalcocite and covellite may form layers up to 30 metres thick. In these 'porphyries,' silver may exceed 3.1 grams per tonne (0.1 ounce per ton) and gold 0.47 gram per ton (0.015 ounce per ton) and therefore be economically significant [for example, Riga (MI 94E-3, 4, 5), Fin (MI 94E-16), Pillar (MI 94E-8), Rat (MI 94E-25), Mex (MI 94E-57), Kemess (94E-21)].

(2) *Skarn* – contact of limestone and host rock resulting in formation of small bodies of magnetite, galena, and sphalerite [for example, Castle Mountain (MI 94E-27) and several other minor showings west of Duncan Lake].

(3) *Precious and base metal epithermal* – gold-silver±copper±lead±zinc

(a) Fissure-vein type – the most important economic type. It is associated with predominantly silicified zones (quartz veins and/or older volcanic 'centres') related to repeated, extensive block faulting and possible tensional fractures formed during late doming. Large and small-scale faulting were integral processes in the sequential development of calderas formed by progressive emplacement and subsequent collapse of different phases of composite magmas (batholiths). So far, no distinct superimposed complex zones have been identified as isolated calderas in the Toodoggone area. Many calderas have a moat structure around their periphery, which is infilled by lacustrine sedimentary and pyroclastic rocks, mainly volcanic ash, deposited penecontemporaneously in the moat. Local fanglomerate deposits form adjacent to the steeper walls away from tributary streams. In the Toodoggone area, recurrent faulting during crater building would guide intrusions and the soft lacustrine sedimentary rocks may have acted as an impermeable barrier to mineralizing solutions.

Principal ore minerals include fine-grained argentite, electrum, native gold, and native silver with minor amounts of chalcopyrite, galena, and sphalerite. Rare constituents include bornite, polybasite, stromeyerite, and secondary chalcocite and covellite. Gangue minerals include, in order of decreasing abundance: amethystine to white quartz, chalcedony, calcite, hematite, manganese oxide, and rare barite and fluorite. Deposits occur in the form of vein fillings, stockworks, irregular branching fissures, and large, recurrently brecciated fault zones. Common textures include comb structures, symmetrical banding, crustifications, and drusy cavities – all typical features of epithermal deposits formed at shallow depths and at low temperatures. Alteration is commonly restricted to vein systems [Chappelle (MI 94E-26), Lawyers (MI 94E-17), Metsantan Lake (MI 94E-35), McClair, Cliff Creek, Shas (MI 94E-50), Saunders (MI 94E-37)].

(b) Hydrothermally altered and mineralized type – associated with major fault zones and possibly after subsidence of volcanic centres followed by a doming of caldera cores. Pyrite is the most common sulphide present with minor amounts of galena and sphalerite and rare molybdenite and scheelite. This type is probably somewhat older or contemporaneous with fissure-type mineralization. Cauldron zones are strongly leached and sulfotarically altered to varying degrees to clay minerals and silica; some areas contain alunite (for example, Alberts Hump). Epidote is a common alteration mineral in both hydrothermal and fracture zones [for example, Kodah, Alberts Hump, Saunders (MI 94E-17), Chappelle (MI 94E-26), Oxide].

(c) Alteration generally associated with the precious and base metal epithermal is as follows:

  (i) Epidotization and silicification in the vicinity of quartz veins,
  (ii) Laumontite in fractures,
  (iii) Extensive pyritization,
  (iv) Anhydrite as veinlets and fractures up to 70 metres or more long,
  (v) Hematization near surface, and
  (vi) Carbonatization at depth.

(4) *Stratabound* (?) — galena±sphalerite±chalcopyrite occur in or adjacent to limestone with interbedded chert in Takla Group (?) volcanic agglomerates and tuffs. This type of deposit, which may have been deposited on the flank of a volcano adjacent to a limestone reef, usually has associated low-grade silver values [for example, Firesteel (MI 94E-2), Attycelley (MI 94E-22)].

MINERAL PROSPECTS

BAKER MINE (DU PONT OF CANADA EXPLORATION LIMITED)

Construction of the Baker, formerly Chappelle (MI 94E-26), gold-silver mine continued during the summer and fall and production at a rate of 90 tonnes per day is scheduled for early 1981. Capital costs were estimated at $12 million and, as mentioned earlier, access is provided via a 13-kilometre road to the minesite. Mineable reserves are listed at 90 718 tonnes containing 25.5 grams gold per tonne and 594 grams silver per tonne. Mining will be carried out by both surface cuts and underground methods.

Seven quartz vein systems have been identified in the area of the mine. The main or A vein, that consists of two more subparallel veins with a width of 10 to 70 metres, has been traced over a length of 435 metres and a vertical depth of at least 150 metres. Fine-grained argentite, pyrite, electrum, chalcopyrite, bornite, native gold, sphalerite, galena, polybasite, and stromeyerite occur within a highly fractured and brecciated quartz system cutting Takla Group andesites (*see* Barr, 1980 for detailed description). One sample of high-grade ore assayed 0.23 per cent molybdenum. Tellurium values for selected high-grade specimens ranged between 16 ppm and 38 ppm.

LAWYERS (S.E.R.E.M. LTD.)

The Lawyers gold-silver prospect is located approximately 12 kilometres north of the Baker mine. During 1980 S.E.R.E.M. completed 2 895 metres of diamond drilling in 18 holes on the 'Amethyst Gold breccia zone.' The drilling was done on two tiers on 30.5-metre spacings to test the steeply dipping fissure structure. The mineralized zone varies from 60 to 75 metres in width and has been partially drill tested over a north-south length of 610 metres and a vertical depth of between 30 and 60 metres.

Fine-grained argentite, electrum, native gold, and native silver, with minor pyrite, chalcopyrite, sphalerite, and chalcocite occur in a gangue of predominant amethystine to white quartz with minor calcite cutting the middle volcanic division of 'Toodoggone' crystal tuffs. Hematite and manganese oxide are common alteration products. Mineralization appears to be more closely associated with the quartz-eye deficient (<5 per cent) 'orange' crystal tuff than the underlying quartz-eye-rich (>5 per cent) 'green to grey' crystal tuff.

The highest grade intersection from drilling was obtained from diamond-drill hole 80-13: 1 554 grams silver per tonne and 119 grams gold per tonne over a 6-metre interval.

The Cliff Creek breccia zone, located approximately 1 600 metres to the west of the Amethyst Gold breccia zone, lies in the same structural setting and has similar characteristics.

SAUNDERS (LACANA MINING CORPORATION)

During 1980 Lacana investigated by trenching and mapping a large anomalous zone containing at least four quartz vein systems intrusive into 'Toodoggone' volcanic rocks. Chalcopyrite, pyrite, sphalerite, molybdenite, and scheelite occur in amethystine to white quartz fissures along a north-northwesterly trending geochemical anomaly 1 220 metres in length and 300 metres in width that is also anomalous in gold and silver. Significant ferricrete occurs adjacent to the quartz veins. The area appears to have been strongly hydrothermally altered, possibly suggestive of a near-vent environment.

METSANTAN (LACANA MINING CORPORATION)

A quartz stockwork with galena, pyrite, chalcopyrite, and gold-silver values exists within 'orange' 'Toodoggone' crystal tuffs of the middle volcanic division. Hydrothermal alteration has produced abundant epidote and quartz veining.

McCLAIR CREEK (TEXASGULF INC.)

Fissure zones of rebrecciated mineralized material occur within the middle volcanic division of 'Toodoggone' crystal tuffs. Rounded to subangular fragments of quartz, chert, jasper, and sulphides, including galena, sphalerite, chalcopyrite, and pyrite as well as gold and silver values, occur in a fine matrix of brecciated crystal tuff cemented by silica. Manganese staining and hematite veining are prominent.

FIN (RIO TINTO CANADIAN EXPLORATION LIMITED)

During 1980, Rio Tinto diamond drilled 10 holes totalling approximately 1 020 metres. The environment is similar to that of the Kemess (MI 94E-21) property (Cann and Godwin, 1980) where a highly altered intrusive complex that is part of the Omineca intrusions has intruded Takla Group volcanic rocks producing 'porphyry' type mineralization with anomalous copper-silver-gold-molybdenum values. At the Fin property, the intrusive rock is highly altered to quartz, sericite, epidote, and chlorite and contains numerous fractures coated by laumontite. It is quite possible that the intrusive rocks at Fin and Kemess represent subvolcanic feeders for the 'Toodoggone' volcanic rocks.

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OTHER INVESTIGATIONS

PRELIMINARY INVESTIGATIONS AS TO THE EFFECTS OF SHEAR ON COAL QUALITY IN SOUTHEASTERN BRITISH COLUMBIA (82)

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INTRODUCTION

In southeastern British Columbia coal seams of the Mist Mountain Formation were in part sheared and comminuted during Late Cretaceous and Tertiary tectonism. Extensive deposits of sheared coal exist, and even in areas of mild deformation the coal seams may be sheared locally (Bustin, 1979). The quality of the sheared coal varies markedly; it is commonly oxidized, even far from the present weathering horizon (Bustin, 1980), and locally it has a disproportionately large amount of ash and poor washability characteristics.

In order to document the effect of shear on coal quality, a study of sheared coal seams from southeastern British Columbia was undertaken. In conjunction with Fording Coal Limited two seams, locally referred to as the No. 5 and No. 7, were sampled in the Fording mine area, east of Elkford. In the mine area both the No. 5 and No. 7 seams are repeated by faulting. In the footwall of the fault the seams are virtually unsheared, but in the hangingwall the same two seams are pervasively sheared, thereby providing an opportunity to compare them to determine the effect of shear on the same seams in close proximity. Other samples were collected from the Vicary Creek area, north of Coleman, Alberta, Coal Mountain, Corbin, and Tent Mountain, directly north of Corbin.

This preliminary report documents the effect of shear on the washability characteristics of coal samples collected from the No. 5 and No. 7 seams at the Fording minesite. Some observations on sheared coal collected from other localities are also briefly considered.

METHOD OF STUDY

Samples of sheared and unsheared coal from the Fording minesite were crushed to 1.25 centimetres, then washability and proximate analysis were performed and heating value and free-swelling index (FSI) determined. The specific gravity (s.g.) separates of sheared and unsheared seams were further crushed to 0.8 millimetre and briquettes prepared and polished. The samples were then point counted to determine the relative abundance of the macerals. An average of 500 points per sample was counted. Additional samples of sheared coal from Vicary Creek, Alberta and Tent Mountain were also examined microscopically.

RESULTS

GENERAL DESCRIPTION

The extent of shearing of coal seams in the southeastern Cordillera is highly variable. In general there is a good correlation between the extent of structural deformation and degree of shearing of the coal. In areas such as Vicary Creek, however, comminution of the coal is largely the result of interstratal slip and the coal is locally pervasively sheared whereas the over and underlying strata may be essentially planar. The sheared coal seams consist of coarse to finely granular coal and rock partings; cleat, if ever present, has been largely or completely destroyed. The sheared coal is polished and pervaded by slickensided surfaces. Discrete, traceable shear surfaces are rarely present; rather, the coal has an over-all cataclastic fabric.

WASHABILITY ANALYSIS

The results of the washability analysis of the No. 5 and No. 7 seams are summarized in Tables 1 and 2.* On Figures 41 and 42 the characteristic washability curves for No. 7 seam are shown and on Figures 43 and 44 the characteristic washability curves for No. 5 seam are shown. The most noticeable difference between the sheared and unsheared seams is the greater amounts of ash and lower clean coal yields of the sheared coal. For example, if a coal with an 8-per-cent ash is required, the yield of No. 7 seam (unsheared) would be 87 per cent but sheared only 24 per cent; the specific gravity (s.g.) required for washing would be 1.67 per cent unsheared and 1.38 per cent sheared. The ash in the discard would be 58 per cent in the unsheared coal and 61 per cent in the sheared coal. The near density material of the coal would be 6 per cent if unsheared but 25 per cent if sheared. Similarly, if a coal with an 8 per cent ash is required of No. 5 seam the yield of the unsheared coal would be 81 per cent, which would require a specific gravity of separation of 1.46, the ash content of the discard would be 47 per cent, and the near density material would be 30 per cent. No. 5 seam sheared would yield 50 per cent, require a specific gravity of separation of 1.67, the ash content of the discards would be 85 per cent and the near density material would be 5 per cent. In addition, almost every specific gravity fraction of the sheared coal has a somewhat greater ash content than the unsheared coal (compare column 3, Direct Ash, of Tables 1 and 2 of the sheared and unsheared coal). Such results indicate that the ash of the sheared coal is more difficult to remove from the organic fraction than that of the unsheared coal. For example, the ash content of the 1.3 to 1.4 specific gravity fraction of No. 5 seam is 7.7 per cent unsheared and 8.2 per cent sheared; the same fraction of No. 7 seam has values of 8.9 per cent and 11.7 per cent respectively. The near density material (Tables 1 and 2) of the unsheared coal was found to be generally greater than that of the sheared coal, which indicates that the sheared coal is more amenable to separation if separation of these specific gravity fractions is necessary. Such results are, however, a product of the much lower total yields of the sheared coal in these fractions and do not reflect greater ease of washing.

Preliminary examination of the ash mineralogy indicates that it consists predominantly of kaolinite, quartz, and calcite. Additional studies to determine if a variation in the mineralogy of the ash exists are underway.

PROXIMATE AND SULPHUR ANALYSIS

The results of proximate and sulphur analysis of the No. 5 and No. 7 seams are summarized in Tables 1 and 2. The variation in volatile matter, with specific gravity of each seam, is shown graphically on Figure 45. Coal separates with a specific gravity less than 1.6 show little variation in composition between sheared and unsheared coal; in the fractions heavier than 1.6 specific gravity, the sheared coal has lower volatile matter

*Tables and figures are on pages 137 to 147 at end of text.

and generally lower fixed carbon contents than the unsheared coal. Such results are considered to reflect the small difference in ash content between sheared and unsheared coal in the less than 1.6-specific-gravity fractions as compared to the much greater abundance of ash in the sheared coal in the higher specific gravity fractions.

The sulphur content of all the analysed samples is low and there is no observable variation between the sheared and unsheared coal. In all seams sulphur decreases with increased specific gravity which indicates that sulphur is associated with the organic rather than the inorganic fraction.

HEAT CONTENT AND FREE–SWELLING INDEX

The variation in heat content (calorific value) and free-swelling index (FSI) of No. 5 and No. 7 seams are given in Tables 1 and 2. Heat content and free-swelling index are plotted against specific gravity on Figures 46 and 47 respectively. The heat content of the sheared coal is generally less than that of the unsheared coal and the heat content of the seams decreases markedly in the higher specific gravity fractions. The free-swelling index also decreases with increasing specific gravity, but there is no consistent difference between the sheared and unsheared coal.

PETROGRAPHY

The petrography of the samples is summarized in Tables 1 and 2 and the relative abundance of vitrinite, on an ash-free basis, is shown graphically on Figure 48. The samples were point counted on an ash-free basis because of errors associated with estimating mineral matter in coal microscopically (Ting, 1978). The relative abundance of ash was obtained from the proximate analysis.

All the samples consist mainly of vitrinite, fusinite, and semifusinite; trace amounts of macrinite, micrinite, and exinite are present. In all the seams fusinite and semifusinite are most abundant in the 1.3 through 1.6-specific-gravity fractions. On an ash-free basis, vitrinite (Fig. 48) is most abundant in the less than 1.3-specific-gravity fraction, decreases in abundance, and passes through a minimum in the 1.4 to 1.5-specific-gravity fraction and then progressively increases in the heavier specific gravity fractions, the only exception being the 1.8 to 1.9-specific-gravity of No. 5 seam. Such changes in the relative abundance of vitrinite are controlled by the relative density of the macerals and their mode of occurrence: in the less than 1.3-specific-gravity fraction, vitrinite occurs as homogeneous fragments with only minor inclusions of fusinite and semifusinite; in the 1.3 through 1.6-specific-gravity fractions, larger fragments of fusinite, semifusinite, and virtinite occur (Fig. 49); in the greater than 1.6-specific-gravity fractions vitrinite occurs intercalated with or disseminated in argillaceous partings (Fig. 50). In this high specific-gravity fraction fusinite and semifusinite occur mainly as inclusions in the vitrinite or as isolated fragments; they are rarely intercalated or disseminated in the argillaceous partings. Vitrinite is concentrated in higher specific-gravity fractions because it is associated with argillaceous partings; it is concentrated in the less than 1.3-specific-gravity fractions because it is of lower density than either fusinite or semifusinite.

There is no consistent variation in abundance of the macerals between the sheared and unsheared coal. In No. 5 seam, vitrinite is less abundant in the lower specific gravity fractions of the unsheared than the sheared coal, but more abundant in the higher specific gravity fractions of the unsheared than in the sheared coal. In No. 7 seam the sheared coal has a greater abundance of vitrinite in every specific gravity fraction.

The microfabric of the sheared coal is generally similar to that of the unsheared coal. On a microscopic level the finely granulated, sheared coal consists of fragmented larger clasts with no evidence of internal deformation. Some samples of sheared coal from Tent Mountain contain aggregates of angular fragments of inertinite in a groundmass of vitrite or clarite. Here the inertinite components underwent brittle deformation whereas the clarite or vitrite were apparently plastically deformed. Ductile behaviour of the clarite and vitrite is also evident from the occurrence of microfolds of similar style and 'wild' folds (Fig. 51).

DISCUSSION AND CONCLUSIONS

The results of the preliminary investigation indicate that the sheared coal of No. 5 and No. 7 seams have a disproportionately large amount of ash and have lower yields on washing than the unsheared coal of the same seam. The relative increase in ash in sheared coal may be related to several factors. Sheared coal seams throughout the southeastern Rocky Mountains have numerous ash and rock partings; perhaps the presence of such partings facilitated interstratal slip and shearing through the seam; thus the high ash content of the seams may have promoted rather than been caused by shearing. In addition, shearing of the coal is accompanied by comminution and distribution of formerly discrete partings throughout the seam; this would have deleterious effects on washing because it would increase the proportion of fine ash. The apparent high ash content of some seams may be related to the increased difficulty in distinguishing and separating sheared roof and floor strata from the coal seam during mining.

The higher ash content observed in all the specific fractions of the sheared as compared to the unsheared coal may also be the result of greater abundance of ash and accompanied loss of efficiency in washing. Generally, the finer the size-consist of the coal the greater the mechanical separation of inorganic from organic fractions (*B.C. Ministry of Energy, Mines & Pet. Res.*, Coal in B.C., 1976). However, the sheared coal of this study, although much finer grained, contained more ash than the unsheared coal. Microscopic examination did not reveal any features to account for the poorer separation of the sheared coal. It is probable, however, that the finer size-consist of the sheared coal causes argillaceous partings to break down to a greater degree during washing and results in a further increase in the fine fraction which would result in poorer separation during washing. In sheared coal from Tent Mountain, plastic flow of the vitrite and clarite resulted in formation of local aggregates in which separation of the organic from the inorganic fractions would be exceedingly difficult; however, no such aggregates were observed in either No. 5 or No. 7 seams.

Some of the variation in quality of the coal observed with increasing specific gravity is undoubtedly the result of concentration of the macerals during washing. Inasmuch as the ash content and the abundance of macerals both vary with increasing specific gravity, their relative effects on coal quality cannot be assessed without further analysis.

ACKNOWLEDGMENTS

I wish to thank Fording Coal Limited, and particularly Peter Daignault, for assistance in collecting samples and for providing analystical results.

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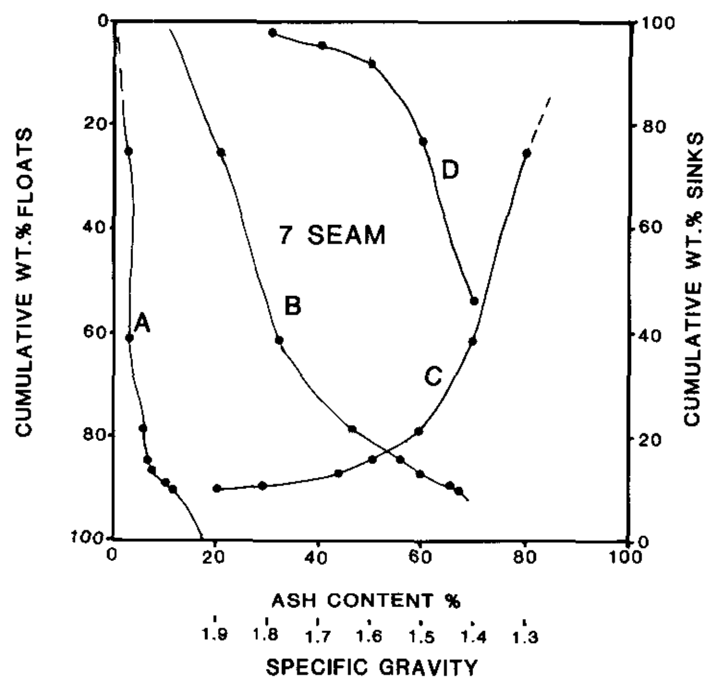


Figure 41. No. 7 seam washability curves:

A Clean coal curve – shows cumulative coal floating (yield) versus the average ash content of that coal (Cumulative Wt. % Floats axis is read against the Ash Content % axis).

B Discard curve – shows ash content of discards at any particular yield of clean coal (Cumulative Wt. % Sinks axis is read against Ash Content % axis).

C Specific gravity yield curve – shows percentage material floating at any given specific gravity (Cumulative Wt. % Floats axis is read against Specific Gravity axis).

D Distribution curve – shows amount of material that occurs within ±0.1 of the specific gravity being considered; it expresses the ease with which a coal may be cleaned in a specific-gravity range. The more material that is within ±0.1 of the specific gravity used for washing the more difficult, the more difficult the separation (Specific Gravity axis is read against Cumulative Wt. % Floats axis). The Coal Task Force (1976) suggests the following classification: 7 to 10 per cent near density material, simple separation; 7 to 15 per cent near density material, moder-moderately difficult; 10 to 15 per cent near density material, difficult; 15 to 20 per cent density material, very difficult; 20 to 25 per cent near density material, exceedingly difficult; and greater than 25 per cent near density material, formidable.

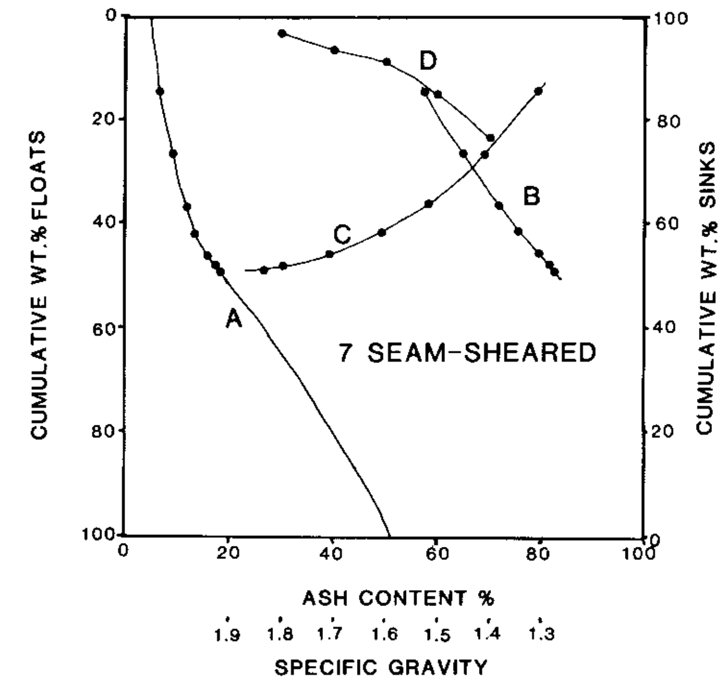


Figure 42. No. 7 seam-sheared washability curves. Refer to explanation of curves on Figure 41.

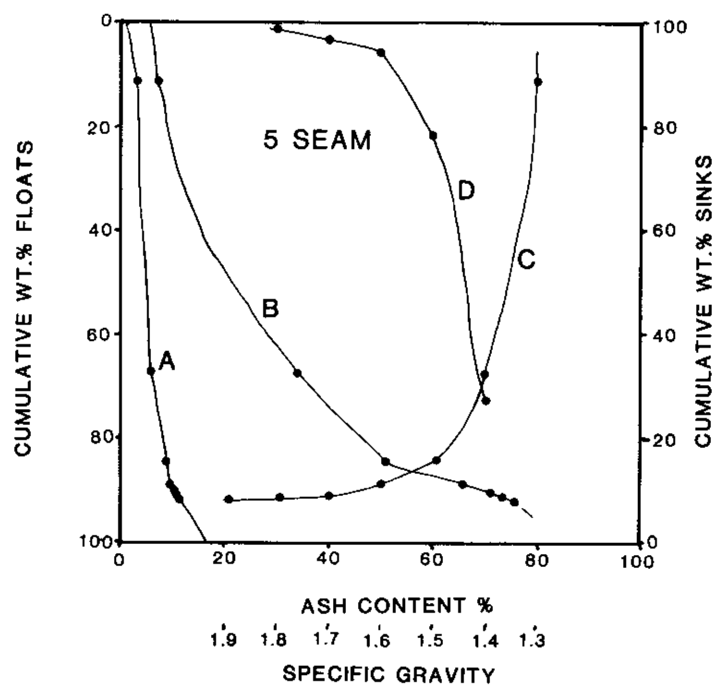


Figure 43. No. 5 seam washability curves. Refer to explanation of curves on Figure 41.

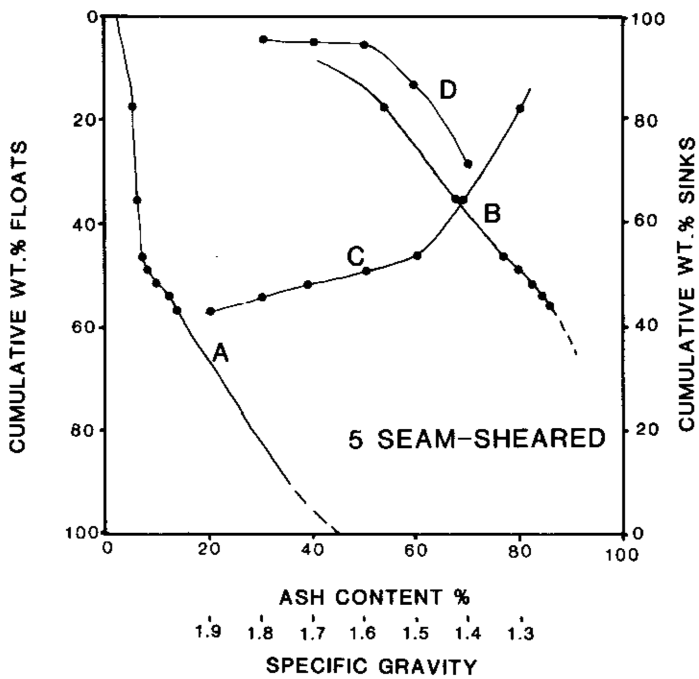
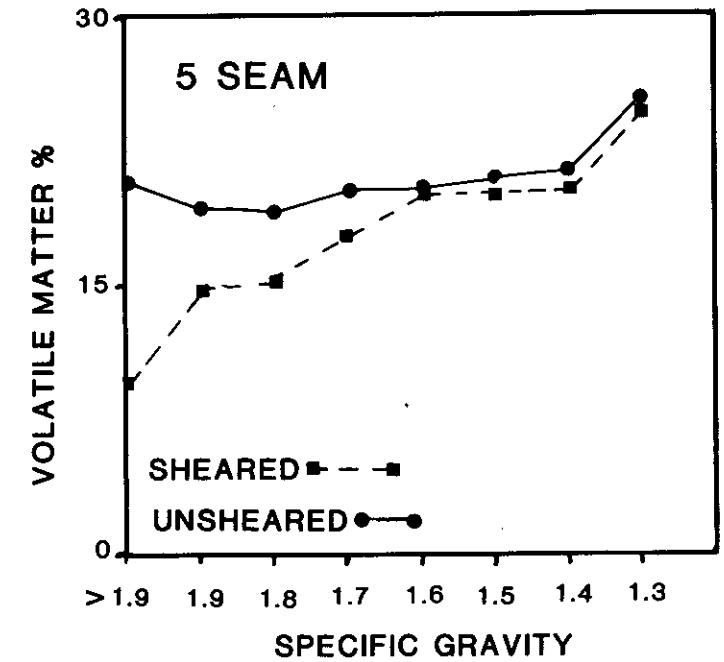


Figure 44. No. 5 seam-sheared washability curves. Refer to explanation of curves on Figure 41.



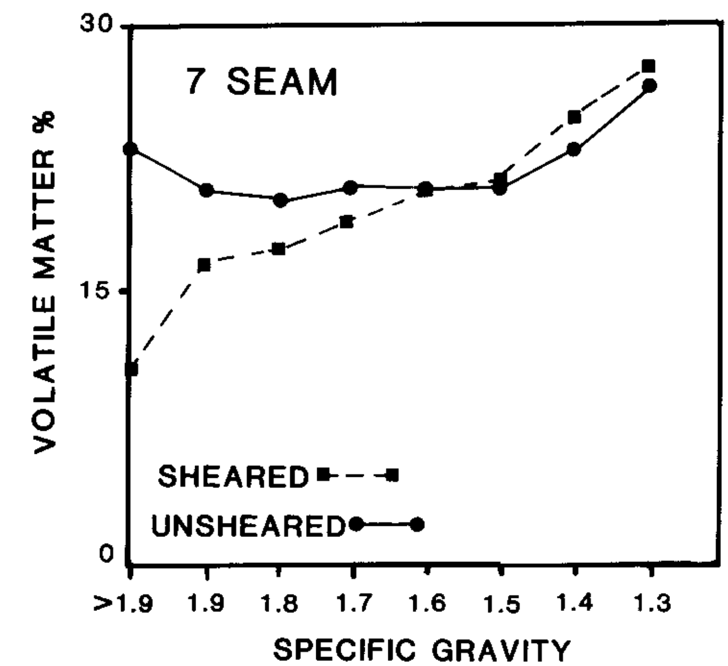


Figure 45. Volatile matter versus specific gravity of No. 5 and No. 7 seams, Fording mine area. In this and other diagrams a specific gravity of 1.3 indicates that the coal fraction floated on a liquid of 1.3 specific gravity; a specific gravity of 1.4 indicates that the coal fraction floated on a liquid of specific gravity 1.4 and sank in a liquid with a specific gravity of 1.3 and so on.

