ESSO
COAL DIVISION

ESSO RESOURCES CANADA LTD. (E.R.C.L.)

B.C. RECONNAISSANCE

PROSPECT EVALUATIONS

PHASE I : SOUTH CENTRAL COAL BASINS
(PHASE I OF 1982 RECON. AND CHILCOTIN)
NICOLA AND PRINCETON AREAS
92H, 92I — B. WRIGHT

PHASE II : FRASER RIVER TREND
(PHASES 2 & 3 OF 1982 RECON.)
QUESNEL AREA
93B, 93G — L.KLATZELMUDRY

APRIL 1986

Esso

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B.C. Reconnaissance :
Area I : Chilcotin

OPEN FILE

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M E M O R A N D U M

86 05 30

TO: File - Library - General (B.C.)

FROM: Brenda Wright

SUBJECT: CENTRAL B.C. RECONNAISSANCE

Objective

In order to identify new coal reconnaissance targets in British Columbia, Louise Klatzel Mudry and myself have compiled and re-assessed previous coal department reconnaissance efforts in central B.C. The purpose of this exercise was to document what has been done, the geological strategy used and what additional work could be undertaken in the future.

Approach

Because much of the data resulting from previous programs is scattered in various files and reports, the first step involved the compilation of all available information. This information varied between programs, therefore, they will be discussed separately.

Louise Klatzel Mudry evaluated Phase II of the 1982 B.C. Reconnaissance program, and that work will be covered in a separate memo.

I have evaluated Phase I of the 1982 program as well as the Chilcotin prospect work carried out in both 1983 and 1984. (Refer to Figure 1.)

PHASE I RECONNAISSANCE - 1982

The purpose of the 1982 B.C. Reconnaissance program was to:

- locate sedimentary basins outside of existing known occurrences using varous geological models;
- discover coal within these basins thus generating new prospects

Prior to the field season, data was collected from in-house reports, B.C. Open files and G.S.C. geology maps. A number of theories or targets put forth were modelled after the Tertiary Princeton, Tulameen, Merritt and Hat Creek coal basins. Criteria for target selection were as follows:

- o Eocene sediments on basement rock
- o Eocene volcanics and sediments interbedded on basement rock
- o Eocene sediments under Eocene or younger volcanic (cap) rock
- o Eocene volanics on basement rocks (previous misidentification or inliers of sediment not previously realized)
- o Miocene volcanics on basement (possible windows of sediment)
- o Topographic lows in basement rocks that could contain isolated occurrences

At this point, I would like to recap the regional geological setting of south-central British Columbia.

Regional Geological Setting

The existence of Tertiary coal fields in south-central British Columbia have been explained using two theories:

- o sediment was deposited in a wide spread Tertiary sea but only remnants of the large coal swamps are preserved along its western margin

- o sediment was deposited in topographic lows created in the basement rock by erosion, downfaulting or igneous events

These small Eocene basins are linked together by large throughgoing faults. Where they have been studied, these fault zones are 1-3 kilometres wide. Strike-slip movement began 53 Ma ago along these interconnected faults, some of which may have had prior Mesozoic movement (refer to figure 2). As a result of crustal extension, some blocks subsided and received up to 500 m of fluvial, deltaic and lacustrine sediments (Ewing, 1981).

Some basins received ash and pillowed lava flows as a result of volcanism. Other basins, more distant from volcanic activity, received more nonvolcanic sediment and developed locally signficant coal zones. As volcanic activity increased, a layer of volcanics covered much of the region.

Field Work

Targets identified before the start of the field season were assigned a priority status dependant on the supposed validity of the model.

Priority 1:
- Eocene sediments on GSC maps
- interbedded sediments and volcanics of the Princeton and Kamloops Group

Priority 2:
- Eocene volcanics on GSC maps (possible unmapped sedimentary inliers)

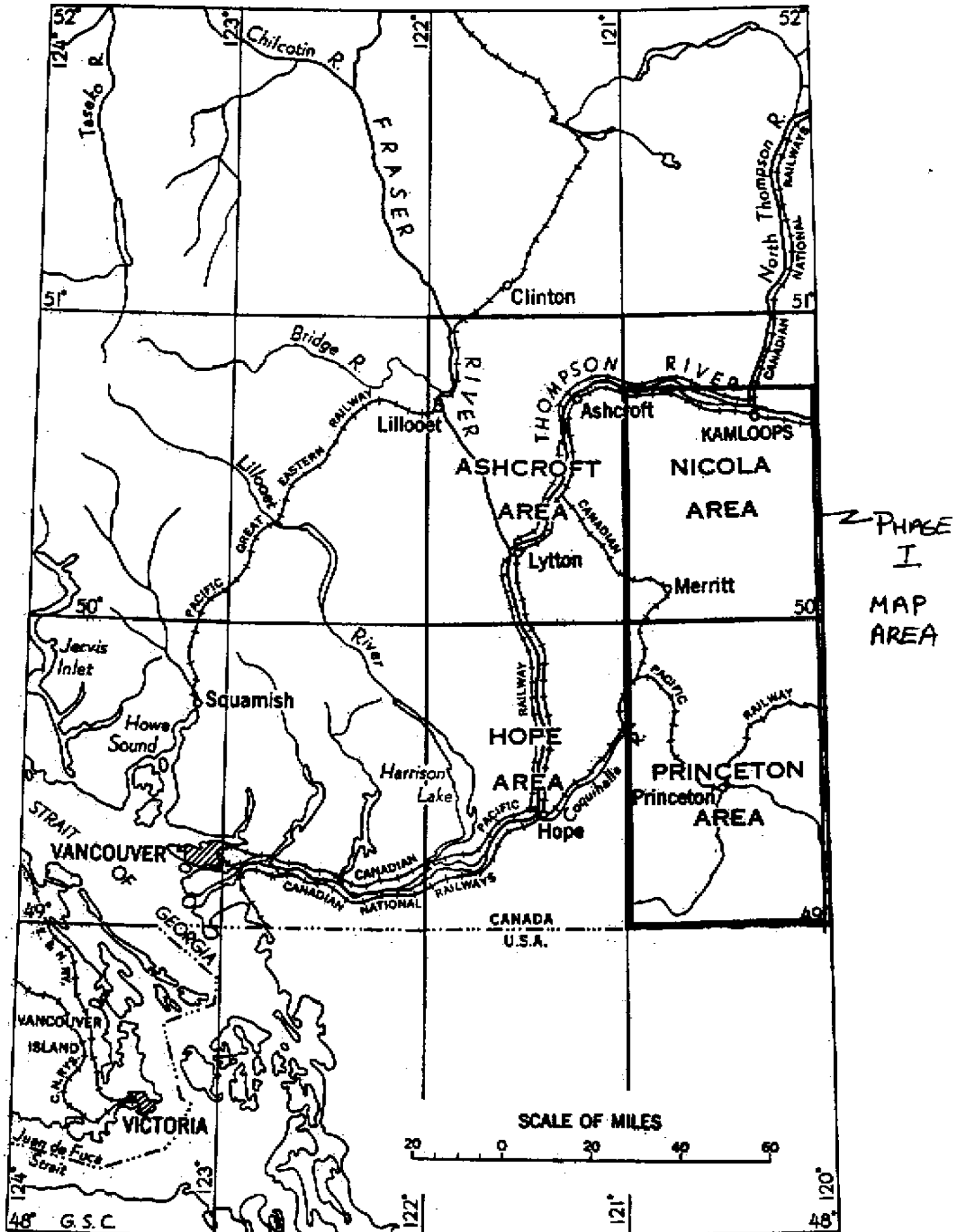

FIGURE 1.

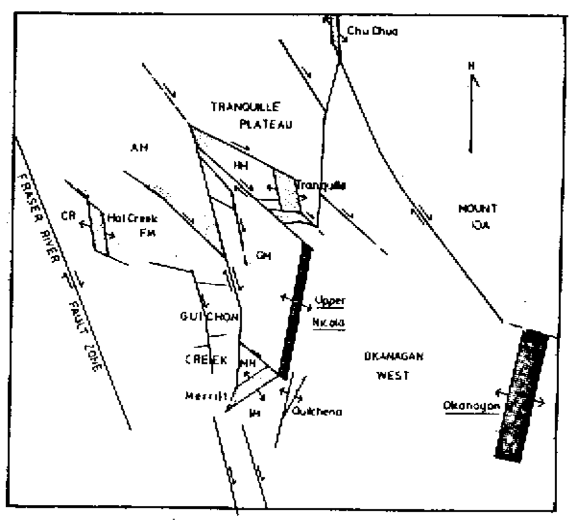

FIG. 7. Idealized sketch of major Eocene tectonic features in south-central British Columbia. Throughgoing faults, extensional grabens, and core complexes divide the area into many blocks. Abbreviations: HH = Hardie Hill; GM = Greenstone Mountain; AH = Arrowstone Hills; FM = Forge Mountain; CR = Clear Range; MN = Merritt North; IM = Iron Mountain.

FIGURE 2.

Priority 3: - Miocene volcanics on GSC maps (unmapped Eocene sedimentary inliers)

Priority 4: - topographic lows in rocks prsently considered basement rock as foci of deposition

Forty-three targets in all were investigated by road and foot traverses. The only target group that yielded undiscovered sedimentary rocks were the Eocene volcanics on basement rock. These sequences appeared as intervolcanic layers.

The dominant lithologies in the sediments were coarse grained. No mudstone or shale was found. Three conglomerate outcrops contained carbonaceous logs, but no coal was found within the study area.

Follow-up Work

Information for this phase was brought together into a single binder. This data consists of the final report (Hopkins, 1982), target summaries, traverse descriptions by target, field copy maps and sample lists. In addition, pertinent geology maps, outcrop cards and the 1:50,000 topographic maps used to outline target areas were inserted.

I have plotted all target areas on two single 1:250,000 topographic maps (Ashcroft 92I and Hope 92H). These areas have been coded according to level of coverage achieved (attached). Two targets of possible interest were not covered adequately and may warrant future consideration.

1) Target 11 - located near Similkameen Flats south of Princeton (see figure 3)
   - inadequate coverage due to obstructed roads
   - mapped by G.S.C. as Princeton Group andesite and basalt
   - might be associated with coal-bearing sediments as is the case in the Princeton coalfield

2) Target 31 - located north of Kamloops Lake and straddling the Tranquille River (see figure 4)
   - report recommends more work could be done
   - area is fairly large and has been mapped as Kamloops group volcanics
   - coal-bearing Tranquille sediments have been reported interbedded with the lavas
   - work should be concentrated to the north on the Bonaparte Lake map sheet.

(Refer to attached figures for these two target locations)

Recommendations

The above areas are what I would consider the most likely coal-bearing targets by virtue of their size and their relationship to previously

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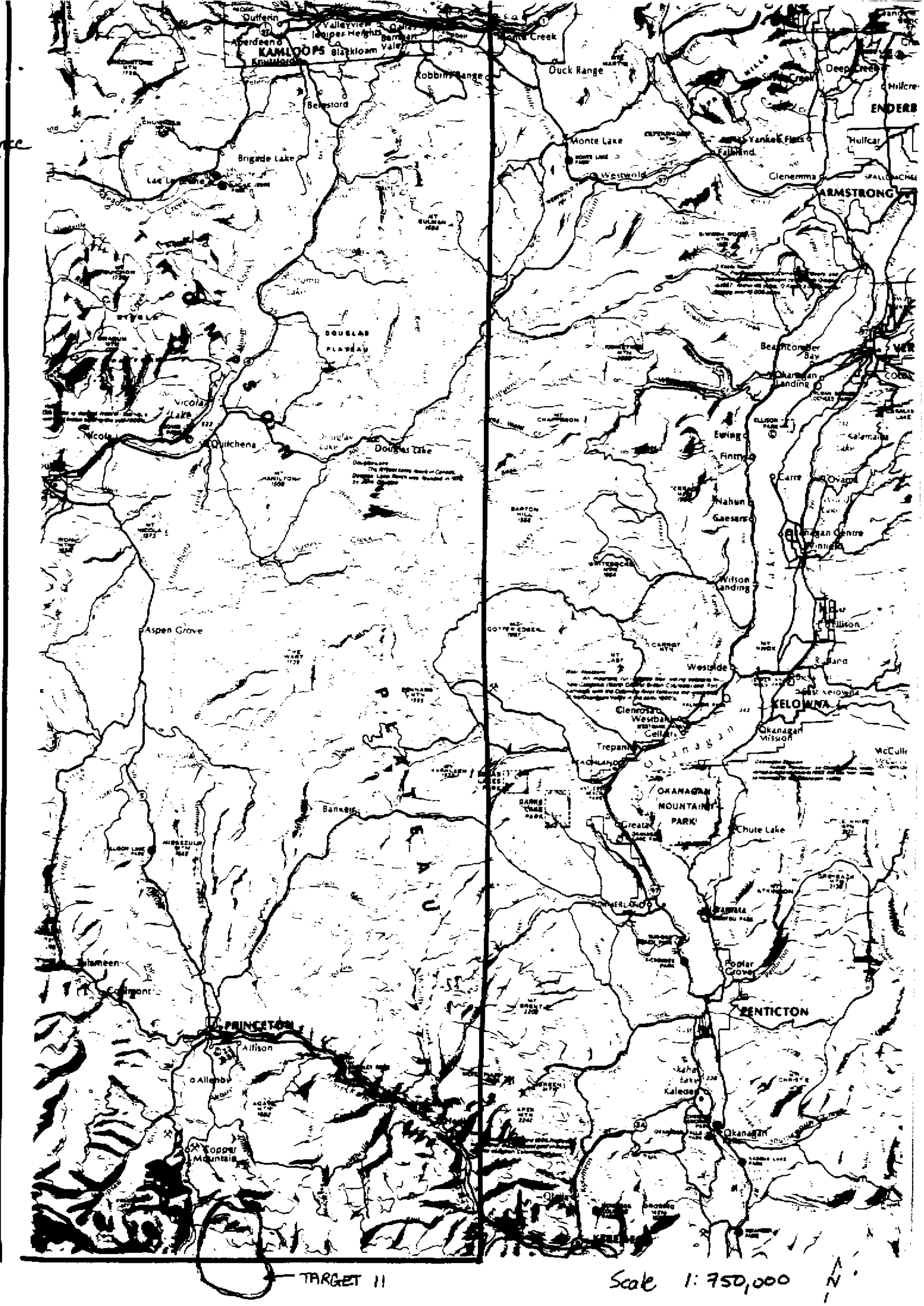
PHASE I

Figure 3.



TARGET 11

Scale 1:750,000

N

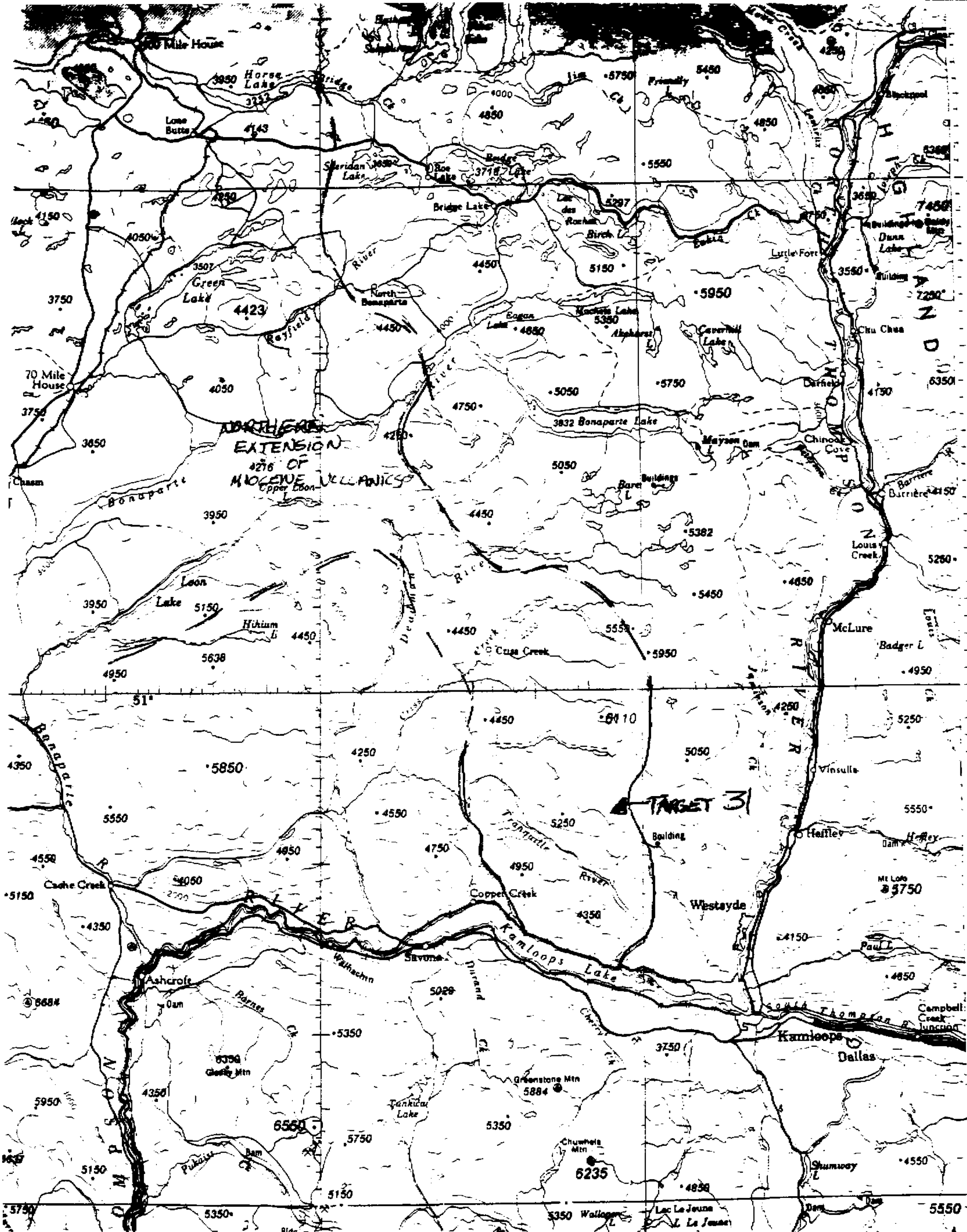


Figure 4 Scale 1:500,000 N

TABLE OF FORMATIONS

SYSTEM AND SERIES		STAGE	FORMATION		LITHOLOGY	THICKNESS (METERS)
CRETACEOUS	UPPER CRETACEOUS	CENOMANIAN AND LATER	KINGSVALE GROUP	DIVISION D	ANDESITIC AND BASALTIC TUFFS AND BRECCIAS	1220 m+
				DIVISION C	VOLCANIC CONGLOMERATE, GREYWACKE, SHALE AND CONGLOMERATE	61 m– 183 m+
				DIVISION B	ANDESITIC AND BASALTIC TUFFS AND BRECCIAS, MINOR LAVAS	1830 m+
		? ?		DIVISION A	PEBBLE AND COBBLE CONGLOMERATE, GREYWACKE, SHALE, SILTSTONE	1650 m+
	LOWER CRETACEOUS	UPPER (?) MIDDLE AND	TAYLOR CREEK GROUP		CHERT PEBBLE CONGLOMERATE, BLACK BANDED LIMY SHALE, GREEN TUFFS, VOLCANIC BRECCIAS, ANDESITE AND BASALT	3230 m+
		LOWER ? ALBIAN ?	JACKASS MOUNTAIN GP.	DIVISION C	GREYWACKE, SHALE, THIN PODS AND LENSES OF CONGLOMERATE, ARKOSE	2440 m+
		APTIAN		FRENCH BAR FORMATION (DIVISION B)	BOULDER CONGLOMERATE, MINOR LENSES OF PEBBLE AND COBBLE CONGLOMERATE, GREYWACKE, ARKOSE	610 m– 915 m+
				DIVISION A	GREYWACKE, SHALE, THIN BEDS OF CONGLOMERATE SIMILAR TO DIVISION C	1220 m+
			PROBABLE MAJOR UNCONFORMITY WITH JACKASS MOUNTAIN GROUP; POSSIBLE DISCONFORMABLE RELATION WITH TAYLOR CREEK GROUP			
			RELAY MOUNTAIN GROUP			

(JELETZKY AND TIPPER, 19

discovered coals. I believe that most of the rest of the project area has been adequately covered with no success and therefore no further mapping is recommended.

The Hat Creek deposit was discovered on the basis of only a single creek exposure of coal. Other coal deposits, then, could be present but not well exposed. Remote sensing devices (gravity or other geophysical methods) may be the best way to explore for sub-volcanic coal-bearing sediments.

The targets that I have indicated could both be explored in under two weeks. I would consider the entire area as low priority due to the fairly extensive mapping coverage in the past by this department, other mining companies and the G.S.C.

CHILCOTIN RECONNAISSANCE - 1983 and 1984

The objective of the Chilcotin reconnaissance (figure 5) was to locate the sedimentary sequence which represents the transition between the marine and terrestrial environments and which ideally would hold the greatest potential for coal accumulation.

Regional Geological Setting

The Tyaughton Trough is a large Jurassic - Cretaceous depositional basin in southwest British Columbia. Marine deposits were lain down during the Upper Jurassic and Lower Cretaceous. Uplift in the Lower Cretaceous caused a shift in the trough toward the east. This successor basin was then filled with marine Taylor Creek and non-marine Jackass Mountain Group sediments. Sedimentation and subsidence continued with an increase in non-marine deposition. The stratigraphy was then complicated by post-depositional faulting (see figure 6). Plutonic and volcanic activity took place both before and after deposition within the Tyaughton Trough (see figures 7 and 8).

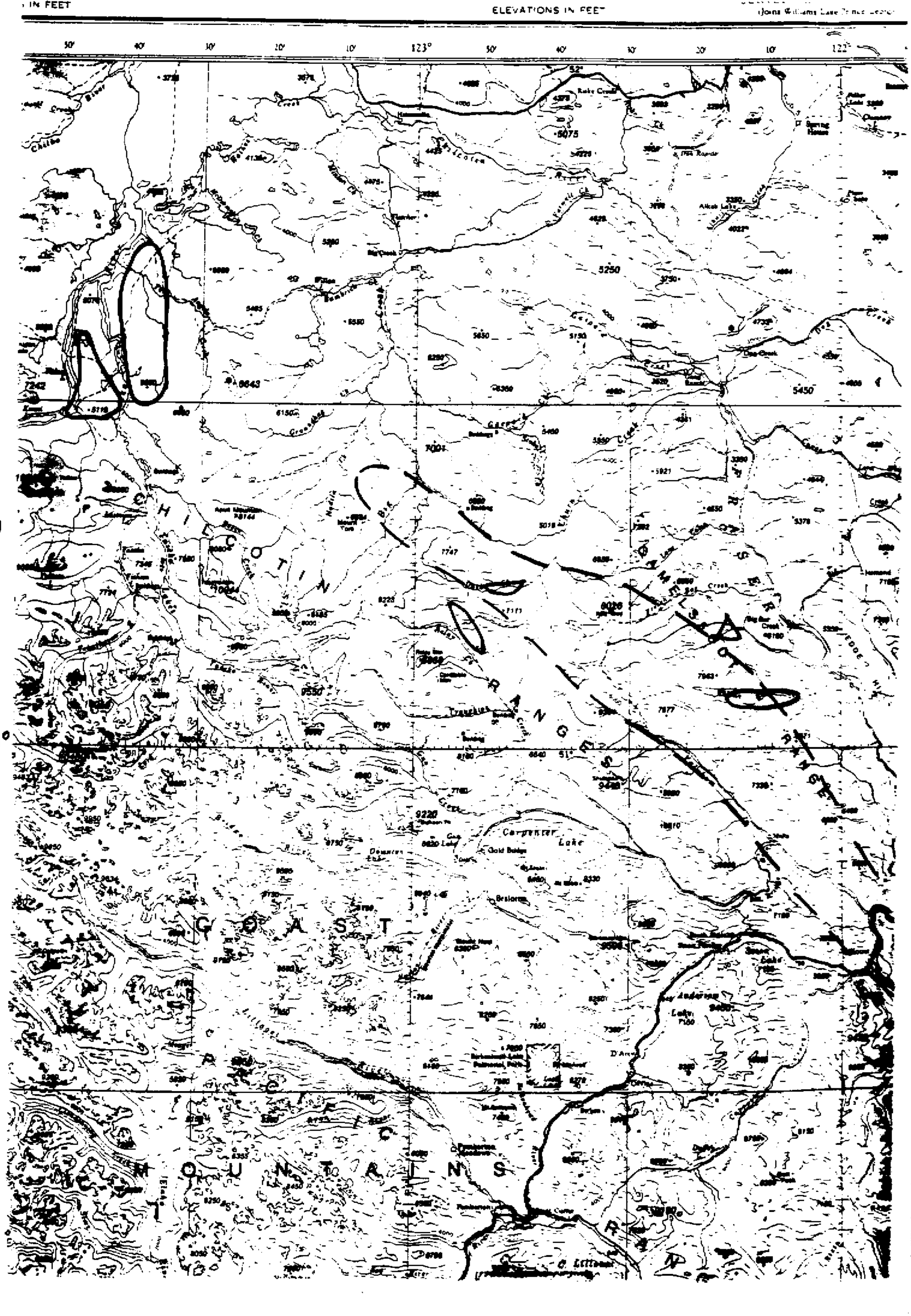
Field Work - 1983

The 1983 reconnaissance team attempted to build a stratigraphic section of the Jackass Mountain group. Because the marine/terrestrial boundary lies somewhere within the Jackass Mountain succession, it is thought to hold the greatest potential for coal deposition. No coal has been reported within this group, however, carbonaceous wood and plant fragments are present.

The purpose of building a stratigraphic section was to:

- o identify sedimentary structures and lithologies that would indicate the zones that favour coal development,

Figure 5

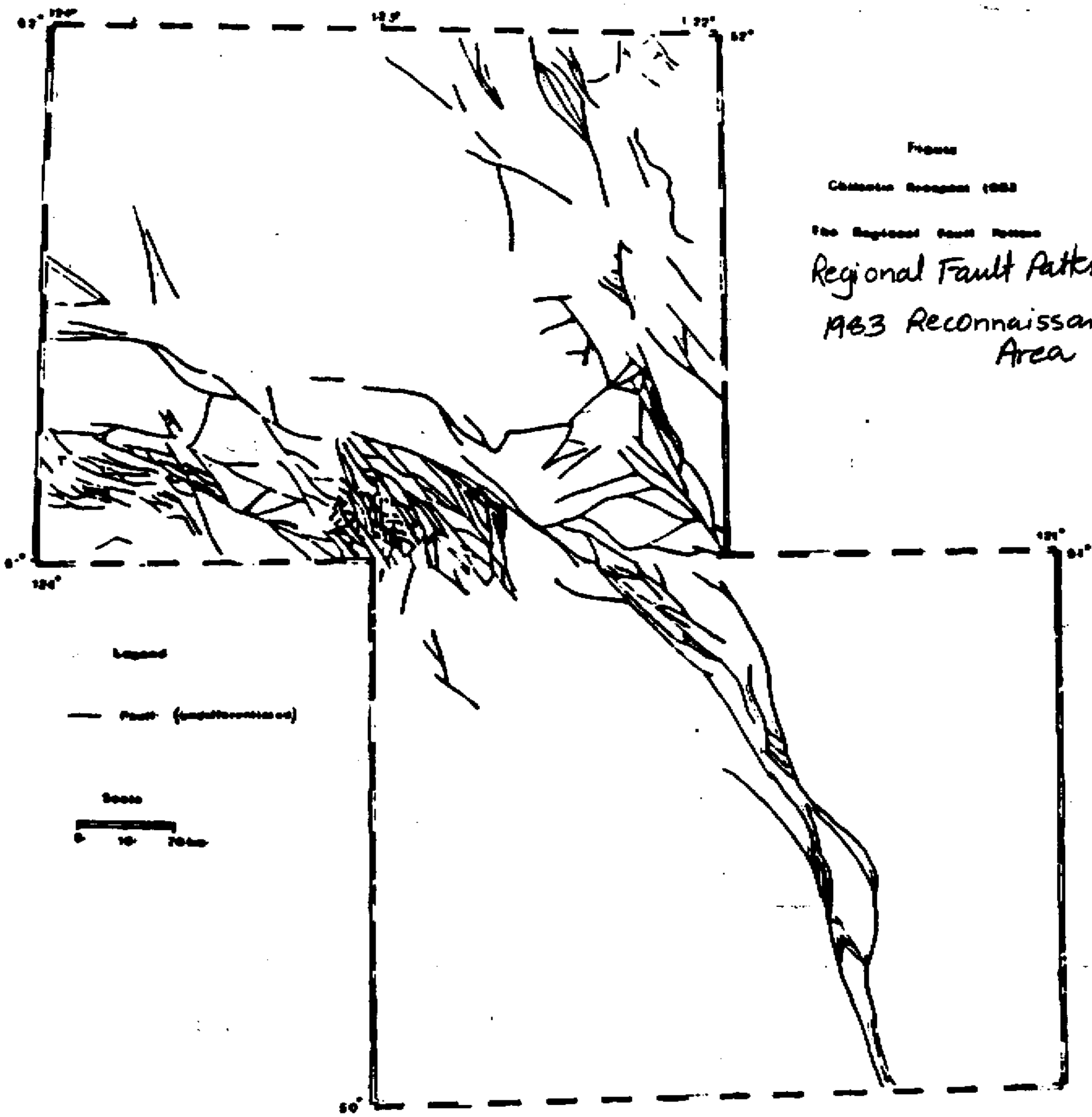


NTS 92 NE

1983 Recon. Area

1984 Recon. Area

Chilcotin



Regional Fault Pattern
1983 Reconnaissance Area

Figure 6

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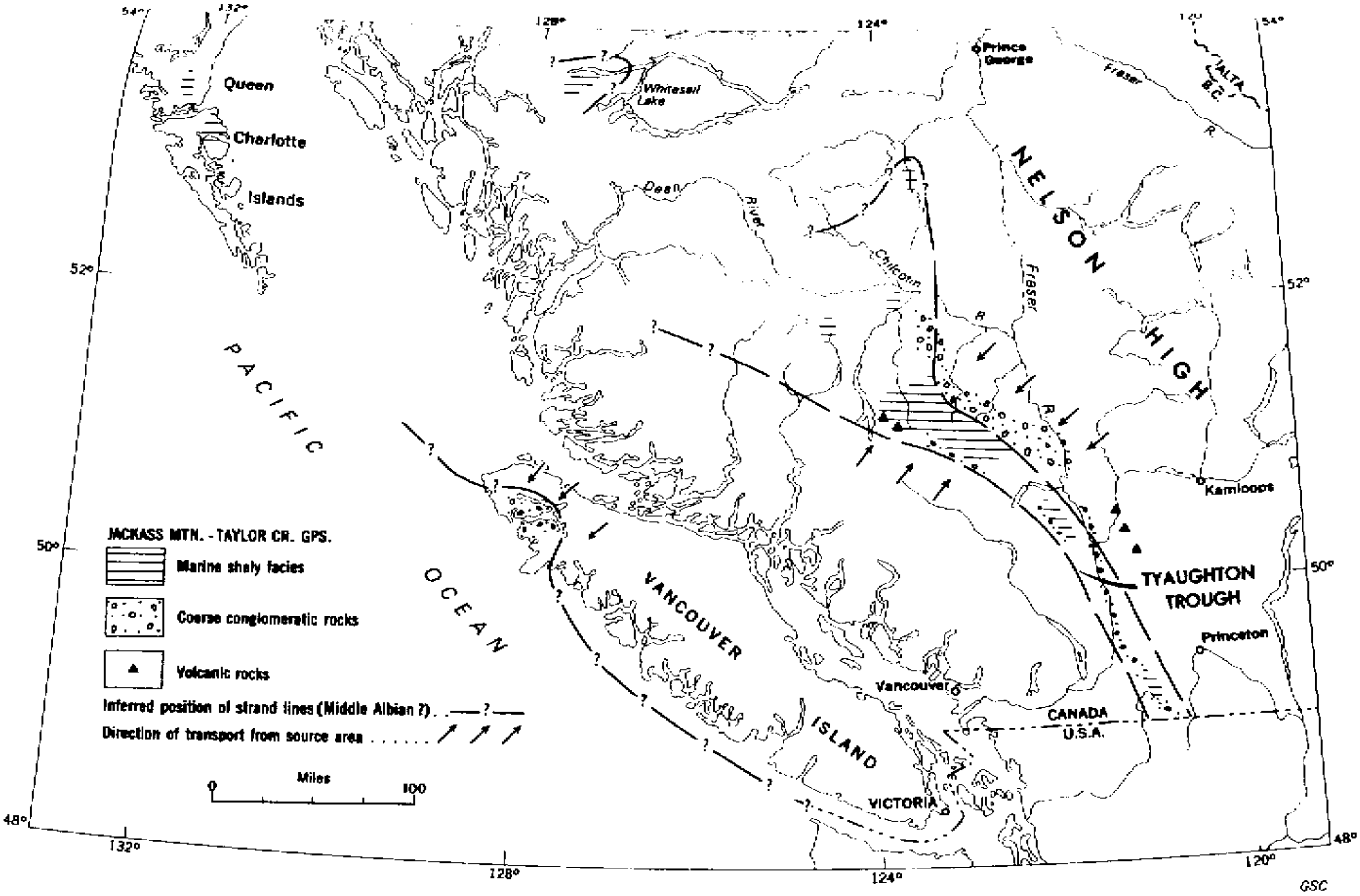


Figure 7 Distribution of volcanic and sedimentary rocks of Aptian to Albian time.

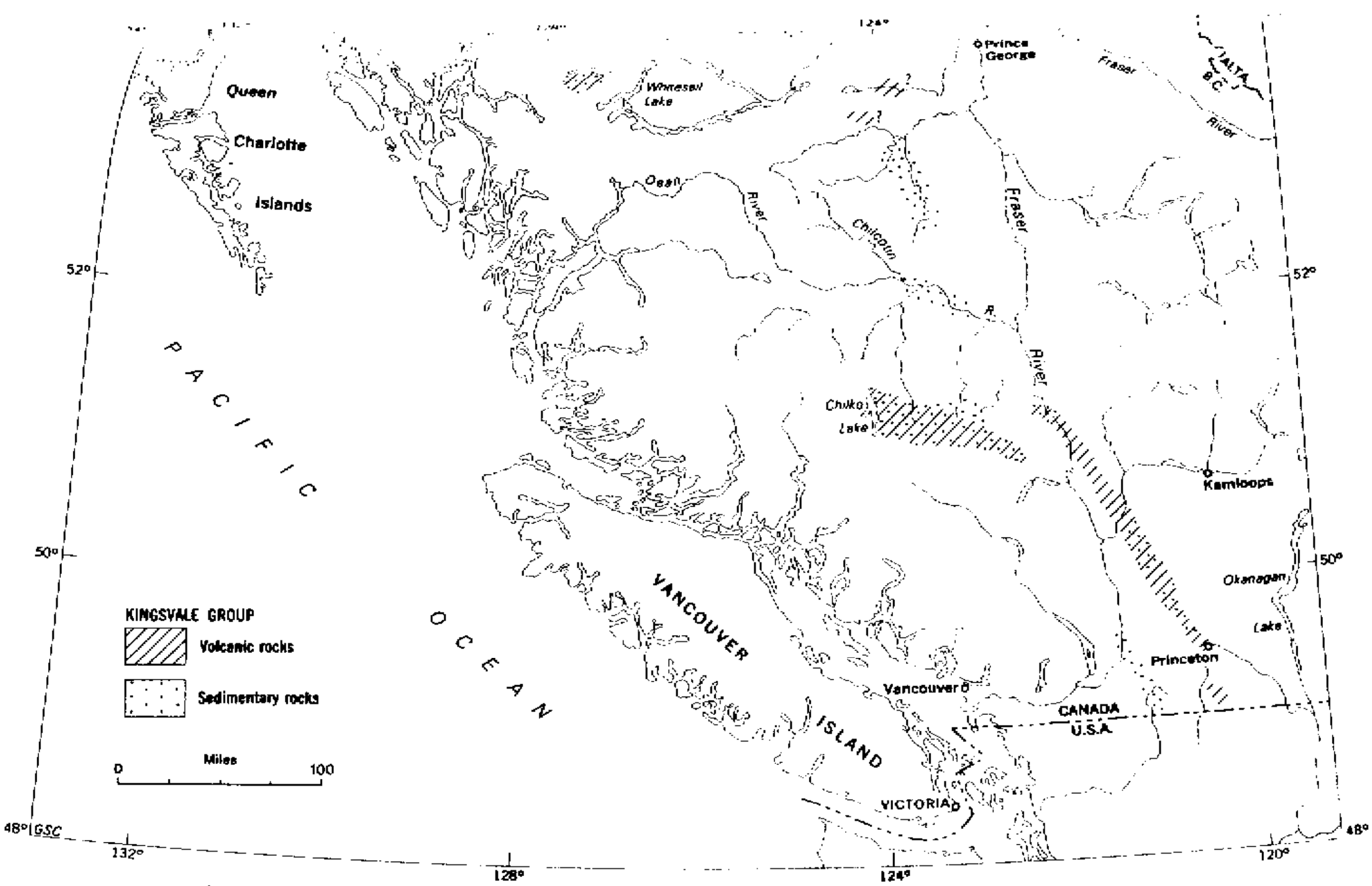


Figure 8 Distribution of volcanic and sedimentary rocks of late Albian to middle late Cretaceous time.

o identify distinctive horizons within the sequence that could be used as markers.

The Jackass Mountain Group is 4800 m thick and divided into three divisions; A, B, and C.

Division A - unconformably overlies the marine Relay Mtn. Group (see stratigraphic column)
- alternating beds of fine to medium grained carbonaceous litharenite, dark carbonaceous shale
- large pieces of carbonaceous wood and high concentrations of plant fragments
- 1200 m thick
- not well studied during the 1983 field season
- Al Peach suggests that this division is an alluvial flood plain environment and is the most prospective area in which to find coal

Division B - overlies Division A
- cobble conglomerate and coarse grained sandstone
- 610 - 915 metres thick
- Al Peach suggests an alluvial fan conglomerate - type environment

Division C - overlies Division B
- greywacke, arkose, siltstone, shale and pebble conglomerate
- 2440 metres thick

The Chilcotin area has only a few access roads and these are of poor quality. During July and August, six fly camp locations were established as centres of activity.

The 1983 mapping project concluded that Division A would be the most prospective portion of the Jackass Mountain and recommended further work for the following year. Also recommended was a look at the Upper Cretaceous Kingsvale Group.

Field Work - 1984

This program was designed to further explore those areas delineated in the 1983 program. Six targets were chosen; three were underlain by Kingsvale group sediments and three by sediments of the Jackass Mountain group Division A (figure 9).

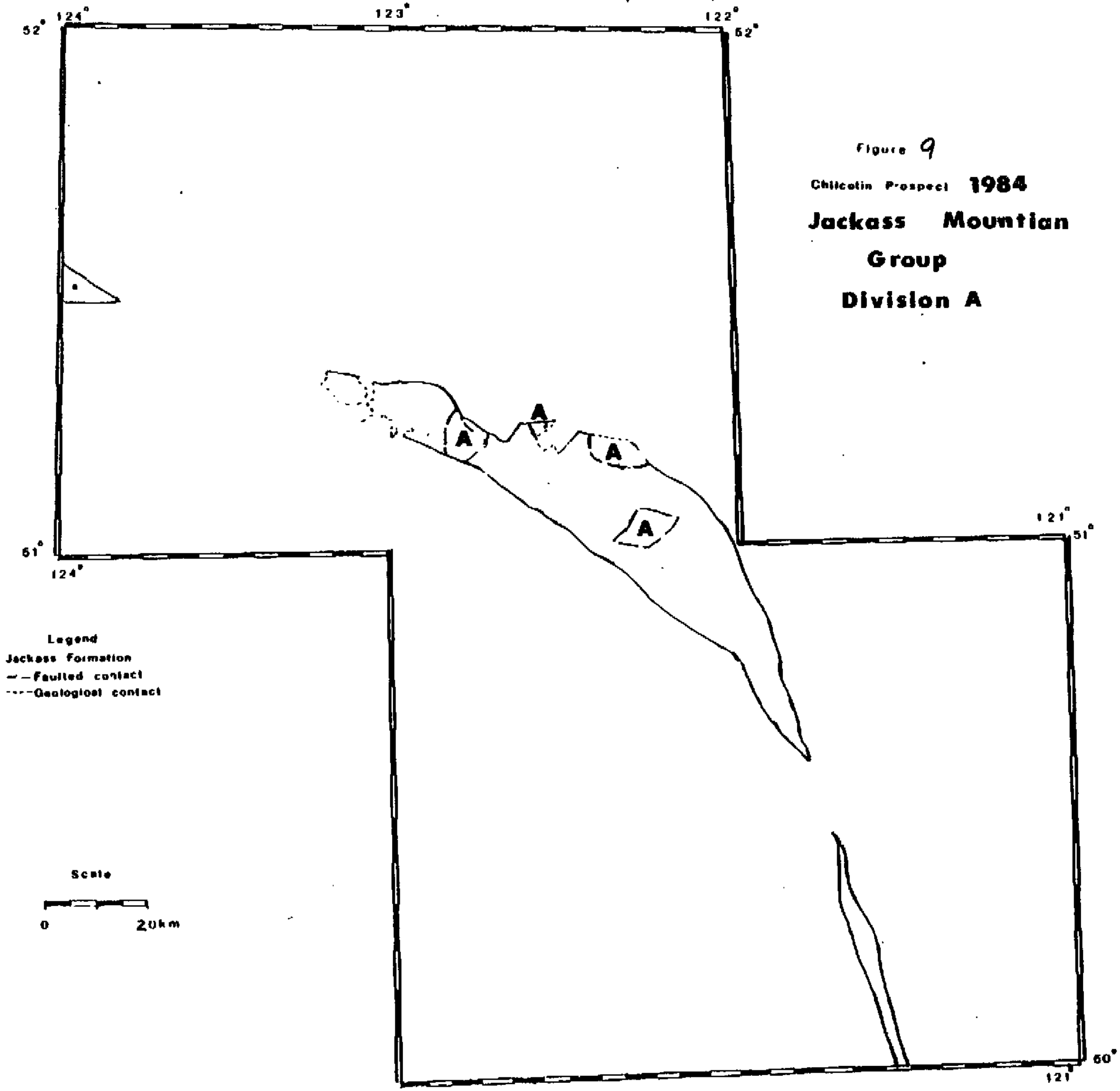
The Kingsvale Group consists primarily of volcanic rocks that lie unconformably above the Spences Bridge Group. In places there is a sedimentary zone that occurs at the base of the Kingsvale. This zone varies between 60-300 m thick. The entire group is more than 4500 metres thick and has been subdivided by Jeletzky and Tipper into four mappable units (base to top):

Figure 9

Chilcotin Prospect 1984

Jackass Mountian Group

Division A



Division A - interbedded buff to greenish grey greywacke, coarse to fine chert and volcanic pebble conglomerate, siltstone and soft dark grey shale. Wood fragments and plant remains are abundant.

Division B - andesitic and basaltic tuffs and breccias, minor lavas.

Division C - volcanic pebble and cobble conglomerate, greywacke and shale.

Division D - andesitic and basaltic tuffs and breccias.

The mapping of these groups was accomplished by fly camps and helicopter traverses (see map).