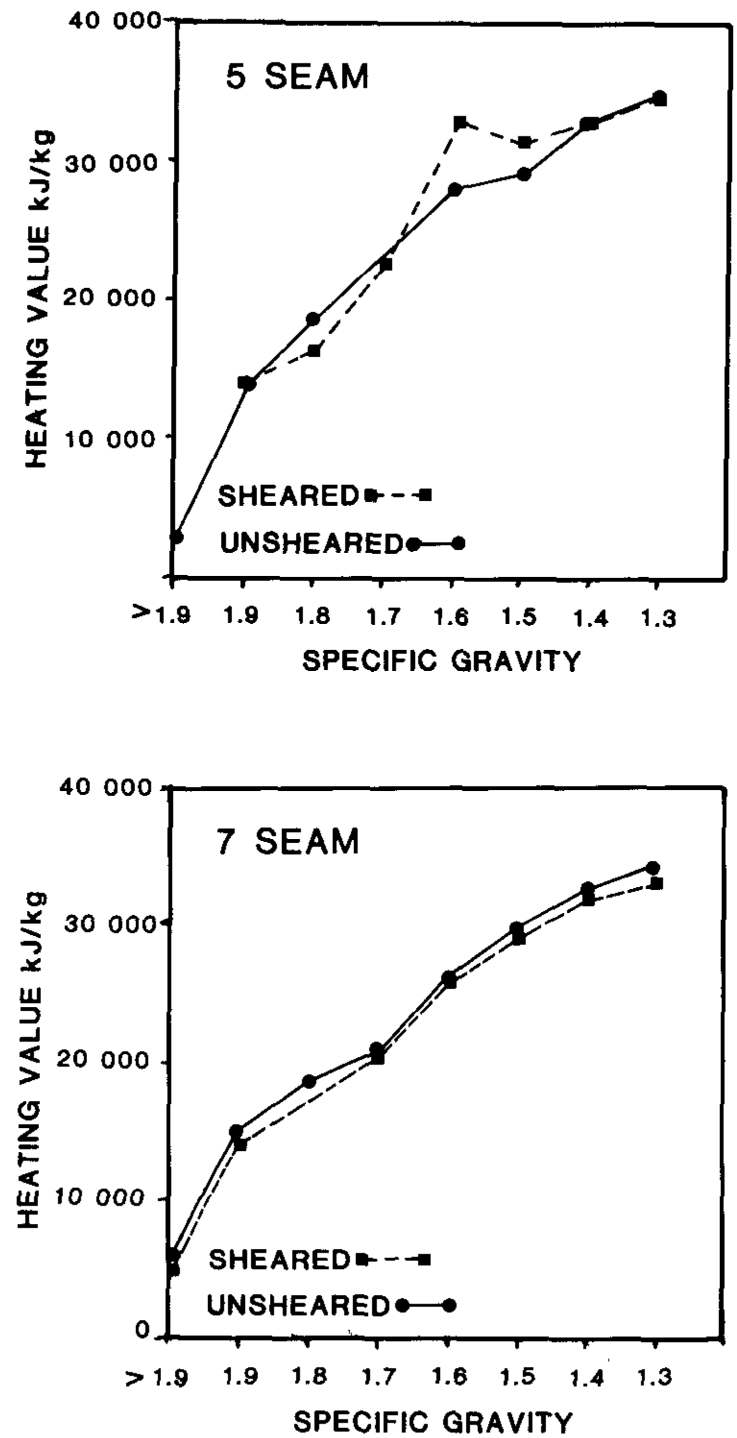


Figure 46. Heating value versus specific gravity of No. 5 and No. 7 seams, Fording mine area.

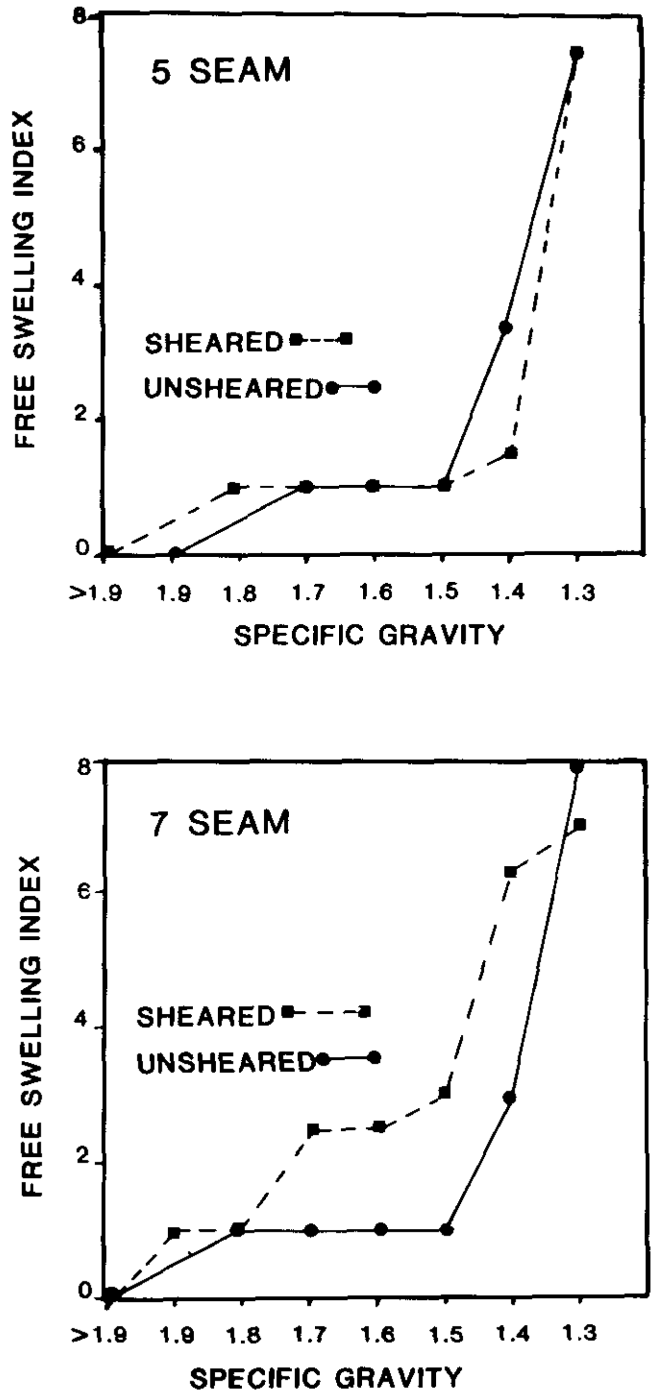


Figure 47. Seven free-swelling index versus specific gravity of No. 5 and No. 7 seams, Fording mine area.

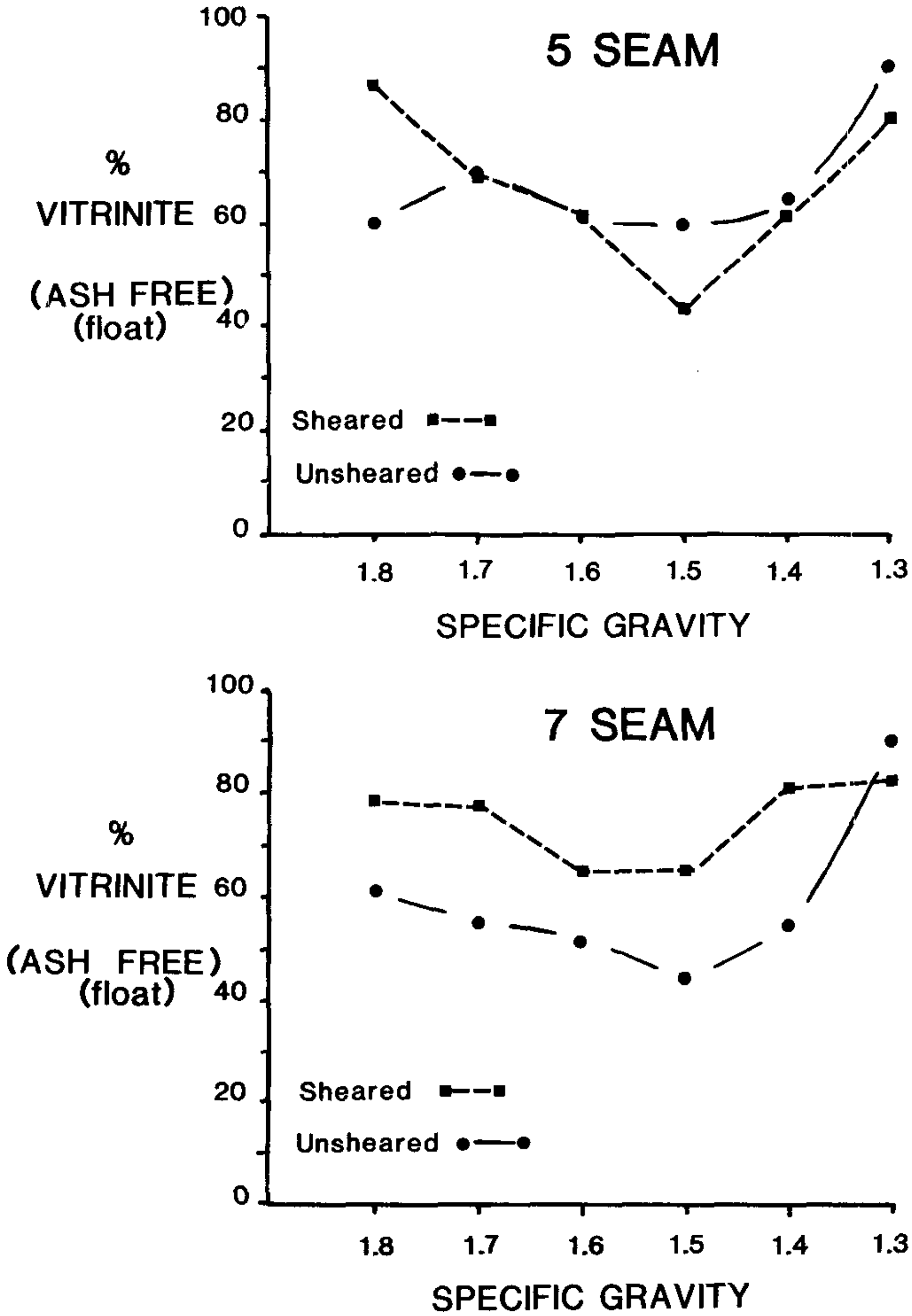


Figure 48. Vitrinite (ash-free basis) versus specific gravity of No. 5 and No. 7 seams, Fording mine area.

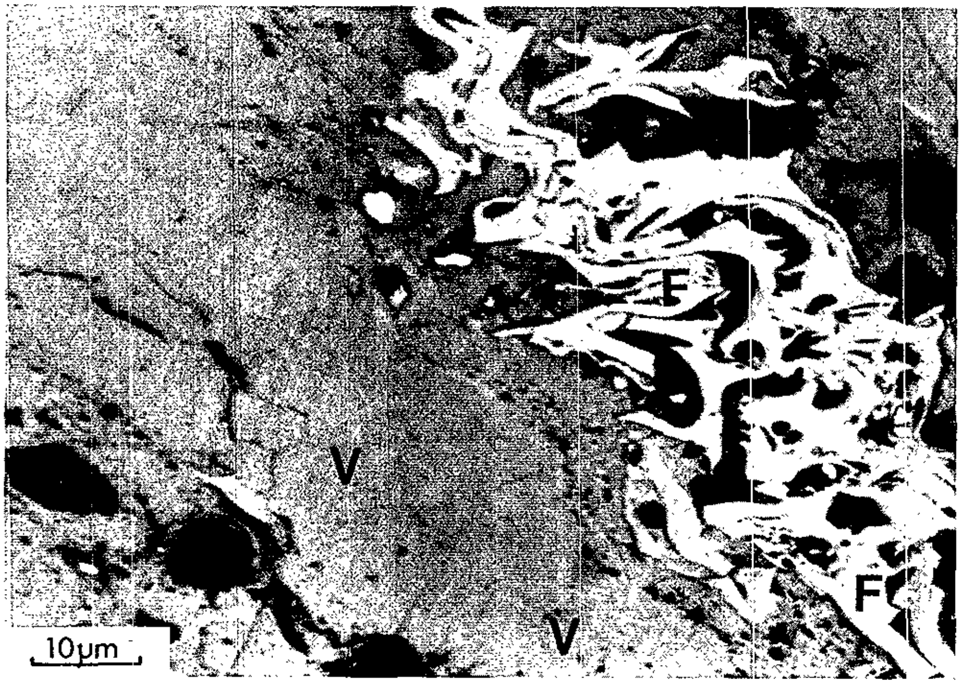


Figure 49. Vitrinite (V) and fusinite (F) in the 1.5 to 1.6 specific-gravity fraction of No. 5 seam, Fording mine area.

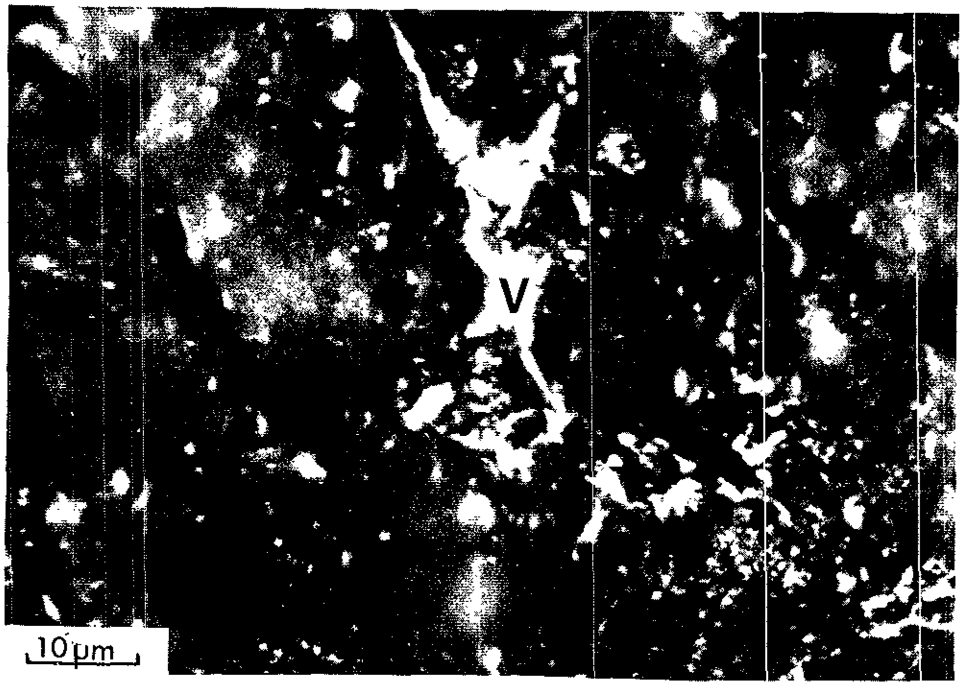


Figure 50. Finely disseminated vitrinite (V) in mineral matter (ash) in the 1.6 to 1.7 specific-gravity fraction of No. 7 seam, Fording mine area.

Figure 51.

Scanning electron photomicrograph of a 'wild' fold developed in clarain from a sheared seam at Tent Mountain, British Columbia.

TABLE 1. NO. 5 SEAM

SUMMARY OF WASHABILITY DATA AND PROXIMATE ANALYSIS, SULPHUR ANALYSIS, HEAT CONTENT, PETROGRAPHY, AND FREE-SWELLING INDEX FOR THE DIFFERENT SPECIFIC GRAVITY FRACTIONS

5 SEAM

Specific Gravity	Washability Data: Direct Weight	Direct Ash	Weight of ash of total	Cumulative weight of ash	Cumulative floats Weight	Cumulative floats Ash	Sink weight of ash	Cumulative sinks Weight	Cumulative sinks Ash	±0.1 Specific gravity distribution S.G.	±0.1 Specific gravity distribution Weight %	Proximate Analysis (Weight %): Internal Moisture	Volatile Matter	Fixed Carbon	Ash	Sulphur	Heat Content KJ/Kg	Petrography (Volume %): Vitrinite	Fusinite	Semifusinite	Ash	Free swelling Index
<1.3	11.8%	2.8%	0.3%	0.3%	11.8%	2.8%	15.0%	88.2%	17.0%			1.2%	24.9%	71.1%	2.8%	0.4%	35,276	87%	2%	8%	3%	7½
1.3-1.4	55.8	7.7	4.3	4.6	67.6	6.9	10.7	32.4	33.0	1.4	73.4%	1.1	21.6	69.6	7.7	0.4	33,050	58	17	17	8	2½
1.4-1.5	17.6	17.4	3.0	7.6	85.2	9.0	7.7	14.8	52.0	1.5	21.5	0.9	20.6	61.1	17.4	0.4	28,995	52	16	16	17	1
1.5-1.6	3.9	19.1	0.7	8.3	89.1	9.5	7.0	10.9	64.2	1.6	5.6	0.8	20.3	59.8	19.1	0.4	28,310	50	14	17	19	1
1.6-1.7	1.7	32.0	0.5	8.8	90.8	10.5	6.5	9.2	70.6	1.7	2.3	0.8	20.0	47.2	32.0	0.4	23,318	46	9	13	32	1
1.7-1.8	0.6	42.3	0.3	9.1	91.4	10.7	6.2	8.6	72.0	1.8	0.8	0.8	19.1	37.8	42.3	0.3	18,766	35	11	12	42	½
1.8-1.9	0.4	50.4	0.2	9.3	91.6	10.9	6.0	8.4	71.4			0.6	19.3	29.7	50.4	0.2	13,750					0
>1.9	8.2	73.4	6.0	15.3	100.	15.8						0.3	20.4	5.9	73.4	0.1	3,052					0

5 SEAM SHEARED

Specific Gravity	Washability Data: Direct Weight	Direct Ash	Weight of ash of total	Cumulative weight of ash	Cumulative floats Weight	Cumulative floats Ash	Sink weight of ash	Cumulative sinks Weight	Cumulative sinks Ash	±0.1 Specific gravity distribution S.G.	±0.1 Specific gravity distribution Weight %	Proximate Analysis (Weight %): Internal Moisture	Volatile Matter	Fixed Carbon	Ash	Sulphur	Heat Content KJ/Kg	Petrography (Volume %): Vitrinite	Fusinite	Semifusinite	Ash	Free swelling Index
<1.3	17.6%	4.3%	0.8%	0.8%	17.6%	4.3%	44.0%	82.4%	53.4%			1.1%	24.2%	70.4%	4.3%	0.4%	34,656	78%	6%	12%	4%	7½
1.3-1.4	17.6	8.2	1.4	2.2	35.2	6.3	42.6	64.8	65.7	1.4	29.0%	1.1	20.5	70.2	8.2	0.4	33,345	57	28	7	8	1½
1.4-1.5	11.4	12.0	1.4	3.6	46.6	7.6	41.2	53.4	77.1	1.5	13.9	1.2	20.1	66.7	12.0	0.4	31,476	41	34	13	12	1
1.5-1.6	2.5	19.8	0.5	4.1	49.1	8.3	40.7	50.9	80.0	1.6	5.0	1.2	20.0	59.0	19.8	0.4	33,398	50	24	6	20	1
1.6-1.7	2.5	35.6	0.9	5.0	51.6	9.6	39.8	48.4	82.3	1.7	5.8	1.1	17.7	45.6	35.6	0.4	22,709	43	13	8	36	1
1.7-1.8	3.3	51.6	1.7	6.7	54.9	12.1	38.1	45.1	84.5	1.8	5.1	1.0	15.1	32.3	51.6	0.3	16,217	42	6	1	52	1
1.8-1.9	1.8	52.2	0.9	7.6	56.7	13.4	37.2	43.3	85.9			1.0	14.6	32.1	52.2	0.2	15,772					½
>1.9	43.3	86.0	37.2	44.8	100.	44.9						0.5	8.9	4.6	86.0	0.1	2,350					0

TABLE 2. NO. 7 SEAM

SUMMARY OF WASHABILITY DATA AND PROXIMATE ANALYSIS, SULPHUR ANALYSIS, HEAT CONTENT, PETROGRAPHY, AND FREE-SWELLING INDEX FOR THE DIFFERENT SPECIFIC GRAVITY FRACTIONS

7 SEAM

Specific Gravity	Washability Data: Direct		Weight of ash of total	Cumulative weight of ash	Cumulative floats		Sink weight of ash	Cumulative sinks		±0.1 Specific gravity distribution	
	Weight	Ash			Weight	Ash		Weight	Ash	S.G.	Weight %
<1.3	25.4%	3.6%	0.9%	0.9%	25.4%	3.6%	16.1%	74.6%	21.6%		
1.3-1.4	35.9	8.9	3.2	4.1	61.1	4.	12.9	38.6	33.4	1.4	54. %
1.4-1.5	18.0	16.9	3.0	7.1	79.4	5.6	9.9	20.6	48.0	1.5	23.2
1.5-1.6	5.2	24.4	1.3	8.4	84.6	6.8	8.6	15.4	55.8	1.6	8.5
1.6-1.7	3.3	34.0	1.1	9.5	87.9	7.8	7.5	12.1	61.9	1.7	5.1
1.7-1.8	1.8	40.8	0.7	10.2	89.7	8.5	6.8	10.3	66.0	1.8	2.9
1.8-1.9	1.1	49.3	0.5	10.7	90.8	11.8	6.3	9.2	68.5		
>1.9	9.3	67.8	6.3	17.0	100.	17.0					

7 SEAM

Specific Gravity	Proximate Analysis (Weight %)				Sulphur	Heat Content KJ/Kg	Petrography (Volume %)				Free swelling Index
	Internal Moisture	Volatile Matter	Fixed Carbon	Ash			Vitrinite	Fusinite	Semifusinite	Ash	
<1.3	2.2%	26.4%	67.8%	3.6%	0.8%	34,935	87%	5%	5%	4%	8
1.3-1.4	1.4	22.7	67.0	8.9	0.6	32,391	49	22	20	9	3½
1.4-1.5	0.9	20.7	61.5	16.9	0.5	29,176	37	30	17	17	1
1.5-1.6	0.6	20.3	54.7	24.4	0.4	25,880	40	21	16	24	1
1.6-1.7	1.1	20.4	44.5	34.0	0.5	21,505	37	21	8	34	1
1.7-1.8	1.4	19.8	38.0	40.8	0.5	18,919	37	16	6	41	1
1.8-1.9	1.0	20.4	29.3	49.3	0.4	15,059					½
>1.9	0.3	22.8	9.1	67.8	0.2	5,774					0

7 SEAM SHEARED

Specific Gravity	Washability Data: Direct		Weight of ash of total	Cumulative weight of ash	Cumulative floats		Sink weight of ash	Cumulative sinks		±0.1 Specific gravity distribution	
	Weight	Ash			Weight	Ash		Weight	Ash	S.G.	Weight %
<1.3	14.0%	5.1%	0.7%	0.7%	14.0%	5.1%	49.3%	86.0%	57.3%		
1.3-1.4	12.1	11.7	1.4	2.1	26.1	8.1	47.9	73.9	64.8	1.4	22.6%
1.4-1.5	10.5	17.4	1.8	3.9	36.6	10.8	46.1	63.4	72.7	1.5	15.7
1.5-1.6	5.2	23.3	1.3	5.2	41.8	12.6	44.8	58.2	76.9	1.6	8.6
1.6-1.7	3.4	39.7	1.3	6.5	45.2	14.8	43.5	54.8	79.3	1.7	5.7
1.7-1.8	1.3	48.4	0.6	7.1	47.5	16.5	42.9	52.5	81.7	1.8	3.5
1.8-1.9	1.2	56.1	0.7	7.8	48.7	17.5	42.2	51.3	82.2		
>1.9	52.3	80.8	42.2	50.0	100.	50.1					

7 SEAM SHEARED

Specific Gravity	Proximate Analysis (Weight %)				Sulphur	Heat Content KJ/Kg	Petrography (Volume %)				Free Swelling Index
	Internal Moisture	Volatile Matter	Fixed Carbon	Ash			Vitrinite	Fusinite	Semifusinite	Ash	
<1.3	1.9%	27.0%	61.0%	5.1%	0.7%	33,814	78%	9%	7%	5%	7
1.3-1.4	1.4	24.1	62.8	11.7	0.5	31,370	71	4	12	12	6½
1.4-1.5	1.1	20.7	39.2	17.4	0.5	29,206	55	12	16	17	3
1.5-1.6	1.0	20.2	53.9	24.9	0.5	26,140	48	15	11	25	2½
1.6-1.7	0.8	18.8	40.7	39.7	0.4	20,929	47	7	6	40	2½
1.7-1.8	0.8	18.0	32.8	48.4	0.3	17,181	40	2	9	48	1
1.8-1.9	0.8	16.2	26.9	56.1	0.3	14,279	38	3	3	56	1
>1.9	1.0	10.3	7.9	80.8	0.2	4,809	17	1	1	81	0

TABLE 1. TWO-WAY CONTINGENCY TABLE ROCK TYPE (PROVENANCE) VERSUS STREAM VELOCITY FOR STREAM SEDIMENT SAMPLES (NTS 82F)

ROCK AND AGE COMBINED	WATER FLOW RATE 44						
	N.E.	STAGNT	SLOW	MOD.	FAST	TORRNT	OTHER
GRNT35	1		46	245	177	16	
SYNT42	1		2	15	6	1	
ANDS34			7	34	21		
LMSN12			1	4	4		
SLTE10			3	17	31		
ARGL33			1	15	15		
QRTZ45	6	6	34	145	124	3	
GNSS30	4	2	15	33	18	1	
SLTE32			1	13	16	3	
SCST32			2		8		
TILL			1	5	1		
SLTE46			6	24	27	4	
QRTZ12		1		9	20	2	
ARGL45		1	2	29	23	3	
SCST10			4	14	16		
ANDS46				2	2	1	
CGLM46				1	4		
SHLE12				4			
DLMI45			1	6	2		
ANDS32				4	2		

TABLE 2. TWO-WAY CONTINGENCY TABLE FOR GROUPED DATA*

Rock Type	Velocity Category: Slow	Moderate	Fast	Totals
GRNT, SYNT	48(48.5)	260(242.5)	183(200)	491
ANDS	7(7.1)	40(35.6)	25(29.3)	72
SLTE	10(13.6)	54(68.2)	74(56.2)	138
ARGL	3(8.4)	44(42)	38(34.6)	85
QRTZ	34(32.8)	154(164.0)	144(135.2)	332
GNSS	15(6.5)	33(32.6)	18(26.9)	66
Totals	117	585	482	1184

$\chi^2_{(.05;\ d.f.\ 10)} = 18.31$

* Number in brackets are expected values

A PRELIMINARY EVALUATION OF CATEGORICAL FIELD OBSERVATIONS FOR REGIONAL STREAM SEDIMENT SAMPLES (82 F, K)

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INTRODUCTION

We are in the process of examining regional stream geochemical data obtained during a joint Federal-Provincial Uranium Reconnaissance Program of NTS map-areas 82 F and K released in 1978. The purposes of our study are to evaluate the usefulness of individual variables coded in the course of these surveys, to develop a statistical procedure for extracting useful information from the data, and to utilize the data base as an effective means of defining problems of geological interest that warrant further investigation. Our work is developmental in nature and is confined to data for NTS map-area 82F.

Initial work (Sinclair and Fletcher, 1980) considered only numeric (concentration) data and emphasized a systematic approach to its evaluation using standard statistical procedures. However, in addition to the quantitative data the Uranium Reconnaissance Program files contain field observations describing the drainage sediments and collection site for each sample. For example, in addition to rock type, coded comments are recorded to describe the presence of contamination, the nature of the bank material, water and sediment colour, texture, the presence of organics or precipitates, and such physiographic features as landscape maturity, drainage pattern, and stream class. Although similar data are often collected as part of drainage surveys, they are so seldom utilized in any systematic fashion that a recent review (Meyer, *et al.*, 1979) suggested limiting field observation to those of proven significance. Our ongoing studies attempt to establish which field observations are significant and to assess their influence on metal content of the drainage sediments. Two complementary procedures are being utilized:

(1) Contingency tables and the chi-square test, and
(2) Duncan's multiple range test.

CONTINGENCY TABLES

Two-way contingency tables represent an ordered arrangement of counts of 'intersection' of pairs of variables. A simple example is illustrated in Table 1 for rock type versus stream velocity for 1 318 stream sediment samples from NTS map-area 82F. The count of 245 at the intersection of the GRNT-35 and MOD columns means that 245 sediments from the area are characterized by both these features. With such a table one can quickly, if subjectively, evaluate the distribution of one variable in relation to another. For example, in Table 1 we can look at the distribution of samples in velocity categories for individual rock types (that is, distribution of counts along rows) and compare the distribution for one rock type with the distribution for another. Conversely the data can be viewed in terms of the distribution of counts along each column. That is, dominant stream velocity categories may differ over each rock type and different distribution patterns may occur in different columns.

It is apparent that contingency tables permit rapid qualitative evaluation of paired variables although the importance of this feature is not particularly obvious in viewing Table 1. However, the usefulness of a computer-generated two-way contingency table for 40 or more variables, as is the case with stream sediment samples collected during the Uranium Reconnaissance Program, is apparent. Two-way tables for such a large number of variables are difficult and impractical to obtain manually. They can, however, be produced with ease on the computer and a program in FORTRAN designed specifically for dealing with publically available magnetic tapes of regional geochemical data for the Uranium Reconnaissance Program has been developed. Because the table is symmetrical about the main diagonal, only half is printed by the program. Row and column totals are also output. For 182 categories of about 15 variables, 45 pages of computer output are necessary to generate an entire contingency table.

In reality such a two-way table consists of a series of self-contained subsets of which Table 1 is one example. Using a chi-square test these subsets can be examined rigorously to see whether one variable is statistically dependent on the second variable.

As an application of the chi-square test, consider the data of Table 1. The chi-square test requires that there are no zero values and that no more than 20 per cent of the values are less than 5. Rows and columns must be grouped or eliminated to meet these conditions. In the case of Table 1 a possible grouping leads to the arrangement in Table 2.

In conducting a chi-square test, it is assumed that summations of rows and columns represent a best estimate of independence of the two variables. Consequently, these summations are used to estimate expected values for each intersection according to the formula

$$E_{ij} = \frac{r_i c_j}{N}$$

where r_i is the sum of row i and c_j is the sum of column j.

The values determined represent an expected value assuming that the variables are independent. Differences between observed and calculated values $(O_{ij} - E_{ij})$ are examined by the chi-square test to evaluate whether or not they could result from random sampling:

$$X^2_{calc.} = \sum_{ij} \frac{(O_{ij} - E_{ij})^2}{E_{ij}}$$

If differences are small $X^2_{calc.}$ is small, and the two variables are said to be independent. If $X^2_{calc.}$ is greater than some critical value, $X^2_{(d.f.,\ L)}$, that depends on the number of degress of freedom and the level of significance of the test, then one variable is said to be dependent on the other.

For the example of Table 2, $X^2_{calc.}$ is 32.63 which is much greater than the critical value of 18.31 obtained from tables such as those given in Krumbein and Graybill (1965) for 10 degrees of freedom and a test level of 0.05. Consequently, we can say with assurance that stream velocity depends on rock type; more specifically, some rock types are characterized by high stream velocities and others by low velocities. Because higher stream velocities generally mean steeper gradients we see the physiographic information contained within such tests. Within the test area, for example, siltstone (SLTE) is generally resistant and forms steep slopes in contrast to gneiss (GNSS) which is recessive and more prevalent in valleys.

A similar test can be done between any two variables. For example, we can compare sediment colour against rock type, bank type versus stream velocity, and so on.

DUNCAN'S MULTIPLE RANGE TEST

METHOD

Duncan's multiple range test (Duncan, 1955, 1957) provides a method of testing if differences among a group of means are significant. It has previously been applied to regional geochemical data by Miesch (1976) and Doyle and Fletcher (1979). The test assumes that the means $m_1, m_2 \ldots\ldots m_n$ are independently drawn from 'n' normal populations having true means of $\mu_1, \mu_2 \ldots\ldots \mu_n$ respectively. However, as previously reported (Sinclair and Fletcher, 1980) much of the metal concentration data from the Uranium Reconnaissance Program is log-normally distributed and it is often multimodal. Consequently, before the significance of field parameters for a background population could be evaluated using Duncan's multiple range test, it was necessary to log-transform the data and eliminate anomalous results. For this report the procedures involved and results will be illustrated with respect to streams draining granites (GRNT-35) in map-area 82F.

The first step is to partition the log-probability plot, using the method of Sinclair (1976), for each element into low (probably background) and high (probably anomalous) populations. Anomalous samples are then rejected leaving only background samples for classification into groups based on the field observations. For example, considering copper in sediments associated with GRNT-35, 12 samples (from a total of 485) are rejected as anomalous; if sediment colour is the field observation of interest the remaining 473 sediments can then be divided into seven (red, white, black, yellow, green, grey, and pink) groups and log means and standard deviations calculated. However, the only colours recorded with reasonable frequency are red (n = 341), white (105), and black (23) with corresponding means of 9, 9, and 15 parts per million (ppm). The significance of the differences among these means are then calculated (0.05 confidence level) using Duncan's multiple range test. Results of the test establish that concentrations of copper in white and red sediments are indistinguishable but those in black sediments are significantly greater. The results are conveniently presented as Venn diagrams in which overlapping or shared circles indicate groups whose means are not significantly different (Fig. 52; figures at end of text, pages 155 to 158).

RESULTS

Data for 11 of the elements reported were subdivided into groups according to their classification with respect to four sediment characteristics (fines, sand, organic content, and colour) and six environmental parameters (physiography, water flow, stream class, drainage pattern, bank type, and contamination). The significance of differences of means among groups were then tested and presented as Venn diagrams as shown on Figures 52 to 54. Results can be summarized as follows:

(1) Bulk composition — fines (absent; minor <33 per cent; medium 33 to 67 per cent; major >67 per cent, Fig. 52). Except for tungsten, variation in the content of fines in the sediment has no apparent influence on metal concentrations.

(2) Bulk composition — sand (absent; minor <33 per cent; medium 33 to 67 per cent; major >67 per cent). Although lead, zinc, uranium, manganese, and mercury concentrations in sediments estimated to contain medium amounts of sand are lower than those in other sediments, it is only for lead that this group forms a statistically independent population. Similarly, sediments in which sand is absent or a minor component contain relatively high concentrations of zinc, uranium, manganese, and mercury without their constituting a significantly different statistical group. Sand content has no apparent influence on concentrations of copper, nickel, molybdenum, iron, and cobalt.

(3) Bulk composition – organic (absent; minor <33 per cent; medium 33 to 67 per cent; major >67 per cent, Fig. 53). Sediments can be divided according to the presence or absence of organic matter; those with no organic matter contain significantly lower concentrations of zinc, lead, uranium, manganese, and mercury. Copper, molybdenum, iron, and cobalt do not appear to be affected by variations in organic content. The difference between the presence of minor or medium quantities of organic matter does not seem to be important for any of the elements.

(4) Sediment colour (red, white, black, yellow, green, grey, and pink, Fig. 54). As might be anticipated, red sediments contain higher average concentrations of iron and manganese than white or black sediments; uranium shows the same pattern. Between the red and white sediments the difference in means for these elements is also significant. In contrast, the greater average concentrations of copper, nickel, lead, and mercury form a statistically significant group associated with black sediments. For lead and mercury, red sediments comprise a statistically independent group of intermediate concentrations.

(5) Physiography (plateau, hilly undulating, mountainous mature, mountainous youthful). Zinc, lead, manganese, copper, and mercury have their lowest concentrations in the youthful category which, for the first three of these elements, forms a statistically significant group, Conversely, molybdenum (and tungsten) have their maximum values in this category. Nickel, cobalt, and iron concentrations show no relationship to the physiographic classification.

(6) Stream class (permanent, secondary, tertiary, quaternary). Zinc, molybdenum, uranium, tungsten, iron, and mercury show no significant differences in concentration related to stream class. Concentrations of copper are significantly different in each of the three classes, highest concentrations being associated with secondary drainages. Secondary drainage also comprises a significantly distinct group of high concentrations for cobalt and nickel. In contrast, maximum manganese content is associated with quaternary streams.

(7) Water flow (zero, slow, moderate, fast, torrential). Molybdenum, uranium, tungsten, iron, and manganese concentrations cannot be subdivided on the basis of flow velocities. For the remaining elements (except cobalt) there is a tendency for maximum values to be associated with slow flow rates. There is, however, considerable overlap between the groups.

(8) Drainage pattern (poorly defined, dendritic, herringbone, rectangular, discontinuous, basinal, other). Only copper and lead form significantly distinct groups with their lowest concentrations in areas with poor and herringbone drainages respectively. Lowest concentrations of zinc, manganese, and mercury are also found in areas of poor drainage but concentrations are not significantly different between those with dendritic or herringbone patterns.

(9) Bank type (undefined, alluvial, colluvial, glacial till, glacial outwash, bare rock, talus, organic predominant). With seven categories sample size is often small. Nevertheless, relatively high nickel, molybdenum, and cobalt values are significantly associated with talus slopes. Results for uranium and iron show a similar pattern but they are not significantly different to all other groups.

(10) Contamination (none, possible, probable, definite, mining, agriculture, forestry, domestic). Of the six categories of contamination only the association of low concentrations of copper and cobalt with domestic contamination is significantly different to concentrations in all other categories.

DISCUSSION

Despite their very qualitative, subjective character it is apparent that the field observations can be related to variations in the trace element content of sediments associated with a single rock unit, in this case GRNT-35. Under these circumstances it is of obvious interest to:

(1) Consider if the relationships observed are consistent with factors known to influence trace element behaviour, and
(2) To establish the interactions between the field parameters with a view to eliminating those that are either redundant or appear to have little influence on trace element concentrations.

Considerably more work is required on both topics, however, a summary (Fig. 55) does indicate those field parameters which influence the greatest number of elements. From this we note that sediment colour, physiography, and bank type significantly influence concentrations of 8 out of the 11 elements whereas, rather surprisingly, content of fines only influences zinc concentrations. Conversely, the susceptibility of an element to influence by the field parameters decreases from lead, which is significantly affected by eight factors, in the order manganese and zinc (7), copper, nickel, and uranium (6), cobalt and mercury (5), tungsten (4), and iron and molybdenum (2).

Clearly the composition of a particular sediment reflects the interaction and relative strengths of many factors which, by reinforcing or counteracting each other, impart a low, average, or high metal content. At present we do not know why many of the factors, especially those related to physiography, produce the results observed. However, it is encouraging to note that the results are in accord with some well-known controls on the behaviour of trace elements in sediments. For example, scavenging of metals by organic matter and hydrous oxide precipitates probably cause the associations between zinc, lead, uranium, manganese, and organics and mercury and of zinc, copper, lead, uranium, manganese, mercury, and iron with red sediments.

Finally, the need for caution in interpreting interacting factors should be emphasized. For example, relatively low background concentrations of copper are apparently associated with streams receiving domestic contaminants. Although this may reflect good housekeeping it seems more likely that it means that townsites were developed in valleys, alongside quaternary drainages which have low copper contents. Higher in the mountains secondary and tertiary drainages have relatively higher copper contents.

CONCLUSIONS

As far as we are aware, this is the first systematic attempt to evaluate the significance of field observations in relation to background variations in metal contents of drainage sediments. We conclude:

(1) Despite their subject character field observations can be related to significant variations in metal content of drainage sediments associated with a single rock unit.
(2) Two-way contingency tables are a useful means for rapidly identifying those paired categorical variables for which enough samples exist for statistical analysis. For practical use, however, a computerized system of generating such tables is essential.
(3) Subsets from large two-way contingency tables for regional stream sediment samples can be tested rigorously for dependence or independence using a chi-square test. An example

from NTS 82F map-area indicated preferential occurrence of certain rock types in certain physiographic environments as indicated by stream velocity.

(4) Duncan's multiple range test, used in conjunction with probability plots, enables the significance of field observations to be systematically related to variations in background metal content of sediments. This provides a basis for studying the interactions of environmental factors and determining which are most relevant to geochemical exploration programs.

ACKNOWLEDGMENTS

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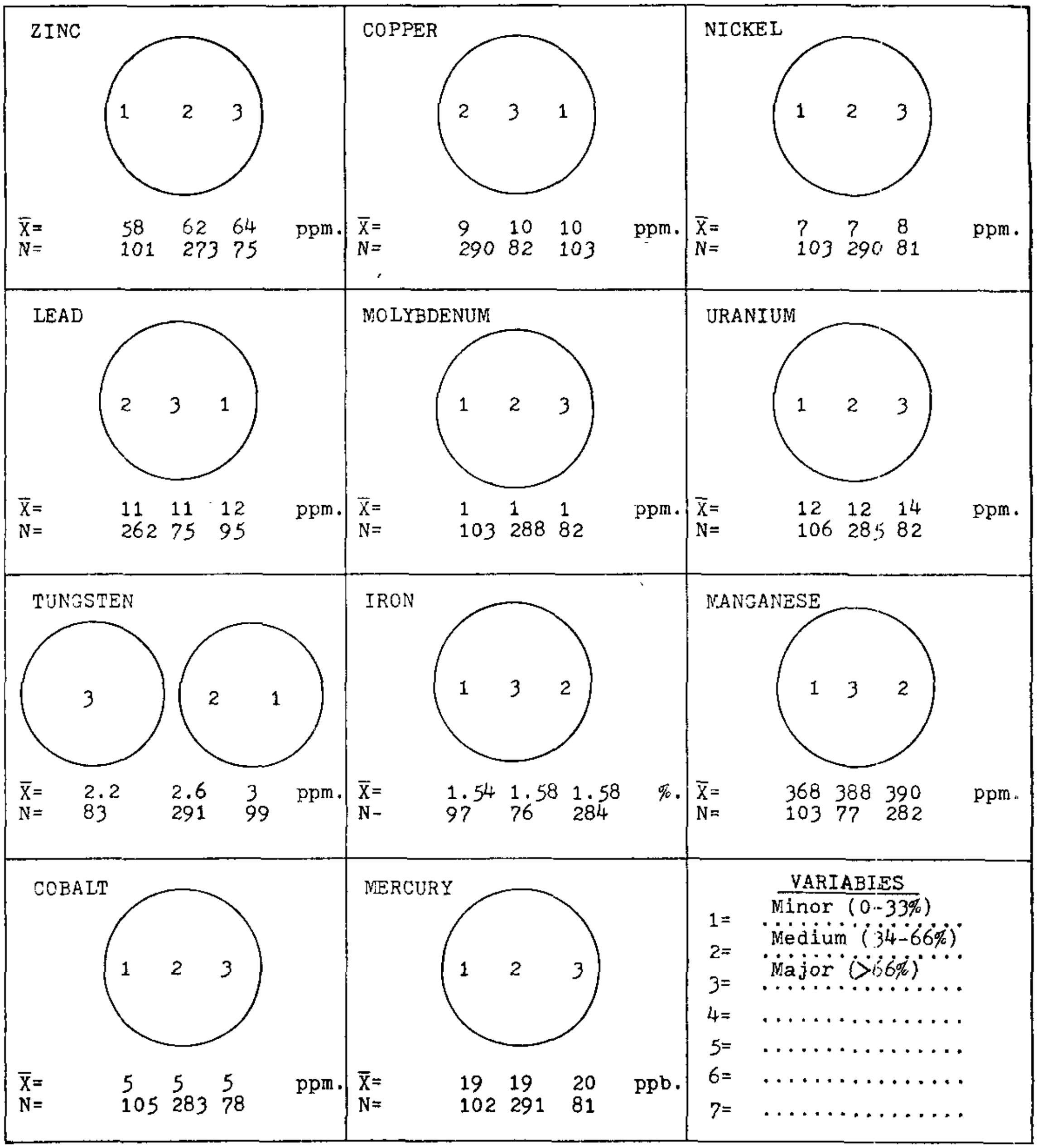

Figure 52. Duncan's multiple range test for the influence of per centage of fines on metal content of stream sediments associated with granites (GRNT-35), map-area 82F. Common or overlapping circles indicate that group means are not significantly different at the 0.05 confidence level.

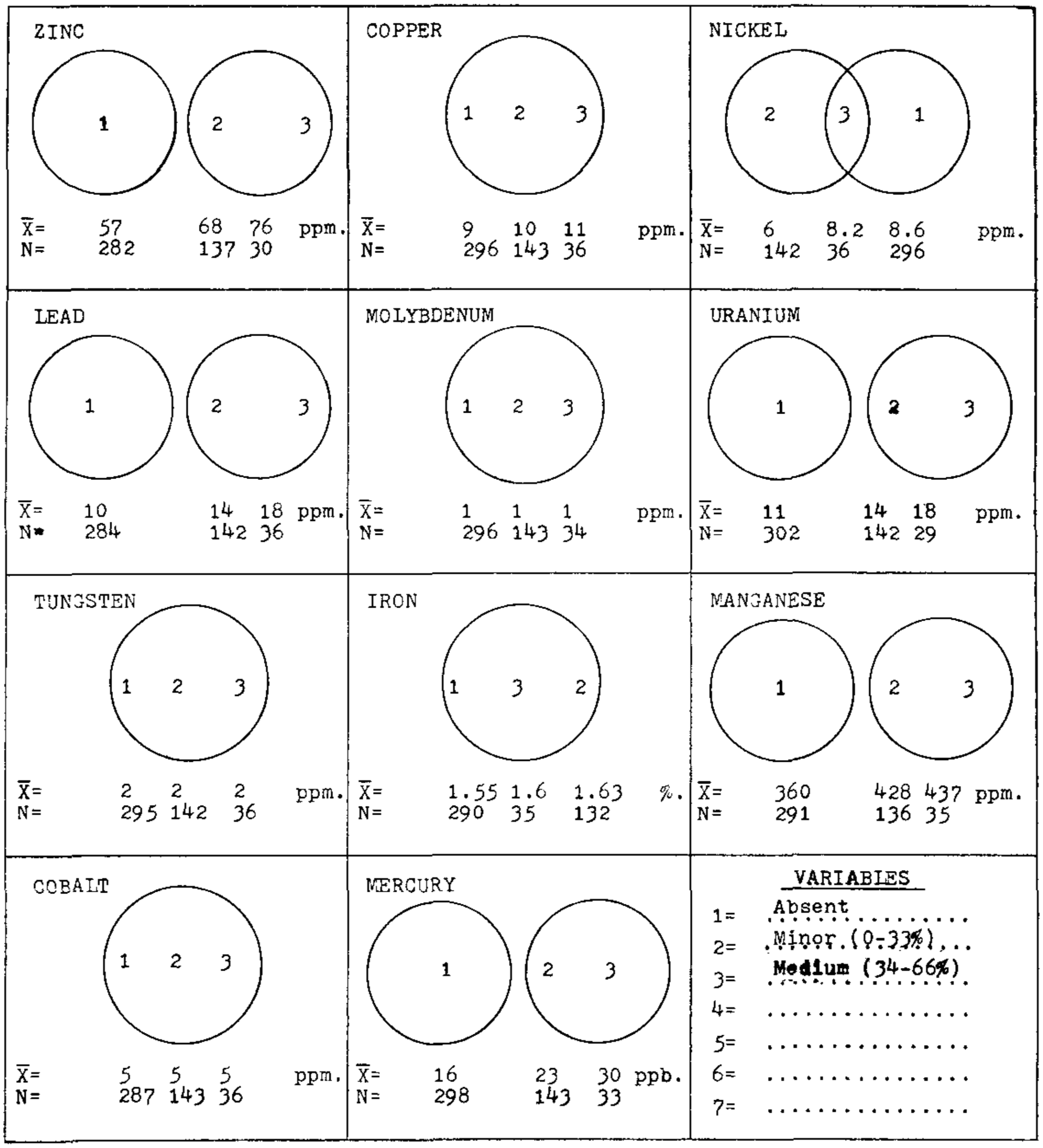

Figure 53. Duncan's multiple range test for the influence of organic matter content on metal content of stream sediments associated with granites (GRNT-35), map-area 82F. Common or overlapping circles indicate that group means are not significantly different at the 0.05 confidence level.

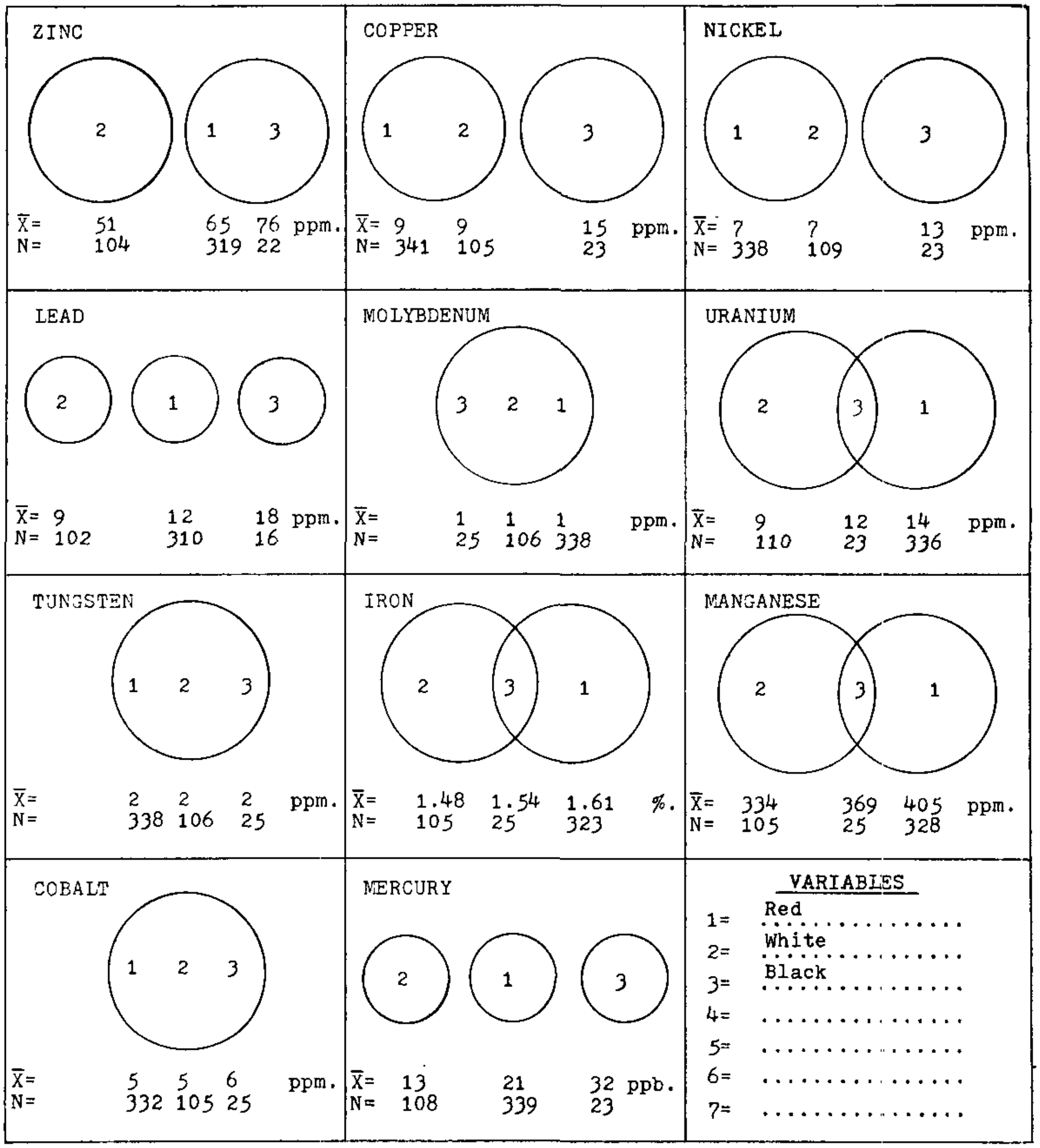

Figure 54. Duncan's multiple range test for the influence of sediment colour on metal content of stream sediments associated with granites (GRNT-35), map-area 82F. Common or overlapping circles indicate that group means are not significantly different at the 0.05 confidence level.

FACTORS AFFECTING ELEMENTAL CONCENTATIONS

	Zn	Cu	Ni	Pb	Mo	U	W	Fe	Mn	Co	Hg	Total
Bulk comp. (Fines)							X					(1)
Bulk comp. (Sands)	X			X		X	X		X		X	(6)
Bulk comp. (Orgs.)	X		X	X		X			X		X	(6)
Sediment Color	X	X	X	X		X		X	X		X	(8)
Physio-graphy	X	X		X	X	X	X		X		X	(8)
Waterflow Rate	X	X	X	X						X	X	(6)
Stream Class		X	X	X					X	X		(5)
Drain Pattern	X	X		X		X	X		X	X		(7)
Bank Type	X		X	X	X	X		X	X	X		(8)
Contamin-ation		X	X							X		(3)
Total	(7)	(6)	(6)	(8)	(2)	(6)	(4)	(2)	(7)	(5)	(5)	

Figure 55. Chart summarizing the relationships between metal concentrations and field observations for stream sediments associated with granites (GRNT-35), map-area 82F; X indicates the presence of a significant interaction on the basis of the Duncan's-multiple-range-test data.

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

By Paul Schiarizza

INTRODUCTION

During the 1980 field season approximately 325 square kilometres between Chu Chua Mountain and Clearwater were mapped at a scale of 1:15 840. This mapping is an extension of the Barriere Lakes-Adams Plateau project initiated in 1978 under the direction of V. A. Preto (Preto, 1979; this report; Preto, *et al.*, 1980). The area is underlain primarily by rocks of the Late Paleozoic Fennell Formation. The mapping was aimed at a better understanding of the internal stratigraphy and structure of this formation as well as its relationships with rocks of the Eagle Bay Formation which contact it to the east. In contrast to the interpretation of Fennell/Eagle Bay contact relationships advanced by Preto, *et al.* (1980), evidence from this area suggests that the Fennell Formation overlies the Eagle Bay, although the contact, at least locally, may be a fault.

This study forms part of a graduate thesis being undertaken at the University of Calgary and supported, in part, by the British Columbia Ministry of Energy, Mines and Petroleum Resources.

STRATIGRAPHY

EAGLE BAY FORMATION (UNITS 1 TO 6)

Rocks of the Eagle Bay Formation underlie an area of generally poor outcrop in the northeast corner of the map-area (Fig. 56). Immediately south of Clearwater westernmost exposures of the Formation are of dark grey to black phyllite with interbeds of siltstone, sandstone, and grit (unit 6). This unit is very similar to Eagle Bay rocks immediately east of the Fennell Formation in the Barriere Lakes area (unit 6 of Preto, *et al.*, 1980). There, early Mississippian conodonts (Okulitch and Cameron, 1976; Preto, *et al.*, 1980) were extracted from two lenses of limestone in unit 6. Okulitch (1979) correlates this unit with the carboniferous Milford Group of the Kootenay Arc and suggests that it unconformably overlies the bulk of the Eagle Bay Formation. South of Clearwater unit 6 dips to the northeast and structurally overlies rocks of the Fennell Formation; however, rare graded beds within the unit suggest that it is overturned. Overturning is also suggested by bedding/cleavage relationships (bedding dipping more steeply northeast than cleavage) within this unit and in immediately adjacent bedded chert of the Fennell Formation.

To the east, black phyllite of unit 6 appears to be interbedded with and structurally overlain by light silvery green quartz-sericite schists and pyrite-quartz-sericite schists (unit 5). 'Eyes' of clear quartz are sometimes present and may represent volcanic quartz phenocrysts. Also within unit 5 are somewhat more massive feldspathic rocks with relic textures that suggest they were coarse-grained felsic intrusive rocks.

Unit 6 apparently pinches out to the south and, in the vicinity of Foghorn Mountain and upper Foghorn Creek, the Eagle Bay Formation consists of rusty weathering, greenish grey, moderately to weakly foliated

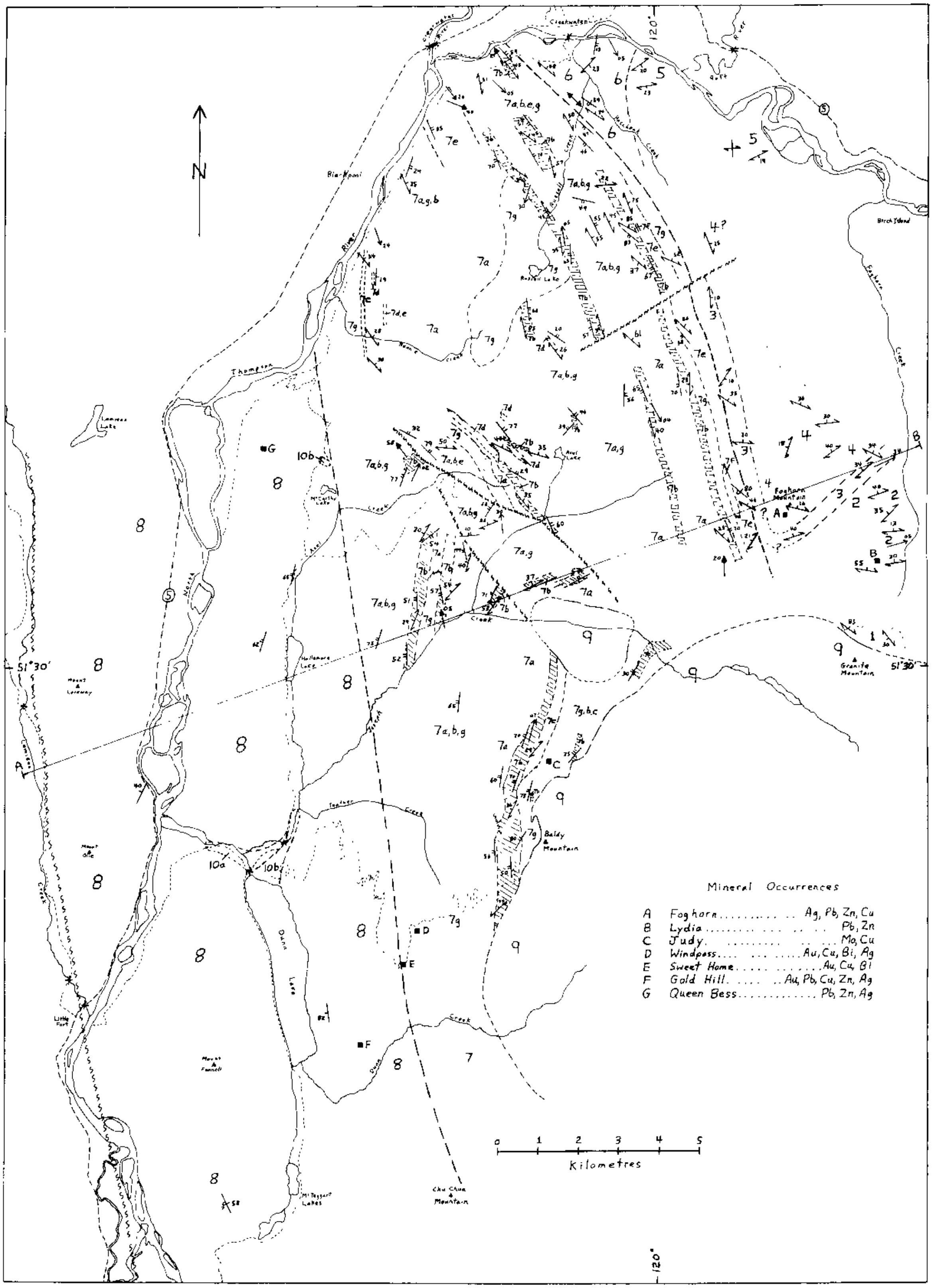

Figure 56. Generalized geological map of the Clearwater area.

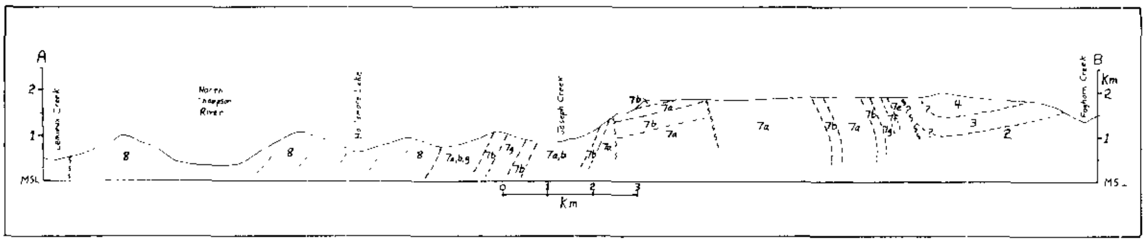

Figure 57. Vertical cross-section to accompany Figure 56.

LEGEND

EOCENE AND LATER (?)

10 (b) SKULL HILL FORMATION: VESICULAR ANDESITE
(a) CHU CHUA FORMATION: CONGLOMERATE, SANDSTONE, SHALE

CRETACEOUS

9 BIOTITE QUARTZ MONZONITE OF BALDY BATHOLITH AND JOSEPH CREEK STOCK

MISSISSIPPIAN (?) AND/OR LATER (?)

FENNELL FORMATION

8 WESTERN (UPPER ?) FENNELL FORMATION: PILLOWED AND MASSIVE BASALT, MINOR CHERT, AND BASALT BRECCIA

7 EASTERN (LOWER ?) FENNELL FORMATION

(g) GABBROIC AND DIORITIC ROCKS
(f) LIMESTONE
(e) ARGILLITE, PHYLLITE; MINOR SANDSTONE AND QUARTZITE
(d) CONGLOMERATE
(c) QUARTZ FELDSPAR PORPHYRY
(b) BEDDED CHERT
(a) MASSIVE AND PILLOWED BASALT

MISSISSIPPIAN (?) AND EARLIER (?)