The 1984 program concluded that the sediments in both groups "represented an area where the overall energy of the flow regime and unstable nature of the basin prevented proper conditions for coal swamp accumulation" (A.R. Peach, 1984). Some coaly material and plant fragments were observed, but no coal occurrences of economic value were found.

The recommendation at the end of the 1984 season was to do no further work in the areas covered in 1983 and 1984.

Follow-up Work and Recommendations

These programs were well documented and organized. Very little follow-up work was needed, except to read through the field reports as well as some G.S.C. papers. The basic premise used in the Chilcotin exploration was good - ie. look for coal at the marine/continental boundary. If coals were found in the Cretaceous age sediments, they would be higher in rank than those in the Tertiary basins and would therefore be more suitable for export. Intense faulting and lack of good marker horizons will make this task difficult.

The lower Kingsvale and lower Jackass Mountain Groups present promising targets in areas to the northwest (figure 10). I would suggest that this be considered a target area for B.C. reconnaissance utilizing the same approach as the 1984 program. Access will again be a problem, however, it is those areas that have not been well looked at in the past that have the best chance of an undiscovered coal find.

B.M. Wright

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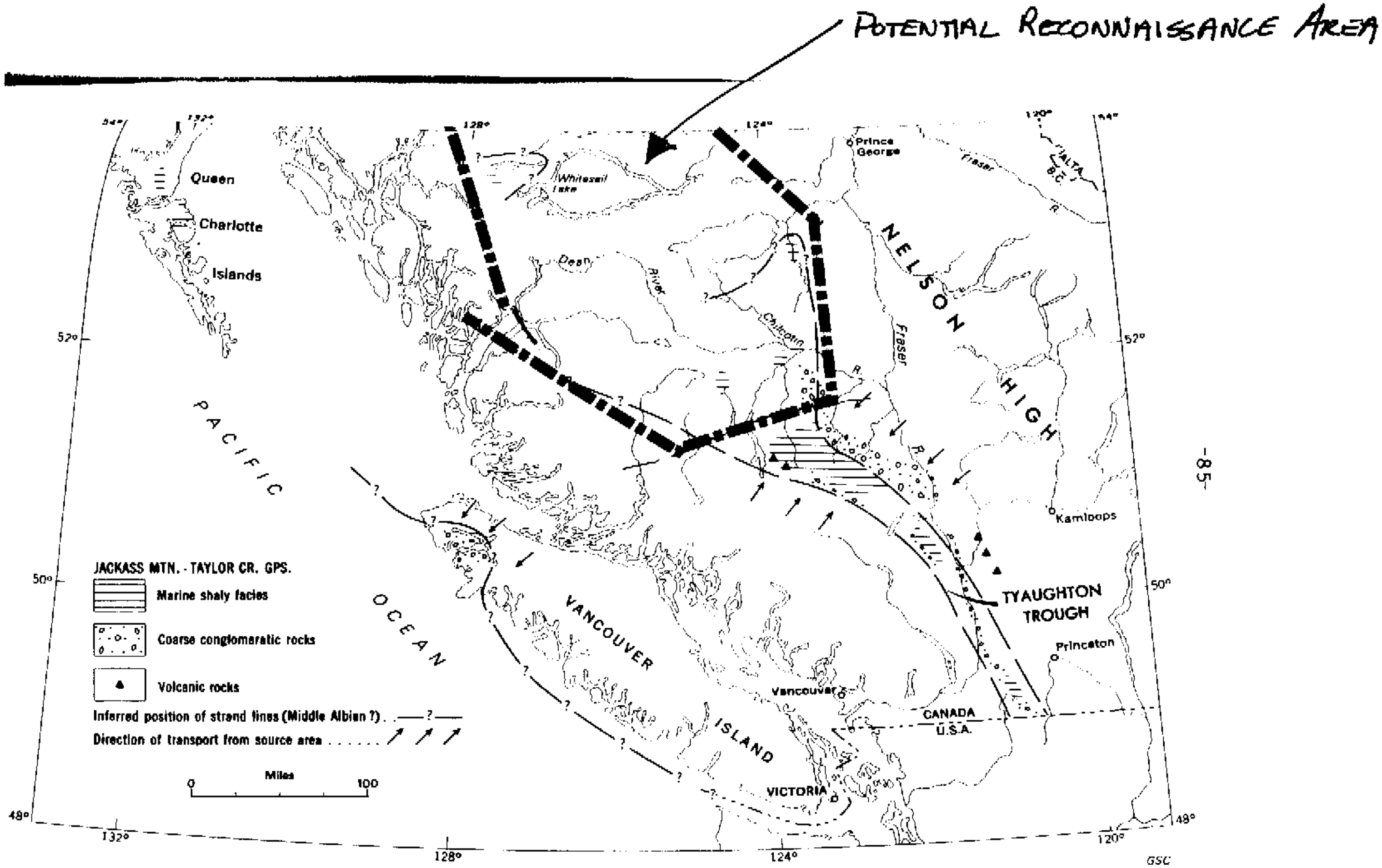

Figure 10 Distribution of volcanic and sedimentary rocks of Aptian to Albian time.

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Dolmage, Campbell and Associates Ltd., 1975: "Similkameen Coal", in Coal Resources of British Columbia IV; British Columbia Hydro and Power Authority.

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Maps

Ashcroft Map 1010A, One Inch to Four Miles, by Duffell and McTaggart, 1945-1947.

Nocola Map 886A, One Inch to Four Miles, by Cockfield, 1939-1943.

Princeton Map 888A, One Inch to Four Miles, by Rice, 1939-1944.

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Attachments

KEY REFERENCES
CHILCOTIN RECONNAISSANCE

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H. Hopkins; Chilcotin Prospect Update, 1983-09-06

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A.R. Peach, H.E. Hopkins, R.L. Berg; B.C. Reconnaissance Technical Review (Presentation), March 22, 1984?.

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Roddick, J.A. Woodsworth, G.J. and Hutchison, W.W.; Pemberton Map Area (92J), 1:250,000, 1977

B.C. Reconnaissance
Phase II + III

MEMORANDUM

86 09 04

TO: File - 93B, 93G

FROM: L. Klatzel Mudry

SUBJECT: EVALUATION OF THE UPPER FRAZER RIVER FORMATION, QUESNEL AREA, CENTRAL BRITISH COLUMBIA

Introduction

Coal occurances along the Frazer River have been mapped and drilled by a variety of government and industry geologists. In 1982, Esso Resources completed a mapping program and recommended that:

1. additional mapping on the Frazer River be conducted when the water was at a low level and;

2. drilling should be completed to evaluate areas with heavy glacial cover.

As a follow up to the 1982 program, I have evaluated the previous work and made a literature review on this area to determine the need for an additional program.

Previous Work by Esso

In 1979 B.D. Vincent recommended that application be made for coal licenses over an 8195 ha. area, north of Australian Creek, on the east side of the Frazer River. A drilling and mapping program was targeted to evaluate the Upper Frazer River Formation. Interest in this area was kindled from the then, recently published G.S.C. Paper 78-1B by P.S. Graham; "Geology and Coal Resources of the Tertiary Sediments, Quesnel-Prince George Area, British Columbia". The licenses were never applied for, however, and interest in the area died until 1982.

The 1982 Quesnel program was part of a regional exploration program conducted to evaluate the coal potential of central British Columbia. The Frazer River and its tributaries were explored in the Quesnel and Australian Creek areas (see attached 1:250,000 topo maps with target areas).

General Geology

The Upper Frazer River formation consists of 200 metres of mudstone, siltstone, sandstone, conglomerate and coals. The coals are reported to vary in thickness from a few centimetres to four metres and are discontinuous. The coals were deposited in fluvial and lacustrine sediments. Graham (1978) states that the lateral migration in the river valley did not exceed six kilometres, however, the facies change rapidly.

Mappping and drilling data have confirmed the rapid facies changes. In G.S.C. open file 599, three drill holes completed by the G.S.C. are described. Drill holes Q-2, and Q-3 are only 1400 metres apart; drill hole Q-2 is predominantly shaley and very carbonaceous with only a thin conglomerate bed at the base. Q-3 on the other hand is predominantly conglomerate with interbedded shales and significantly less carbonaceous material. Q-1 was drilled near Australian Creek 30 kilometres south of the previous holes. A parted coal seam approximately two metres thick occurs at 61 metres. Other thinner seams occur below the main seam while conglomerate exists at the base of the hole. Other companies have drilled near Australian Creek (1930's, Manalta 1972) but the results have all been discouraging.

The coal quality is reported to vary from lignite to subbituminous B and C.

Although similar aged sediments are well preserved in Tertiary Basins throughout central and southern B.C., the Frazer River valley was not condusive to sediment preservation. Mathews and Rouse (1981) suggest that the river occupying the valley during the Miocene flowed north and that the valley was a major drainage channel controlled by faulting. Initiation of the southward flow and subsequent regional uplift would therefore, diminish the propensity to preserve previously deposited sediments.

Outcrop exposures are limited in the Frazer River area because the Tertiary sediments are covered with Quaternary deposits.

Results from the 1982 Program

Thin coal seams on the banks of the river have been reported. One of these seams was visited during a helicopter reconnaissance of the Frazer River. The seam was near Alexandria on the north side of the river. 3.5 metres of coal was exposed as well as 1 - 1.5 m of clinker. The coal measures consisted of interbedded mudstones and sandstones containing petrified wood and ironstone concretions. The bedding orientation is 85°/10°S. Coal lenses were also seen in the strata elsewhere but the 1982 report concluded that the stratigraphic sequence represents a depositional environment with a high energy regime. This high energy regime would not accommodate extensive coal swamp development. In areas where the mapping was inconclusive, drilling was recommended to test the Upper Frazer River Formation.

Recommendations from 1986 Review

The purpose of the 1986 review of B.C. by Brenda and myself was to establish if further work is warranted in previously explored areas. Due to the paucity of coal outcrops, the nature of the stratigraphic section and discouraging results from previously published work, I recommend that no further work be carried out in the Quesnel area to evaluate the Upper Frazer River Formation. Although coals exist in the area, they do not appear to be extensive enough to support a commercial power generation plant, nor compete with the Hat Creek deposit in a development seriatim.

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BOWRON RIVER COAL AREA.[1]

(From paper by C. F. J. Galloway.)

This promising field is situated about 45 miles due east of Fort George, and 80 miles north of Barkerville. Bowron[2] river

[1]The Canadian Mining Journal, May 15, 1912, p. 335.
[2]Bowron river is the new name for Bear river which enters the Fraser river east of Fort George and rises near Barkerville.

803

flows through the field in a northwesterly direction in its course from near Barkerville to the Fraser.

The coal-measures lie in a flat basin surrounded by hills consisting of crystalline rock, which define its limits in certain directions, but its actual extent cannot be definitely determined except by extensive drilling, as the ground is entirely covered by alluvial sand, gravel, and clay, and bed-rock is only exposed in a few places in the bed and banks of the river.

Igneous intrusions occur in a few places, locally disturbing the measures, but the greater part of the area seems to be entirely free from such disturbance.

An area of fourteen sections of one square mile each is held by Mr. A. E. Hepburn, of Vancouver, B.C., and within this an area of ten and a half square miles is probably underlain by the coal-measures in an undisturbed condition.

A very limited section of the measures is exposed; but at one place three workable seams outcrop in the bank of the river.

Some development work has been done on these, proving them to have the following sections:—

	Total thickness.	Total coal.
Upper seam	10 ft. 4 in. +	9 ft. 2 in. +
Middle seam	5 ft. 0¾ in.	4 ft. 2¼ in.
Lower seam	11 ft. 11½ in.	7 ft. 8¾ in.
Total coal		21 ft. 1 in. +

The two lower seams, and the lower portion of the upper one, are to a certain extent interbedded with sandstone and shale, as is seen from the above sections; but the upper seven feet of the upper seam contains only one band of four inches of sandstone. A farther thickness of three or four feet of clean coal is reported as existing in this seam above that measured. This the writer could not see, the open-cut in which it was exposed being filled with mud, and being so little above the level of the river that the mud could not be removed. This additional thickness must, therefore, be added to that given above, which represents the measurements acutally made by the writer.

In the measures immediately below these, numerous thin seams of coal occur, up to three feet in thickness, separated by thin bands of shale and sandstone, and it is quite possible that some of these will come together, forming workable seams under portions of the area. Other thin seams appear elsewhere, apparently on a slightly higher horizon.

Taking the thickness of workable coal in the three seams exposed, the area controlled by Mr. Hepburn may be estimated to contain on a very conservative basis 150 million tons of coal.

The coal is bituminous, bright, and fairly hard and, in the crucible assay, yielded an excellent hard and firm coke.

The following analyses were made by Mr. J. O'Sullivan, F.C.S., of Vancouver:—

	"A."	"B."	No. 1.	No. 2.
Hygroscopic water	3·5	3·5	6·0	4·0
Volatile combustible matter	37·5	40·8	37·3	44·4
Fixed carbon	54·0	48·3	54·3	46·9
Ash	4·0	6·0	1·0	3·5
Sulphur	1·0	1·4	1·4	1·2
	100·0	100·0	100·0	100·0

At the point where the three workable seams are exposed the measures dip at an angle of about 43 degrees; but this appears to be on the flank of an anticlinal roll, and the dip moderates towards the northeast, so that the measures may reasonably be expected to lie comparatively flat under the greater part of the area.

As the ground underlain by the coal-measures is all flat bench land, the coal will have to be worked entirely from shafts, practically none being above drainage level.

The ground is well timbered with black pine and spruce suitable for mining purposes.

An inexhaustible supply of water is furnished at all seasons by the Bear river.

This coal-field lies within about fourteen miles of the line of the Grand Trunk Pacific railway in the valley of the Fraser, above the canyon, being separated from it by Seymour pass, a low divide, only some 300 feet higher than the coal exposures, the construction of a railway over which will offer no difficulties.

Target No's.

Map Sheets: 93G ——— 75a insufficient coverage —
75b not covered

93B
58 barrensst. — 75c " "
59 coal outcrop — 75d " "
60 only check from air — 75e " "
61 ? — 76 " "
62 - covered one creek trav. — 77a " "
63 - ~~not found~~ — 77b " "
67 - covered — 78 insufficient coverage
68 - coverered on traverse — 79 not covered on foot but flown

80a " " large
80b " "
80c " " "
81a " " - large
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89 "
90
91a sufficently
91b
92 covered sufficently small
93 not covered small
94a
94b

803

GEOLOGICAL SURVEY OF CANADA
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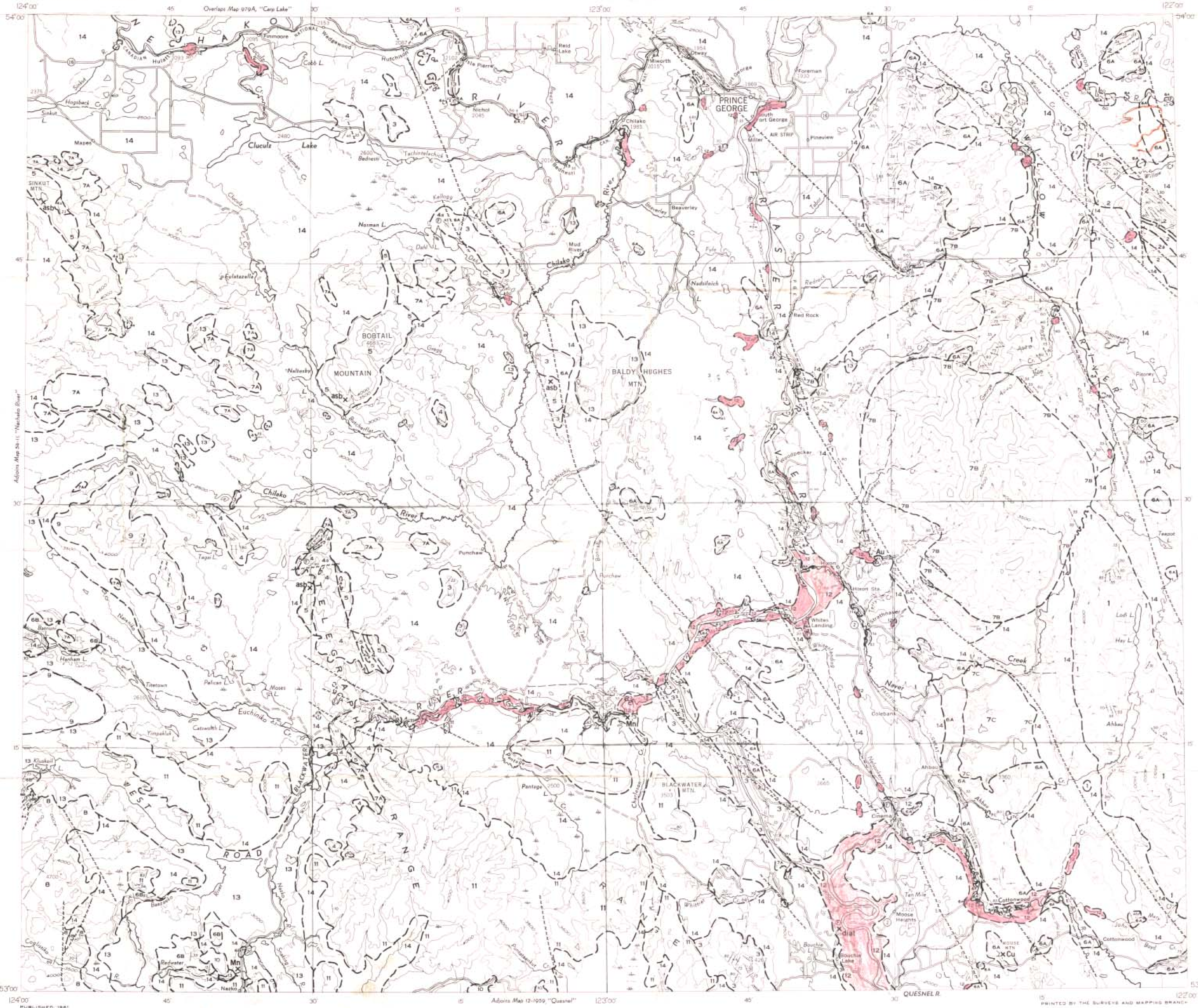
ADVANCE EDITION

SHEET 93 G



LEGEND

CENOZOIC

QUATERNARY
PLEISTOCENE AND RECENT
14 Till, gravel, sand, clay, and silt

TERTIARY
MIOCENE AND/OR LATER
ENDAKO GROUP
13 Basalt, andesite, related tuff and breccia

MIOCENE (?)
12 Conglomerate, sandstone, mudstone, lignite, and diatomite

PALEOCENE (?) TO OLIGOCENE
11 Andesite, basalt, breccia, and tuff; 11a, minor sediments
10 Rhyolite, dacite, trachyte, related tuff and breccia; minor sediments
9 Andesite, basalt, breccia, and tuff; minor rhyolite

MESOZOIC

JURASSIC
MIDDLE JURASSIC
HAZELTON GROUP (in part)
8 Green to dark grey andesite and basalt, related pyroclastic rocks, chert-pebble conglomerate, argillite, and greywacke

LOWER JURASSIC AND (?) LATER
7 7A. TOPLEY INTRUSIONS: granodiorite, quartz diorite, diorite, biotite granite
7B. Quartz monzonite, monzonite, and granite; minor diorite
7C. Granodiorite, diorite, granite, minor gabbro

TRIASSIC AND JURASSIC
UPPER TRIASSIC (?) AND LOWER JURASSIC (?)
6 6A. Eastern group: argillite, greywacke, green, grey, black, purple andesite and basalt and related tuffs and breccias; minor conglomerate and limestone
6B. Western group: chert-pebble conglomerate, red, brown, and black shale, greywacke; minor purple to green andesite

TRIASSIC
POST-PERMIAN, PRE-UPPER TRIASSIC (?)
5 Serpentinized peridotite, serpentinite

PALAEOZOIC

PENNSYLVANIAN (?) AND PERMIAN
CACHE CREEK GROUP
3 4 3. Black to dark grey ribbon chert, black argillite
4. Green to black basic volcanic rocks, grey limestone; minor argillite and chert; 4a, mainly grey limestone

MISSISSIPPIAN (?)
SLIDE MOUNTAIN GROUP
2 Grey and buff chert, argillite, basalt and related pyroclastic rocks; 2a, diabase

CAMBRIAN AND/OR LATER
LOWER CAMBRIAN AND/OR LATER
CARIBOO GROUP
1 Grey micaceous quartzite, black to dark grey paylite and argillite; minor grey limestone

Geological boundary (defined, approximate or assumed)
Bedding (inclined, vertical, overturned)
Schistosity (inclined)
Fault (defined, approximate, assumed)
Anticline (defined, approximate)
Syncline (defined, approximate)
Glacial striae
Fossil locality
Mineral occurrence ×Cu

MINERAL SYMBOLS

Asbestos . . . asb	Gold . . . . . Au
Copper . . . . Cu	Manganese . . . Mn
Diatomite . . . diat	

Geology by H.W. Tipper, 1959-1960

Air photographs covering this area may be obtained through the National Air Photographic Library, Topographical Survey, Ottawa

In response to public demand for earlier publication, Preliminary Series maps are issued in this simplified form and will be clearer to read if all or some of the map-units are hand-coloured

DESCRIPTIVE NOTES

Bedrock is everywhere poorly exposed but outcrops are sufficiently well distributed to permit a reasonable interpretation of the major geological features. Glacial drift, although widespread, is probably not deep. Bedrock is best exposed along major creeks and rivers and on higher hills in the eastern and southern parts of the area.

No fossils have been found in the Cariboo group (1) in this area but the rocks exposed there are believed to be the upper two formations of this group. They are, in part, more highly metamorphosed than in the type area, which is to the southeast in the Barkerville district, due to contact-metamorphic effect of intruding granitic rocks (7B).

Rocks of the Slide Mountain group (2), as here represented, are unfossiliferous but are lithologically identical with part of the group in the type area near Barkerville. Basic dykes and sills (2a) cut the group and may be correlative with the Mount Murray intrusions.