EAGLE BAY FORMATION

6 DARK GREY TO BLACK PHYLLITE WITH INTERBEDDED SILTSTONE, SANDSTONE, AND GRIT

5 LIGHT SILVERY GREEN (±PYRITE)–QUARTZ–SERICITE SCHIST

4 RUSTY WEATHERING, GREENISH GREY, FELDSPATHIC CHLORITE–SERICITE SCHIST: IN PLACES FRAGMENTAL. MINOR SANDSTONE AND QUARTZITE

3 DARK TO MEDIUM GREEN CHLORITE SCHIST

2 LIGHT GREEN SILICEOUS PHYLLITE; MINOR GREY PHYLLITE AND LIMESTONE

1 FINE TO MEDIUM-GRAINED BIOTITE–QUARTZ GNEISS; MINOR AMPHIBOLITE AND PELITIC HORNFELS

SYMBOLS

BEDDING: TOPS KNOWN, OVERTURNED . . . .

BEDDING: TOPS NOT KNOWN . . . .

SCHISTOSITY: INCLINED, HORIZONTAL . . . .

EARLY MESOSCOPIC FOLD AXIS . . . .

LATE MESOSCOPIC FOLD AXIS . . . .

INFERRED FAULT . . . .

GEOLOGICAL CONTACT . . . .

MINERAL OCCURRENCE . . . . ■

feldspathic chlorite-sericite schists (in places fragmental) with minor amounts of interbedded sandstone and quartzite (unit 4), medium to dark green chlorite schists (unit 3), and light green siliceous phyllites with interbedded medium to dark grey phyllite and minor limestone (unit 2). Unit 2 is primarily of sedimentary origin, whereas units 3 and 4 appear to be mainly of volcanic origin. The rocks are poorly exposed so the contact relationships and outcrop patterns of these units were not established with certainty. However, east of Foghorn Mountain the lithologic contacts appear to strike northeasterly and dip to the northwest and are at a high angle to those in adjacent Fennell rocks. Scattered outcrops of chlorite schist northwest of Foghorn Mountain suggest that unit 3 may swing around the mountain into a trend roughly parallel to the Fennell contact and outline a northerly plunging synform cored by unit 4.

Eagle Bay rocks adjacent to the Baldy batholith immediately north of Granite Mountain consist of fine to medium-grained biotite-quartz gneiss with minor amphibolite and dark purplish grey pelitic hornfels (unit 1).

FENNELL FORMATION (UNITS 7 AND 8)

As was the case further south (Preto, 1979; Preto, *et al.*, 1980), the Fennell Formation can be divided into an eastern unit (unit 7) consisting of massive and pillowed basalt, bedded chert, argillaceous rocks, conglomerate, quartz feldspar porphyry, and gabbroic to dioritic rocks and a western unit (unit 8) consisting almost entirely of pillowed and massive basalt. It appears that the formation as a whole faces west with unit 8 overlying unit 7, although easterly (apparently overturned) dips prevail in the eastern part of unit 7.

EASTERN FENNELL (UNIT 7)

Basalt (7a) is the most common rock type of unit 7. It may be pillowed or massive, is generally fine grained to aphanitic, and is mainly in medium to dark shades of grey to grey.

Chert (7b) is generally well bedded, with beds up to 15 centimetres thick separated by thinner argillaceous partings. It occurs in a variety of colours with light shades of grey and green predominating. Individual chert units provide the best local markers within unit 7 and have been traced for distances approaching 10 kilometres.

Two bodies of quartz feldspar porphyry (7c) were outlined in the eastern Fennell (Fig. 56); both appear to be concordant with the local stratigraphy. Clasts of similar porphyry in conglomerate (7d) overlying the quartz feldspar porphyry body south of Blackpool suggests that it may be of extrusive origin.

Discontinuous lenses of conglomerate (7d) occur in a number of places within unit 7. Clasts are generally angular and similar in composition to adjacent Fennell rocks. The best exposures of conglomerate are found at the microwave station west of Axel Lake where there are a number of lenses of conglomerate containing chert, basalt, and argillite fragments and interlayered with beds of these same rock types.

Argillite, phyllite, and interbedded sandstone and quartzite comprise a relatively minor, but locally important, proportion of the eastern Fennell. In places competent beds within this unit are broken and disrupted by what appears to have been soft sediment slumping. West of Foghorn Mountain graded bedding in a well-bedded, easterly dipping sequence of sandstone and phyllite of this unit indicates that the beds are overturned and facing west.

Two apparently discontinuous lenses of limestone were mapped in the vicinity of the Fennell/Eagle Bay contact. These limestone bodies appear to be enclosed by typical Fennell rocks and so were included in this formation (7f) despite the fact that limestone is known to occur within the Eagle Bay Formation immediately adjacent to the Fennell contact in the Barriere Lakes area (Preto, *et al.*, 1980). Both limestone bodies are apparently unfossiliferous but will be checked for microfauna.

Medium to coarse-grained, dioritic to gabbroic rocks (7g) are common components of unit 7. These commonly occur as concordant sill-like bodies, although irregular discordant masses are also present and are presumed to be intrusive equivalents of the Fennell basalts.

WESTERN FENNELL (UNIT 8)

The western part of the Fennell Formation consists almost entirely of pillowed and massive basalt. Basalt breccia and chert are present in minor quantities. Very little structural data was obtained from these rocks, but in good exposures pillows indicate that the unit generally dips and faces to the west.

UNIT 9

Coarse-grained biotite quartz monzonite of the Cretaceous Baldy batholith underlies the southeastern corner of the map-area and cuts the Fennell/Eagle Bay contact. A smaller body of similar rock outcrops in Joseph Creek valley just northwest of the main batholith. Intrusion of these granitic bodies appears to have have postdated most or all of the deformation in the country rocks. Potassium-argon age determinations on biotites from the batholith have yielded ages of 96±5 Ma and 80±6 Ma (Wanless, *et al.*, 1966).

UNIT 10

Conglomerate, sandstone, and shale of the Chu Chua Formation (10a) and overlying vesicular andesitic volcanic rocks of the Skull Hill Formation (10b) unconformably overlie the Fennell Formation in the Joseph Creek valley immediately north of Dunn Lake. Plant fossils from the Chu Chua Formation have yielded Eocene ages (Campbell and Tipper, 1971).

STRUCTURE

A schistosity pervades rocks of the Eagle Bay Formation and sedimentary units of the Fennell Formation. Fennell basalts and gabbros are locally weakly to moderately foliated near the Eagle Bay contact but are generally not foliated. The schistosity is axial planar to early, generally northwest-plunging, tight to isoclinal mesoscopic folds of the bedding and is itself folded about two generations of later mesoscopic folds with generally southeasterly (or northwesterly) and easterly trends. Despite a complex array of mesoscopic folds, best displayed in bedded rocks of units 6, 7b, and 7e, only one macroscopic fold has been tentatively outlined in the area; it is the northerly plunging synform in Eagle Bay rocks near Foghorn Mountain. This fold exists, it is a late structure which folds schistosity along with the lithology.

As noted by Okulitch (1975, 1979), bedding/cleavage relationships in the vicinity of the Fennell/Eagle Bay contact indicate westerly overturning. 'Tops' from graded beds in units 6 and 7e adjacent to the contact confirm that these northeasterly dipping beds are in fact overturned. This suggests that an early synclinal hinge may be present in Fennell rocks west of the contact although the presence of such a hinge has not been proven. Apparent truncation of Eagle Bay against Fennell near Foghorn Mountain (Figs. 56 and 57) indicates that, at least locally, the contact may be a fault.

A pair of northwesterly trending faults between Joseph Creek and Axel Lake separates structurally discordant blocks of Fennell rocks. The age and nature of the movement on these faults are not known with certainty but they appear to be relatively late structures. Slickensided and brecciated shear zones with both northerly and easterly trends that are found throughout the area do not appear in general to have caused any significant displacement.

MINERAL DEPOSITS

Mineral showings occur in both Fennell and Eagle Bay rocks in the map area; locations of the most important of these are indicated on Figure 56. Showings were not studied in detail this season but most were visited during the course of the mapping. All appear to be in quartz or quartz-carbonate veins and many are associated with local shear zones. Among them the Queen Bess (lead, zinc, silver) and Windpass and Sweet Home (gold, copper, bismuth, silver) properties have some past production.

Also of interest are rare, massive sulphide (pyrite-chalcopyrite) clasts in conglomerate (unit 7d) at the microwave station west of Axel Lake. These clasts resemble mineralization at the CC property on Chu Chua Mountain to the south (Preto, *et al.*, 1980; McMillan, 1980). Perhaps there is similar mineralization in this area.

ACKNOWLEDGMENTS

Mark Stevens provided able assistance in the field. The writer benefitted from visits to the map-area by V. A. Preto, P. S. Simony, G.P.E. White, and E. D. Ghent.

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A QUANTITATIVE APPROACH TO REGIONAL METALLOGENY IN THE VANCOUVER–HOPE MAP–AREAS (92 G, H, I, J)

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INTRODUCTION

Regional metallogeny deals with broad aspects of the genesis of mineral deposits, particularly their distribution in time and space. Here we are concerned with such a study of a 28 700-square-kilometre area in the southwestern corner of British Columbia, including much of the Vancouver and Hope map-areas (NTS 92 G and H) and small parts of the adjoining map-areas to the north (NTS 92 J and I)

This region is of interest because it contains two large past producers and one present producer; as well, many mineral occurrences are known in the area. Geologically the area is complex and is centred on the intersection of three major tectonic belts (Fig. 58). The Coast Crystalline Belt forms the northwestern part of the area, the Intermontane Belt underlies the eastern part, and the Cascade Belt forms the south-central part. For purposes of the following discussion the Intermontane Belt has been further subdivided from *east to west into the Eagle Plutonic Belt, Hozameen Trough, Ladner Basin, and Spuzzum Plutonic Belt.* Tectonic history of the area is summarized briefly in Table 1 (for tables and figures, *see* pages 169-177).

METHOD OF DATA ACCUMULATION

Mineral deposit data were compiled from the literature for 258 metal occurrences. Some deposits were examined in the field, and, in many cases, information was discussed with exploration personnel who had greater familiarity with some areas than the authors. Eventually, verified information was coded in the MINDEP system and entered into a computer file for storage and retrieved in a variety of forms. A simple example is illustrated in Table 2 which summarizes general information for the major deposits in the area.

A classification of deposit types was required for our study and, because of limitations of published descriptions, we adopted the following rudimentary categories as a basis for data collection and subsequent *data analysis.*

(1) Magmatic – nickel-copper sulphides, for example, Giant Mascot.
(2) Porphyry-type – large, low-grade accumulations of copper and/or molybdenum sulphides commonly in or near felsic to intermediate intrusions, for example, Canam.
(3) Skarn – calc-silicate and ore-mineral assemblages produced by replacement at contacts of intrusions.
(4) Volcanogenic – tabular sheets of syn-sediment sulphides within volcanic sequences, for example, Britannia.
(5) Vein – tabular discordant zones of epigenetic, hydrothermal origin, for example, Aurum.
(6) Shear – coatings of minerals on shear surfaces.
(7) Disseminated – sparsely distributed grains or aggregates of ore minerals.
(8) Massive – pods of massive ore minerals of uncertain origin.

The detailed structure of the MINDEP file is included elsewhere (Wynne-Edwards and Sinclair, 1978). In general, for each deposit we recorded information on commodities, location, physiography, classification, tectonic setting, geological attributes of host rocks, geological features of the deposits themselves, grade, and production information. Of course, information on all these topics was not available for every deposit. These data formed the basis for a variety of retrievals designed to aid in a metallogenic interpretation for the area.

DATA ANALYSIS

It is not possible to reproduce all the tabulations of data derived from the computer file of mineral deposits in the Vancouver-Hope area, these are shown by Ditson (1978). Some of the more important results are summarized diagrammatically on Figures 59 to 63 and most of what follows can be derived from the numerical information in Table 3. Of the 258 deposits considered in this study, deposit classification could be determined for only 228. For reasons emphasized by Sinclair, *et al.* (1978) we do not distinguish deposits and occurrences on the basis of size except to indicate in some of the diagrams where past producers plot relative to the total number of known occurrences.

Figure 59 shows the number of cases in which various commodities were recognized in each deposit class. If we arbitrarily consider that only counts greater than 10 are significant, the list of commodity associations as a function of deposit type is clearly demonstrated (Table 4). Magmatic and porphyry-type categories contain traditional commodities. Vein, disseminated, volcanogenic, and shear categories have much in common. Gold is particularly prominent in vein deposits, but the polymetallic character of these classes is evident. Massive deposits are omitted because of lack of data. Skarn deposits represent a mixture of several mineral associations.

Spatial density of commodity occurrences can be determined from the data of Table 3 and, compared with figures for the Coast Crystalline Complex as a whole, spatial densities in the study area range from 1 to 13 times average values for the Coast Crystalline Belt. The area is particularly enriched in zinc, nickel, arsenic, lead, silver, and cobalt relative to the Coast Crystalline Belt. It is of interest to note that gold is economically important and is present in many deposits but it generally has other commodities associated with it and does not appear as the commodity of principal importance in many cases. In summary, the area has above-average spatial densities of many principal commodities and gold is a common associate in these occurrences. Higher than average values occur because much of the area is underlain by transitional or contact zones at the margins of crystalline complexes (Sinclair, *et al.*, 1978).

Relative spatial densities of occurrences of some of the more important commodities are shown on Figure 60. It is evident that large differences exist from one tectonic environment to another. Tectonic units consisting largely of plutonic intrusive rocks have few mineral occurrences. The Hozameen Trough, Ladner Basin, and pendants within the Coast Crystalline Belt stand out as having much higher relative densities of mineral occurrences. These three tectonic subdivisions are dominated by sedimentary and/or volcanic rocks close to large complexes of intrusive rocks. The probability of success in finding new mineral occurrences is relatively high in such an environment.

Mineral deposit types are also unevenly distributed in the various tectonic environments. Pendants in the Coast Crystalline Belt have greatest diversity of deposit types with high proportions of skarn, volcanogenic, shear, and disseminated deposits; the Spuzzum Plutonic Belt intrusions contain most of the magmatic sulphide deposits; the Cascade Belt has relatively more abundant skarn occurrences; the Hozameen Trough encompasses higher than average numbers of magmatic, skarn, disseminated, and massive occurrences; and the Ladner Basin contains a large proportion of vein and shear occurrences.

In a general way host rock exerts considerable influence on ore-rock associations (Stanton, 1972). In our study of spatial densities, rock type can be considered in several ways. For example, the distributions of deposit types of commodities can be examined as a function of host rock type (Figs. 61, 62, and 63). Veins are abundant in all three broad rock categories considered here (intrusive, sedimentary, and volcanic). Porphyry-type and magmatic deposits are almost exclusively in intrusive rocks, skarn deposits are mainly in sedimentary rocks, and other categories (disseminated, shear, massive, volcanogenic) are usually in volcanic units. The distinction between volcanic and sedimentary is important; in our usage 'volcanic' includes volcaniclastic rocks. As is stated previously, some deposit types differ dramatically among rock types. In view of the relatively large proportion of the area underlain by intrusive rocks and the correspondingly small proportion of the area underlain by intrusive rocks and the correspondingly small proportion underlain by volcanic rocks, the number of volcanic-hosted deposits is striking. Of the 245 deposits for which host rock type is known, 85 are in volcanic rocks, 88 are in intrusive rocks, and 72 are in sedimentary rocks.

Principal commodities are plotted against rock type on Figures 61, 62, and 63. Copper is common in deposits in all rock types and, as shown earlier, is a common constituent of many deposit types. Gold and silver are less abundant but similarly both are also fairly evenly distributed among main rock categories.

In contrast, zinc and lead-bearing deposits are most common in volcanic rocks, and molybdenum and nickel are most abundant in intrusive rocks (albeit of different character).

Mineral deposits of all types and in a variety of volcanic sequences (greenstones, acid volcanic rocks, volcaniclastic, and unclassified) are all characterized by the metal association copper-zinc-gold-silver-lead. Volcanic-sedimentary deposits throughout the world commonly have this association, presumably because the metals are derived principally from the volcanic rocks themselves. Perhaps many so-called shear, disseminated, and massive deposits with the same metal association also derived their metals from the subjacent volcanic pile.

In clastic sedimentary rocks the dominant association is gold-silver-copper (in decreasing order of frequency) whereas in limestones the association is copper-silver-gold. In general, precious metals predominate in a sedimentary environment and base metals predominate in a volcanic environment. Perhaps, in part, this reflects contribution of metals from wallrocks to the mineralizing solutions.

CONCLUSIONS

The preparation of a mineral deposit computer file results in a rigorous approach to data accumulation and provides quantitative information for calculating spatial densities and quantitatively study the various relationships between commodities, deposit type, and rock type as well as other variables not considered here.

For the Vancouver-Hope map-area several obvious relationships and less obvious metallogenic implications are as follows:

(1) Tectonic belts consisting dominantly of intermediate intrusive plutons have relatively few mineral occurrences.

(2) Volcanic or sedimentary terranes, with or without associated plutonic rocks, are favoured environments for mineral occurrences.

(3) Sedimentary rocks are characterized by deposits containing gold and silver.

(4) Volcanic rocks are characterized by deposits with a polymetallic assemblage containing silver, gold, zinc, lead, and copper.

(5) The distinctive commodity associations in volcanic and sedimentary terranes are consistent with the concept of rock-ore associations expounded by Stanton (1972). There appears to be a genetic relationship between principal commodities and host-rock lithology. For volcanogenic deposits, and perhaps other deposits types in the same lithologic terranes, the polymetallic assemblages are apparently derived from the subjacent volcanic pile. By analogy the predominance of gold and silver in sedimentary rocks may result from derivation of these metals from the volcanic rocks themselves.

ACKNOWLEDGMENTS

This study is part of an M.Sc. thesis project by G. M. Ditson under the supervision of A. J. Sinclair. Financial support was obtained from the British Columbia Ministry of Energy, Mines and Petroleum Resources and the federal Department of Energy, Mines and Resources. We appreciate the contributions of many of our colleagues, members of industry, and members of both provincial and federal governments. All these people, too numerous to list individually, cooperated in helping achieve the over-all high quality of information needed for our evaluation.

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TABLE 1. SUMMARY OF TECTONIC HISTORY

	TIME SPAN	EVENTS	UNITS INVOLVED
I.	Pre-Devonian	Formation of basement	YA in C-2
II.	*Upper Paleozoic/Lower and Middle Triassic*	*Marine eugeosynclinal deposition in a basin which shallows westward (or, if right-lateral offset is considered, shallows to the south).*	*CH, HZ (TI?, BI?, YA in C-4?)*
III.	Permian/Triassic	Deformation.	YA in C-4 (TI?, BI?)
IV.	Lower and Middle Jurassic	Volcanism in the Coast Plutonic Belt and extensive volcanism east of the study area forms the *Intermontane Belt. Deposition of marine turbidites begins in the southern section.*	PI, N *C*
V.	Lower and Middle Jurassic	Deep-water deposition in the Ladner Trough begins from a high source area to the east. Deposition continues in the south, and a burst of acidic volcanism occurs on the eastern edge of the Coast Plutonic Belt, followed by deposition in local basins of varying relief.	L C, D HL, BME
VI.	Upper Jurassic	Plutonism of unknown extent in the Coast Plutonic Belt, deformation and metamorphism begins along a north-south axis in the Spuzzum and Cascade Belts. Deposition of trench-like sediments along this axis beings Shallow-water deposition of more easterly derived sediments in the Ladner Trough and possible intrusion of the Eagle Complex.	CR, FL (AP?, K?) SS, Custer Gneiss D DC Eagle ?
VII.	Lower Cretaceous	Considerable marine volcanism and sedimentation in the Coast Plutonic Belt along with the beginning of intense plutonism and/or cooling of plutons to the point where they have begun to retain argon. Axial deformation continues, and the Giant Mascot ultramafic body has also cooled below argon retention temperature. Trench-like deposition along the metamorphic axis ceases by mid-Lower Cretaceous. Easterly derived marine deposition continues in the Ladner Trough, but becomes westerly derived and nonmarine by the close of Albian time, indicating considerable uplift to the west, presumably of the Coast Plutonic Complex. The Eagle Complex is also shedding debris into the Ladner Belt by Albian.	G, CEH, FL, PN, BH CR SS, Custer Gneiss D um NK JM, P
VIII.	Mid-Cretaceous (limits undefined)	Major thrusting directed away from the central metamorphic axis brings up mantle-derived (?) ultramafic rocks and basement material. Genetically related folding accompanies thrusting in the Cascade Belt, Hozameen Basin, and Ladner Trough. Uplift of the Eagle Plutonic Belt occurs.	Shuksan, Church Mountain, Hozameen, Pasayten Faults um Eagle
IX.	Upper Cretaceous	The majority of the Coast Plutonic Complex (and Spuzzum) K/Ar dates are clustered in this period, but by the end of Cretaceous time large-scale plutonism had ceased. Major deformation and thrusting in all areas also ceased by latest Cretaceous.	CR, Spuzzum, Scuzzy
X.	Tertiary	The Coast Plutonic Belt records volcanism and sedimentation which began in latest Cretaceous, uplift and erosion continue in the Coast Mountains. One K/Ar date records late cooling/intrusion of plutonic rocks. Major right-lateral-movement along the Straight Creek — Fraser River fault zones and related (?) sedimentation and intrusion occurred before Oligocene. *High-level plutons are concentrated in the Cascade Belt, but are also scattered throughout the area; coeval volcanic rocks were extruded.*	s, bv, CR Straight Creek — Fraser River Zone, CK, Yale Intrusions Hell's Gate, Silver Creek, *Chilliwack, Mount Barr, Needle Peak* av, SK, CQ
XI.	Pleistocene	Calc-alkaline volcanism in the Coast Plutonic Belt.	GB

ABBREVIATIONS USED TO IDENTIFY UNITS IN TABLE 1

[Units are arranged alphabetically within tectonic belts; *see* text for description and ages.]

I. Eagle Plutonic Belt

CQ	Coquihalla Group
N	Nicola Group

II. Ladner Trough

CQ	Coquihalla Group
CR	Coast Plutonic Complex
DC	Dewdney Creek Group
JM	Jackass Mountain Group
L	Ladner Group
P	*Pasayten Group*

III. Hozameen Basin

CR	Coast Plutonic Complex
HZ	Hozameen Group
Qs	Quaternary sediments

IV. Cascade Belt

C	Cultus Formation
CH	Chilliwack Group
CK	Chuckanut Formation

IV. Cascade Belt—*Continued*

CR	Coast Plutonic Complex
D	Darrington Phyllite
NK	Nooksack Group
QS	Quaternary sediments
SK	*Skagit Formation*
YA	Yellow Aster Crystalline Complex

V. Spuzzum Plutonic Belt

av	acid volcanic rocks
CR	*Coast Plutonic Complex*
gn	gneiss
ms	metasedimentary rocks
Qs	Quaternary sediments
SS	Settler Schist

VI. Coast Plutonic Belt

AP	Agassiz Prairie Formation
av	acid volcanic rocks
BH	Brokenback Hill Formation
BI	Bowen Island Group

VI. Coast Plutonic Belt—*Continued*

BME	Billhook Creek Formation Mysterious Creek Formation Echo Island Formation
bv	basic volcanic rocks
CEH	*Cheakamus Formation* Empetrum Formation Helm Formation
CR	Coast Plutonic Complex
FL	Fire Lake Group
G	Gambier Group
GB	*Garibaldi Group*
gn	gneiss
HL	Harrison Lake Formation
K	Kent Formation
m	metamorphic rocks
ms	metasedimentary rocks
PI	Pioneer Formation
PN	Peninsula Formation
Qs	Quaternary sediments
s	sedimentary rocks
TI	Twin Islands Group

TABLE 2. GRADE AND TONNAGE OF MAJOR DEPOSITS*

	Cu *per cent*	Pb *per cent*	Zn *per cent*	Au *per cent*	Ag *oz/ton*	Ni *per cent*	Production *tons*	Total Resources *tons*
Britannia G-3	1.1		.65	.02	.20		52,783,964	
Giant Mascot HSW-4	.33					.77	6,081,133	7,577,000
Northair J-130		2.7	4.0	.40	4.60			330,637
Canam HSW-1	.61							8,000,000
Aurum HNW-3				.098				3,000,000

*Sources of information are documented by Ditson, 1978.

TABLE 4. PRINCIPAL COMMODITIES VERSUS DEPOSIT TYPE

Deposit	N	Commodities Recognized in 10 or More Deposits*				
Vein	78	Au	Cu	Ag	Pb	Zn
Porphyry	41	Cu	Mo	Ag		
Disseminated	39	Cu	Zn	Ag	Au	
Skarn	22	Cu	Ag	Au	Fe	
Shear	24	Cu	Ag	Zn		
Magmatic	15	Ni	Cu			
Volcanogenic*	4	Au	Zn	Pb	Ag	Cu

*Total abundance of volcanogenic deposits is 4.

TABLE 3. NUMBER OF COMMODITY OCCURRENCES AND DEPOSIT TYPES EACH TECTONIC BELT OR BELT SUBDIVISION IN THE STUDY AREA*

	Iron	Cobalt	Nickel	Copper	Zinc	Arsenic	Molybdenum	Silver	Cadmium	Antimony	Tungsten	Gold	Lead	Bismuth	Uranium	Magmatic	Porphyry	Skarn	Volcanogenic	Vein	Shear	Disseminated	Massive	Total
Coast Plutonic Belt Intrusions 10 186 km^2	2		1	32 (3)	5 (1)		19 (1)	9 (3)				7 (2)	1			1	21 (1)			8 (1)	1	4		35 (2)
Coast Plutonic Belt Pendants 2 652 km^2	10 (3)			59 (9)	32 (7)		4 (1)	30 (9)		1 (1)	3 (3)	25 (9)	15 (6)	1			7	9 (2)	2 (2)	13 (5)	14 (2)	19 (1)	1	65 (12)
Spuzzum Plutonic Belt Intrusions 3 097 km^2		1	10 (1)	11 (1)	1		2	1		1	1	3	1	1		8 (1)	2			2	1	1		14 (1)
Spuzzum Plutonic Belt Pendants 1 145 km^2		1	1	4 (1)		1 (1)		4 (1)				3 (1)						1		4 (1)		1		6 (1)
Cascade Belt 1 619 km^2	3 (1)		2	15 (3)	6		6 (1)	14 (3)			1	9	7 (1)			1 (1)	4	7 (2)		7 (1)	1	3		23 (3)
Hozameen Basin 1 111 km^2	3		3	16 (1)	10 (1)	1	3	15 (1)		3	1	17 (1)	8 (1)			2	1	4		5 (1)		7		23 (1)
Ladner Trough 1 875 km^2	1 (1)		1	21 (7)	17 (5)	1	2 (1)	22 (9)		2		37 (11)	15 (6)		1 (1)	1	1 (1)			34 (10)	7	2		45 (11)
Eagle Plutonic Belt 1 787 km^2	1		1	18	6		5	9				10	6			1	5	2		7		2		17
Total 23 473 km^2	20 (5)	2	19 (1)	176 (25)	77 (14)	3 (1)	41 (2)	104 (26)	1	7 (1)	6 (3)	111 (24)	53 (14)	2	1 (1)	14 (1)	41 (2)	23 (4)	2 (2)	80 (19)	24 (2)	39 (1)	5	228 (31)

*The lower number in parentheses is the number of deposits with production records; this number is *included in the total count above it.*
Area represented included below each division name.

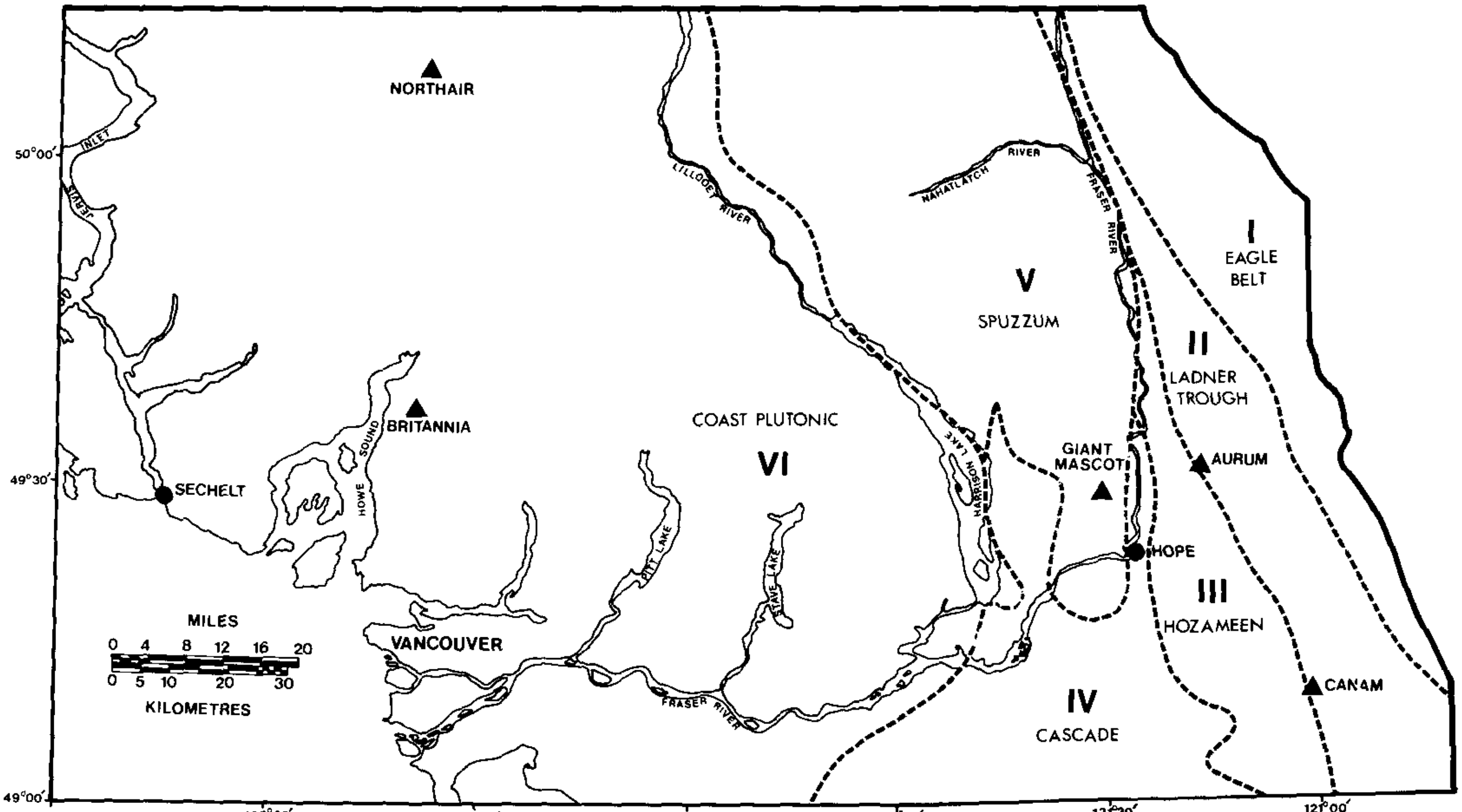

Figure 58. Location map and major tectonic subdivisions, Vancouver-Hope map-area. I – Eagle Plutonic Belt; II – Ladner Trough; III – Hozameen Basin; IV – Cascade Belt; V – Spuzzum Plutonic Belt; VI – Coast Plutonic Belt. Five important mineral deposits are located.

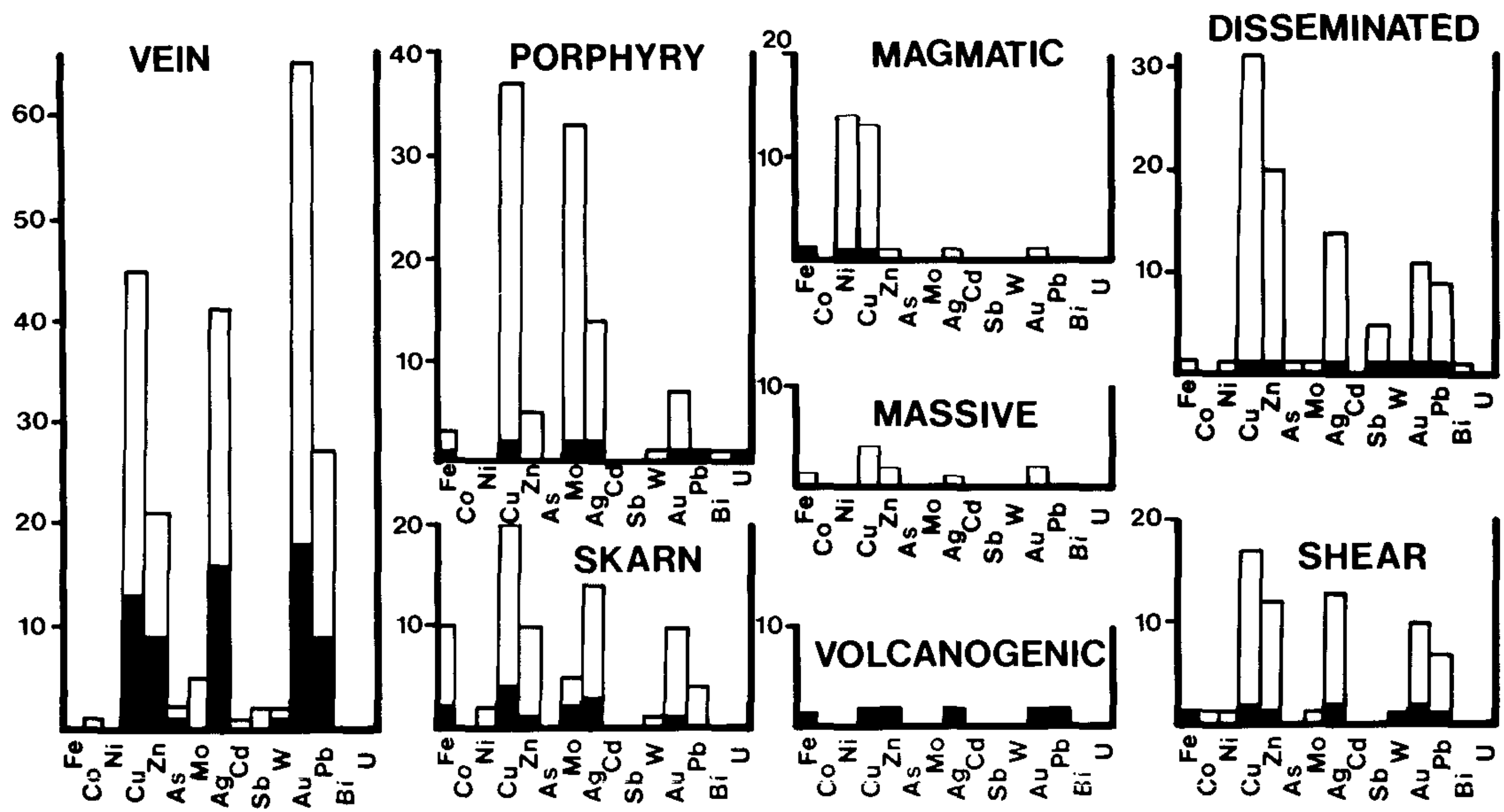

Figure 59. Distribution of commodities as a function of deposit type. Black bars indicate past producers; blank bars are nonproducers.

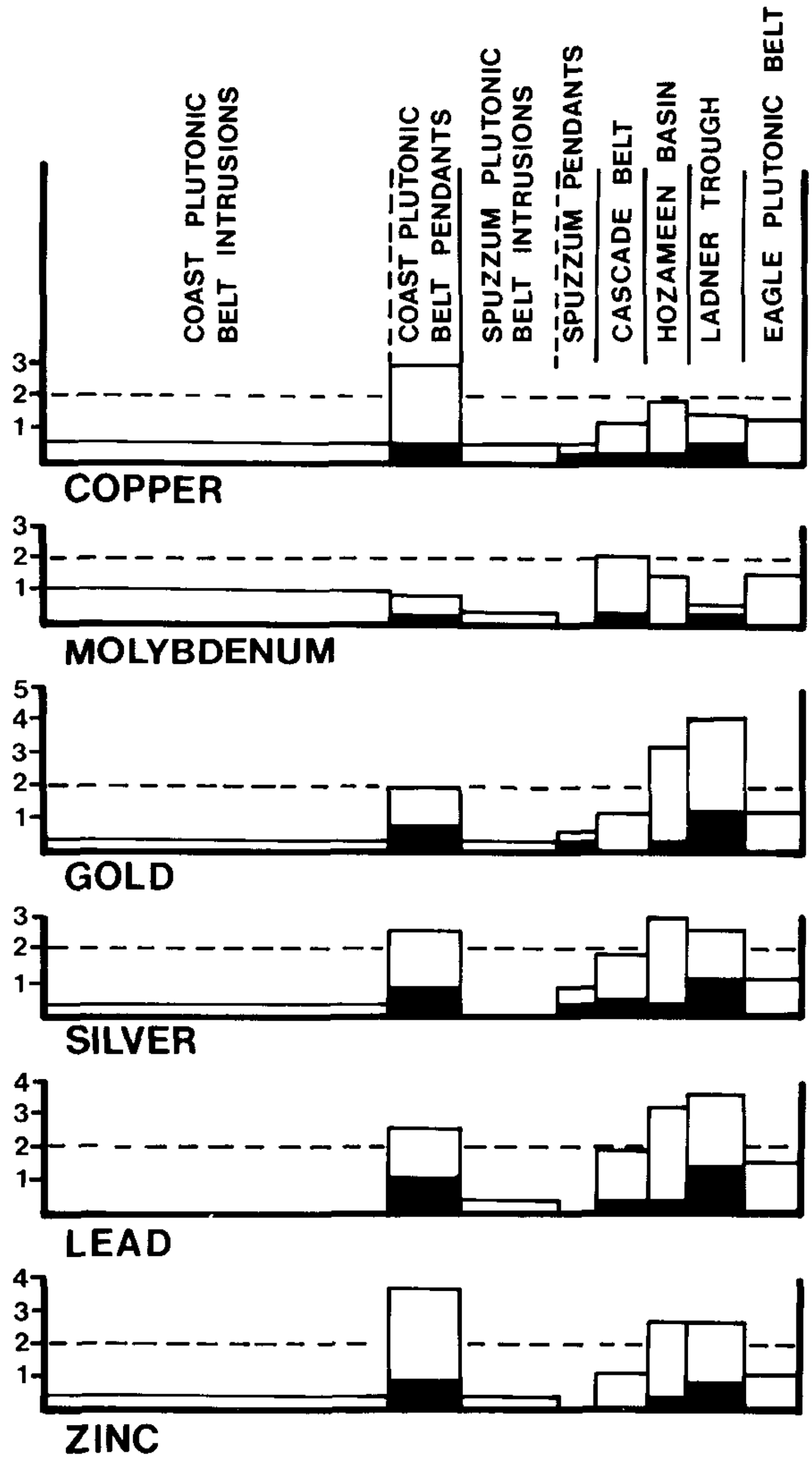

Figure 60. Relative spatial densities of commodity occurrences as a function of tectonic unit. Black bars represent past producers; blank bars are nonproducers.

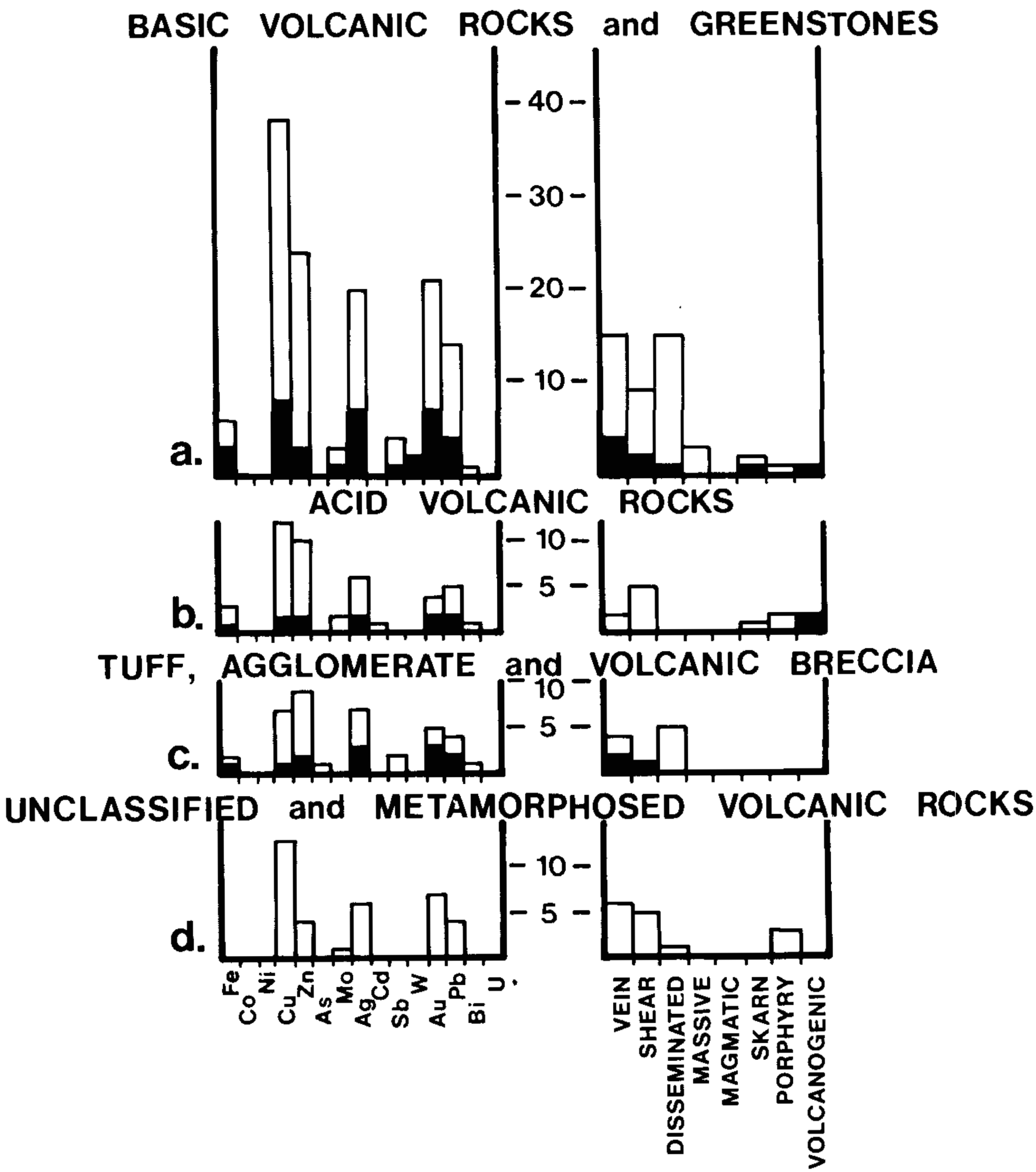

Figure 61. Frequency of deposit occurrences as a function of commodities and deposit type for mineral occurrences in volcanic rocks, Vancouver Island.

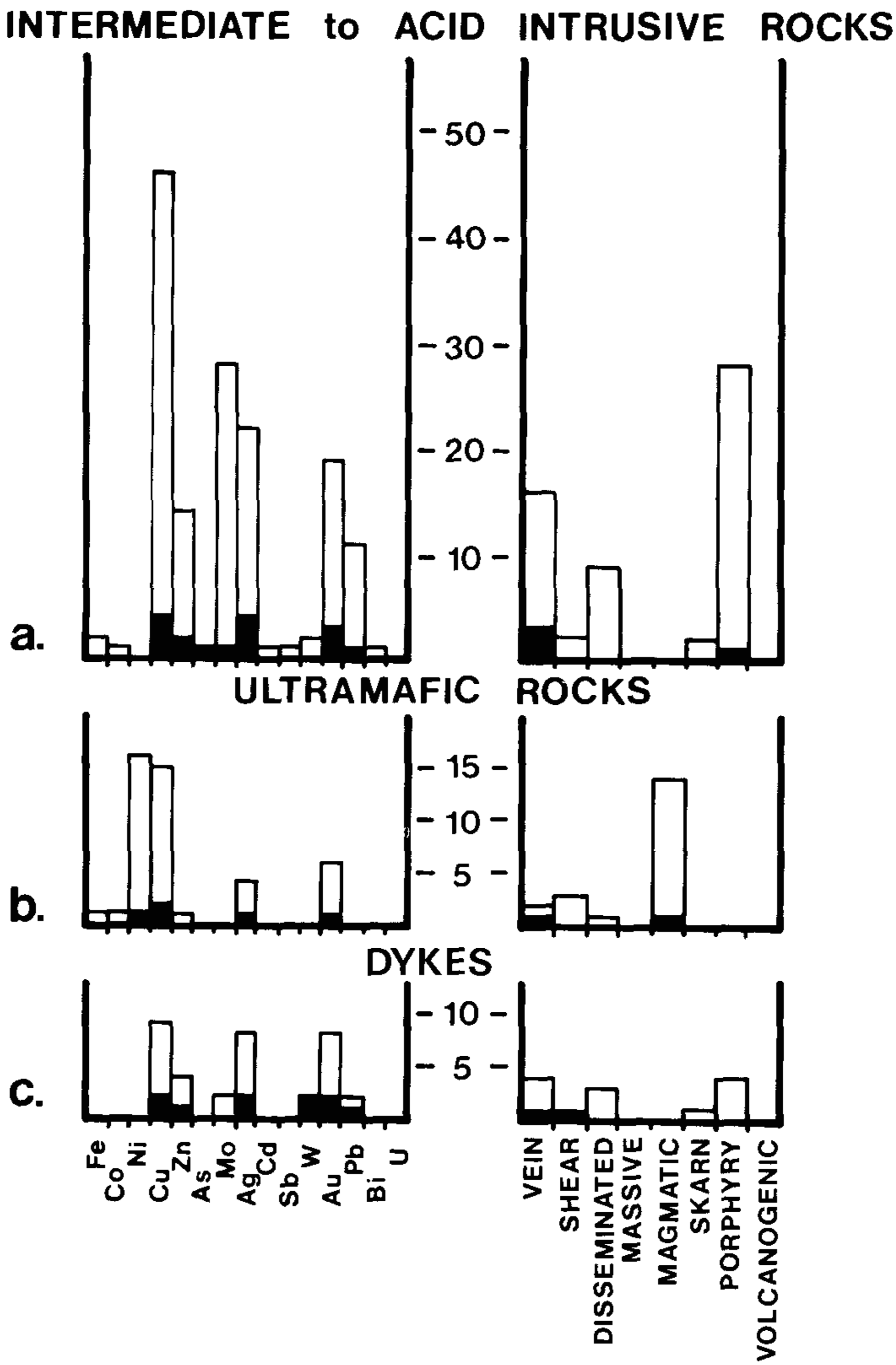

Figure 62. Frequency of deposit occurrences as a function of commodities and deposit types for mineral occurrences in intermediate to acid intrusive rocks, Vancouver-Hope map-area.

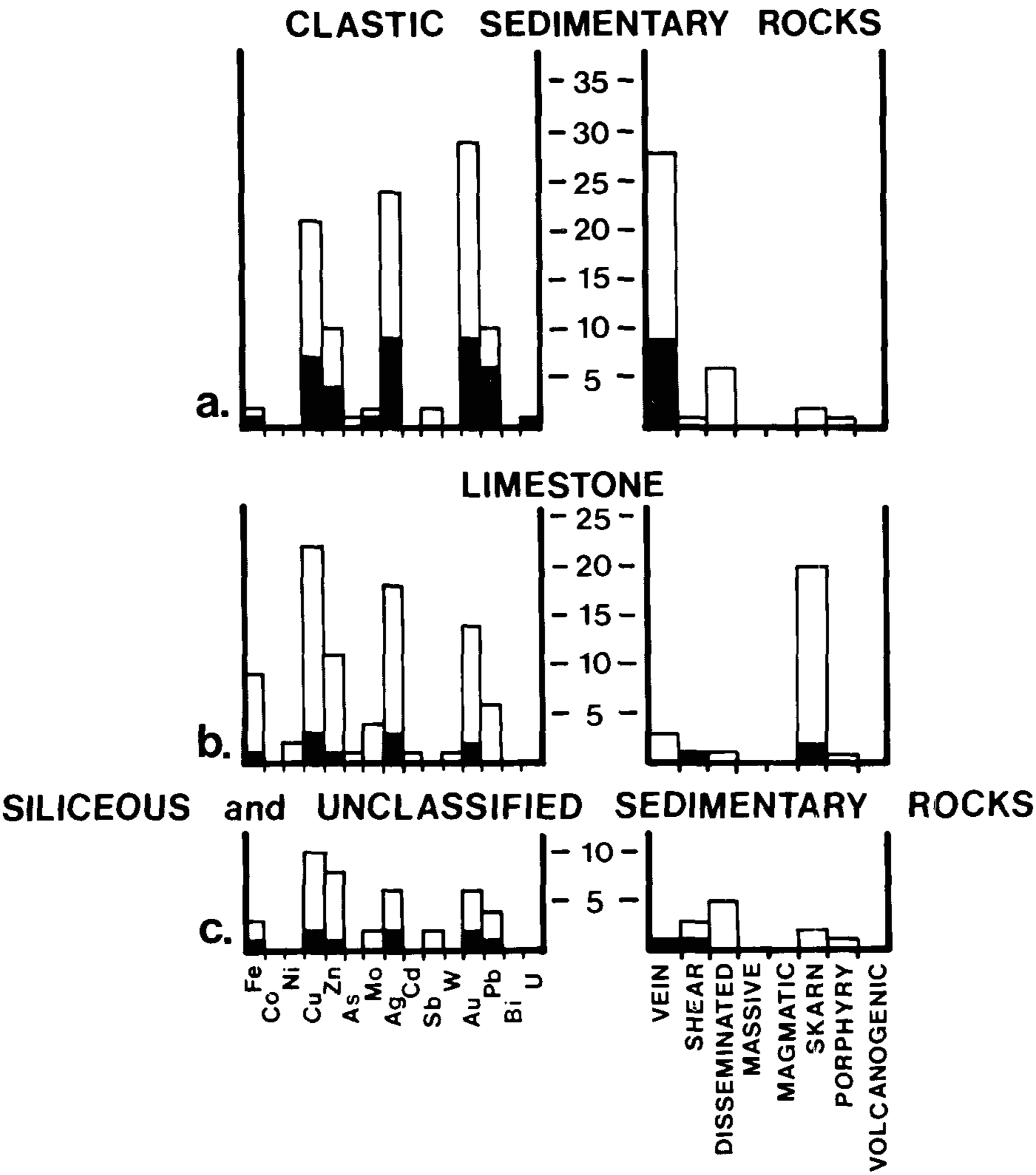

Figure 63. Frequency of deposit occurrences as a function of commodities and deposit types for mineral occurrences in sedimentary rocks, Vancouver-Hope map-area.

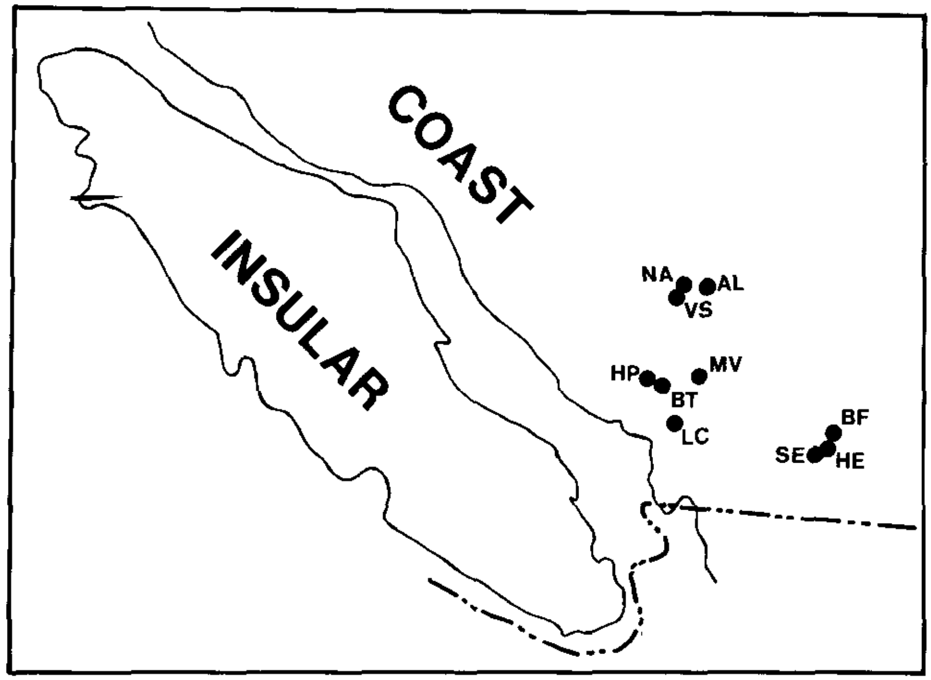

Figure 64. Location of mineral deposits in the southern Coast Crystalline Belt for which lead isotope data were presented by Godwin, *et al.* (1980). *See* Table 1 for abbreviations.

TABLE 1. GENERAL DESCRIPTION OF SOME MINERAL DEPOSITS IN THE SOUTHERN COAST CRYSTALLINE BELT

Deposit	Symbol	
Northair	NA	Layered sulphides (galena-sphalerite-pyrite) intercolated with carbonate in acidic pyroclastic rocks of Early Cretaceous age; cut by sulphide-bearing carbonate veins (Miller and Sinclair, 1979).
Britannia	BT	Volcanogenic polymetallic sulphide deposits with associated barite in acidic pyroclastic sequence of Early Cretaceous age (Payne, *et al.*, 1980).
Alta Lake	AL	Large stringer zone containing chalcopyrite, sphalerite, and galena in metamorphosed rocks of Alta Lake pendant (*B.C. Ministry of Energy, Mines & Pet. Res.*, internal report).
Van Silver	VS	Several small polymetallic sulphide deposits in Callaghan Creek pendant with apparent volcanogenic affiliations (Miller and Sinclair, 1979).
Seneca	SE	Exhalative sphalerite-galena-barite in layered sheet within acid to intermediate volcaniclastic rocks of Middle Jurassic Harrison Lake Formation; copper-bearing siliceous stringer zone also present (Pride, 1973).
Harrison Lake Gold	HE	'Pipe' zone in Jurassic volcanic rocks.
Lynne Creek	LC	Layered and massive sulphides (sphalerite and galena) in carbonate within a small pendant of predominantly pyroclastic rocks.
Hopkins Landing	HP	Massive sulphide volcanogenic deposit in acidic volcaniclastic rocks probably equivalent to Gambier Group.
Big Foot	BF	Sphalerite, chalcopyrite, galena, and barite occur in quartz-carbonate veins confined to a band of strongly altered lapilli tuff.
McVicar	MV	Pyrite and chalcopyrite occur as irregular masses, stringers, disseminations, and quartz-filled fractures within greenstone of the Goat Mountain Formation (Triassic) near its contact with the Coast Range batholith. Sphalerite and galena occur in alternating bands.

INTERPRETATION OF LEAD ISOTOPE DATA SOUTHERN COAST MOUNTAINS

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INTRODUCTION

Lead isotopic data for galena-bearing deposits and showings in the southern end of the Coast Crystalline Belt have been discussed in a regional context by Godwin, *et al.* (1980) as part of an evaluation of lead isotopic data in British Columbia. Here we consider in more detail the geological implications of these data. General characteristics of the mineral deposits in question are summarized in Table 1 and locations are shown on Figure 64.

The area is underlain principally by intrusive dioritic bodies of the Coast Crystalline Belt with potassium-argon model ages commonly in the range 80 to 120 Ma. Older sedimentary and volcanic sequences occur as local pendants or larger bodies at the margins of the Coast Crystalline Belt, and most are Jurassic or Cretaceous in age. The area is cut by Tertiary rocks including stocks and dykes of the Garibaldi volcanic suites, some of which represent volcanic feeders. Ages are commonly in the range 1 to 10 Ma (Woodsworth, *et al.*, 1978). Mineral deposits in the area are concentrated in and near pendants of volcanic sequences (Ditson, 1978; Ditson and Sinclair, this report).

LEAD ISOTOPE ANALYSES

Lead isotope data for the area were obtained in the lead isotope laboratory of the Department of Geophysics and Astronomy, University of British Columbia, as described by Godwin, *et al.* (1980). The data are published elsewhere (Godwin, *et al.*, 1980) and are presented here on Figures 65 and 66. Precision of analysis (laboratory reproducibility as one standard deviation) is about 0.1 per cent or less for the ratios reported.

INTERPRETATION OF LEAD ISOTOPE DATA

The lead isotopic data that are plotted on Figures 65 and 66 on standard diagrams used as a basis for interpretation, are characterized by a restricted range. Model ages, calculated for average values of individual deposits using the model of Stacey and Kramers (1975), are consistently too young for samples where independent age data exists, but are within the 100-million-year error traditionally assigned to such model ages. The cluster of points is within the general range shown by crustal leads but slightly on the low side, indicating development of isotopic ratios in environments that on average have a slightly lower uranium/lead ratio than the crustal average. This result, combined with the model ages that are consistently too young, indicate a multistage origin for the leads. That is to say, the present isotopic ratios developed in more than two separate uranium-thorium-lead environments. The nature or duration of these individual environments is uncertain but the multistage histories of development show crustal derivation of a significant component of the lead.

The two samples analysed from the Seneca deposit represent both the feeder pipe and the overlying layered sequence (Fig. 67) of what has been interpreted as a Kuroko-type volcanogenic deposit (Pride, 1973). Both isotopic results are identical as would be expected in such a case.

Six samples were analysed from various deposits of the Britannia area (Fig. 68). Within experimental limits all are identical. The deposits, which are now dispersed along the Britannia shear zone, are thought to have originated as two deposits (Payne, *et al.*, 1980) of volcanogenic origin. The uniformity of local isotopic ratios is consistent with a volcanogenic origin involving derivation of metals from a common or similar source. For example, the derivation of metals from the underlying volcanic suite, an implicit part of the genetic model for these deposits, is certainly consistent with the isotopic data.

Lead isotopic data from the Northair and Van Silver deposits are of particular interest from a genetic point of view. The samples include deformed, 'layered' sulphides in quartz-carbonate rock and anhedral sulphides from post-deformation, sulphide-bearing carbonate veins at Northair; intensely deformed, layered sulphides from the Tedi pit of Van Silver; and thin sulphide veinlets cutting Garibaldi volcanic rocks between the Tedi and Silver Tunnel (Blue Jack) deposits. All these varieties of mineralization have lead isotopic compositions that are identical within experimental error, a fact in accord with a complex origin for deposits in the area. Miller and Sinclair (1979) suggested that an early exhalative phase of mineralization was followed by remobilization about 80 Ma ago when nearby plutons were emplaced.

A few lead isotope data represent isolated mineral occurrences for which no detailed geological studies are available. Consequently, little can be said about them in detail. As a generalization, however, one might expect such leads to have had an important residence time in volcanic rocks, in common with associated volcanogenic deposits of Middle to Late Mesozoic age. This conclusion arises because of their similarity in isotopic composition to deposits that have demonstrable volcanogenic, particularly exhalative, origins.

A metallogenic scheme for the area (Fig. 69) incorporates an initial episode of volcanogenic mineralization which segregated lead from uranium by formation of galena. During subsequent thermal events this lead was locally remobilized to form the various post-deformation sulphide-bearing vein deposits recognized in the area.

CONCLUSIONS

Lead isotopic data are surprisingly uniform for a variety of mineral occurrences in and about the south end of Coast Crystalline Belt. Where geological controls exist it appears that this uniformity resulted because lead was derived from a thick volcanic sequence. An important implication of this data is that lead in all the deposits studied probably had the same general origin, that is, they were derived from the spatially related volcanic pile.

ACKNOWLEDGMENTS

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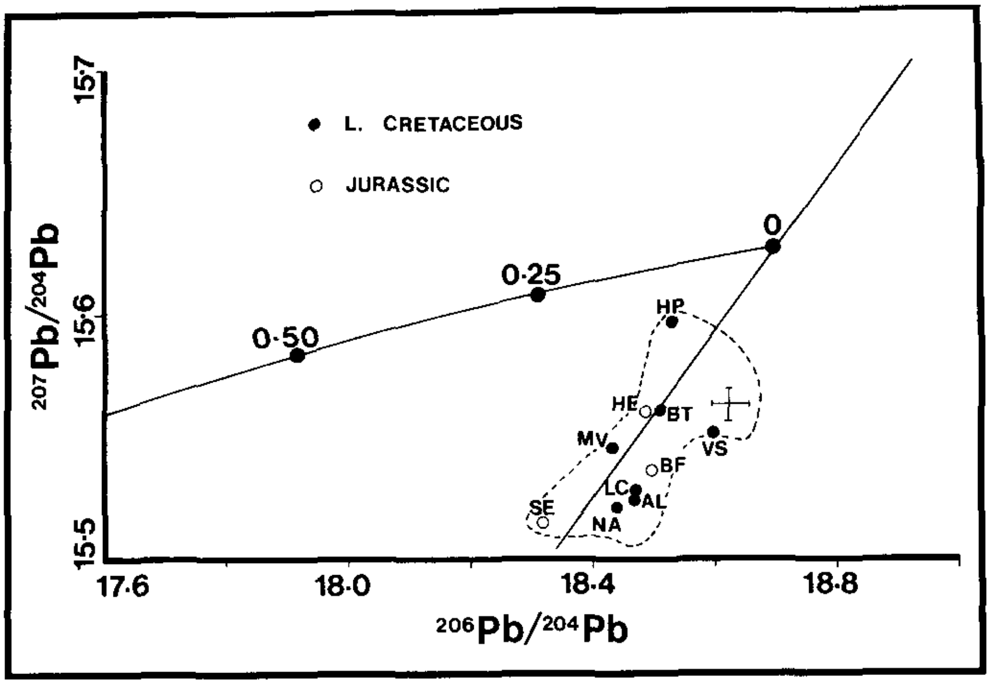

Figure 65. $^{207}Pb/^{204}Pb$ versus $^{206}Pb/^{204}Pb$ plot of average isotopic compositions for lead from deposits listed in Table 1.