Fossils in the Cache Creek group (3, 4) indicate an Upper Permian age, but possibly the whole period is represented. The group is tightly folded and is structurally complex. The stratigraphic relation of the two units mapped is uncertain.

The ultrabasic rocks (5) are not in contact with the Mesozoic rocks (6A, B) but are confined to areas of Palaeozoic rocks. Many small, unmapped bodies probably occur throughout the belt of Cache Creek group rocks. These ultrabasic rocks are almost completely serpentinized wherever encountered.

The Upper Triassic (?) and Lower Jurassic (?) strata were laid down in two basins separated by a land area of Permian rocks and hence are lithologically dissimilar. The western group (6B) is unfossiliferous but overlies Permian limestone and underlies Middle Jurassic rocks (8). The conglomerates and sandstones of this group resemble somewhat the Lower Cretaceous sediments in the Nazko River valley of Quesnel area. The eastern group (6A) contains poorly preserved Jurassic and Triassic marine fossils. Although the unfossiliferous rocks east of Tabor Lake and along Willow River are lithologically similar to known Triassic rocks, they also, in part, resemble the Mississippian (?) rocks (2).

The Topley intrusions (7A) disappear beneath Tertiary and Quaternary deposits but beneath this cover they may be continuous with lithologically similar granites in Quesnel map-area to the south. The granitic rocks in the east half of the map-area (7B, C) may be in part correlative with the Topley intrusions, but some (7C) apparently intrude Lower Jurassic rocks and may be wholly or in part younger than the Topley intrusions.

The volcanic and sedimentary rocks (8) in the south-western quarter are a direct continuation of a lithologically similar succession in adjoining areas, which are believed to represent the lower part of the Hazelton group, although locally no fossils have been found in them.

The Paleocene (?) to Oligocene volcanic and sedimentary rocks (9, 10, 11) are not clearly defined by palaeontological or stratigraphic information. Unit 10 is believed to be equivalent to the Eocene and Oligocene rhyolitic volcanic rocks in adjoining areas. The andesitic and basaltic rocks of unit 11 are more extensive to the south where they overlie the rhyolites (10). The volcanic rocks of unit 9 are lithologically indistinguishable from some flows of units 10 and 11 although to the west of this map-area they were believed to be older than unit 10. The sedimentary rocks of these units are not extensive, suggesting deposition in many small basins.

The Miocene (?) sediments (12) represent the Miocene drainage system of a northward-flowing ancestral Fraser River. These sediments are poorly consolidated, generally undeformed, and in places indistinguishable from Pleistocene or Recent river gravels. They occur below elevation 2,600 feet.

Basaltic and andesitic flows (13) resemble the Endako group to the west and occupy the same stratigraphic position as that group and the group of plateau lavas farther south. Here, they are essentially undeformed. They are not believed to occur extensively beneath the drift-covered areas of low relief, except north and west of Cluculz Lake.

A relatively thin covering of glacial deposits (14), 5 to 20 feet deep, extends with monotonous uniformity over much of the area. The whole area, including the highest hills, was covered by glacial ice moving in its final stages from the west in the northwest quarter, from the southwest quarter, and from the south in the southeast quarter. Proglacial lake deposits are widespread around Prince George, along Nechako River, and north of West Road (Blackwater) River.

Characteristic of the area is a strong northwesterly trend of fold axes and faults. Local variations occur and the intensity of deformation and metamorphism varies from one group to another. The Cariboo group (1) has been domed by the batholith north of Naver Creek. The Mississippian (?) rocks (2) apparently were thrust to the northeast onto Upper Triassic rocks near Bowron River. The Cache Creek group (3, 4) is more complexly folded and faulted and more metamorphosed than the Mississippian (?) rocks. Mesozoic rocks along Fraser River and eastward are tightly folded and, in places, overturned to the northeast. The early Tertiary rocks (9, 10, 11) are warped into broad open folds and are cut by many normal faults. Late Tertiary rocks are essentially undeformed. The eastern half of the map-area has many northerly to northwesterly trending faults; one that extends southeasterly across the area from near Hutchison is probably an extension of the Pinchi fault to the north.

Chrysotile asbestos has been noted in four ultrabasic bodies (5). Good-quality cross-fibre, up to 1/2 inch long, occurs on Bobtail Mountain. The ultrabasic rocks were not closely examined by the writer and to his knowledge they have not been carefully prospected in the past.

The occurrence of diatomite in map-unit 12 north of Quesnel has been known for many years.

Psilomelane occurs in fractures in Cache Creek chert along the lower West Road (Blackwater) River. A bog manganese deposit of Tertiary or later age occurs along Nazko River valley.

Chalcopyrite occurs disseminated in sheared Jurassic volcanic rocks southeast of Ten Mile Lake.

A lode gold mine was formerly operated by Quesnel Quartz Mining Co. on Hixon Creek. Placer mining for gold has been carried out along Fraser River and its eastern tributaries since the Cariboo gold rush and is still carried on sporadically by a few miners. The Miocene (?) gravels (12) or recent gravels downstream from them appear to be the main source of the placer gold.

PUBLISHED, 1961

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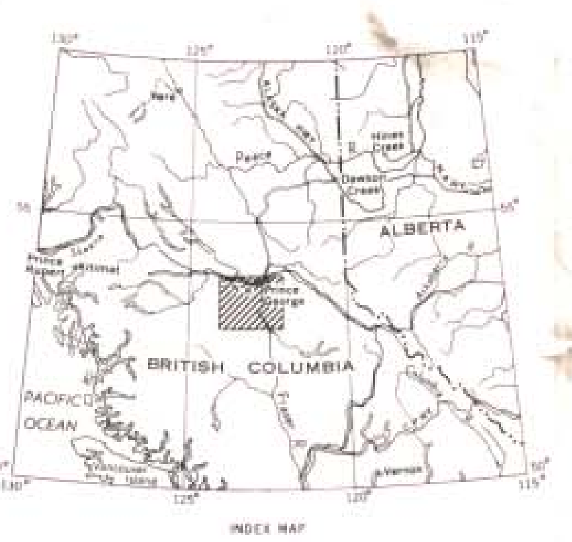


From Bowman 93-H-13 ...

MAP 49-1960
GEOLOGY
PRINCE GEORGE
CARIBOO DISTRICT
BRITISH COLUMBIA

Scale: One Inch to Four Miles $\frac{1}{253,440}$

Miles

4 2 0 4 8 12

Geographical names subject to revision

COPIES OF THIS MAP MAY BE OBTAINED FROM THE DIRECTOR, GEOLOGICAL SURVEY OF CANADA, OTTAWA

LEGEND

Main highway
Other roads (all weather, dry weather)
Cart track
Railway
Intermittent stream
Marsh
Contours (interval 500 feet)
Height in feet above mean sea-level . . . 3503

Cartography by the Geological Survey of Canada, 1961

Approximate magnetic declination, 26° 12' East

MAP 49-1960
PRINCE GEORGE
BRITISH COLUMBIA
SHEET 93 G

00803 (1)

803

GEOLOGICAL SURVEY OF CANADA
DEPARTMENT OF MINES AND TECHNICAL SURVEYS

PRELIMINARY SERIES

SHEET 93 B

LEGEND

CENOZOIC

QUATERNARY
RECENT

9	9a, basalt and basalt breccia; 9b, volcanic ash

PLEISTOCENE AND RECENT

8	Till, gravel, sand, clay, and silt

TERTIARY
MIOCENE AND (?) PLIOCENE

7	Basalt, andesite, related tuff and breccia; minor conglomerate, greywacke, shale and diatomite; 7a, may be Pleistocene; 7b, mainly sediments

EOCENE AND/OR OLIGOCENE

6	Basalt, andesite, related tuff and breccia; minor conglomerate, sandstone, and shale
5	Conglomerate, sandstone, greywacke, shale, lignite; minor breccia, tuff, and basalt

PALEOCENE AND/OR EOCENE

4	Rhyolite, dacite, trachyte; related tuff and breccia; andesite and basalt; minor sediments; 4a, mainly andesite and basalt

MESOZOIC

JURASSIC OR CRETACEOUS

3	Conglomerate, greywacke, and argillite

JURASSIC
MIDDLE JURASSIC
HAZELTON GROUP (in part)

2	Andesite, basalt; related tuff and breccia; conglomerate, greywacke, shale

PALAEOZOIC

PERMIAN AND (?) EARLIER
CACHE CREEK GROUP

1	Chert, argillite, limestone, greenstone; minor greywacke and conglomerate

MESOZOIC

A	Granodiorite, granite, gneissic granite, quartz diorite, and diorite

Geological boundary (defined, approximate, assumed)
Limit of geological mapping
Bedding (inclined; vertical, tops not indicated)
Fault (defined, approximate, assumed)
Lineament (from air photographs)
Anticline (defined, approximate)
Syncline (defined, approximate)
Glacial striae
Fossil locality
Mineral occurrence ... × Cu

MINERAL SYMBOLS

Copper	Cu	Manganese	Mn
Diatomite	diat.	Nickel	Ni

Geology by H. W. Tipper, 1957

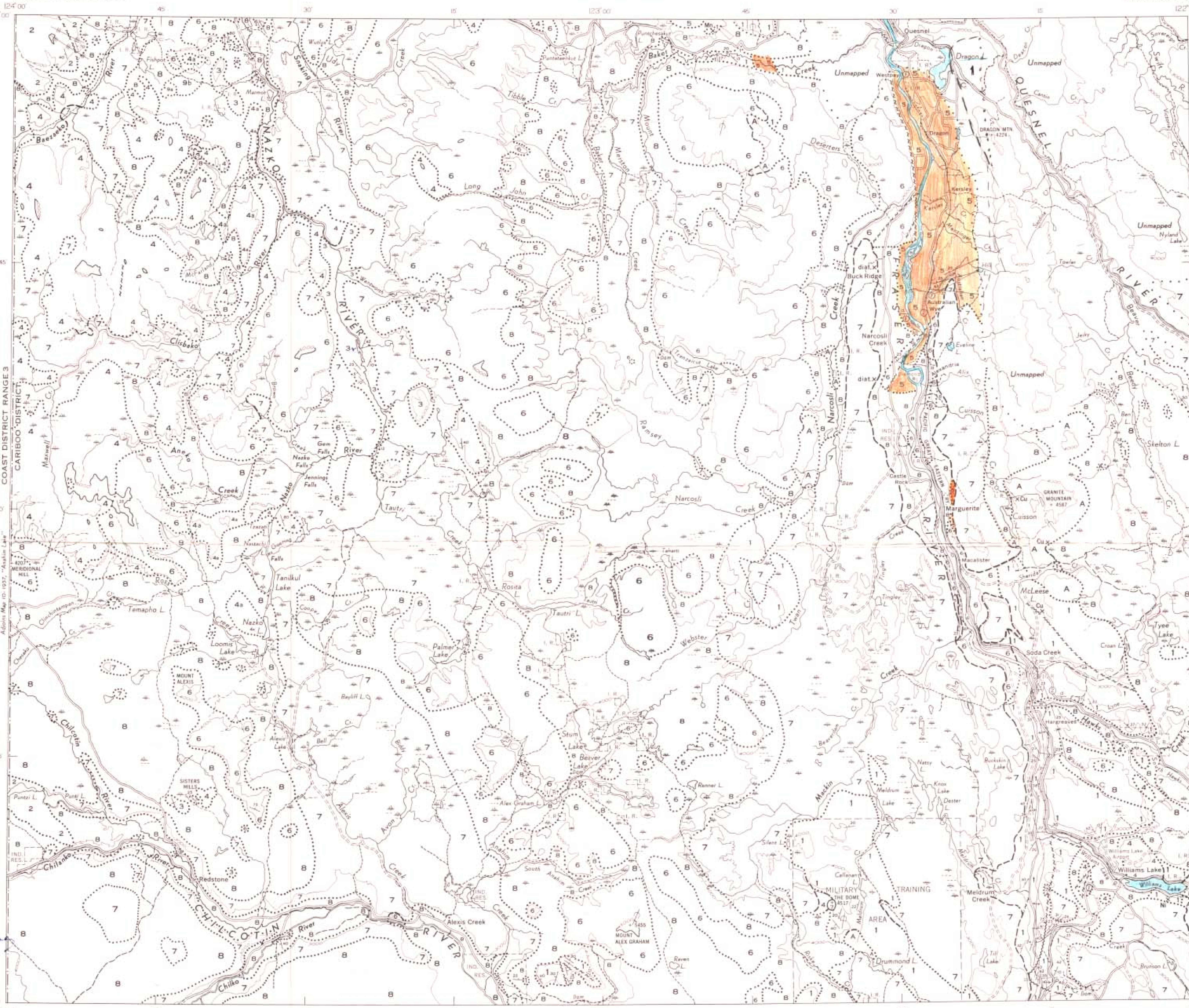
Main highway
Other roads
Wagon road
Trail
District boundary
Indian Reserve boundary
Intermittent stream
Marsh
Sand or gravel
Contours (interval 1,000 feet) ... 5000
Height in feet above mean sea-level ... + 4587

Cartography by the Geological Survey of Canada, 1959

Approximate magnetic declination, 25° 40' East

In response to public demand for earlier publication, Preliminary Series maps are now being issued in this simplified form, thereby effecting a substantial saving in time. There is no loss of information, but the maps will be clearer to read if all or some of the map-units are hand-coloured.

Air photographs covering this area may be obtained through the National Air Photographic Library, Topographical Survey, Ottawa, Ontario



PUBLISHED, 1959
COPIES OF THIS MAP MAY BE OBTAINED FROM THE DIRECTOR, GEOLOGICAL SURVEY OF CANADA, OTTAWA

PRINTED BY THE SURVEYS AND MAPPING BRANCH

DESCRIPTIVE NOTES

Bedrock outcrops over less than 5% of the map-area. Rock is only well exposed along some creeks and rivers and on the steeper hills; elsewhere small, widely scattered outcrops rise above the glacial drift, which in most places is 25 to 50 feet thick.

No fossils have been found in the Cache Creek group (1) but it is lithologically similar to the rocks of the type area. Along Fraser River and eastward the group is tightly folded, contorted, sheared, and metamorphosed, but between Meldrum Lake and Alexis Creek it is less deformed and comparatively unmetamorphosed.

Hazelton group rocks (2) are in part a continuation of this group from Nechako River map-area and are lithologically similar but unfossiliferous.

The Jurassic or Cretaceous sediments (3), at least 700 feet thick, are poorly consolidated and in general only slightly deformed. The chert pebbles of the conglomerates resemble the chert of the Cache Creek group. No fossils have been found in the unit.

The early Tertiary rocks (4) rest unconformably on the Jurassic or Cretaceous rocks (3). The unit is faulted and folded but the structure is difficult to interpret. The group is characterized by light-coloured rocks, mostly cream-coloured but also mauve, green, grey, and salmon-coloured. The thickness of the group varies from a few hundred feet in some isolated outcrops to 1,500 feet or more north of Meridional Hill. No diagnostic fossils were found but the group is lithologically similar to fossiliferous early Tertiary rocks to the northwest.

Sedimentary rocks (5), occurring mainly in Fraser River valley, underlie the volcanic rocks (6) conformably and in part are interbedded with them. The sediments are poorly consolidated but are folded and faulted. Near Australian Creek they are not less than 1,200 feet thick. Fossil plants are found at several places. Although these sediments appear to be confined to Fraser River valley, the group may extend westward to Puntchesakut Lake.

The Eocene and/or Oligocene volcanic rocks (6) rest unconformably on the early Tertiary rocks (4) in the west half of the area. This unit is believed to occur in broad, northwest-trending folds in the south half of the area and to plunge gently southeast. In the north half the structure is unknown.

The comparatively undeformed plateau-type lavas (7) are similar to those of the Endako group to the northwest. They rest with angular discordance on the older groups but at several places, particularly in Fraser River valley, are underlain conformably by poorly consolidated sediments (7b), including diatomite. Much of the drift-covered plateau west of Fraser River is believed to be underlain by rocks of this group. Some lavas (7a) mapped with this group may be as young as Pleistocene. Although the group covers a large area it is not thought to be very thick in this map-area, probably 500 to 1,000 feet at most.

Glacial drift and recent alluvium (8) cover most of Quesnel map-area to depths of 25 to 50 feet, and in some places to as deep as 600 to 700 feet. Along Fraser River near Diamond Island, two and probably three distinct till sheets can be recognized.

One small volcanic cone and the accompanying ash and debris comprise the Recent volcanic rocks (9), and these rest on glacial till. The cone is extinct and these rocks may be only slightly younger than the flows mapped as (7a) which occur in the same area.

The granitic rocks (A) have been mapped as a single unit, but the various bodies may be unrelated. All the granitic masses west of Fraser River are coarse-grained, equigranular, biotite granites and granodiorites whereas the two masses east of the river are coarse gneissic granodiorites, diorites, and quartz-diorites. These rocks are deeply weathered and, with the exception of Granite Mountain, are topographically subdued. Little is known of their origin or their precise age.

The linear feature extending up Fraser River valley from the south to Soda Creek and thence northward through McLeese Lake valley and along the straight front of the Granite Mountain-Dragon Mountain range appears to be a zone of faults and of tight folds, at least along the southern half of the feature. No single, large fault has, however, been traced along it.

The area has been prospected without noteworthy success. The Tertiary rocks of the western two thirds of the area generally appear to be barren of ore minerals. The Cache Creek rocks, particularly near the granitic masses, and the granite pluton of Granite Mountain are the only rocks in the area in which ore minerals were observed. Thus around Granite Mountain and to the south of it, copper minerals were noted at several places and a nickel occurrence is reported south of Williams Lake. These have all been investigated recently by mining companies. Psilomelane occurs filling fractures in cherts north of Baker Creek.

Diatomite has been known in the Quesnel area for many years but the occurrences near and to the south of Buck Ridge have not previously been described. The diatomite there is exposed only in road cuts and is a light weight, cream-coloured, compact material as much as 25 feet thick; in places probably much thicker.

Lignite is common, occurring in the Eocene and (?) later sediments (6). Seams over 40 feet thick are known along Fraser River.

Various types of clay of Tertiary to Recent age occur in Fraser River valley, between Macalister and Quesnel. These are of various origins. Some of these clays may be suitable for bricks, tile, pottery, or other uses.

MAP 12-1959
GEOLOGY
QUESNEL
CARIBOO DISTRICT
BRITISH COLUMBIA

Scale: One Inch to Four Miles = $\frac{1}{253,440}$

Miles
4 2 0 4 8 12

00803 (2)

MAP 12-1959
QUESNEL
BRITISH COLUMBIA
SHEET 93 B

GEOLOGY AND COAL RESOURCES OF THE TERTIARY SEDIMENTS, QUESNEL-PRINCE GEORGE AREA, BRITISH COLUMBIA

Project 760056

Peter S.W. Graham
Institute of Sedimentary and Petroleum Geology, Calgary

Abstract

Graham, Peter, S.W., Geology and coal resources of the Tertiary sediments, Quesnel-Prince George area, British Columbia; in Current Research, Part B, Geol. Surv. Can., Paper 78-1B, p. 59-64, 1978.

Coal occurs in both the upper and lower members of the Oligocene-Miocene Fraser River Formation which outcrops along the Fraser River from Prince George to Alexandria Ferry, 38 km south of Quesnel, British Columbia. Deposition of sediments was controlled by an ancient south-flowing river system which drained a more subdued terrain under wetter and warmer conditions than those that presently prevail. Thicker coal seams, up to 21.9 m thick, are restricted to the lower Fraser River Formation. The coal is Subbituminous "B" to "C" in rank, contains many clay partings and has an inherently high ash content. Potentially economic areas are restricted to south of Quesnel.

Introduction

Throughout central British Columbia, many scattered Tertiary sedimentary basins occur in which coal or coaly material has been recorded. The Geological Survey of Canada, in co-operation with the British Columbia Department of Mines and Petroleum Resources, has initiated a study of some of these basins. This paper discusses geology and coal resource potential in the vicinity of Quesnel and Prince George, an area of more immediate economic interest. Previous work in this area has been done by Dawson (1877), Reinecke (1920), Cockfield (1932), Lay (1940, 1941), Mathews and Rouse (1963), McCallum (1969) and Piel (1971, 1977). Information for this study has been taken mainly from published and unpublished reports, supported by field observations of the writer.

General Geology

Figure 10.1 summarizes the geology as interpreted by Lay (1940), McCallum (1969) and others. Recent work on the palynology, vertebrate remains and potassium argon dating by Mathews and Rouse (1963), Piel (1971) and Hopkins (written comm.) has solved most of the time stratigraphic problems

Figure 10.1

Table of formations

Age	Group or formation	Members & Thickness (Lay 1940)	Members – Facies (McCallum 1969)	Members This Report	Lithology
Early Pliocene-Late Miocene	Endako Group (?) (Tipper 1960)	Upper Volcanics 15 m	Not Studied	Upper Volcanics	Olivine basalt, andesite
Early Pliocene to Late Miocene	Fraser River Formation (Reinecke 1920)	Diatomite Member 50 m	Tertiary C	Upper Fraser River Formation	Claystone, siltstone, sandstone, diatomaceous clays, minor coal
Mid- to Late Miocene		Gravel Member 150$^+$ m	Tertiary B: Channel / Off Channel		Conglomerate, sandstone, occasional claystone
UNCONFORMITY					
Early Oligocene		Australian Member 360$^+$ m	Tertiary A: Arkose / Gritty clay / Gravel	Lower Fraser River Formation	Claystone, siltstone, sandstone, conglomerate, coal
UNCONFORMITY					
Eocene	Unit 4 (Tipper 1959)	Lower Lavas 600$^+$ m	Early Tertiary Volcanics	Lower Lavas	Andesite, related tuffs and breccias, minor conglomerate and sandstone
UNCONFORMITY					
...n-Permian	Cache Creek Group (Tipper 1959)				Chert, argillite, limestone, greenstone, minor greywacke and conglomerate

which were due to poor bedrock exposure and the lithologic similarity of units. A further stratigraphic problem is the angular unconformity described by Lay (1940) within the Tertiary sedimentary sequence. The present study deals mainly with the coal resource potential of the Tertiary sediments. Revision of the stratigraphic nomenclature is currently being undertaken by Rouse and Mathews of the University of British Columbia. Tentatively, the Fraser River Formation is treated informally as upper and lower units separated by the unconformity.