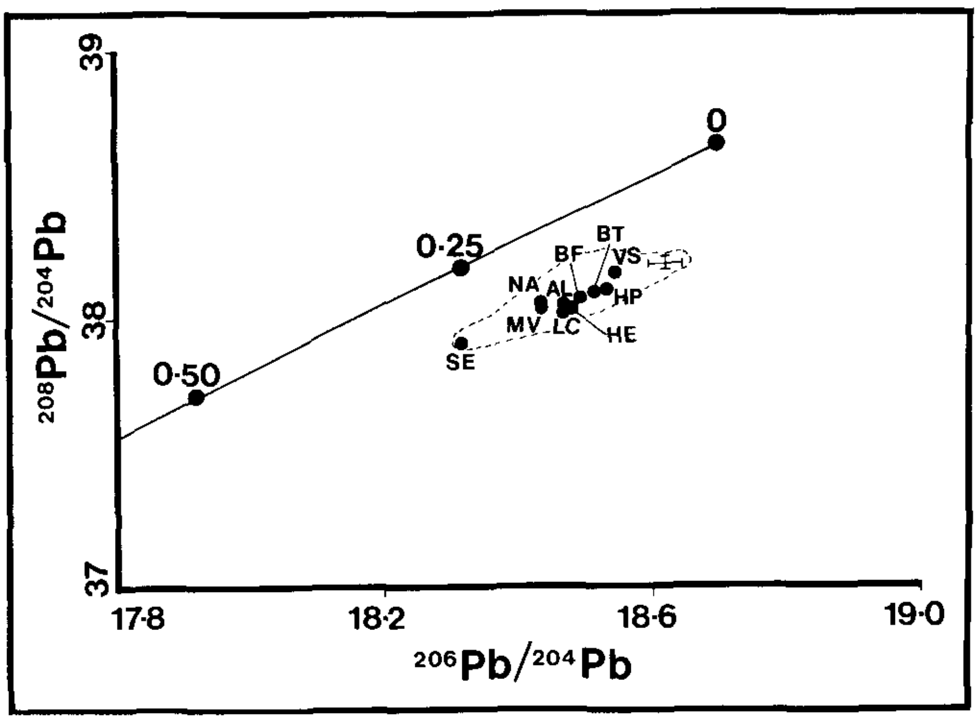

Figure 66. $^{208}Pb/^{204}Pb$ versus $^{206}Pb/^{204}Pb$ plot of average isotopic compositions for lead from deposits listed in Table 1.

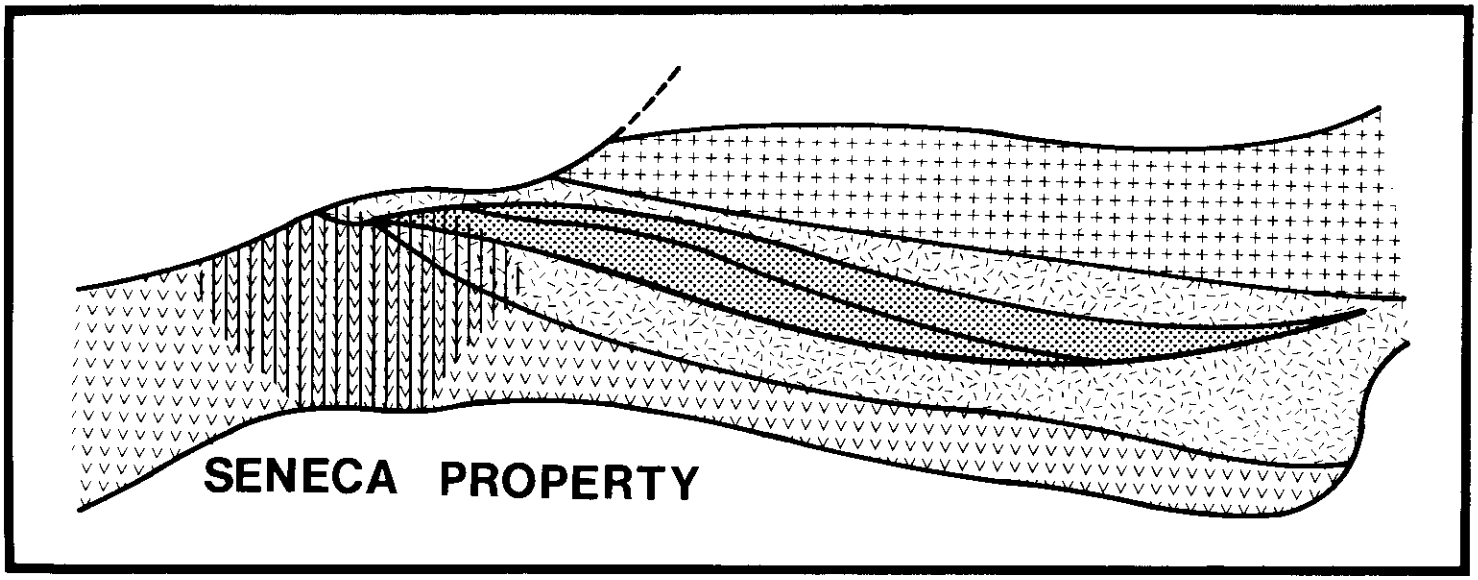

Figure 67. Schematic cross-section of Seneca deposit shows layered ore in a transition zone between underlying acidic fragmental rocks and andesitic-dacitic flows that form part of the Middle Jurassic Harrison Lake Group. A pipe zone is illustrated on the left.

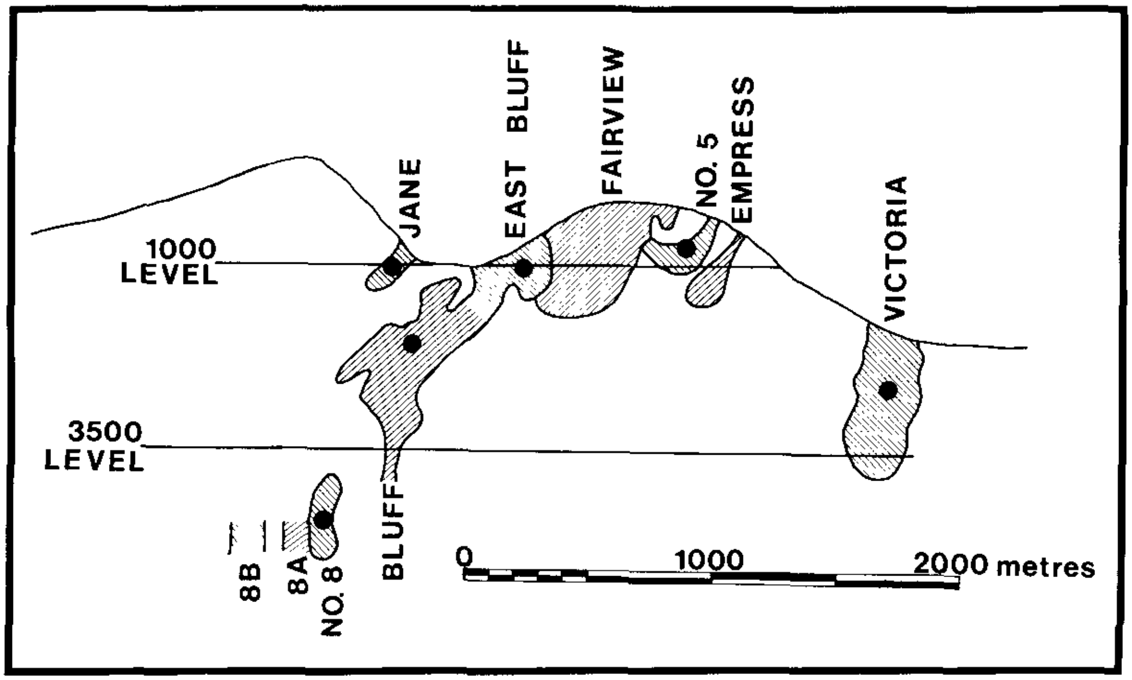

Figure 68. Longitudal section along the Britannia shear zone showing approximate outlines of individual ore zones and locations of six samples analysed for lead isotopic compositions. All six samples have identified ratios within experimental error.

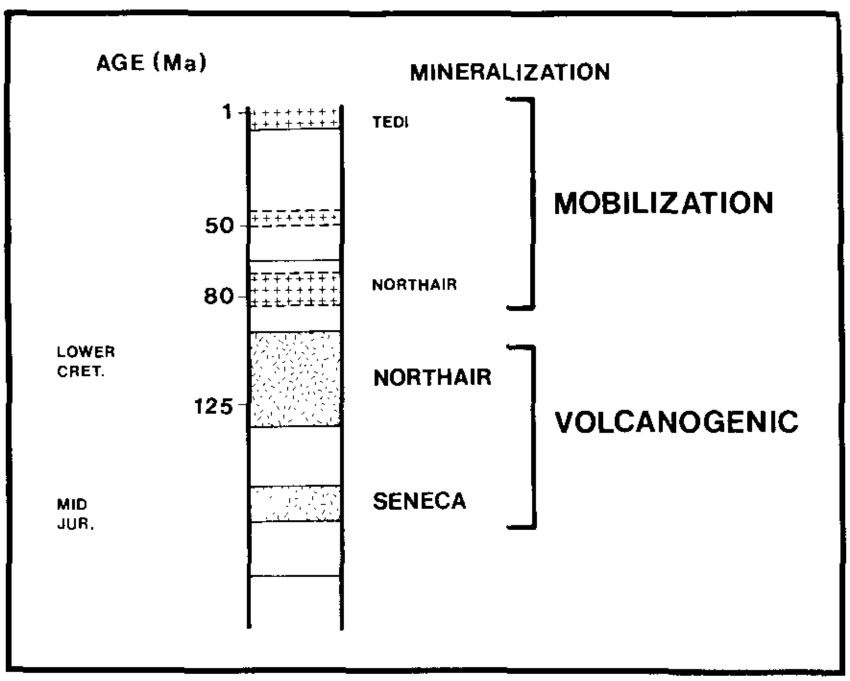

Figure 69. Outline of a general metallogeny for polymetallic sulphide deposits within volcanic rocks of the southern Coast Crystalline Belt. A volcanogenic phase of mineralization is identified in the Middle Jurassic and Lower Cretaceous. Subsequent mobilization of sulphides has occurred in response to local heat centres related to emplacement of intrusions at various times.

PRELIMINARY INTERPRETATIONS OF LEAD ISOTOPES IN GALENA–LEAD FROM SHALE–HOSTED DEPOSITS IN BRITISH COLUMBIA AND YUKON TERRITORY

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INTRODUCTION

Large stratiform, syngenetic deposits commonly yield galena-lead isotope 'model' ages that agree closely with the stratigraphic ages of their host rocks. However, analyses in Table 1 from stratiform, shale-hosted deposits (located on Fig. 70) of Cambrian to Devono-Mississippian age in or adjacent to the Selwyn Basin in British Columbia and Yukon Territory do not give reasonable ages if the models of Stacey and Kramers (1975) or Cumming and Richards (1975) are used. In fact, ages calculated with these models are unrealistically young, although isotopic analyses from the British Columbia and Yukon Territory deposits, plotted on a $^{207}Pb/^{204}Pb$ versus $^{206}Pb/^{204}Pb$ graph form distinct clusters (Fig. 71). Each cluster can be characterized by a specific deposit age and the locations of the clusters are in an appropriate order and position to define a growth curve (Fig. 70). The four clusters identified on Figure 71 are:

(1) Devono-Mississippian (*circa* 370 Ma), for example, MacKenzie area, British Columbia and Tom-Jason, Yukon Territory.
(2) Silurian (*circa* 425 Ma), for example, Howards Pass, Yukon Territory—Northwest Territories.
(3) Ordovician (*circa* 475 Ma), for example, MacKenzie Fold Belt, Northwest Territories.
(4) Cambrian (*circa* 550 Ma), for example, Anvil district, Yukon Territory.

Growth curves on the $^{207}Pb/^{204}Pb$ versus $^{206}Pb/^{204}Pb$ plot can be calculated in several ways. Here, we postulate that the growth curve for the shale-hosted deposits started from some point on the 'average crustal' growth curve of Stacey and Kramers. An appropriate point in time to begin the curve is about 2.0 Ma ago, which is near the expected time of homogenization of continental basement by the Hudsonian orogeny, and slightly older than the basement source age indicated by the galena-lead isotope isochron for pre-Ordovician ('old') carbonate-hosted deposits that we have defined elsewhere at 1.887 Ma (Godwin, *et al.*, in press). Using the 'old' deposit age and measured lead-isotope ratios as constraints, an average uranium to lead ratio of 11.8 was calculated for an 'average shale' growth curve that passes through each average and closely predicts the mean ages of the four clusters. We conclude from the relatively high uranium to lead ratio that the Precambrian basement source is 'upper crustal' (Doe and Zartman, 1979), therefore probably sialic and an appropriate source for the abundant lead commonly found in these deposits.

Figure 72 illustrates our model for an 'average shale' growth curve which is applicable to the northern Canadian Cordillera. The 'average shale' curve is in reality the last part of a three-stage model for lead evolution. A meteoric growth curve generated in an environment with a relatively low uranium-lead ratio of 7.19 is applicable for the period between 4.57 and 3.7 Ma. Much evidence indicates that near 3.7 Ma an accretional stage of continental growth began. At this time a uranium-enriched differentiated crust formed with a slightly higher uranium-lead ratio of 9.74. Evolution of lead in average crust followed this growth curve until about 2.0 Ma ago. From this point onward the lead evolved in an even more uranium-rich environment with ratio 11.82.

TABLE 1. LEAD ISOTOPES ANALYSES[1] ON GALENA[2] FROM ZINC-LEAD DEPOSITS OF KNOWN AGE

Sample Number	Deposit Name	Map Name	Lat.° North	Long.° West	Lead Isotope Data (Relative 1S Error as %) $^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$	Remarks
Skarn Deposits (negative model age)								
10084-001	A+B	YT084	60.12	130.43	19.516 (.08)	15.714 (.07)	39.657 (.11)	L.Cam PHYL
10093-001	Pike	YT093	62.18	130.65	19.324 (.06)	15.731 (.11)	39.428 (.10)	Had-M.Cam PHYL (skarn)
10095-001	Mar	YT095	62.03	129.84	19.324 (.12)	15.722 (.09)	39.460 (.09)	Had-M.Cam PHYL-QZIT(sk)
Epigenetic: Cretaceous (ca. .12 Ga model age)								
10093-001	McMillan (Qz Lk)	YT089	60.50	127.93	20.098 (.06)	15.820 (.09)	39.889 (.16)	Had ARGL-QZIT-LIMS
Devonian-Mississippian (ca. .37 Ga)								
G78AK-001	Alcock	BCOAK	57.67	125.42	18.984 (.09)	15.764 (.08)	39.561 (.09)	Dev-Miss SHAL
G78CQ-001	Cirque	BCOCQ	57.52	125.12	18.795 (.08)	15.689 (.08)	39.166 (.08)	Dev-Mis SHAL
G78DC-AVG	Driftpile (n=3)	BCODC	58.07	125.95	18.859 (.08)	15.669 (.06)	39.113 (.09)	Dev-Mis SHAL
G78EF-001	Elf	BCOEF	57.42	124.72	18.834 (.09)	15.661 (.09)	39.310 (.04)	Dev-Mis SHAL
G78FK-001	Fluke	BCOFK	57.42	124.87	18.846 (.08)	15.714 (.04)	39.477 (.06)	Dev-Mis SHAL
G79PI-001	Pie (float)	BCOPI	57.45	124.78	18.888 (.03)	15.739 (.10)	39.526 (.09)	M.Dev LIMS-SHAL
G79RG-001	Rough (shear)	BCORG	58.27	126.17	18.709 (.03)	15.617 (.07)	38.548 (.11)	Cam-Ord LIMS
10077-AVG	Jason (n=5)	YT077	63.15	130.25	18.695 (.07)	15.666 (.09)	38.863 (.10)	Dev-Mis SHAL
10078-AVG	Tom (n=5)	YT078	63.17	130.15	18.662 (.08)	15.672 (.06)	38.712 (.07)	Dev-Mis SHAL
20017-007	Keg (float)	NW017	64.00	129.23	18.907 (.10)	15.741 (.09)	39.086 (.11)	Ord? SHAL
20076-AVG	Vulcan (n=11)	NW076	62.31	128.21	18.839 (.08)	15.702 (.08)	39.094 (.10)	L-M.Dev SHAL-DOLM-CHER
Average for Dev-Mis SHAL: n=11, arith. average = $\bar{x}$					[18.820 (.07)]	[15.694 (.07)]	[39.132 (.09)]	
std. error of mean = $S \cdot n^{-1/2}$					0.029	0.013	0.099	
Young Carbonate Cluster (ca. .37 Ga)								
10034-AVG	Birkeland (n=2)	YT034	64.15	131.92	18.808 (.04)	15.707 (.06)	38.488 (.08)	Had DOLM
10050-001	Odd	YT050	63.91	132.00	18.813 (.09)	15.696 (.07)	38.476 (.03)	Had DOLM
20003-002	Palm	NW003	64.40	129.80	18.879 (.08)	15.695 (.08)	38.771 (.04)	L. Cam DOLM
20004-002	Jude	NW004	64.37	129.87	18.892 (.05)	15.710 (.07)	38.925 (.12)	Ord-Sil DOLM
20008-009	Backbone	NW008	63.85	129.17	18.739 (.07)	15.647 (.05)	38.460 (.09)	Dev LIMS
20009-002	Weather	NW009	63.97	129.28	18.761 (.06)	15.700 (.08)	38.574 (.13)	Dev DOLM
20011-001	Lau	NW011	63.85	129.35	18.800 (.05)	15.692 (.06)	38.807 (.07)	L. Cam DOLM
20012-006	Twitya	NW012	64.03	129.27	18.691 (.05)	15.652 (.09)	38.564 (.09)	M. Dev DOLM
20022-001	Guild	NW022	64.63	130.10	18.798 (.08)	15.680 (.12)	38.761 (.05)	Ord-Dev? DOLM
20023-014	Rev:Main	NW023	64.13	129.33	18.762 (.22)	15.675 (.08)	38.537 (.29)	Ord-Sil DOLM
20023-098	Rev:Waterfall	NW023	64.13	129.33	18.747 (.09)	15.662 (.02)	38.498 (.09)	Ord-Sil DOLM
20023-137	Rev:Cirque	NW023	64.13	129.33	18.767 (.06)	15.653 (.08)	38.509 (.05)	Ord-Sil DOLM
20025-008	Tegart	NW025	64.53	130.17	18.770 (.10)	15.680 (.09)	38.823 (.08)	Ord-Sil DOLM
20034-007	Kind	NW034	64.37	129.73	18.779 (.10)	15.684 (.08)	38.846 (.06)	Ord-Sil DOLM
Average for Carb Cluster: n=14, arith. average = $\bar{x}$					[18.786 (.08)]	[15.681 (.07)]	[38.646 (.01)]	
std. error of mean = $S \cdot n^{-1/2}$					0.014	0.006	0.044	

Silurian (ca. .44 Ga)								
10064-001	Kate	YT064	62.25	130.68	18.712 (.17)	15.720 (.10)	38.874 (.08)	Ord-Sil QZIT-SHAL
10069-001	Maxi	YT069	61.63	129.17	18.749 (.10)	15.726 (.06)	38.843 (.07)	L.Pal PHYL
10094-001	Pay	YT094	61.98	130.50	18.672 (.05)	15.704 (.12)	38.788 (.05)	Sil-L.Dev QZIT-CARB
10091-001	Howards Pass-XY	YT091	62.47	129.18	18.590 (.10)	15.621 (.10)	38.592 (.09)	L.Sil SHAL
10091-002	Howards Pass-AN	YT091	62.47	129.18	18.602 (.10)	15.657 (.08)	38.583 (.11)	L.Sil SHAL
10091-003	Howards Pass-OP	YT091	62.47	129.18	18.553 (.08)	15.630 (.04)	38.561 (.08)	L.Sil SHAL
10073-001	Matt Berry	YT073	61.47	129.40	18.689 (.07)	15.698 (.06)	38.576 (.08)	L.Pal PHYL
Average for Sil SHAL: n=7, arith. average = $\bar{Y}$					[18.652 (.09)]	[15.679 (.08)]	[38.688 (.08)]	
std. error of mean = $S \cdot n^{-1/2}$					0.027	0.016	0.053	
Ordovician (ca. .48 Ga)								
20016-001	Tap	NW016	63.95	129.13	18.440 (.08)	15.665 (.10)	38.511 (.07)	Ord SHAL
20029-002	Sonnendrucker	NW029	64.83	131.50	18.477 (.08)	15.637 (.10)	38.683 (.07)	Ord-Sil SHAL
20065-003	Show: 106/B/14W	NW065	64.8A[3]	131.2A[3]	18.586 (.06)	15.739 (.06)	38.983 (.05)	Ord-Sil SHAL-LIMS
20068-007	Show: 106/B/10W	NW066	64.6A[3]	130.8A[3]	18.543 (.07)	15.692 (.05)	38.655 (.06)	Ord-Sil SHAL-LIMS
Average for Ord SHAL: n=4, arith. average = $\bar{Y}$					[18.512 (.07)]	[15.683 (.08)]	[38.708 (.06)]	
std. error of mean = $S \cdot n^{-1/2}$					0.032	0.022	0.099	
Cambrian (ca. .55 Ga): Anvil District[4]								
10092-AVG	Grum (n=8)	YT092	62.27	133.23	18.470 (.09)	15.678 (.09)	38.427 (.08)	Cam SCHS-PHYL
10109-AVG	DY (n=22)	YT102	62.23	133.20	18.411 (.09)	15.649 (.09)	38.360 (.09)	Cam SCHS
10110-AVG	Faro (n=3)	YT110	62.37	133.37	18.357 (.08)	15.648 (.10)	38.286 (.10)	Cam SCHS
10125-AVG	Swim (n=2)	YT125	62.22	133.03	18.332 (.08)	15.637 (.06)	38.217 (.08)	Cam PHYL
10126-AVG	Vangorda (n=5)	YT126	62.23	133.22	18.349	15.659	38.282	Cam PHYL*
10127-AVG	SB (n=4)	YT127	62.18	133.90	18.481 (.07)	15.669 (.09)	38.500 (.12)	Cam SCHS-PHYL
10128-AVG	Sea (n=2)	YT128	62.18	133.90	18.350	15.644	38.280	Cam SCHS*
Average for Anvil District: n=4, arith. average = $\bar{Y}$					[18.393 (.08)]	[15.655 (.09)]	[38.336 (.09)]	
std. error of mean = $S \cdot n^{-1/2}$					0.023	0.005	0.037	
Epigenetic: Cambrian (ca. .51 Ga model age)								
100001-004	Carne/Eg	YT001	64.85	133.13	17.933 (.07)	15.587 (.10)	37.841 (.09)	Had SHAL
Syngenetic: Helikian (ca. 1.43 Ga model age)								
10082-AVG	Hart River (n=2)	YT082	64.63	136.87	16.519 (.10)	15.455 (.08)	36.374 (.12)	Hel ARGL

1. All analyses done in the Geology - *Geophysics Laboratory, The University of British Columbia.*
2. Host rock ages recorded as: Cam=Cambrian, Dev=Devonian, Had=Hadrynian, Hel=Helikian L=Lower, M=Middle, Mis=Mississippian, Ord=Ordovician, Pal=Paleozoic, Unk=unknown, ?=uncertain.
3. Host rock types redorded as: ARGL=argillite, CARB=carbonate, CHER=chert, DOLO=dolomite, LIMS=limestone, PHYL=phyllite, QZIT=quartzite, SCHS=schist, SHAL=shale.
4. *Values, from LeCouteur (1973), are adjusted to conform* to the same standard base used in our analyses.

In the northern Canadian Cordillera, at least, our 'average shale' growth curve is more suitable for calculating model ages of stratiform shale-hosted deposits than any published models. Because we can either calculate model ages from the growth curve or assign ages to deposits if their measured isotopic ratios coincide with established clusters, we can make some interesting and significant interpretations.

(1) 'Young' (post-Cambrian) carbonate-hosted zinc-lead deposits have galena-lead isotope ratios (Table 1) that plot within the Devono-Mississippian shale cluster but are distinct from shale clusters of other ages (Figs. 71 and 73). This strengthens arguments made elsewhere (*ibid.*) that these two types of deposit, although formed in different environments, are related to the same metallogenic event – namely, dewatering of the Selwyn shale basin during Devono-Mississippian time.

(2) Vulcan deposit, Northwest Territories, has galena-lead isotope ratios that plot near the centre of the Devono-Mississippian shale cluster on Figure 71. A year ago host rocks for this deposit were thought to be of Ordovician to Silurian age. Recent field mapping, however, has shown the host rocks to be Early to Middle Devonian in age (R. Hewton, 1980, personal communication). It is significant to geological exploration that our galena-lead isotope data indicate that the deposit is syngenetic; by the earlier stratigraphic interpretation it was epigenetic. It apparently formed during a Devono-Mississippian metallogeny related to dewatering of the Selwyn shale basin and consanguineous deposition of stratiform, syngenetic shale-hosted deposits like the Tom-Jason deposit in Yukon Territory and those north of MacKenzie.

(3) The Rough showing is situated close to the newly discovered shale-hosted deposits in northeastern British Columbia but lies in a possible shear zone in Ordovician carbonates. Lead isotope data from this deposit fall in the field of Devono-Mississippian deposits on Figure 71, so the deposit is probably epigenetic.

(4) Matt Berry and Maxi deposit, Yukon Territory, have galena-lead isotope ratios that plot in the Silurian shale cluster (Fig. 71). Both deposits occur in phyllite with a poorly defined Early Paleozoic age. Thus, the deposits formed during a Silurian metallogenic event and it is plausible that they are syngenetic.

(5) Anvil district, Yukon Territory (point 4, Figs. 70 and 73) is, according to isotopic evidence, Cambrian in age (Fig. 71), as suspected by others.

(6) The Carne/Eg deposit, Yukon Territory (point 5, Figs. 70 and 73), is in Hadrynian shale. Galena-lead isotope ratios from this deposit give a model age, based on our average shale growth curve, of about 520 Ma. Consequently, the deposit is probably epigenetic. Coincidentally, perhaps, this is the age of mineralization in most pre-Ordovician ('old') carbonate rocks determined previously by us from galena-lead isotopes (*ibid.*), minor elements in sphalerite, and stratigraphic distribution of the deposits (McLaren and Godwin, 1979a and 1979b).

(7) The Hart River deposit, Yukon Territory (point 6, Figs. 70 and 73), is in Helikian argillite. Galena-lead isotope ratios from this deposit give a model age of about 1.43 Ma. This is slightly older than ages reported in Morin (1979) calculated from models of Stacey and Kramers (about 1.3 Ma) or Cumming and Richards (about 1.2 Ma). Since the host rock age is apparently the same as the deposit model age, the deposit is likely to be syngenetic.

(8) The McMillan (Quartz Lake) deposit, Yukon Territory (point 7, Figs. 70 and 73), hosted by Helikian sedimentary rocks, is unlikely to be syngenetic as is widely believed. Galena-lead isotopes from this deposit are highly radiogenic suggesting a complex history of formation. It is perhaps significant that our average shale growth curve defines a model age for this deposit of about 120 Ma (Cretaceous). Granitic intrusions in the vicinity of

this deposit are also Cretaceous. We conclude that the deposit is epigenetic and speculate that the granitic intrusions might be responsible for its formation.

(9) Galena-lead isotopes from several deposits plot in a field on Figure 73 that we previously defined (*ibid.*) for vein and skarn deposits of Cretaceous age. From our average shale growth curve, negative ages were obtained for these deposits. Although the field relationships of these deposits could not conclusively distinguish whether they are metamorphosed syngenetic deposits or epigenetic skarn deposits, the isotopic evidence shows them to be the latter.

We believe that definition of our average shale growth curve for the northern Canadian Cordillera on Figures 71 and 72 has both theoretical and obvious exploration applications. From galena-lead isotope data we are able to define:

(1) basement source ages and geochemistries,
(2) a series of major metallogenic events and relationships between different classes of deposits,
(3) the age of a deposit in many instances, and
(4) *whether a deposit is syngenetic or epigenetic.*

This information, particularly the last two items, can be of critical importance in defining exploration models for the evaluation of properties.

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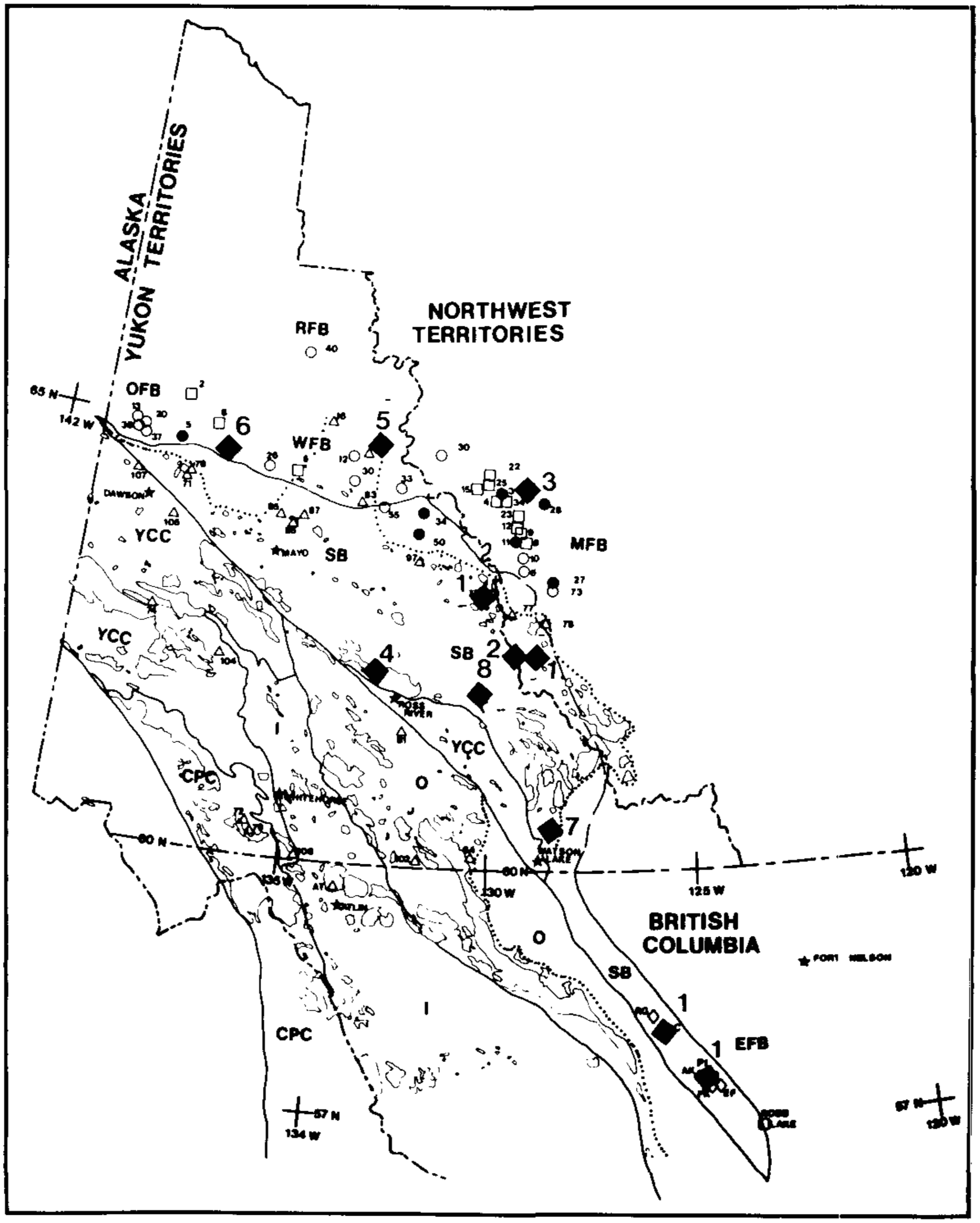

Figure 70. Location of galena-lead isotope analyses on Figure 71. Small circles are 'old carbonate' hosted, small squares are 'young carbonate' hosted, and small triangles are 'silver rich' vein and skarn deposits. Large numbered diamonds locate those sale-hosted deposits with analyses in Table 1. 1 = Devono-Mississippian; 2 = Lower Silurian; 3 = Ordovician; 4 = Cambrian; 5 = Cambrian model age; 8 = negative model age. I = Intermontane Belt; O = Omineca Crystalline Belt; SB = Selwyn Basin; OFB = Ogilvie Fold Belt; WFB = Wernecke Fold Belt; RFB = Richardson Fold Belt; MFB = Mackenzie Fold Belt; EFB = East Fold Belt.