The lower Fraser River Formation, which is the main coal-bearing part, consists of at least 360 m of claystone with lesser amounts of sandstone, conglomerate and coal. Individual lithologic beds are commonly thin. Vertically they contain evidence of rapid changes in depositional environment. Generally sandstones are thin bedded, medium to coarse grained and occur in fining-upward sequences. Thicker sandstone-conglomerate sequences are also present but do not appear to be associated with the coal-bearing parts of the formation. They may represent main channel facies whereas the coal-bearing sequences may represent off channel or floodplain facies. Coals occur in several parts of the lower Fraser River Formation and have been reported up to 21.9 m thick (Fig. 10.2, loc. 4). These coal zones commonly contain many clay partings. Both the coal beds and the clay partings are lenticular over short distances.

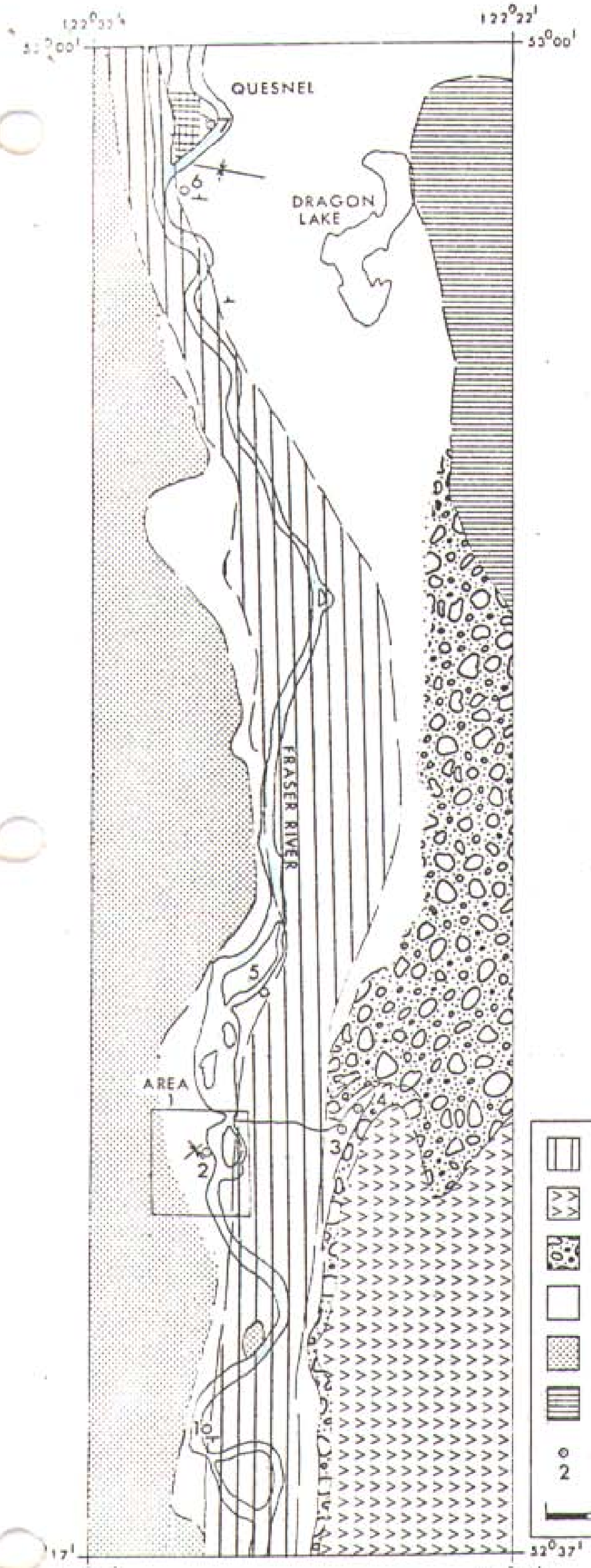
From palynological evidence, Piel (1971) and Hopkins (written communication, 1978) have concluded that a large and varied floral assemblage was present during deposition of the lower Fraser River Formation in early Oligocene time. The flora observed was predominantly from angiosperms, conifers with non-bladdered pollen grains, ferns and lower plants, the taxa of which indicate a humid, warm temperate paleoclimate (Hopkins, written communication).

Regionally, the lower Fraser River Formation is restricted to the present Fraser River Valley from Quesnel to Alexandria Ferry, 38 km farther south (Fig. 10.2, loc. 1). However, two other possible occurrences have been reported. Interbedded sandstones, conglomerate, claystones and "thin beds of lignite" outcrop on Haggith, Brodman and Tabor creeks, 10 km south of Prince George (McCallum, 1969). This succession has been dated by Rouse and Piel (in McCallum, 1969) as early Oligocene. Another succession of sandstones and siltstones of possible Oligocene age was found on the Blackwater River 60 km northwest of Quesnel. Although coal was not found in place, it was observed as debris in the creek.

A minor tectonic event prior to the deposition of the upper Fraser River Formation caused tilting of the coal measures. Dips of up to 55 degrees have been reported (McCallum, 1969, p. 9) but are more commonly less than 20 degrees.

The upper Fraser River Formation consists of at least 200 m of massive conglomerates and sandstones grading up to siltstones, claystones with occasional diatomaceous clay, and coal. Separating the upper and lower units is an angular unconformity recognized by Lay (1940) at Big Bend, 11 km north of Quesnel. The upper unit characteristically dips less than 5 degrees. It is poorly indurated which makes it almost indistinguishable from some interglacial sediments located in the region.

Most exposures of the upper unit of the formation are located on the Fraser River between Prince George and Quesnel. It has also been observed in the upper reaches of Australian Creek (Fig. 10.2, loc. 4) and may cover a considerable area west of the Fraser River.



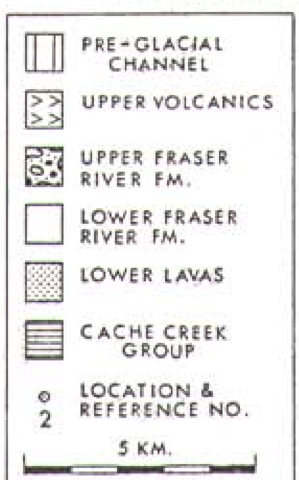


Figure 10.2. Generalized geology map, Quesnel area. Modified after Tipper (1959).

The upper unit was deposited during a much cooler period than the lower unit as indicated by a dramatic increase in the conifer population (Mathews and Rouse, 1963; Piel, 1971, 1977). These authors have assigned a mid-late Miocene age for the upper Fraser River Formation.

Coal seams have been recorded in the upper unit and except in one place are very thin, dirty and discontinuous (Reinecke, 1920; Laurence, 1953). On the Nechako River 20 km west of Prince George, however, Lay (1941, p. 35) described two coal seams 1.5 and 1.8 m thick. The age of these coals has not been well established and may prove to be Oligocene and, hence, within the lower unit.

Environments of Deposition

Tipper (1959) and McCallum (1969) state that deposition of sediments was from a north-flowing river system; however, Lay (1940) had previously shown convincing evidence for a southerly flow direction after Eocene time. Lay's interpretation was confirmed by the present author's observations of pebble imbrication. The upper Fraser River Formation was deposited by an ancestral river which drained a relatively subdued terrain. The river system occupied a valley along the trend of the present Fraser River Valley in this area. South of Quesnel, lateral river migration apparently did not exceed 6 km. Relatively humid conditions in the early Oligocene

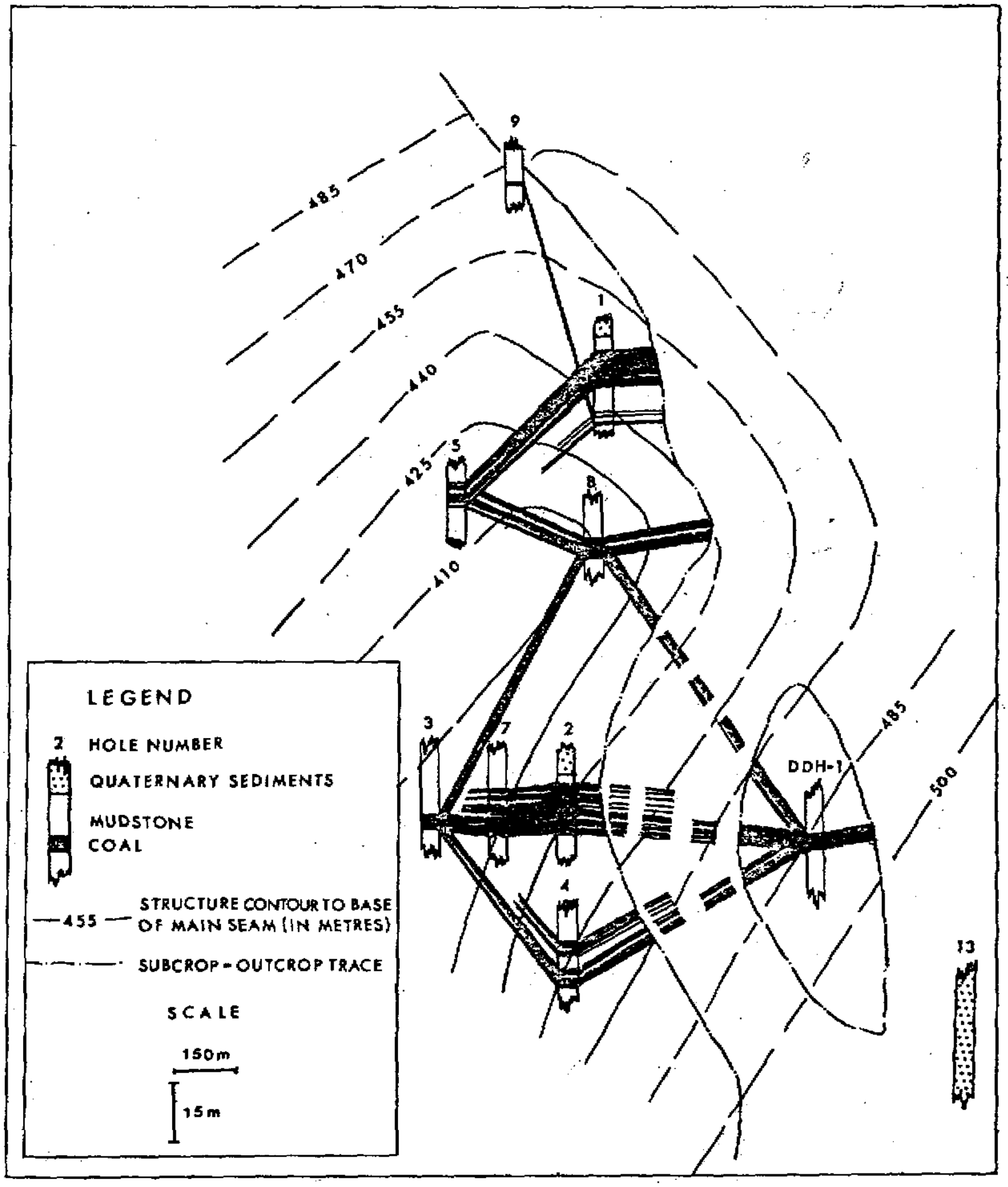


Figure 10.3. Fence diagram and structure contour map of main seam, Area 1. For location of area, see Figure 10.2.

may have been responsible for the abundance of local paludal and lacustrine conditions in the overbank areas. Occasional flood conditions could have caused the thin, fining-upward sandstone units. This type of environment should lead to rapid facies changes both perpendicular and parallel to the direction of stream flow. Subsequent to the deposition of the lower unit, mild tectonism caused local tilting of the strata before erosion and final deposition of the upper Fraser River Formation. Clasts in the conglomerate of the upper unit are predominantly composed of older quartzites and metamorphosed material (Reinecke, 1920) which indicates that the reactivation of the river system occurred after a period of tectonism rather than volcanism. Because of cooler climatic conditions and the higher fluvial energy regime in the upper unit, major peat accumulation would not be expected.

A short period of volcanism occurred during and after deposition of the upper unit (McCallum, 1969, p. 19). Subsequently, the river was re-established and cut a deep channel through the upper and lower units of the Fraser River Formation prior to Pleistocene glaciation (Fig. 10.2).

Deposition of fluvial sediments along the present Fraser River has occurred sporadically since early Oligocene time. This could indicate that the Fraser River fault zone recognized farther south by Trettin (1961) and others continues into the study area and runs close to the present river channel. Reactivation of the fault zone must have occurred from late Eocene to early Oligocene and also from mid-Oligocene to mid-Miocene time. This is indicated by the angular unconformities separating the sedimentary units.

Areas of Economic Interest

Except for two thick coals reported by Lay (1941, p. 35) west of Prince George, all other major seams reported occur south of Quesnel. These occurrences have been divided into four separate areas and are discussed individually.

1. Red Cliff

A cliff of reddish clays is located immediately south of the Quesnel townsite and was altered by the burning of an underlying coal seam. A series of holes drilled by the British

Figure 10.4

Coal seam data, Quesnel, B.C.

Location	Source of Data	Coal Thickness (metres)	Interval between seams	% Moisture	% Volatile Matter	% Fixed Carbon	% Ash	Sulphur	kCal/kg	Reference
1. Alexandria[1] Ferry	outcrop	1.07 1.22 1.22	0.6 0.46	6.9[3] 5.1 3.4	39.7 38.2 38.8	39.7 38.5 36.8	13.7 18.2 21.0			B.C. Rep. Minister 1924, p. A127
2. Doyle's Ranch	outcrop	min. 2.4		33.9	23.4	27.2	15.5	0.6	3300	Can. Dep. Mines Tech. Surv. Rep. Analyses 1940
	outcrop	min. 2.4		21.0[5] 0	25.5 42.8	31.8 57.2	21.7 0			B.C., Rep. Minister 1931, p. A172
2. Doyle's Ranch	7 Rotary[2] Test holes 1 DDH	3.2 to 13.2 net coal		45.8 0	19.3 49.3	18.5 51.7	16.4 30.2[4]	0.23	2547	Yoon, 1972 Lakes, 1930
3. Australian Creek	Adit	1.13		11.5 0	30.6 49.8	28.5 50.2	29.4 0			Reinecke, 1920
4. DDH 3	diamond-drill hole	4.2 21.9	141.7							Lakes, 1930
5. Howard's Ranch	outcrop	1.3		3.6 0	40.2 52.0	35.6 48.0	20.6 0			B.C. Rep. Minister of Mines, 1924, p. A127
6. Red Cliff	15 auger holes B.C. Dep. of Highways	18 net 30 gross								B.C. Dep. Highways unpub. rep. on Plywood Hill Slide
7. Quesnel	3 rotary holes B.C. Dep. of Highways	2 to 6 m								B.C. Dep. Highways unpub. rep. on Quesnel Bridge 1958

[1] Numbers represent locations on Figure 1.

[2] Analysis averaged from 8 samples.

[3] Analysis on an "as Received" basis.

[4] Ash calculated on a moisture free basis.

[5] Dry ash free analysis calculated using the Parr Formula.

Columbia Department of Highways (Fig. 10.2, loc. 6), 560 m southwest of this cliff, penetrated a possible 30 m coal zone containing an average of 60 per cent coal by volume. Further evidence of a major coal zone at least 18 m thick was found in a water well 800 m east of the drillholes. These three points give an approximate regional dip of 5 degrees north. At location 7 (Fig. 10.2), three shallow holes were drilled for bridge pilings, and penetrated a seam ranging from 2 to 6 m thick. A dip of 16 degrees southwest was calculated here. From additional surface evidence an east-west trending syncline is proposed (Fig. 10.2). The area between location 6 and Dragon Lake should have the highest potential for near-surface coal.

2. West Australian Creek

Master Exploration Ltd. (Yoon, 1972) drilled a series of rotary holes of which 7 penetrated a major coal zone on the west bank of the Fraser River west of Australian Creek (Fig. 10.2, Area 1). Results of the drilling (see Fig. 10.3) showed this zone to average 75 per cent coal and 25 per cent clay partings. Furthermore the zone is lenticular, ranging from 3.4 m (net) to 13.2 m (net) over a distance of 500 m. Measured, Indicated, and Inferred Resources have been calculated (by the writer) at 4, 10 and 14.5 million tonnes, respectively. Calculations were based on Cordilleran coal parameters established by the Department of Energy, Mines and Resources (EMR Rep. EP77-5). Erosion by the preglacial channel restricts the seam almost entirely to the west bank of the Fraser River. The coal measures have been folded into a southwest-plunging syncline with dips on the limbs of approximately 10 degrees (see Fig. 10.3).

3. East Australian Creek

A diamond-drill hole, 4 km east of Area 1, penetrated two major coal zones 4.2 and 21.9 m thick (Fig. 10.2, loc. 4). Records show that this coal contains numerous clay partings similar to coals in the other areas. Measured surface dips range from 15 to 25 degrees northeast, which should bring the lower, thicker seam nearer to the surface farther southwest. However, the seam may have been truncated and partially removed prior to the deposition of the upper Fraser River Formation.

4. Alexandria Ferry

An outcrop located just south of the old Alexandria Ferry (Fig. 10.2, loc. 1) contains several thin coal seams and one major coal zone with 3.5 m coal in a 4.7 m thick interval and dipping 15 degrees south (B.C. Department of Mines, 1924, p. A126). Immediately east of this outcrop is a deeply incised preglacial channel which eliminates the economic potential of much of the area. There is, however, a small area to the east and south of the Alexandria Ferry crossing which may be underlain by a major coal seam.

Coal Rank and Quality

Several coal analyses have been previously reported and are summarized on Figure 10.4. According to the Parr Formula (ASTM, 1973, p. 56), the coal ranks Subbituminous "B" to "C" on a moisture mineral matter free basis. Excluding the clay partings, the coal continues to display an inherently high ash content, averaging between 20 and 30 per cent on a moisture-free basis. Although rank and quality are low, they are comparable to the coal seams at Hat Creek 200 km farther south (Church, 1977).

Conclusions

The mid-Tertiary sediments in the Quesnel-Prince George area can be divided into two distinct stratigraphic units of which the lower has greater economic potential. Coal seams are lenticular and high in ash. Some of the subsurface data presently available are of dubious quality and further drill hole information is required to better determine the stratigraphy and obtain more accurate coal resource information.

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The Gang Ranch – Big Bar area, south-central British Columbia: stratigraphy, geochronology, and palynology of the Tertiary beds and their relationship to the Fraser Fault

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Tertiary rocks in the Gang Ranch – Big Bar area, south-central British Columbia, consist of (1) Early or Middle Eocene (50 Ma) lavas, breccias, and tuffs capped by a mappable unit of conglomerate and clays, totalling 1600 m in thickness; (2) Early Miocene basalt and obsidian, only locally present on high summits; (3) Mid-Miocene gravels and tuffs estimated to be up to 300 m thick; and (4) Pliocene "plateau basalts" up to 130 m thick, locally underlain by fluvial and lacustrine sediments. A rich, probably subtropical, palynoassemblage supports the correlation of the first unit with the Kamloops Group of south-central British Columbia, and the palynomorphs from unit (3) indicate equivalence with the Fraser Bend Formation of the Quesnel area.

The northwest-trending Fraser Fault transects the area. Eocene and underlying mid-Cretaceous beds are confined to the west side of the fault; Triassic metasediments and metavolcanic rocks form the east wall. The west side of the fault has been structurally lowered by at least 1.6 km in Eocene and(?) later time. Some 70 km of dextral displacement since mid-Cretaceous time is suggested but is not unequivocally demanded. Major movement has occurred since and possibly during deposition of the Eocene beds. Pliocene beds overlying the fault and Mid-Miocene beds adjacent to the fault trace are apparently undisturbed.

Pliocene drainage appears to have been northward. Slight northerly tilting has occurred since, but notwithstanding this the southward-flowing Fraser River has become established here. Glacial diversion of an earlier drainage pattern is suspected.

Les roches tertiaires de la région de Gang Ranch – Big Bar, dans le centre-sud de la Colombie-Britannique, incluent: (1) des laves, des brèches et des tufs de l'Eocène inférieur ou moyen (50 Ma) recouverts par une unité cartographiable composée de conglomérat et d'argiles, totalisant une épaisseur de 1600 m, (2) un basalte et une obsidienne du Miocène inférieur qui apparaissent localement sur les hauts sommets seulement, (3) des graviers et des tufs du Miocène moyen dont l'épaisseur maximale est estimée à 300 m et (4) des "basaltes des plateaux" du Pliocène, pouvant atteindre une puissance de 130 m, recouvrent localement des sédiments lacustres et fluviatiles. Un palynoassemblage abondant, probablement subtropical, corrobore la corrélation de la première unité avec le groupe de Kamloops du centre-sud de la Colombie-Britannique, et les palynomorphes de l'unité (3) marquent l'équivalence avec la formation de Fraser Bend de la région de Quesnel.

La faille de Fraser de direction nord-ouest coupe la région. Des couches de l'Eocène et des couches sous-jacentes du Crétacé moyen n'apparaissent que sur le côté occidental de la faille; des métasédiments et des métavolcaniques triassiques occupent la lèvre orientale de la faille. Le côté ouest de la faille a été abaissé structuralement par au moins 1,6 km durant l'Eocène et(?) ultérieurement. Un déplacement dextre de quelques 70 km depuis le Crétacé moyen est proposé, cependant non sans équivoque. Un mouvement majeur s'est produit depuis et possiblement durant l'accumulation des sédiments à l'Eocène. Les couches du Pliocène recouvrent la faille et les couches du Miocène moyen adjacentes à la trace de la faille ne semblent pas avoir été perturbées.

Le drainage au Pliocène semble avoir été en direction nord. Un léger basculement du côté nord s'est manifesté depuis, mais en dépit de ceci, l'écoulement en direction sud de la rivière Fraser s'est établi à ce moment. Le motif de l'ancien drainage a certainement été modifié par la glaciation.

[Traduit par le journal]

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Introduction

An investigation of the Tertiary beds of the Gang Ranch – Big Bar area (Fig. 1) was undertaken by the writers as a continuation of their work to the north at Quesnel (Rouse and Mathews 1979) and near Prince George (Rouse and Mathews, in preparation). The present study, like its predecessors, was directed at the Tertiary stratigraphy, geochronology, and palynology as an aid to correlation of contemporaneous rocks in other parts of the interior of British Columbia and to the dating of Tertiary floras and climates both here and elsewhere in northern North America. Structure of the Tertiary rocks had not been of prime interest for our earlier work but here the close association of Tertiary beds with the regionally important Fraser Fault provided justification for its special attention.

Within the Gang Ranch – Big Bar area most of the Tertiary rocks, with the exception of the Pliocene flood basalts and associated sediments, lie west of the Fraser Fault and mostly west of Fraser River on the lower valley slopes where timber is sparse or lacking. Unfortunately Quaternary sediments provide an all too extensive cover that locally reaches a thickness of 200 m. These sediments and the numerous and large landslides severely restrict the collection of bedrock data.

Pre-Tertiary rocks

Pre-Tertiary rocks on the east side of the Fraser Fault have been mapped (Tipper 1978) as Triassic Pavilion Group consisting dominantly of chert and argillite with minor tuff, limestone, lithic sandstone, and flow rocks. Near the fault the argillite has been converted to a very dark phyllite.

The pre-Tertiary rocks west of the Fraser Fault are mid-Cretaceous volcanic and sedimentary beds equivalent to the Spences Bridge or Kingsvale formations (Duffel and McTaggart 1952; Rice 1947; Monger 1982; Tipper 1978). On Churn Creek 11 km west of Fraser River yellow–brown pebble conglomerate, sandstone, and minor mudstone have yielded palynomorphs indicating a Cenomanian–Turonian age (northwesternmost F in Fig. 1). Some 2 km to the northeast is an isolated knoll of banded rhyodacite from which a whole-rock K–Ar date of 101 ± 3 Ma (i.e., latest Albian or earliest Cenomanian) has been obtained (Fig. 2). Volcanic rocks

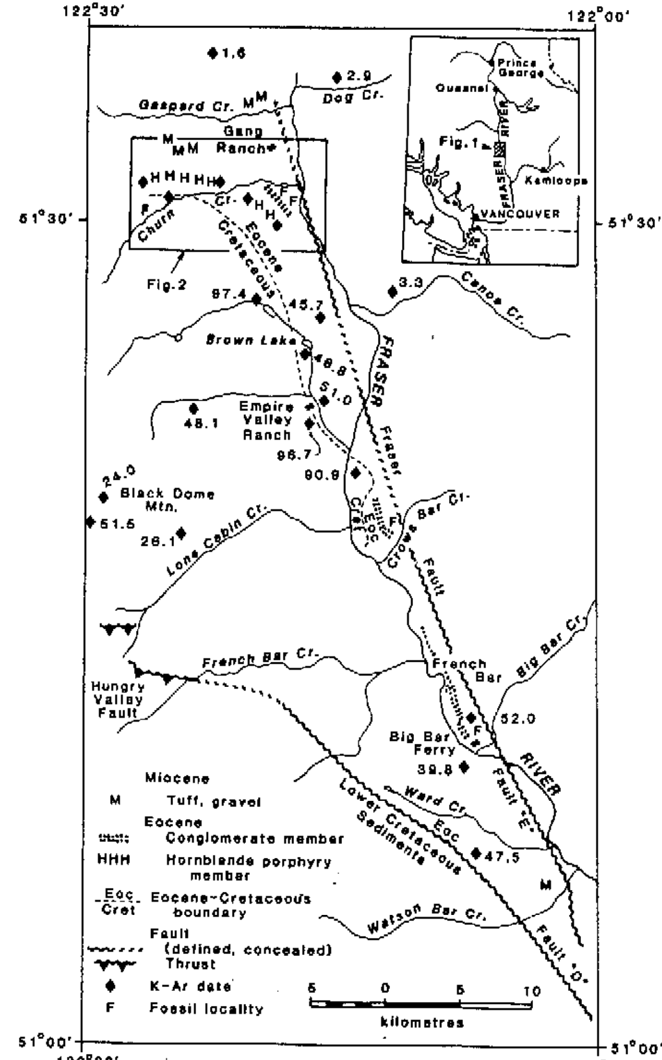


FIG. 1. Gang Ranch – Big Bar area: place names and geology.

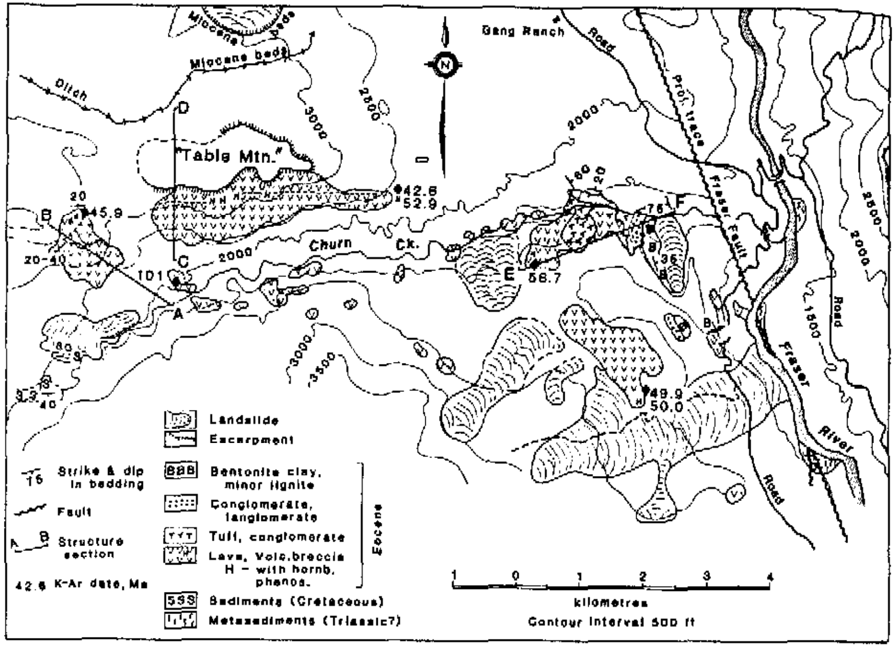


FIG. 2. Churn Creek and vicinity: geology.

10–25 km farther southeast have yielded dates ranging from 91 to 97 Ma (Fig. 1; Table 1). In the southern part of the area (Fig. 1) the early Tertiary volcanic rocks are mapped as being in fault contact with Early Cretaceous conglomerates of the Jackass Mountain Group (Trettin 1961; Tipper 1978).

Early Tertiary beds

Distribution and lithology—Churn Creek

The early Tertiary succession is best observed in two strips mapped along Churn Creek valley (Figs. 2, 3). The first of these is on the north slope of Churn Creek valley about 10 km west of Fraser River, the slope leading up to "Table Mountain" and the hill to the west. The second strip lies on the south side of Churn Creek canyon 2–4.5 km west of Fraser River.

The first strip exposes a predominantly massive volcanic succession. A red hornblende-bearing lava can be traced from the eastern exposure rising gradually westward (ca. 6°) parallel to the trace of a faint stair-step topography, to the top of the slope at the western end of "Table Mountain." Hornblende-bearing lava is also exposed on the eastern brow of the next hill to the west. Here it overlies a local pale tuff member dipping 20° to the north. Farther along strike to the west again this tuff is found to dip northwesterly at 20° to as much as 40°. On the basis of the continuity of the hornblende-bearing lava and underlying tuff member, the rocks of this strip are believed to lie within a single block dipping generally 20° northward (Fig. 3, cross sections A–B and C–D). The tuff is directly underlain by massive volcanic rocks, about 600 m in thickness, extending down to the drift-covered base of the hillside. The next outcrops both to the southwest and southeast, half a kilometre away, consist, respectively, of the mid-Cretaceous sediments and the 101 Ma old lava described above. It is unclear at this site whether the Cretaceous–Tertiary contact is a fault or an unconformity.

The base of the succession in the second mapped strip, on lower Churn Creek, consists of a hornblende porphyry, with or without biotite, in a southeasterly trending belt separated from the "Table Mountain" succession to the northwest by a covered interval about 2 km across. This is overlain (Fig. 3, section E–F) by a succession of rhyodacitic to basaltic lavas lacking phenocrysts of either hornblende or biotite, together with breccias, conglomerates, pale tuffs, bentonites, and a seam of coal, all dipping northeasterly at from 20 to 60°. Some of these units are identifiable 1.5–2.5 km to the southeast, beyond the canyon rim, and again 4.5 km to the southeast. No significant faults were recognized, and none is required to account for the distribution of these rocks. This succession is bounded on the southwest by a series of major landslides and by drift-covered terrain, and on the east it is limited by the disturbed zone bordering the Fraser Fault. Between these limits a section with an aggregate thickness of approximately 1000 m can be reconstructed (section E–F in Fig. 3). It is considered that the hornblende porphyry at the top of the first section is the same unit as that found at the base of the second section. Accordingly the early Tertiary succession is here at least 1600 m thick.

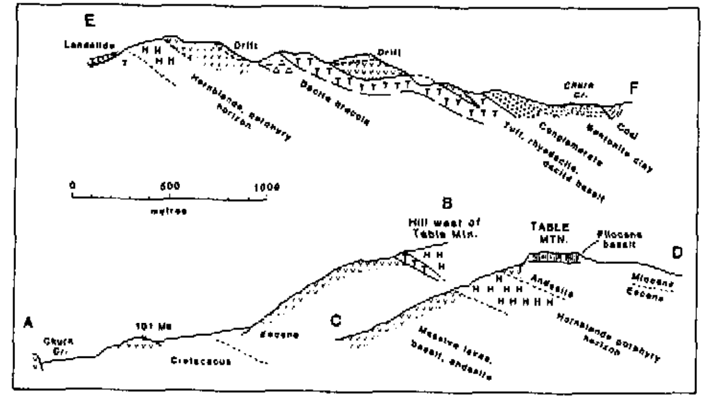


FIG. 3. Churn Creek area: structural sections.

The early Tertiary volcanic rocks of the Churn Creek succession show a marked diversity of color, composition, and mineralogy. Many are aphyric: others are sparingly porphyritic, usually with less than 5% feldspar phenocrysts: a few flows in the middle of the succession are characterized by hornblende phenocrysts, in places altered, and a very few of the hornblende-bearing rocks contain biotite. The bulk composition of the igneous rocks varies from basalt (refractive index (RI) of fusions (Mathews 1951) = 1.58, i.e., SiO_2 ca. 52%) to rhyodacite (RI = 1.51, SiO_2 ca. 75%). Color ranges through shades of brown, yellowish brown, red, grey, and, locally, green. Weathered surfaces are generally in shades of brown or red. Vesicular or amygdaloidal lavas are uncommon, in apparent contrast to the underlying Cretaceous lavas. Massive to irregularly fractured flows dominate in the lower part of the succession: crude columnar jointing is only locally visible; autobrecciated flows and breccias of unspecified origins are present. Flow contacts are generally inconspicuous. In most respects these volcanic rocks are indistinguishable in the field from those of Cretaceous age. Only the dearth of vesicular varieties and the scarcity of chalcedonic, quartzose, and calcitic or zeolitic infillings seem distinctive of the younger lavas.

Lenses of rhyolitic vitric lapilli tuff are generally white, but some with a greenish cast on weathered surfaces are present in the middle and upper parts of the succession. Bedding is generally readily visible. Immediately beneath lavas the stratification in the tuff may be highly distorted, possibly because of burial while still plastic.

A conglomerate unit, almost 150 m thick, on Churn Creek is made up of subrounded pebbles and cobbles up to 30 cm long, in a subordinate sandy to muddy matrix. Clasts are mainly of grey, black, red, and, locally, green volcanic rocks, many of which are amygdaloidal. Their source is undetermined, but is perhaps more likely to be Cretaceous than early Tertiary. In either event a source to west or south, where rocks of these ages are known to occur, is suggested. Also present among the clasts is minor chalcedonic quartz and rare cherty argillite. Some sandstone is interbedded with the conglomerate.

Clays overlying the conglomerate and forming the upper part of the Churn Creek succession weather to a greyish orange and display a conspicuous crumb structure indicative of marked expansion and contraction on exposure to the elements. X-ray diffraction indicates a high montmorillonite content. The fresh clay is soft, relatively homogeneous, and with a weakly developed fissility. Locally the clays contain pebbles either as isolated clasts or as gravelly bands. Much of the clay succession is prone to landsliding and accordingly is poorly exposed.

A seam of subbituminous coal, 45 cm thick, is the uppermost bed exposed in the Churn Creek section.

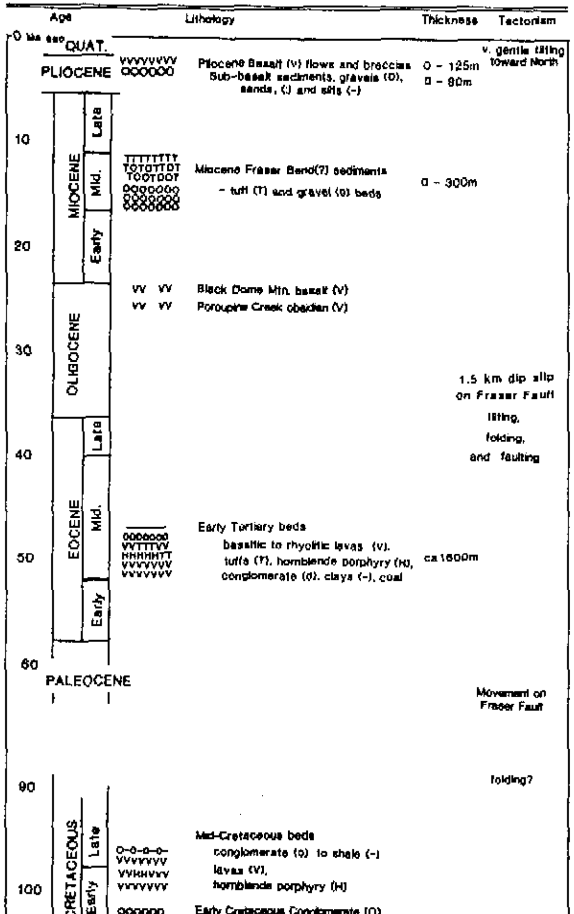
Distribution and lithology south of Churn Creek

Some 20 km southeast of Churn Creek, at and west of Crows Bar Creek, there is a succession of pale tuffs and varicolored lavas and volcanic breccias overlain by a thick and resistant conglomerate member overlain in turn by greyish orange bentonitic clays. The similarities of both lithology and palynoassemblage with those of the upper part of the Churn Creek section are striking and the two are clearly correlative. The succession here strikes southerly; dips are for the most part gentle to the east except in the clays where tight folding is observable. Proximity to the Fraser Fault is probably responsible for the local deformation; incompetence of the clays may also facilitate the folding.

Some 10 km farther south, near French Bar, the thick conglomerate member is again well exposed, dipping moderately to steeply east. This is overlain by clays and these in turn by pale tuffs and tuff breccias. The conglomerate here has been mapped by Trettin (1961) who referred to it as the "French Bar Formation." This name would have been most appropriate were it not that this name was originally applied (MacKenzie 1921) to a conglomerate bearing numerous granitic clasts occurring 15–25 km to the west on upper French Bar Creek. This conglomerate is now considered to be of Early Cretaceous age (Tipper 1978) and not Tertiary. At French Bar Canyon on Fraser River the Tertiary conglomerate rests directly on and is apparently conformable (Trettin notwithstanding) with volcanic rocks assigned to the "Ward Creek Assemblage" from which Eocene K–Ar dates have been obtained.

At Big Bar Ferry, 5 km south of French Bar, exposures of

TABLE 1. Table of formations; 1983 geologic time scale from DNAG (Palmer 1983)



conglomerate terminate against a major drift-covered area. Here the beds dip steeply (65–90°) east beneath a clay, with or without scattered pebble bands or isolated pebbles, and this in turn dips beneath tuffs and breccias (Trettin 1961, p. 74) from which an Eocene date has been obtained (Table 2).

South of Big Bar Ferry, Trettin's (1961, pp. 70–71) Ward Creek Assemblage is exposed on the west side of Fraser River. Here, between Ward and Watson Bar creeks, exposures indicate a general northeasterly dip complicated, however, by faults, local folds, and landslides. At the west a quartz- and sanidine-bearing rhyolite (RI = 1.49, SiO_2 ca. 75%) yields an age of 47.5 Ma. This is separated from Lower Cretaceous conglomeratic beds to the west by fault "d" of Trettin (1961) (see also Tipper 1978). Farther east, and presumably higher in the succession, are basalts and white to purplish tuffs.

Isotopic dating

Some 12 potassium–argon determinations have been obtained from the early Tertiary volcanic rocks (Table 2). Although establishment of the age of the succession was the prime objective in this study, a secondary objective was to determine the internal consistency in the dates (see also Armstrong 1970). To this end dates have been obtained from five mineral separates and one whole-rock sample from the hornblende-bearing member in the middle of the succession. Dates of 52.9 Ma for hornblende and 42.6 Ma for whole rock show the spread of

TABLE 2. Potassium–argon dates

Sample name	Rock	Material dated	Lat. N	Long. W	UTM coord.	K (%)	$^{40}Ar^*/^{40}Ar_{tot}$	$^{40}Ar^*$ (STP cm^3/g × 10^{-5})	Age (Ma)
				Plateau lavas (Pliocene)					
Prentice Gulch	Basalt	Whole rock	51°37.7′	122°22.2′	435198	0.895	20.4	0.00459	1.3±0.1
Canoe Cr.[a]	Basalt	Whole rock	51°27.5′	122°11.6′	—	0.879	50.8	0.01148	3.3±0.1
Dog Cr.[a]	Basalt	Whole rock	51°35′	122°15′	—	0.515	24.3	0.00574	2.9±0.2
Leon Cr.[a]	Basalt	Whole rock	50°58.2′	121°55.4′	—	0.685	7.0	0.00591	2.2±0.3
				Miocene volcanics					
Black Dome[b]	Basalt	Whole rock	51°20′	122°29′	—	0.697	82.8	0.06552	24.0±0.8
Porcupine Cr.[c]	Obsidian	Whole rock	51°18.5′	122°24′	—	3.52	47.0	0.3602	26.1±0.9
Flapjack Pk.[b]	Basalt	Whole rock	51°18.5′	122°37′	—	1.49	81.2	0.1191	20.5±0.8
				Eocene volcanics					
CH 29B	Dacite	Hornblende	51°31.4′	122°26.6′	387080	0.649	76.8	0.1172	45.9±1.6
CH 2	Basalt	Whole rock	51°31.4′	122°22.2′	430081	1.011	80.8	0.1692	42.6±1.5
		Hornblende	51°31.4′	122°22.2′	430081	0.549	80.2	0.1144	52.9±1.8
CH 13	Dacite	Biotite	51°31.0′	122°20.5′	457072	5.13	91.8	1.1482	56.7±2.0
CH 41	Rhyodac.	Biotite	51°30.0′	122°18.7′	478052	5.13	94.5	1.0106	50.0±1.7
		Hornblende	51°30.0′	122°18.7′	478052	0.678	25.9	0.1333	49.9±1.7
CH 49	Andesite	Whole rock	51°26.8′	122°16.3′	505694	2.36	87.2	0.4249	45.7±1.6
CH 50	Andesite	Whole rock	51°25.2′	122°16.8′	501967	2.24	57.0	0.4127	46.8±1.6
CH 44	Rhyodac.	Hornblende	51°23.5′	122°15.9′	510932	0.67	75.1	0.1346	51.0±1.8
CH 23	Tuff	Biotite	51°21.8′	122°24.8′	410802	7.08	93.1	1.3404	48.1±1.7
BKM 254[c]	Dacite	Hornblende	51°19.1′	122°29.8′	–	0.483	71.5	0.09820	51.5±1.9
Big Bar 3	Tuff brec.	Biotite	51°11.8′	122°07.3′	613719	6.74	93.9	1.3817	52.0±1.8
Big Bar Ferry	Andesite	Plagioclase	51°10.3′	122°07.8′	608690	1.74	74.7	0.2720	39.8±1.5
Ward Cr. 2	Rhyolite	Sanidine	51°06.8′	122°07.1′	618627	6.57	90.0	1.2306	47.5±1.7
				Cretaceous volcanics					
CH 32	Rhyolite	Whole rock	51°30.9′	122°25.3′	401071	2.60	83.3	1.0545	101.0±3
CH 42	Andesite	Whole rock	51°27.2′	122°20.1′	461002	1.55	93.6	0.6027	97.4±3.4
CH 40	Dacite	Hornblende	51°22.5′	122°16.4′	502914	0.17	57.0	0.0656	96.7±3.4
Crows Bar 2	Basalt	Whole rock	51°20.6′	122°14.2′	531880	0.47	61.0	0.1703	90.0±3.2

NOTES: Analyses by K. Scott (K) and J. Harakal (Ar) at Department of Geological Sciences, University of British Columbia. K is determined in duplicate by atomic absorption using a Techtron AA4 spectrophotometer and Ar by isotope dilution using an AEI MS-10 mass spectrometer and high-purity ^{38}Ar spike. Errors reported are for one standard deviation. The constants used are: $\lambda_\varepsilon = 0.581 \times 10^{-10}$ year^{-1}, $\lambda_\beta = 4.962 \times 10^{-10}$ year^{-1}, and $^{40}K/K = 0.01167$ at.%.