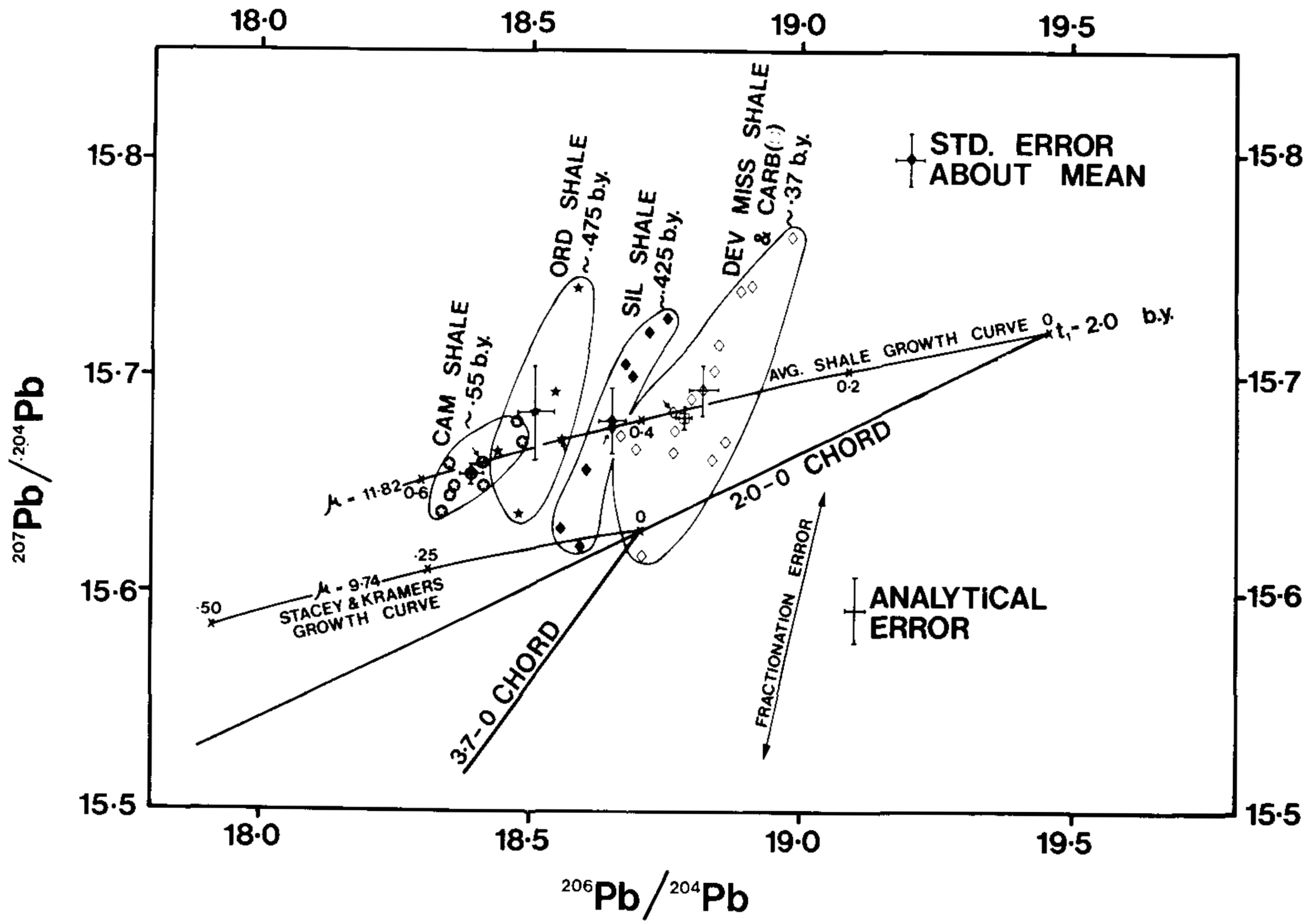

Figure 71. Detailed plot of isotopic ratios in Table 1 from shale-hosted deposits grouped from Cambrian to Devono-Mississippian in age. Stacey and Kramers' growth curve and our average shale growth curve for the northern Canadian Cordillera are defined.

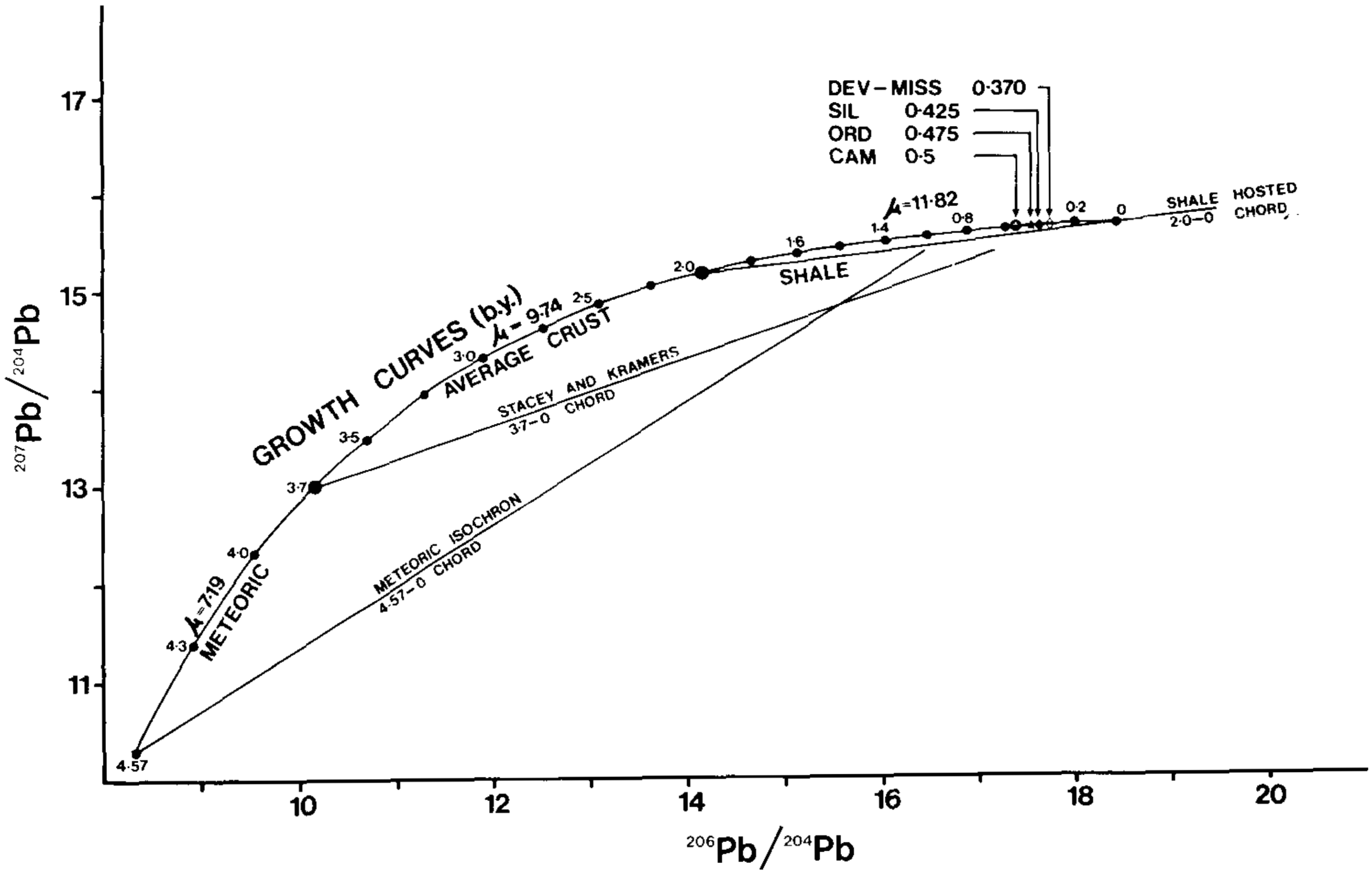

Figure 72. Galena-lead isotope analyses from stratiform, shale-hosted deposits of Cambrian to Devono-Mississippian age in or adjacent to the Selwyn Basin, British Columbia, and the Yukon Territory. A three-stage evolution in the growth curves is implied for the northern Canadian Cordillera (4 300 to 3 700 Ma, 3 700 to 2 000 Ma, and 2 000 to 0 Ma). Note that analyses for labelled deposits fall too close to the 3 700 to 0 cord of Stacey and Kramers to give meaningful ages. Model ages from our average shale growth curve appropriately are between 300 and 600 Ma.

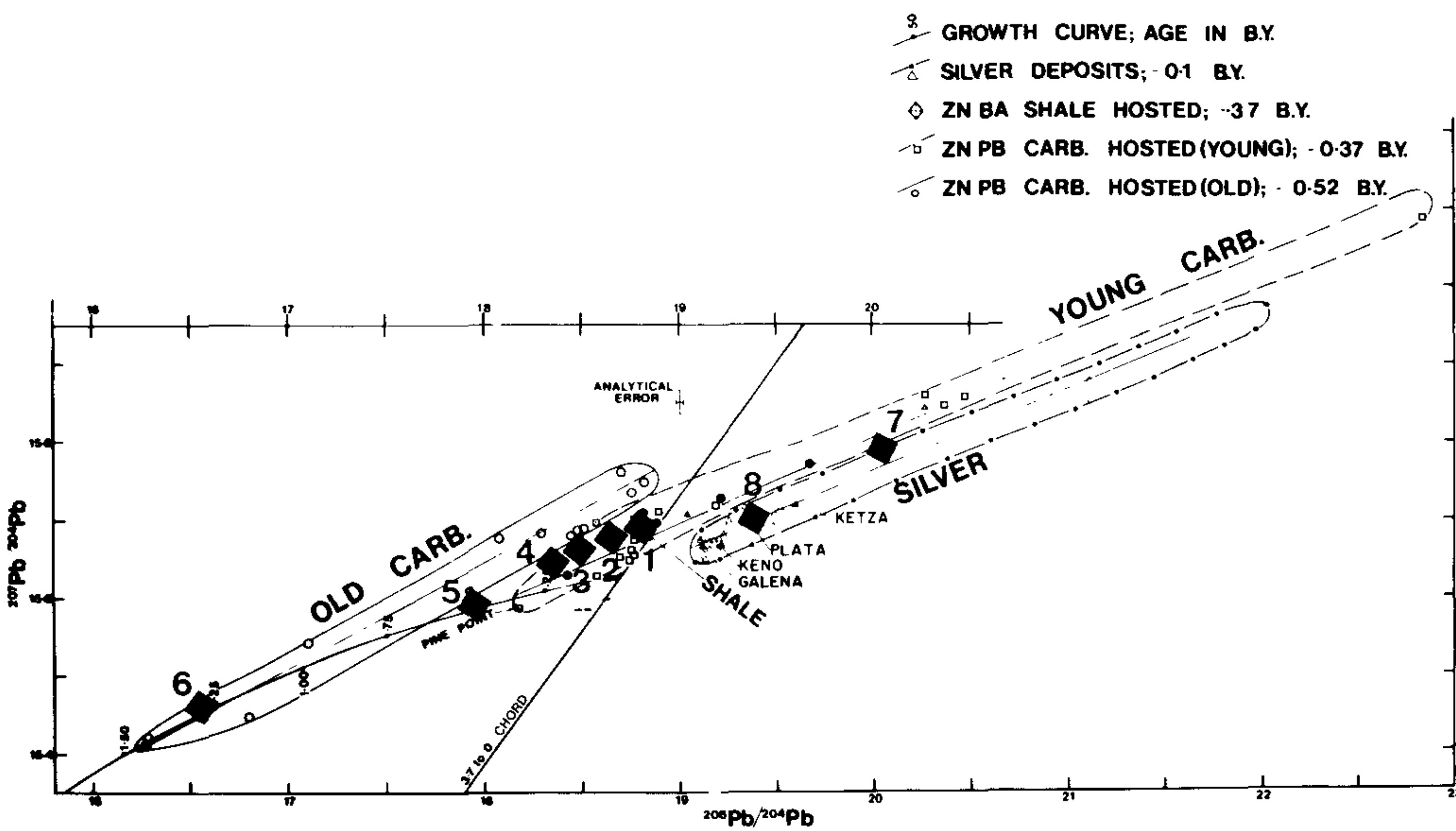

Figure 73. Galena-lead isotope analyses from shale-hosted deposits plotted as large diamonds on a figure adapted from Godwin, *et al.* (in press) which shows fields where most isotope values fall for: (1) pre-Ordovician ('old') carbonate-hosted deposits, (2) post-Cambrian ('young') carbonate-hosted deposits, and (3) vein and skarn 'silver' rich deposits. Numbers on large diamonds are referred to in the text and in caption of Figure 70.

PACIFIC OCEAN MINERALS PROJECT: PROGRESS REPORT OCTOBER 1980

By R. L. Chase, E. V. Grill, and J. W. Murray

INTRODUCTION

The Pacific Ocean Minerals Project has as its objective location and evaluation of mineralization by hydrothermal processes on the actively spreading Juan de Fuca and Explorer Ridges in the Northeastern Pacific Ocean west of British Columbia. Since mid-1977, three cruises aboard a Canadian oceanographic vessel have resulted in study of four areas at ridge crests. Of the following resultant M.Sc. thesis projects, four are nearing completion, and the fifth is in its initial stages:

(1) G. Beland (1977) – Rocks and Sediments of the Western Rift of the Northern Explorer Ridge.
(2) R. Cook (1977) – Sediments of Northern Juan de Fuca Ridge.
(3) M. Price (1978-1980) – Sediments of Juan de Fuca Ridge at 47°N Latitude.
(4) K. Hansen (1979) – Sediments of the Eastern Rift of Explorer Ridge.

A manuscript has been accepted for publication concerning a hydrothermal deposit from the eastern rift of Explorer Ridge (Grill, *et al.*, in press).

METHODS

Work at sea included echo-sounding and continuous seismic-reflection profiling, magnetometry, sediment coring, rock dredging, and water sampling. Resultant profiles and contour maps of bathymetry and sediment thickness showed details of the rift system formed by recent spreading.

Laboratory work by graduate students, designed to elucidate relative importance of various inputs to the sediment near the ridge crests, included chemical analysis, mineralogy, grain-size analysis, and study of x-radiographs. E. V. Grill analysed pore fluids and sediment of selected cores.

RESULTS

The region has received terrestrial sediment at a rate far higher than the average rate for spreading oceanic ridges, because of its proximity to a heavily glaciated continent of high relief. As a result, inputs on heavy metals to the sediment due to hydrothermal effusion at the ridge crest, if they exist, are masked in most areas by glaciogenic sediment. This is particularly true on Juan de Fuca Ridge, where open-ended valleys and proximity to the sediment-flooded Cascadia Abyssal Plain allowed relatively free access of turbidity currents to the ridge crest. Explorer Ridge, with rift valleys more sheltered from turbidite deposition, is the site of at least one hydrothermal deposit (Grill, *et al., op. cit*). Minerals developed here are oxides of manganese and iron-rich montmorillonites, indicative of the low-temperature effusion like that described on

Galapagos Ridge rather than the high-temperature effusion encountered west of Mexico which produced the copper-zinc-rich 'black smokers'. Further indications of hydrothermal input on Explorer Ridge come from anomalously high manganese content of pore waters in a core from the east rift.

The following work is planned for 1980-1981:

(1) Further analysis of core samples.
(2) A Q-mode factor analysis of chemical and grain-size data.
(3) Petrography and analysis of major and trace elements of basalt from Explorer Ridge.

REFERENCE:

Grill, E. V., Chase, R. L., MacDonald, R. D., and Murray, J. W. (in press): A Hydrothermal Deposit From Explorer Ridge in the Northeastern Pacific Ocean, *Earth Planet. Sci. Lett.*, in press.

GENETIC IMPLICATIONS OF FLUID INCLUSION STUDIES CINOLA GOLD DEPOSIT QUEEN CHARLOTTE ISLANDS

By S. Kun, N. Champigny, and A. J. Sinclair
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INTRODUCTION

At the Cinola gold deposit Miocene sedimentary rocks, a shale sequence, and a coarse clastic sequence of fluviatile origin were intruded by a Middle Miocene stock of quartz feldspar porphyry (Champigny and Sinclair, 1980). The mineralized system, exposed over an area of more than 1 square kilometre, consists of an intensively silicified zone with late-stage veins and stockworks superimposed on both the rhyolitic intrusion and the adjacent sedimentary rock sequence. Silicified host rocks and veins contain about 3 per cent disseminated pyrite and marcasite with submicroscopic and rare visible gold. Other sulphides and oxides are seldom observed. The veins are divided into four successive events on the basis of form and crosscutting relationships. These are black to grey chalcedonic quartz (earliest) and hematitic quartz, white and cherty quartz, and calcite (youngest). Quartz deposition began before formation of all sulphides (mainly pyrite) and native gold and continued during deposition of these opaque minerals. Veins at Cinola exhibit crustification, ribbon texture, and development of drusy vugs; some calcite crystals attain 2 centimetres in length. This report describes preliminary studies of fluid inclusions in fracture-controlled, gold-bearing veins present in the Cinola orebody. Samples for this study were collected from drill core during the summer of 1979.

DESCRIPTION OF FLUID INCLUSION

Six specimens of quartz were selected to test the application of fluid inclusion data to the development of a genetic model for the deposit. The specimens were collected to represent a large area of the Cinola mineralized system. Fluid inclusions range from 5 to 47 microns in their longest dimension and all have two phases: a liquid and a vapour that total from 1 to 15 volume per cent and average 5 volume per cent. Most of the inclusions were along crystal growth zones, but some are from crystals developed in vugs or as crustiform layers. There is no evidence of deformation and we feel confident that inclusions studied are primary.

HOMOGENIZATION DATA

Homogenization temperatures by vapour disappearance were recorded from 36 inclusions (Fig. 74). The population is bimodal with a low temperature mode between 150 and 160 degrees celsius and a higher temperature mode between 270 and 280 degrees celsius. These two populations of filling temperatures probably represent at least two episodes of mineral deposition and mineralization within the late-stage white quartz and calcite veins. Of seven measurements above 275 degrees celsius, five were from translucent quartz cementing pebbles and matrix in a conglomerate unit. This accords with an early stage of deposition of quartz cement observed by Champigny and Sinclair (1980).

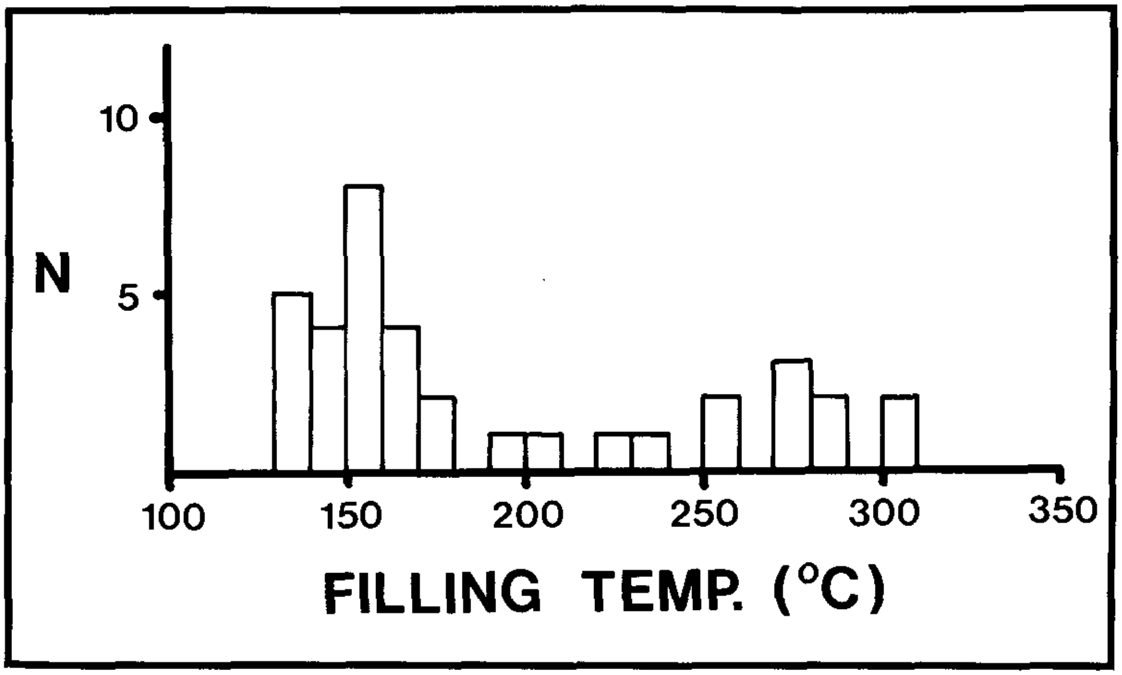

Figure 74. Histogram of homogenization temperatures of fluid inclusion in quartz, Cinola deposit.

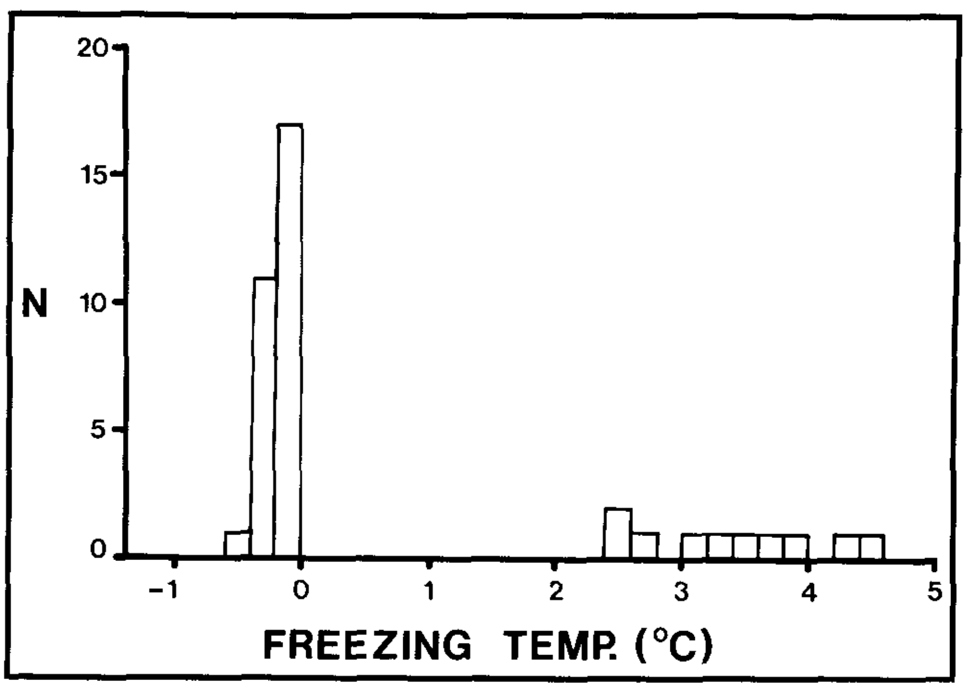

Figure 75. Histogram of freezing temperatures of fluid inclusions in quartz, Cinola deposit.

FREEZING DATA

Most of the freezing temperatures measured from 39 inclusions fall between -0.1 and -0.5 degrees celsius (Fig. 75). Temperatures from 2.5 to 4.9 degrees celsius are considered to be evidence for the presence of dissolved CO_2 (clathrates) in the aqueous solution (Collins, 1979). Melting points of these clathrates ranged from 3.0 to 3.4 degrees celsius and from 2.5 to 4.9 degrees celsius in the two samples where they were observed. Double freezing, a characteristic phenomenon of clathration, was very difficult to observe because the inclusions and gas bubbles are small. Salinity estimates for the inclusion fluids were obtained using the formula of Potter, *et al.* (1978). NaCl equivalent in solution varies from 0.2 to 0.9 weight per cent with an average of 0.4 weight per cent. Small amounts of CO_2 may be trapped in the ore fluid but would not significantly change the estimated salinities (Collins, 1979, Fig. 5).

PRESSURE CORRECTIONS

The homogenization data are not corrected for the effects of pressure. Host rocks at Cinola are mainly conglomerates which correlate with the base of the Skonun Formation as found in the Tow Hill well (Sutherland Brown, 1976). Sixty-five kilometres to the northeast of Skonun Point exposed Skonun sedimentary rocks are weakly cemented and highly porous. This, combined with the extensive fracturing in the mineralized zone, suggests that pressure during vein deposition was hydrostatic. Average thickness of the Skonun sedimentary rocks from five wells drilled is 1 200 metres, and 1 760 metres of strata is present at Tow Hill. At these depths hydrostatic pressure is approximately 117 and 172 bars respectively. From this pressure corrections of 15 degrees celsius or less for a solution of 1 per cent NaCl equivalent could apply (Potter, 1977), that is, actual temperatures of deposition are no more than 15 degrees celsius higher, on average, than the filling temperatures reported here.

DISCUSSION

From the homogenization and freezing data, it is apparent that mineralizing fluids at Cinola had a relatively low and only slightly variable salinity. They contained very minor amounts of NaCl equivalent and CO_2. Low salinities are characteristic of gold quartz veins and Carlin-type deposits (Nash, 1972) and are consistent with a meteoric origin for the ore fluids. In the present case superheated pore waters of the Skonun sedimentary rocks are a likely source of mineralizing fluids. The sedimentary host rocks at Cinola are of fluviatile origin and therefore pore waters should have low NaCl and CO_2 content which is consistent with the fluid inclusions data.

Open-space filling textures and the absence of coexisting vapour-dominated inclusions at Cinola suggest either that boiling did not occur or that the boiling 'top' of the system has been removed by erosion. For maximum filling temperatures of 300 degrees celsius and a salinity of 0.4 per cent NaCl equivalent solution, a hydrostatic pressure equivalent to a depth of 1 100 metres below surface is necessary to prevent the system from boiling (Haas, 1971). This depth is considered a minimum for mineral deposition in that part of the Cinola system available for study because of the absence of boiling. Based on the total maximum thickness of the overlying stratigraphic section to the east (Sutherland Brown, 1968) the maximum possible depth of mineralization appears to be 1 800 metres.

Clathration, observed in two samples, indicates the presence of small amounts of CO_2 and it is possible that a very small amount of CO_2 also occurs in inclusions where clathration was not recognized. The Skonun

Formation is a plausible source for this CO_2. Local shell-rich layers are a characteristic feature of the Skonun Formation and are well exposed at the type locality at Skonun Point on the north shore of Graham Island (Sutherland Brown, 1968). Thin zones of Skonun sandstones and conglomerates are cemented by calcite for as much as 30 centimetres from shell-rich layers that are normally only a few centimetres wide. Similar shell-rich layers occur in drill core at the Cinola deposit (Champigny and Sinclair, 1980).

CONCLUSIONS

Although these fluid inclusion studies are not comprehensive they provide important constraints on a genetic model for the Cinola deposit. The low salinities and low CO_2 content of the ore fluid are consistent with the suggestion that the fluid originated as pore water in the fluviatile Skonun Formation. Filling temperatures, and the absence of textures resulting from boiling, suggest a minimum depth of formation of about 1 100 metres and stratigraphic information suggests a maximum depth of formation of about 1 800 metres.

The two major peaks of filling temperatures suggest that two principal temperature regimes existed during the depositional history. These peaks indicate an early period of high temperature deposition and a late period of lower temperature deposition.

ACKNOWLEDGMENTS

Financial support for this study was provided by Consolidated Cinola Mines Ltd.

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STRATIGRAPHY AND PRECIOUS–METAL OCCURRENCES OF THE BIG MISSOURI CLAIM GROUP STEWART AREA (104B/1)

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INTRODUCTION

The Big Missouri claims are 25 kilometres northeast of Stewart and consist of 23 Crown-granted claims, 64 reverted Crown-granted claims, and 11 recently staked claims (Fig. 76). Access is by the Granduc road to the Silbak Premier millsite and then by a smaller road to the abandoned Big Missouri townsite where Tournigan Mining Explorations Ltd. has established an exploration camp (Fig. 77).

The majority of the claims were consolidated in 1973 by Tournigan Mining Explorations Ltd. In 1978, Western Mines Limited of Vancouver optioned the properties and have continued exploration to date with soil sampling, detailed surface and underground mapping, and diamond drilling. The objective is to assess the potential for a precious metal open-pit operation.

The Big Missouri mine is the only past producer on the claim group. It was operated from 1938 to 1942 by Buena Vista Mining Company Limited, subsidiary of The Consolidated Mining and Smelting Company of Canada, Limited (Cominco Ltd.), producing 847,615 tons of ore containing 58,384 ounces of gold, 52,677 ounces of silver, 2,712 pounds of lead, and 3,920 pounds of zinc (Grove, 1971). The Silbak Premier minesite, 5 kilometres south of the Big Missouri claims, produced 4.7 million tons of ore yielding 1.8 million ounces of gold and 41 million ounces of silver (Barr, 1980). The Granduc mine, 25 kilometres north of the Big Missouri claims, was a major copper producer until 1975.