[a]Bevier (1983).

[b]Church (1982).

[c]B. N. Church (personal communication, 1983).

answers obtainable from different components of a single specimen. Though the hornblende has the lower potassium content and is therefore more sensitive to contamination or more prone to analytical error, it is also more retentive of argon than the microcrystalline matrix with its potassium in feldspar and altered or devitrified glass. Accordingly the hornblende date is considered to be the more reliable. The three hornblende ages, 45.9, 52.9, and 49.9 Ma (averaging 49.6 ± 2.9 Ma), may give a better approximation of both age and precision.

Biotite from CH13 gives a curiously higher age (56.7 Ma) than the other mineral separates, but the biotite is low in potassium, unusually pale, and surrounded by alteration rims, and hence may have suffered some secondary loss of potassium. The biotite from CH41, on the other hand, is similar in potassium content but appears to be free of alteration and yields a concordant date. The Big Bar Ferry date is from an altered plagioclase and should be considered of doubtful reliability. The Ward Creek 2 date, from the lowest part of the succession in the southern part of the study area, and the Big Bar 3 date, from the highest part, are of clean unaltered material with a high potassium content and low air contamination. The fact that the stratigraphically higher sample yields a date 4.5 Ma *older* than the lower sample again indicates uncertainty in real age, but the difference is within the 2σ limits and hence not highly significant.

It can be concluded that the mean of the nine more reliable determinations, 49.9 Ma, is the best estimate of age, with a standard deviation of ±2 Ma representing its uncertainty. As most of this variance can be attributed to analytical uncertainties the span of time for deposition of the dated rocks must be within about 2 Ma. The age of the rocks corresponds in the Berggren (1972) time scale to either Early or Middle Eocene, or in the 1983 Decade of North American Geology (DNAG) time scale (Palmer 1983) to Middle Eocene.

Vitrinite reflectance

Vitrinite reflectance of coaly matter from several sites within the Eocene succession has been measured (Fig. 4). Most of the values, approximately 0.6%, are in the range common for Eocene rocks elsewhere in the southern interior of British Columbia, and could have been produced by heating to 70°C for the full 50 Ma of their existence or to higher temperatures (say 100°) for a briefer period (20 Ma) (from Karweil's (1956) nomogram modified with Teichmüller's (1971) reflectance values). However, three samples from the vicinity of Ward Creek show anomalously high reflectance, and would require heating to about 130°C for their 50 Ma history or to, say, 165°C for 20 Ma. Deeper burial may be the explanation (see below, Fraser

TABLE 3. List of palynomorphs from the Gang Ranch – Big Bar Eocene beds

Fern spores
- *Osmunda heterophyllites*
- *Toroisporis* sp.

Conifer pollen
- *Cedrus perialata*
- *Picea grandivescipites*
- *Pinus* sp.—haploxylon type
- *Pinus* sp.—diploxylon type
- *Sciadopitys stellatus*
- *Taxodiaceaepollenites hiatus*
- *Tsuga heterophyllites*
- *T. mertensiana*

Angiosperm pollen
- *Ailanthipites berryi*
- *Alnus verus*
- *Aroliaceoipollenites granulatus*
- *A. megaporifer*
- *A. profundus*
- *Arecipites engelharti*
- *A.* cf. *inaequalis*
- *Bombacacidites bombaxoides* (Pl. 1, fig. 7)
- cf. *Bursera* sp.
- *Calamuspollenites eocenicus*
- *Caprifoliipites scabratus*
- *C. microreticulatus*
- *Carya vescipites*
- *Cupuliferoipollenites inslevanus*
- *Cupuliferoidaepollenites liblarensis*
- *Diervilla echinata*
- *Eleagnus* type
- *Erdtmanipollis* sp.
- *Fagus granulata*
- *Fraxinoipollenites medius*
- *F. variabeles*
- cf. *Fremontia* sp.
- cf. *Godetia* sp.
- *Holkopollenites*–A
- *Horniella modica*
- *Ilex* sp.

Angiosperm pollen
- *Juglans nigripites*
- *Juglans* sp.
- *Liliacidites vittatus*
- *Liquidambar* sp.
- *Momipites coryloides*
- *Myricipites* sp.
- *Nyssapollenites kruschii*
- *Paraalnipollenites confusus*
- *P.* sp.
- *Pistillipollenites mcgregorii* (Pl. 1, fig. 8)
- *P.* n. sp. (Pl. 1, fig. 9)
- *Platycarya* sp.
- *Quercoidites microhenrici*
- *Rhoiipites angustus*
- *R. latus* (Pl. 1, fig. 6)
- *R. retipillatus*
- *Salixpollenites discoloripites*
- *S. parvus*
- *Tilia crassipites*
- *T. vescipites* (Pl. 1, fig. 5)
- *Tricolpites microhenrici*
- *T. minutus*
- *Tricolporopollenites*–A
- *Ulmipollenites undulosus*

Fungal spores
- *Ctenosporites wolfei* (Pl. 1, fig. 1)
- *Dicellaesporites granuliformis* (Pl. 1, fig. 3)
- *Diporisporites*–A (Pl. 1, fig. 2)
- *D.* spp.
- *Granatisporites cotalis*
- *Multicellaesporites* sp.
- *Pesavis tagluensis* (Pl. 1, fig. 4)
- *Striadiporites sanctaebarbarae*

Algal cysts
- *Sigmopollis hispidus*
- *Schizosporis* spp.
- cf. *Peridinium* sp.

Fault Zone, last paragraph).

Palynology

The palynoassemblage from the early Tertiary beds here clearly match those of the Early to Mid-Eocene sediments from other areas in south-central British Columbia (Rouse and Mathews 1961, 1979; Mathews and Rouse 1963; Mathews 1964; Hills and Baadsgaard 1967; Rouse *et al.* 1971; Rouse 1977). The palynomorphs are listed in Table 3, and some of the more definitive species of this interval are illustrated in Pl. 1, figs. 1–9. Of particular significance is the combination of *Pistillipollenites mcgregorii* (Pl. 1, fig. 8) and *Tilia vescipites* (Pl. 1, fig. 5) among the pollen, and *Ctenosporites wolfei* (Pl. 1, fig. 1) and *Diporisporites*–A (Pl. 1, fig. 2) among the fungal spores. As pointed out earlier (Rouse 1977, Text-fig. 3 and p. 55), the first true *Tilia* pollen occurs at the beginning of the Eocene, whereas *Pistillipollenites mcgregorii* ranges from the Late Paleocene to early Middle Eocene. Thus the presence of both in this and equivalent rock units in south-central British Columbia is definitive for the interval Early – early Middle Eocene.

The 71 palynomorph species reported here (Table 3) from the Gang Ranch – Big Bar area are the most to have been reported from the Early or Middle Eocene in Canada. Furthermore there are several new species in the assemblage that are

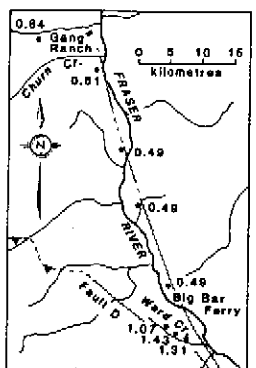


FIG. 4. Gang Ranch – Big Bar area: vitrinite reflectance.

not reported here, so the ultimate number will be somewhat larger. It indicates a very diverse floral assemblage during that interval, supporting the paleoclimatic interpretations (Rouse

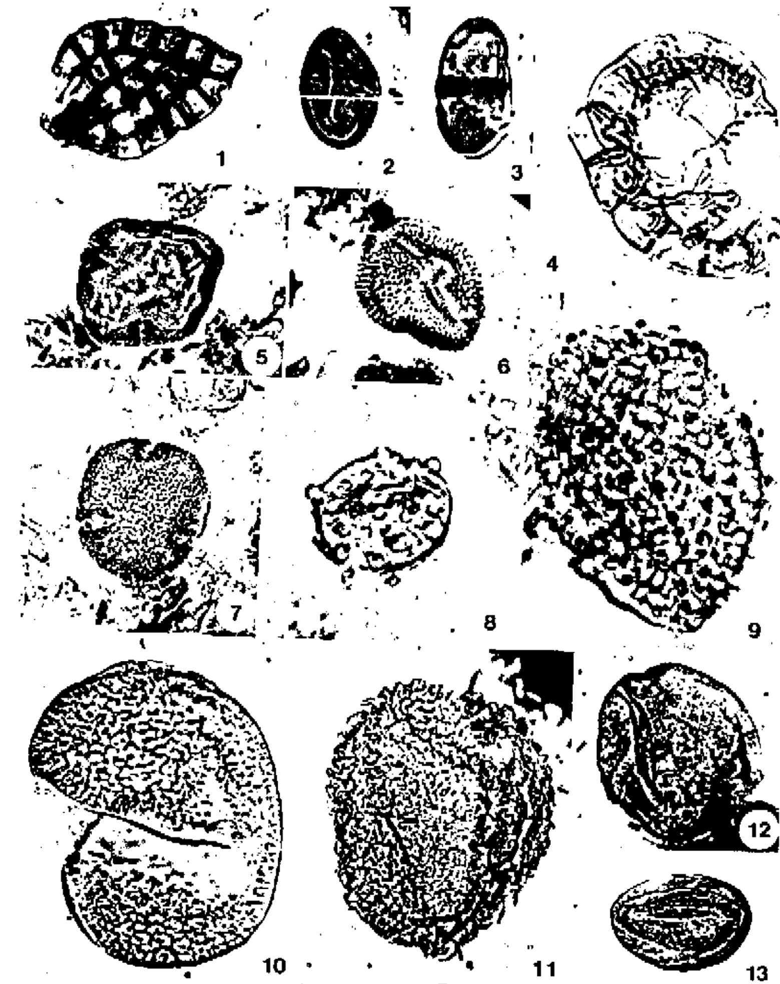


PLATE I

Selected representative palynomorphs from the Eocene and Miocene sediments of the Gang Ranch – Big Bar area. All figures ×1000.

FIGS. 1–9. From the Eocene beds. (1) *Ctenosporites wolfei*. (2) *Diporisporites*–A. (3) *Dicellaesporites granuliformis*. (4) *Pesavis tagluensis*. (5) *Tilia vescipites*. (6) *Rhoiipites latus*. (7) *Bombacacidites bombaxoides*. (8) *Pistillipollenites mcgregorii*. (9) *P.* n. sp.

FIGS. 10–13. From the Miocene beds. (10) *Cedrus perialata*. (11) *Tsuga heterophyllites*. (12) *Fagus granulata*. (13) *Quercus shiabensis*.

1977; Rouse and Mathews 1979) that conditions were much warmer and more humid than present, most likely in the subtropical range, at least for lowland locales.

The distribution of palynomorphs in the sediments investigated here indicates the presence of palynofacies, with the warmest indicator species concentrated in the upper beds of Churn Creek, particularly in the fine-grained beds associated with coal. The assemblages from the Crows Bar Creek and Big Bar sections are more temperate in aspect, suggesting more upland and hence cooler sources.

Correlation

The Eocene succession here is contemporaneous with and lithologically similar to the Kamloops Group (Ewing 1981), 150 km to the southeast, to the "Kamloops Group equivalent" of the Quesnel area (Rouse and Mathews 1979), 150 km to the north, and to similar rocks from Idaho to Yukon Territory.

Miocene volcanic rocks

Basaltic lava and agglomerate yielding Early Miocene dates (Table 2) are reported by Church (1980, 1982) from the tops of Black Dome Mountain and another summit 9 km to the southwest. An obsidian body, possibly a dike, 7 km southeast of Black Dome Mountain, yields a slightly older date (B. N. Church, personal communication, 1983).

Miocene sediments

Distribution and lithology

Miocene sediments occur in the vicinity of Gang Ranch, principally at two sites, one 2.5 km north of the ranch headquarters, exposing the lower beds, the other 4–5 km west of the ranch, where the upper beds can be found.

The occurrences 2.5 km north of Gang Ranch, localized in the headwalls of a compound landslide, consist of 130 m of horizontally bedded gravels and minor sands. The base of this succession is concealed by landslide debris and the top is an erosion surface covered by till.

The lower beds are rusty-weathering pebble to cobble gravel with well rounded clasts up to 30 cm in diameter composed mostly of quartzite embedded in an abundant fine gravel to sand matrix. Foreset beds and imbrication indicate stream flow was here toward the north or northwest, whereas the quartzite, known to occur in place only in the Columbia and Rocky mountains to the north and east, would indicate regional transport to the south or west.

The higher beds consist of finer gravel, with clasts mostly less than 10 cm across. Volcanic rocks dominate, associated with lesser quartzite, chert, sandstone; granitic rocks and phyllite are present but rare. Sorting is moderate; rounding is poor to good. Local beds of clean grey sand, rich in muscovite, are present. A source for the muscovite, like that of the quartzite, is known to the north and east in some of the metamorphic rocks of the Columbia Mountains, but nowhere is there a major source known to the south or west. Silty beds are thin and rare.

The occurrences 4–5 km west of Gang Ranch are higher in present altitude and presumably higher in stratigraphic position. The most complete section is found in a ditch and ravine down which surplus irrigation water has been allowed to flow in excessive quantities (UTM coordinates 422105). Immediately above the base of the exposures in the ravine, at an altitude of 805 m, are horizontal gravels containing poorly sorted subangular pebbles of volcanic and metavolcanic origin and rare chert. These resemble the gravels of the upper part of the succession north of Gang Ranch at a comparable altitude. Beds of tuffaceous silt or fine ash are subordinate. Vitric tuffs become more common upward and above an altitude of 915 m they dominate. The tuffs are composed principally of silt-sized particles of glass, in places moderately sorted and lacking clear shard shapes. Composition approaches that of a rhyodacite (RI of fusion = 1.520). Lenses of pebbles and even cobbles are locally present, suggesting that part if not all of the ash has been reworked by running water. Scattered exposures of white tuffaceous silts occur up to about the 975 m level. Thus about 160 m of horizontal beds occurs in this area, and together with the 130 m of beds north of Gang Ranch suggests a succession approaching 300 m in total thickness.

A pink tuff, overlain by a coarse fanglomerate, 2 km southwest of the mouth of Watson Bar Creek, yields a Miocene palynoassemblage, but the relationships of this occurrence to those at Gang Ranch are unknown.

Structural relationships

The Miocene sediments are located on a structural low in the underlying beds but are themselves apparently undisturbed. The sub-Miocene unconformity is known to transgress the upper 700–800 m of the Eocene succession. Drift conceals the relationship between the Miocene beds and the Fraser Fault Zone.

Palynology

The palynoassemblage obtained from these beds (Table 4; Pl. 1, figs. 10–13) is relatively limited in species, 31 in all, but

TABLE 4. List of palynomorphs from the Gang Ranch Miocene beds

Fern spores
Deltoidospora diaphana
Laevigatosporites ovatus
Conifer pollen
Abies sp.
Cedrus perialata (Pl. 1, fig. 10)
cf. *Keteleeria*–1
Picea grandivescipites
Pinus—diploxylon type
Pinus—haploxylon type
Pinus–3 (Piel 1977)
Pinus–4 (Piel 1977)
Pinus–5 n. sp.
Pseudotsuga sp.
Tsuga heterophyllites (Pl. 1, fig. 11)
Tsuga mertensiana
Angiosperm pollen
Betula claripites
Caprifolipites microreticulatus
Carya viridifluminipites
Caryapollenites simplex
Castanea/Castanopsis sp.
Corylus sp.
Cupanieidites sp.
Fagus granulata (Pl. 1, fig. 12)
Horniella sp.
Juglans periporites
Liquidambar brandonsis
Pterocarya stellatus
Quercus shiabensis (Pl. 1, fig. 13)
Tilia crassipites
T. vescipites
Tricolporate E (Piel 1977)
Ulmipollenites spp.

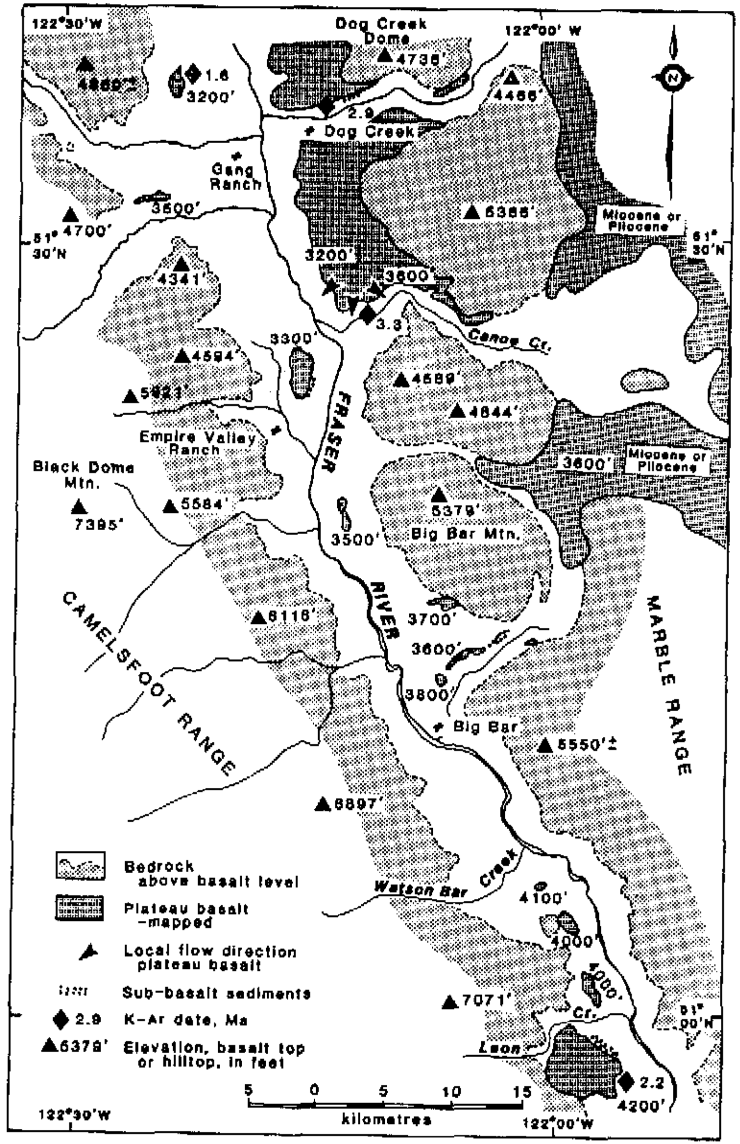


FIG. 5. Gang Ranch – Big Bar area: geology of Pliocene basalts.

is virtually identical to that obtained from the Fraser Bend Formation near Quesnel by Piel (1977) and Rouse and Mathews (1979, pp. 434–435). In addition, the Gang Ranch sections show the same clear split in palynofacies obtained from the Fraser Bend Formation, viz. a *Quercus–Fagus* palynofacies in the white ash beds and a *Tsuga–Cedrus* palynofacies from the silts and sands.

The palynoassemblage from the Gang Ranch beds is interpreted as representing most closely a mixed deciduous–coniferous forest such as now exists in the mid-Mississippi Valley, southern Honshu (Japan), or south-central China (Rouse and Mathews 1979, p. 435). The *Quercus–Fagus* palynofacies is interpreted as representing stands of broad-leaved angiosperm trees with floodplain and backswamp sedimentation. In contrast the dominantly coniferous *Tsuga–Cedrus* palynofacies in the coarser lithofacies is thought to be derived from surrounding valley slopes and hills. The paleoclimate for the lowland (*Quercus–Fagus*) facies is estimated to be warm temperate, with very warm summers and mild winters but with some freezing periods, and a mean annual temperature of about 12–16°C. The climate of the slope facies (*Tsuga–Cedrus*) would have been somewhat wetter and cooler than that of the lowland.

Correlation and age

The overall pollen assemblage and the two palynofacies seen in the Gang Ranch beds so closely resemble those of the Fraser Bend Formation near Quesnel (Rouse and Mathews 1979) that the two units can be equated. Lithology supports the correlation. At both sites the base of the succession is a well sorted cobble gravel characterized by quartzite clasts. At both sites beds then fine upward, first into a succession of moderately sorted and subrounded pebble gravels, mostly of local derivation, interbedded with subordinate sands and silts. They then grade upward into a succession of pale tuffaceous beds containing scattered pebble bands. The exposed thickness near Gang Ranch is greater than the 150 m preserved at Quesnel. The age of the Fraser Bend Formation has been estimated (Rouse and Mathews 1979, p. 435) to fall in the interval of 17–13.5 Ma, or latest Early to Middle Miocene, equivalent to the Barstovian mammalian stage. Sediments of this age are now recognized along Fraser River from Prince George to Watson Bar Creek as well as in southeastern British Columbia (Clague 1974).

Pliocene beds

Distribution and lithology

Lavas previously assigned informally to the "Plateau basalt" (Rice 1947, p. 31; Rouse and Mathews 1979) or to the "Chilcotin Group" (Tipper 1978, marginal notes; Bevier 1983) occur as erosion remnants along the length of the Fraser Valley, rising gradually from 975 m asl north of Gang Ranch to 1275 m asl at Leon Creek, 80 km to the southeast. All appear to be part of a single accumulation of lava that at the time of deposition would have been confined by higher ground to a width of no more than 15 km in the north and to only 5 km at the south (Fig. 5). The Marble Range and the hills to its north have almost completely separated this Fraser Valley belt of lavas from a more continuous and extensive basalt sheet to the east. The relationships of these two sheets are still being investigated.