GENERAL GEOLOGY

The claims are underlain by two major groups of northwest-trending rocks separated by an angular unconformity (Fig. 78). The stratigraphically lower group is gently southwest-dipping flow rocks and volcanogenic sedimentary rocks believed to be of the Lower Jurassic Hazelton Group (Grove, 1971; Smitheringale, 1977; Read, 1979). These rocks occupy the southwest half of the claims. The upper stratigraphic group consists of tightly folded, immature sedimentary rocks of the Middle to Upper Jurassic Bowser Group and occupies the northeast half of the claims.

The main mass of the Coast Plutonic Complex crops out west of the claims across the Salmon Glacier and includes three major plutons, the Texas Creek, Boundary, and Hyder plutons (Grove, 1971). They range in age from Early Jurassic to Cretaceous and in composition from granodiorite to quartz monzonite. A small intrusion known as the Glacier pluton outcrops directly east of the claims at the north end of Long Lake (Fig. 78).

Figure 76. Location map.

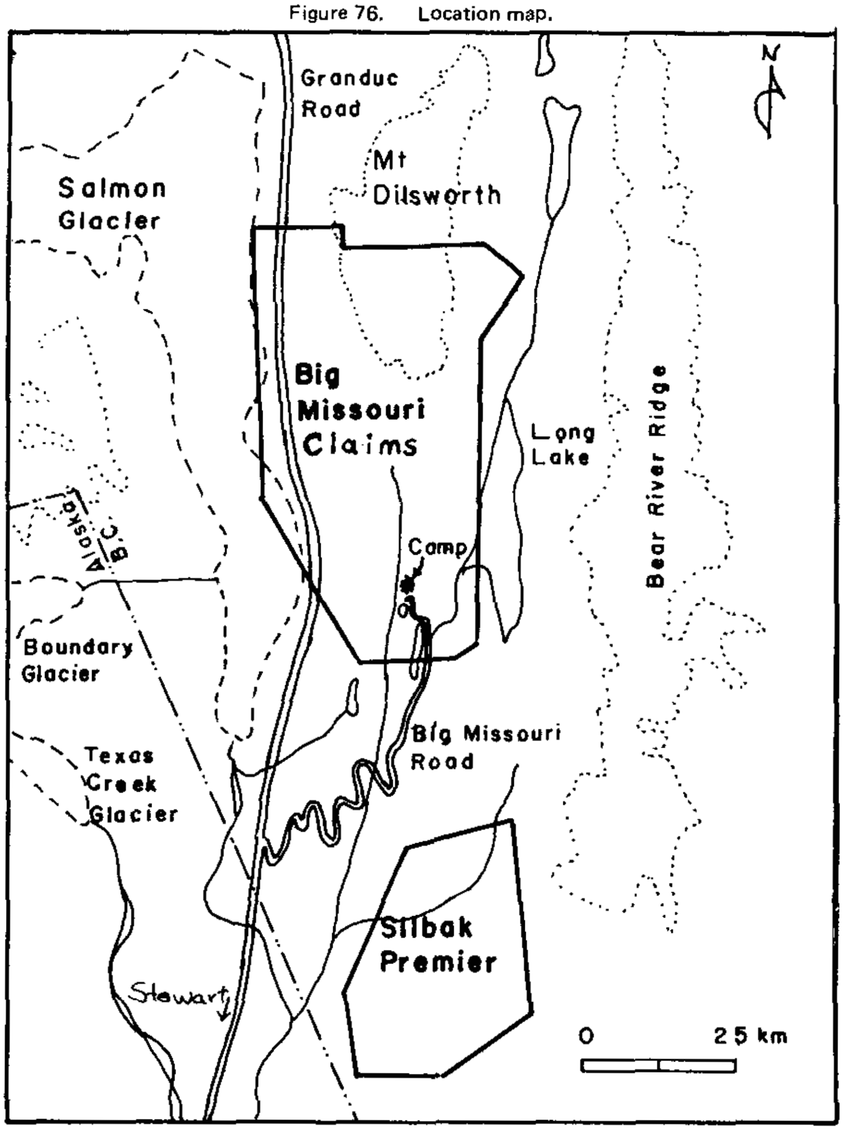

Figure 77. Area of the Big Missouri claims (modified from Smitheringale, W. G. & Associates, 1977).

Two sets of dykes crosscut the claims. In the north there are large quartz feldspar porphyritic granite and granodiorite dykes which strike northwest. In the south there are several generations of diorite dykes which also strike northwest but cut the larger granite and granodiorite dykes.

HAZELTON GROUP

Flow rocks and volcaniclastic sedimentary rocks of the Hazelton Group are approximately 3 000 metres thick. The oldest rocks are near the east margin of the claims where they are in contact with the overlying Bowser Group sedimentary rocks. The youngest rocks are at the west margin of the claims along the Salmon Glacier. Rocks dip shallowly to the southwest and sedimentary and volcanic structures indicate that the section is right-side-up. The section consists of more than 1 000 metres of compositionally varied volcaniclastic rocks in its lower part, overlain by 1 500 metres of compositionally more uniform pyroclastic and effusive flow rocks. Within this upper part are precious and base metal-bearing siliceous horizons (Fig. 79).

UNIT 1a: BLACK TUFF

The base of the section exposed on the claims is black to dark grey pyroclastic rock. There is cyclic grading from tuffaceous agglomerate and lapilli tuff to tuff. Pumice fragments in the tuffaceous agglomerate and lapilli tuff are flat to oblate and inversely graded at several locations. Lithic fragments are angular and include porphyritic andesite and rare banded rhyolite. Matrix varies from an abundant quartz-rich mass to a dark felted mass of possibly devitrified glass. These rocks are massive to slightly foliated and abundantly fractured.

UNIT 1b: HETEROLITHIC AGGLOMERATIC TUFF

A 50-metre layer of heterolithic agglomeratic tuff overlaps the basal black tuff at the southeast edge of the claim group. This agglomerate has a light green matrix and contains subrounded to angular fragments, up to 6 centimetres in diameter, of pumice, dark to light grey tuff, and porphyritic andesite. The larger fragments are found near the centre of the horizon. This rock is relatively massive.

UNIT 1c: GREEN–GREY TUFF

Next in the sequence is a dark green to grey fragmental rock which has a thickness of 150 metres at the southeast corner of the claims and wedges out in approximately 500 metres. This unit is agglomeratic tuff and lapilli tuff in which several flow rocks are present; contacts are difficult to define. Angular to subangular fragments, up to 10 centimetres in diameter, of feldspar porphyritic andesite are abundant in a matrix of feldspar lapilli and fragments of biotite and small angular clasts of principally carbonate and chlorite. Small fragments of finely laminated sedimentary rock are also present in the matrix. The rock is massive to slightly foliated and well jointed.

UNIT 1d: GREY TUFF

A light grey tuff is next in the succession and is thin and sporadic in the south part of the claims, gradually thickening to 300 metres in the central third, and absent from the north part of the claim group. This rock is aphanitic to medium grained with feldspar, quartz and biotite lapilli, thinly laminated sedimentary fragments, and rare agglomeratic layers. The matrix contains what appear to be devitrified glass shards. In its upper part the unit consists of sandstone and conglomeratic equivalents of the tuffs; the epiclastic rocks

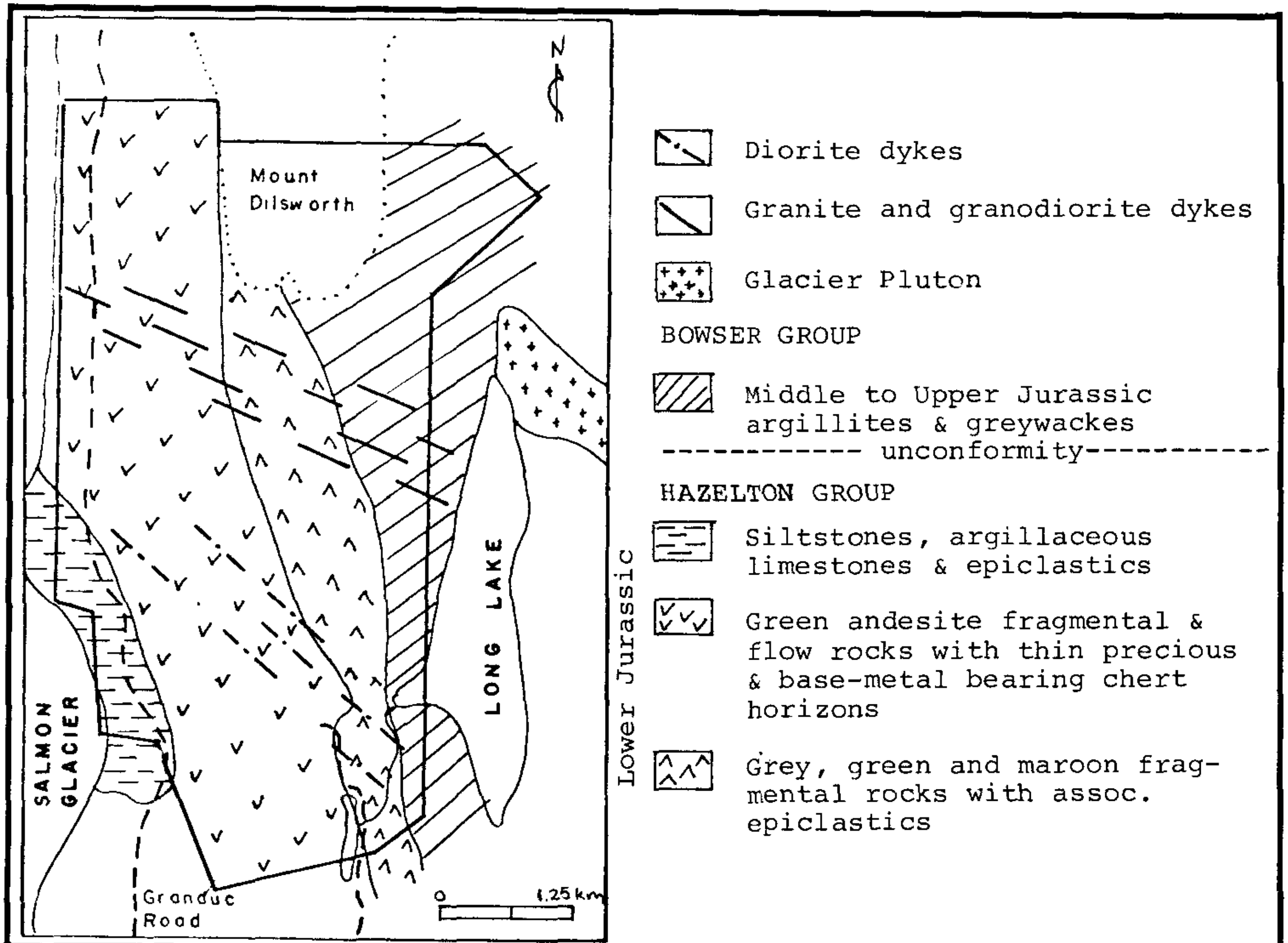

Figure 78. Sketch map of the general geology, Big Missouri claim group.

have layering and graded bedding. The northernmost exposure of this rock type is coarse pyroclastic material with an over-all decrease in grain size toward the south. This is the only rock observed to date which contains quartz lapilli.

DR: DILSWORTH RHYOLITE

A small rhyolite dome intrudes the section on the south flank of Mount Dilsworth where units 1a and 1d are in contact. The dome is 200 metres long in a northwest direction and 50 metres wide. It intrudes units 1a and 1b, and is surrounded by coarse brecciated material from both units. The dome is composed of rhyolite fragments consisting of sericite, quartz, and feldspar and angular coarse-grained grey carbonate fragments up to 50 centimetres in length. Disseminated pyrite comprises up to 20 per cent of the rock. The Bowser-Hazelton contact lies directly east of the rhyolite dome, and the Mount Dilsworth snowfield is directly north and northwest. No stratigraphic equivalents of this rock have been found.

UNIT 1e: MAROON TUFF

A series of predominantly maroon-coloured rocks are next in the stratigraphic column. These rocks comprise a thick wedge in the southeast corner of the claims, disappear in the middle, and reappear in the northern third of the claim where they are more than 300 metres thick. In the south the rocks are massive to well-layered maroon-coloured tuff and lapilli tuff with intercalated green volcaniclastic layers; the green layers become dominant near the middle of the claims. The most massive of the maroon rocks contain green lapilli that are flattened parallel to the layering. Near the south edge of the claim group lenses of reworked maroon volcanic material are abundant. Graded bedding is common with fine to coarse-grained, angular sand-sized particles predominating. Where the maroon rocks are absent from the central part of the claims, the underlying unit (1d) is generally topped by epiclastic beds. The north half of the maroon rock sequence has very coarse agglomerate beds near its base, with boulders of porphyritic andesite up to 1 metre in diameter. This rock is gradational to maroon lapilli tuff and tuff.

UNIT 1f: INTERMIXED TUFF

The maroon tuff is topped by a mixed sequence of maroon and green volcaniclastic rocks which have angular blocks up to 40 centimetres in diameter of maroon and green porphyritic andesite in a green or maroon tuffaceous matrix. Several outcrops have angular rhyolite fragments up to 6 centimetres in diameter and contorted and broken layers of jasper are present in one horizon. Green andesite fragments and matrix dominate the top of the unit.

UNIT 2: GREEN ANDESITE

The next 1 500 metres of the stratigraphic column consists of green andesitic pyroclastic rocks and effusive flows. Most of the layers have feldspar phenocrysts or fragments and many have amphibole crystals or crystal fragments. Biotite is the only primary mafic mineral identified in the lower part of the volcanic sequence. Unit 2 is thickest near the middle part of the claims and always exceeds 1 000 metres in thickness along its strike length. Tuff, lapilli tuff, and agglomerate occur throughout the sequence but the lower 50 to 100 metres is mainly coarse breccias, some of which are heterolithic. Generally, however, matrix and clasts of the coarser rocks are similar in composition. Lava flows within the sequence are massive rocks containing euhedral phenocrysts of feldspar and amphibole. Individual flows are difficult to recognize on the hand-specimen scale because of the uniform green colour of matrix and clasts.

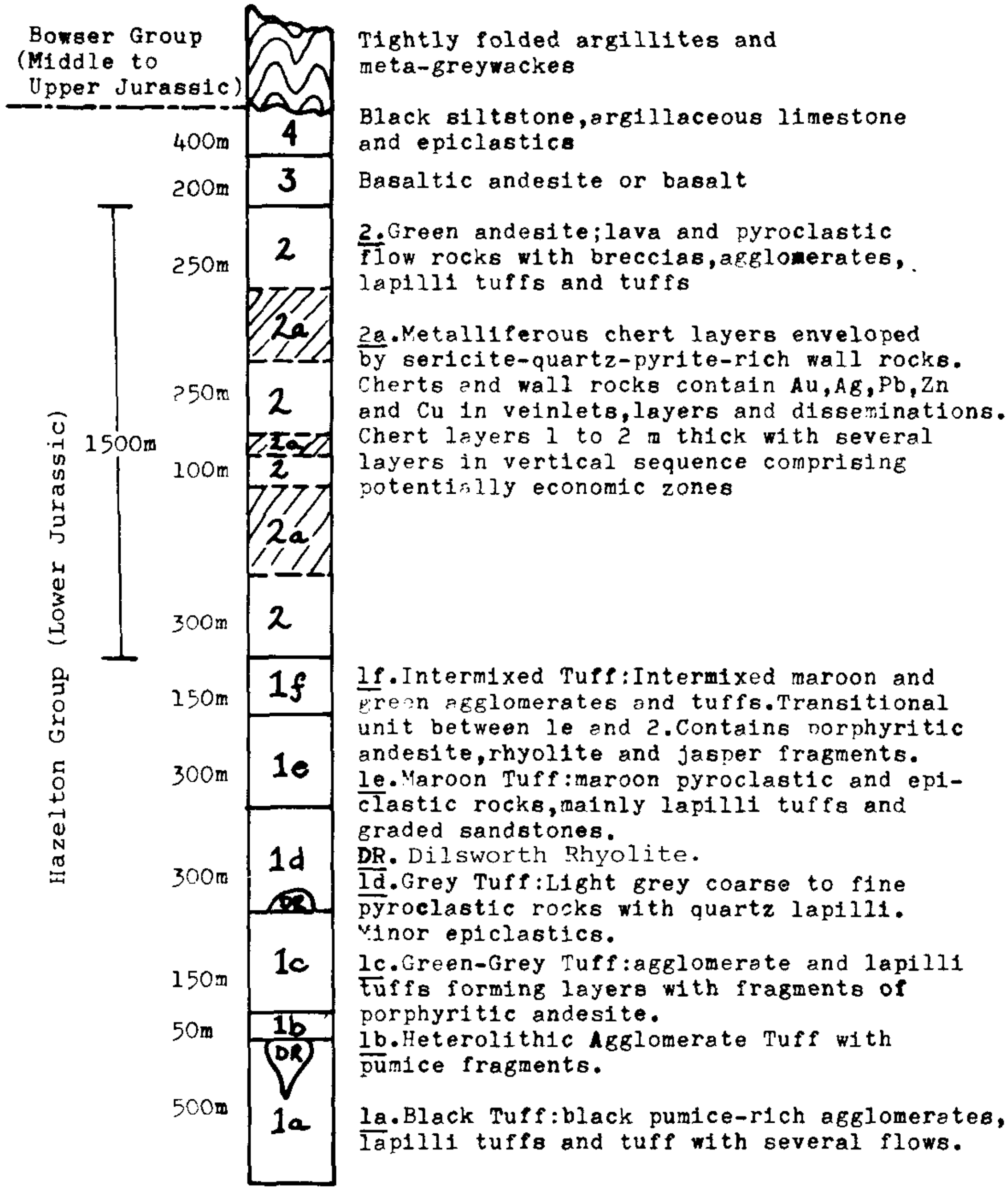

Figure 79. Summary of rock succession, Big Missouri claims.

UNIT 2a: METALLIFEROUS CHERT HORIZONS

The only major variations in composition within the green andesite unit are thin stratiform siliceous layers located at various stratigraphic levels within the andesites and sericite-quartz-pyrite-rich rocks that envelop these 'chert' horizons. These quartz-rich layers and the accompanying sericite-quartz-pyrite-rich rocks are significant because some carry precious metals and base metal sulphides.

UNIT 3: BASALTIC ANDESITE OR BASALT

The green andesite unit is topped by darker green, brown-weathering basaltic andesite or basalt. Most are lapilli tuff and tuff but some may be effusive flows. Carbonate veining is abundant in this unit.

UNIT 4: SILTSTONES, ARGILLACEOUS LIMESTONES, AND WACKES

The Hazelton Group volcanic sequence underlying the claims is overlain by a series of black siltstones, calcareous siltstones, and green-grey, sand-rich epiclastic beds. The unit was followed westward to the Granduc road. Grove (1971) mapped these sedimentary rocks further westward to the Salmon Glacier. Grove placed these sedimentary rocks in the Bowser Group but it is more likely that they are part of the Hazelton succession.

PRECIOUS AND BASE METAL OCCURRENCES

Two types of metal concentration occur on the Big Missouri claims. These are (a) concentrations of precious and base metal sulphide minerals in stratabound cherty horizons and associated sericite-quartz-pyrite-rich zones within unit 2, and (b) large crosscutting veins of vuggy quartz with local concentrations of base metals and silver. The large veins can be traced for several hundred meters but erratic metal concentrations make them lower priority targets than the stratabound occurrences.

The metal-bearing chert horizons are 1 to 2 metres thick and are mainly dark grey to white microcrystalline quartz. Angular fragments of andesite partly altered to sericite and quartz are found near the footwall contacts. Fragments of cryptocrystalline quartz, some finely laminated, occur both in the chert layers and in the immediate hangingwall rocks. Fine-grained amorphous black carbon may comprise 15 per cent of the layers, although the amount varies from one horizon to another. The carbon is found in veinlets and vugs associated with anhedral to subhedral pyrite. In some instances chert horizons are capped by a distinct, carbon-rich layer. Pyrite is abundant as disseminations, layers, and veinlets. There are at least two generations of pyrite and the younger occurs as disseminations in the chert horizons and wallrock andesite. A few showings have lenses of grey, coarse-grained carbonate associated with the sulphide-bearing horizons.

Zinc, lead, copper, silver, and gold are concentrated in the chert layers and their immediate wallrocks. Sphalerite and galena are the most abundant base metal sulphides but chalcopyrite is an accessory in several showings. Silver minerals, electrum, native silver, and gold form disseminations and veinlets in pockets within certain horizons. Silver minerals such as polybasite and pyrargyrite occur along with the electrum, native silver, and gold. Sulphides occur as disseminations, veinlets, and lenses in the chert horizons, as well as in veins and veinlets in the adjacent wallrocks. Pyrite concentrations are generally proportional to base metal sulphide concentrations.

At the base of the chert horizons there are massive sulphide lenses up to 1 metre thick of banded pyrite, sphalerite, galena, and chalcopyrite. Although abundant pyrite may be present in a chert horizon, precious metal content will be negligible unless galena and sphalerite are present. Consequently, an indication whether a horizon may also contain gold and silver is the bluish grey tinge to the quartz caused by the presence of disseminated sphalerite and galena.

IMMEDIATE WALLROCKS

The weathered surface of the sericite-quartz-pyrite-rich wallrocks of the chert horizons are buff coloured with heavy iron oxide staining. This distinctive weathering clearly marks stratigraphic intervals that contain the precious metal-bearing horizons. In drill core these rocks are light grey to white and proximity to potential ore-bearing horizons is marked by increased quartz and quartz sulphide veining.

Sericitization, silicification, pyritization, and minor chloritization of the andesite wallrock have taken place. Ghost textures, such as outlines of feldspar and amphibole phenocrysts, suggest that the rock was originally similar in composition to the unit 2 andesites. Alteration in the andesites gradually intensifies toward chert contacts. Chlorite-sericite-pyrite alteration changes to sericite-quartz-pyrite, quartz-sericite-pyrite, and finally to almost pure quartz with abundant pyrite in veinlets and disseminations.

The frequency of veining increases with proximity to the chert horizons. Small, clear quartz veinlets with associated sericite-quartz-pyrite alteration appear and increase in size and abundance within several metres of a chert horizon. Then large, blue-grey quartz veins up to 30 centimetres in diameter and carrying visible sphalerite and galena become abundant. These large veins resemble the chert layers in texture and composition. Closely-spaced networks of small, clear to white quartz veins are common in the hangingwall rocks. Blue-grey quartz-carbonate and large milky quartz veins crosscut both alteration zones and chert horizons.

Alteration is more extensive in the hangingwall than the footwall rocks. At several showings chlorite-sericite alteration zone is only 1 to 2 metres wide in the footwall rocks of the metal-bearing chert layer, but the hangingwall sericite-quartz-pyrite zone extends for more than 50 metres into the andesites.

STRUCTURE

Two structural directions dominate within the claim group. A well-developed foliation strikes northwest and dips southwest at a steeper angle than the bedding. A second, weaker, northeast-striking foliation warps the dominant foliation and bedding into a large Z-fold. Poles of measurements of the second foliation plane scatter suggesting that a third phase may be present.

Faulting is extensive on the claim group; it is dominated by two north-trending faults known as the Harris Creek and Union-Silver Creek faults. These faults cut all other structures on the properties and may be high-angle reverse faults. Thrust faulting may also have occurred on the claims. Numerous smaller faults offset the section making correlation of individual chert horizons over large distances difficult. However, careful logging of characteristic sequences of green andesite layers in unit 2 in drill core has allowed accurate determination of displacement across several important faults. The claims are in close proximity of the Coast Plutonic Complex which most likely caused the majority of the large-scale structures.

CONCLUSIONS

The sequence of events that led to the deposition of the rocks and concentrations of metals is as follows:

(1) A period of highly explosive volcanism that deposited pumice and glass-rich ash flow and air fall layers was followed by quieter eruptions and extrusion of a thick sequence of andesite lava and pyroclastic flows. The presence of epiclastic rocks in units 1d and 1e indicates an erosional hiatus between the two volcanic events.

(2) During the second volcanic event fumarolic activity caused deposition of thin layers of metal and quartz-rich chemical sedimentary rocks. Sericite-quartz-pyrite alteration took place around fissures in the andesite which acted as conduits for the metal-rich brines. Formation of individual chert layers was terminated by eruption of additional andesite flows. The newly erupted flows were relatively permeable, allowing fluid discharge from fumarolic centres to continue. This continued fumarolic activity produced the hanging-wall alteration present above many of the metalliferous horizons.

(3) Accumulation of intercalated siltstones and reworked volcanic material mark cessation of active volcanism. Epiclastic and jasper beds in the maroon tuff, chert horizons in the green andesite sequence of unit 2, and siltstones of unit 4 that cover the entire section indicate that the environment of deposition was subaqueous during the major part of the volcanic cycle.

Research is continuing in order to fully substantiate the proposed model and investigate the relationship between precious metals and the base metal sulphides. Recognition that these mineral deposits are syngenetic and an understanding of their relationship to the volcanic cycle will facilitate future exploration for volcanic-hosted precious metal deposits in northwest British Columbia.

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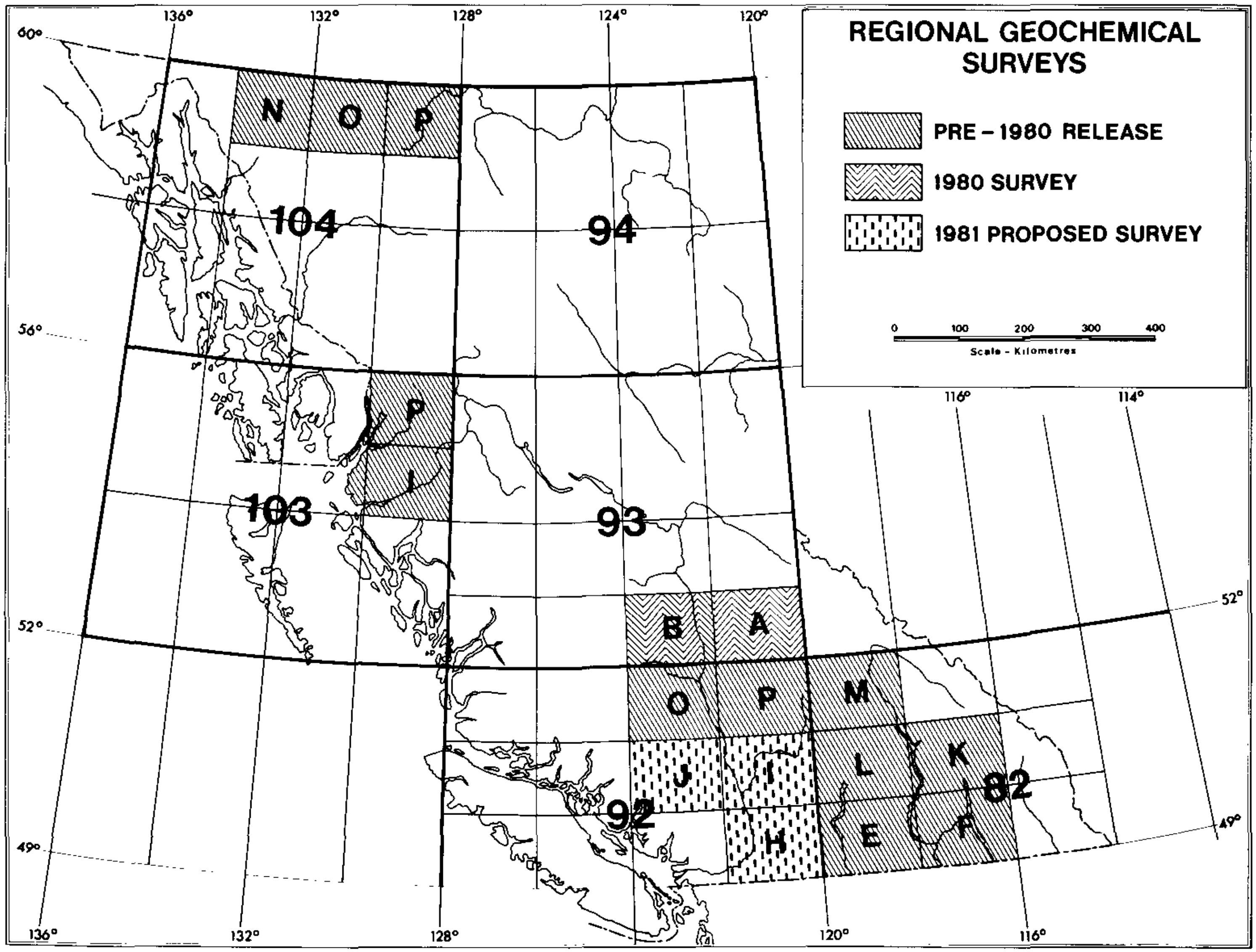

Figure 80. Index map – regional geochemical surveys.

REGIONAL GEOCHEMICAL SURVEY
QUESNEL LAKE AND QUESNEL MAP--AREAS
(93A and B)

By J. Bristow, N. C. Carter, and W. M. Johnson

The British Columbia Ministry of Energy, Mines and Petroleum Resources conducted a regional geochemical survey of NTS map-areas 93A and 93B during the 1980 field season. It is anticipated that the results of the survey will be released in late May of 1981 in the form of sample location maps and data sheets similar to those of previous surveys.

Stream sediment and stream water samples were collected from 1 031 sites during the ground phase of the program and from 96 sites during the helicopter-supported phase. The average sample density was one sample per 15.5 square kilometres (one per 6 square miles). In all, 1 947 samples were collected but field and laboratory duplicates and control reference samples increased the total number of samples submitted for analysis to 2 280.

A six-person sampling crew and equipment for the ground phase and a two-person crew for the helicopter phase were supplied by Stokes Exploration Management Co. Ltd. Both phases were supervised by J. Bristow, the Ministry representative.

Sample preparation was done by Kamloops Research & Assay Laboratory Ltd. The stream sediments were analysed for uranium by Novatrack Analysts Ltd. and for all other elements by Chemex Laboratories Ltd. The stream waters were analysed by Bondar-Clegg & Company Ltd.

The stream sediments were analysed for zinc, copper, lead, nickel, cobalt, silver, manganese, iron, arsenic, molybdenum, tungsten, mercury, uranium, and antimony. The stream waters were analysed for uranium, fluorine, and pH. The data processing was performed by the Geological Survey of Canada data processing group.

Figure 80 shows the map-areas that have been covered to date, the area of the 1980 survey, and the area for the proposed 1981 survey. The results of the 1979 survey in map-areas 92O (Taseko Lakes) and 92P (Bonaparte River) were released on June 6, 1980.