The "Plateau lavas" along the Fraser Valley are uniformly basaltic (RI of fusion = 1.61) and occur in flow units averaging 5–10 m thick and locally reaching 30 m. The basalt is dark grey to grey, depending on crystallinity and hence on position within and thickness of the flow units. Columnar jointing is ubiquitous. In places there are foreset-bedded breccias developed where lavas entered standing water (Fuller 1931). At and north of Canoe Creek where these breccias are extensively developed, their accumulation was from north to south, implying a source somewhere to the north. It is inferred that this lava, moving toward the narrower (and upstream?) parts of the preexisting valley, may very well have dammed it to create the lake into which the breccias were spilled. The 60 m vertical range of the breccias implies ponding of water to at least this depth.

Sub-basalt sediments were observed at two localities: one 3 km northeast of Empire Valley Ranch, the other 1 km south of Leon Creek (Fig. 5). These consist of horizontally bedded pebble and cobble gravel and sand, plus minor silt reaching 90 m in thickness. The gravels near Empire Valley are well sorted and well rounded with a maximum particle size of 40 cm. Granitic and volcanic clasts dominate; vein quartz is conspicuous near the contact with underlying Triassic rocks; chert, greenstone, and greywacke are present in minor amounts. Transport direction has not been determined. These sub-basalt sediments are unlike the tuffaceous beds of the upper part of the Miocene succession and may be part of a younger channel fill preserved by the basalt cover (see also Rouse and Mathews 1979, p. 437). Neither microfossils nor megafossils have been found in these beds.

Structural relationships

The present southward rise of the top of the Pliocene lavas, 300 m in 75 km, in the same direction as the indicated original flow can be explained by differential uplift. The Pliocene lavas and underlying sediments northeast of Empire Valley show no discontinuity at the Fraser River Fault at a locality where only a few metres of vertical displacement could be recognized.

Isotopic dating

Four potassium–argon dates are now available from this area (Table 2) ranging from 1.3 to 2.9 Ma (average 2.4 ± 0.9 Ma). These constitute the youngest dates so far obtained from the "Plateau basalts" and differ significantly from those of the Chilcotin area (6–13 Ma, Bevier 1983), 100 km to the northwest, and from those of the Bonaparte Lake sheet (Campbell and Tipper 1971), about 75 km to the east, where dates of 6–10 Ma have been obtained (Farquharson 1973; Mathews 1964).

The Fraser Fault Zone

The Fraser Fault Zone, identified from the vicinity of latitude 52°N to latitude 50°N and apparently continuing southward in two possible branches into the state of Washington (Roddick *et al.* 1979), is the major structural feature of the Gang Ranch – Big Bar area. Here it consistently separates Triassic or older metasedimentary and metavolcanic rocks to the east from Eocene and Cretaceous rocks on the west.

The fault zone itself, where well exposed 3.5 km south of Churn Creek, consists of two or more discrete steeply dipping shears 100–200 m apart separated and surrounded by belts of less severely granulated rock in which fragments of phyllite or altered (bentonitic) lava can be recognized. To the west of this the strongly folded Eocene succession is present. Near Empire Valley and Crows Bar Creek the main fault zone seems to be narrower, but branching splays may still be present. At Big Bar Canyon the fault is reported to dip 74° southwesterly (Trettin

1961, p. 97).

Significant Cenozoic dip-slip displacement along the fault in the Gang Ranch – Big Bar area can be inferred in view of the 1500 m of Eocene beds plus the large though unmeasured thickness of Cretaceous volcanic and sedimentary rocks on the west, which are completely lacking for many kilometres to the east of the fault. The western side has thus been dropped at least 1.5 km and probably much more in or since Middle Eocene time. Early movement may have led to trapping of westerly derived gravels against the rising east wall and later ponding of water within which the bentonitic clays accumulated.

Pre-Eocene dip-slip movement on the fault is suggested by the great thickness of Cretaceous rocks west of the fault and their absence at this latitude on the east, but other explanations can be entertained.

The Fraser Fault Zone is remarkable not only for its continuity but also for its low sinuosity. In this respect it could qualify as a major transcurrent fault and, indeed, it has been so designated (e.g., Misch *in* Okulitch 1974; and *in* Monger 1977, Fig. 8). Mid-Cretaceous volcanic rocks are known to make contact with the west wall of the Fraser Fault Zone between latitudes 51°20′N and 51°22′N at the present surface and to perhaps 51°30′N at depth. However, these rocks are not known east of this zone anywhere north of latitude 50°49′N (Trettin 1961; Monger 1981). A post-mid-Cretaceous dextral shift of 70–80 km is thus permitted by our data, but in view of the much greater erosion on the east side of the fault such an inference is not mandatory.

A western branch of the Fraser Fault, fault "d" of Trettin (1961), diverges from the main fault (Trettin's fault "e") north from latitude 51°N and may link with Tipper's (1978) Hungry Valley thrust some 20 km west of Big Bar Ferry (Fig. 1). This branch fault may provide an explanation for the anomalously high vitrinite reflectance found along Ward Creek, 2.5 km northeast of the present surface trace of this branch fault (Fig. 4). If this fault formerly flattened up dip, as it apparently does now in the west, it could have tectonically buried the Eocene sediments and caused an increase in maturation of their contained coaly fragments over and above those of contemporaneous rocks farther north where the tectonically emplaced blanket was lacking. Should this explanation be valid it would imply a minimum of 2.5 km northward component of movement of the rocks west of fault "d" with respect to footwall rocks on the northeast.

Development of the Fraser River

Signs of a major river with a source at least 150 km away can be found in the coarse quartzite-rich gravels in the lower part of the Miocene succession north of Gang Ranch. The river that deposited these gravels seems, however, to have been flowing northward and as such can hardly be described as an early stage of Fraser River. Record of a northwesterly flowing Miocene river has also been found on the north wall of Big Bar Creek 8 km east of the present Fraser River (Trettin 1961; Mathews, in preparation).

Confining the Pliocene lavas at the time of their deposition were the walls of a major valley, narrowing southward as if approaching its head. This valley was blocked near Canoe Creek by southward- or southwestward-advancing lava to form a lake as much as 60 m deep into which foreset-bedded breccias were deposited. Such a lake would not be expected had the valley been draining southward at the time. It would appear, therefore, that this Pliocene valley was also not created by Fraser River but only occupied by this southward-flowing stream at a later date.

Initiation of southward flow might have been caused by the lava dam or been consequent on the lava accumulation. This would have to occur before regional uplift had reversed the slope of the lava sheet from south to its present northward inclination. What other cause might exist for a southward-flowing stream to become established at this site? Glacial diversion of streams is known to have been a common event in Pleistocene time in British Columbia and this may be another example of the same process, though not necessarily occurring during the latest glaciation.

Whatever the time and method of initiation, Fraser River must have cut its spectacular inner trench to depths of as much as 1000 m below the lava sheet marking the Pliocene valley floor in no more than about 2 Ma.

Acknowledgments

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File

MEMORANDUM

ESSO MINERALS CANADA

COAL DEPARTMENT

79 03 30

JALW
– At minimum BDV should take his summer crew to this area for a first look
– I think it would be better to apply after the first look, we may not want to make the lead + work litigation.

TO: D. L. West

FROM: B. D. Vincent

SUBJECT: Australian Creek Prospect, Central British Columbia

Introduction

Tertiary-aged strata similar in age to those present at Hat Creek, Merritt, and Princeton are present in the Fraser River Valley from south of Quesnel to Prince George in Central British Columbia. Included in these strata are coal-bearing zones which may contain economic coal deposits.

This report deals with a prospect with its southern boundary at Australian Creek, a tributary of the Fraser River with its mouth approximately 18 miles south of Quesnel. From there, the area extends northward for 12 miles and is 2 to 4 miles wide.

Along the western boundary of the prospect is Highway 97, the main highway between Cache Creek and Prince George, and the British Columbia Railroad line from Vancouver to Prince George. Quesnel is approximately 215 rail miles from Vancouver, 70 rail miles from Prince George, and 460 rail miles from Prince Rupert.

Good location →

Previous Exploration

Initial investigation and local use of the coal in the Quesnel-Australian Creek area began in the 1920's. In 1929 and 1930, the Cariboo Coal and Clay Syndicate explored a small area on the south bank of Australian Creek with three diamond drill holes (Figure 2). In 1971 and 1972, Masters Exploration (Manalta) completed 21 drill holes predominantly on the west bank of the Fraser River in the Hodson Creek area, due west of the mouth of Australian Creek. Coal seams ranging from 2 metres to 13 metres in thickness were defined over an area of 1000 metres by 150 metres. Their coal licenses were allowed to lapse and there are no existing coal licenses in the area to our knowledge.

General Geology

The basement rocks of the area form the Pennsylvanian-Permian Cache Creek Group. Unconformably overlying the Cache Creek

Group are the basic Lower Lavas, Eocene in age. Above another unconformity is the Lower Fraser River Formation. Early Oligocene in age, this unit contains the main coal-bearing horizons along with other clastic sediments. Overlying unconformable is the Upper Fraser River Formation of clastic sediments and minor coals of mid-Miocene to Early Pliocene age. The youngest consolidated rocks in the area are the extensive basalts and andesites of the Upper Lavas. Further stratigraphic descriptions can be obtained in Graham, 1978.

Dips in the Lower Fraser River Formation range from 0 degrees to 45 degrees. Broad open folds are present along with some faulting. At Australian Creek, reported bed orientations indicate the presence of an anticline the axis of which trends SW to NE. The northwest limb shows dips of 25 to 45 degrees. The strike of the beds in this area are to the northeast and in places parallel the slope of the valley wall, a potential dip-slope configuration.

Coal

In the Australian Creek area, most previous exploration has been on the west side of the Fraser River. Masters Exploration found the coals to be lenticular and quite variable yet up to 13 metres in thickness. The easterly-most drill hole completed for Cariboo Coal and Clay Syndicate intersected 4.25 metres of coal at a depth of 1.5 metres as well as 24.3 metres of coal with some partings at a depth of 148 metres (Lakes, 1930). The holes further west did not intersect any substantial thicknesses of coal. It is possible additional folding is present which could bring the thick seam nearer the surface assuming the seam is less lenticular than those on the west bank of the Fraser. Drilling may outline additional seams, not yet documented, which may have considerable reserves.

Graham (1978) summarized previously published coal analyses and states the coal is subbituminous B or C in rank. One may expect the coals to have a moisture content of 10 to 20%, to produce 20 to 30% ash and 6500 to 8000 BTU/lb., and to be 1.0 to 1.6% sulphur. Further analyses may alter this.

Could represent a major problem if confirmed

Conclusions and Recommendations

The Australian Creek prospect has been insufficiently explored to be able to estimate coal reserves or mining and economic potential. The indications from previous exploration suggest the potential of large coal reserves. The location is well suited for power generation or, if the quality can be improved, for export.

It is recommended that application be made for coal licenses over an area of approximately 8195 hectares (20,250 acres). The area is shown in Figures 2 and 3 and the description is attached.

The size of the area is approximate as the dimensions of the lots were measured from a print of a B.C. coal license map.

License rental fees would be $40,500 per year. The work obligation for the first year would be $60,750. For the second and third years it would be $101,750 each.

In order to evaluate this prospect, geological mapping would be required though minimal exposure is expected. Drilling and geophysical logging with coring and coal analyses are essential and the total cost would probably be close to the combined first and second year work obligations.

References

(Includes only those quoted above. Additional reference material is presently filed under B.C. Prospects - Quesnel.)

Graham, P.S. (1978)
"Geology and Coal Resources of the Tertiary Sediments, Quesnel-Prince George Area, British Columbia"; in "Current Research, Part B", Geol. Surv. Can. Paper 78-1B, p. 59-64.

Lakes, A. (1930)
"Preliminary Report on the Cariboo Coal and Clay Syndicate Property at Australian"; private report; B.C. Department of Energy, Mines, and Petroleum Resources; Open File.

Bruce D. Vincent

Bruce D. Vincent

BDV/cyg

Attachments

File: B.C. ~~Properties~~ Prospects - Quesnel

Australian Creek Prospect

British Columbia

Description of land over which coal license application is recommended.

All areas within the following lots and areas in the Australian Creek to Dale Lake area, Cariboo Land District:

Lot 3960	Lot 2000	Lot 5041	Lot 6735
" 3961	" 9892	" 5042	" 9526
" 7260	" 4527	" 2927	" 2195
" 9796	" 4528	" 19	" 5038
" 9792	" 4532	" 5047	" 5039
" 3979	" 4531	" 5048	" 2196
" 3978	" 4526	" 5031	" 2194
" 3975	" 4525	" 5032	" 9694
" 9791	" 4534	" 5033	" 8669
" 12438	" 4533	" 5080	" 9119
" 3977	" 10	" 6723	" 9473
" 4529	" 5046	" 5037	" 6046
" 6688	" 5046A	" 5036	" 12424
" 4530	" 5045	" 6721	
" 11956	" 5044	" 6722	

Unnamed area A commencing at southwest corner of Lot 4532;
thence approximately 660 feet south,
thence approximately 660 feet east,
thence approximately 660 feet north,
thence approximately 660 feet west to point of commencement.

Unnamed area B commencing at southeast corner of Lot 5038;
thence 1 mile south,
thence 1 mile east,
thence 1 mile north,
thence 1 mile west to point of commencement.

Unnamed area C commencing at southeast corner of Lot 5038:
thence 2640 feet west,
thence approximately 1584 feet south,
thence 2640 feet west,
thence approximately 3696 feet south,
thence 1 mile east,
thence 1 mile north to point of commencement.

Unnamed area D commencing at southwest corner of Lot 2196;
thence 3696 feet south,
thence approximately 4224 feet west,
thence approximately 1046 feet north,
thence approximately 1584 feet east to Australian Creek,
thence approximately 3696 feet along creek to point of commencement.

Unnamed area E commencing at southeast corner of Lot 12424;
thence 4488 feet east,
thence 1 mile north,
thence 4488 feet west,
thence 1 mile south to point of commencement.

Unnamed area F commencing at a point 1 mile south of southeast corner of Lot 5038;
thence 1 mile south,
thence 1 mile west,
thence 1 mile north,
thence 1 mile east to point of commencement.

Unnamed area G commencing at a point 1 mile south of southeast corner of Lot 5038;
thence 1 mile east,
thence 1 mile south,
thence 1 mile west,
thence 1 mile north to point of commencement.

Total area described is approximately 20,250 acres or 8195 hectares. Distances described are approximate because they were measured from a print of a B.C. coal license map of a scale 1 inch equalling 1 mile.

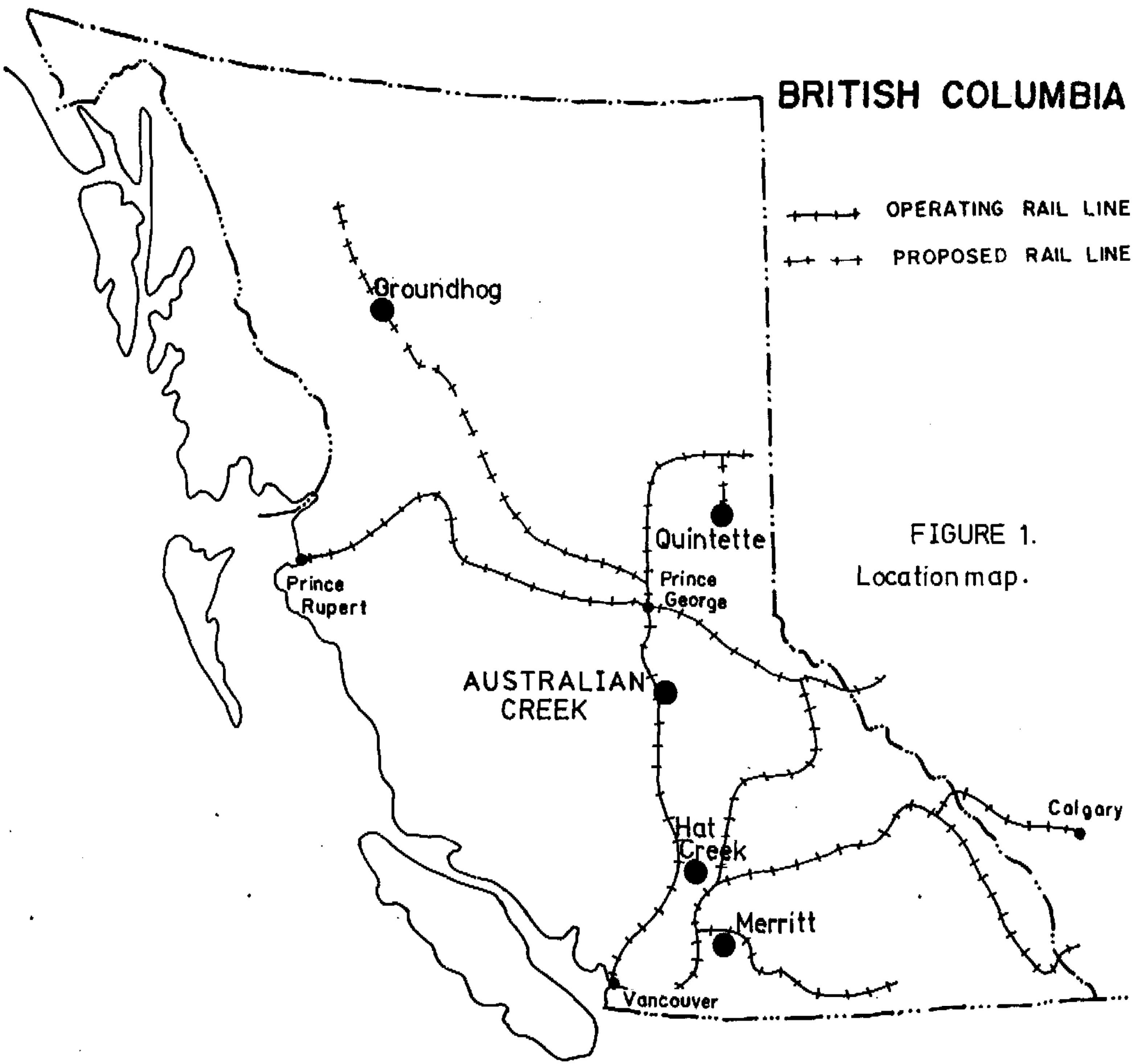

FIGURE 1.
Location map.

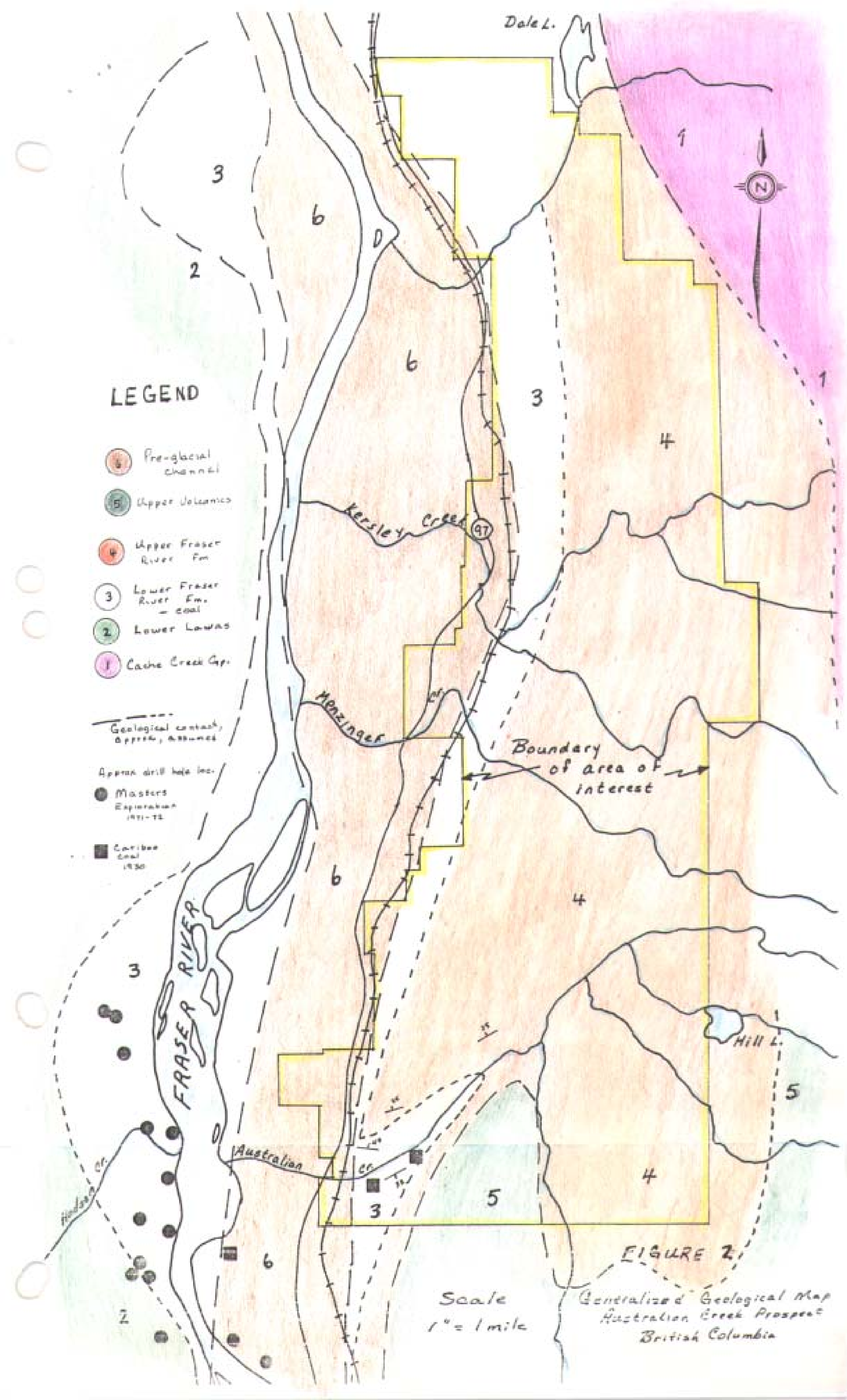

FIGURE 2

Generalized Geological Map
Australian Creek Prospect
British Columbia

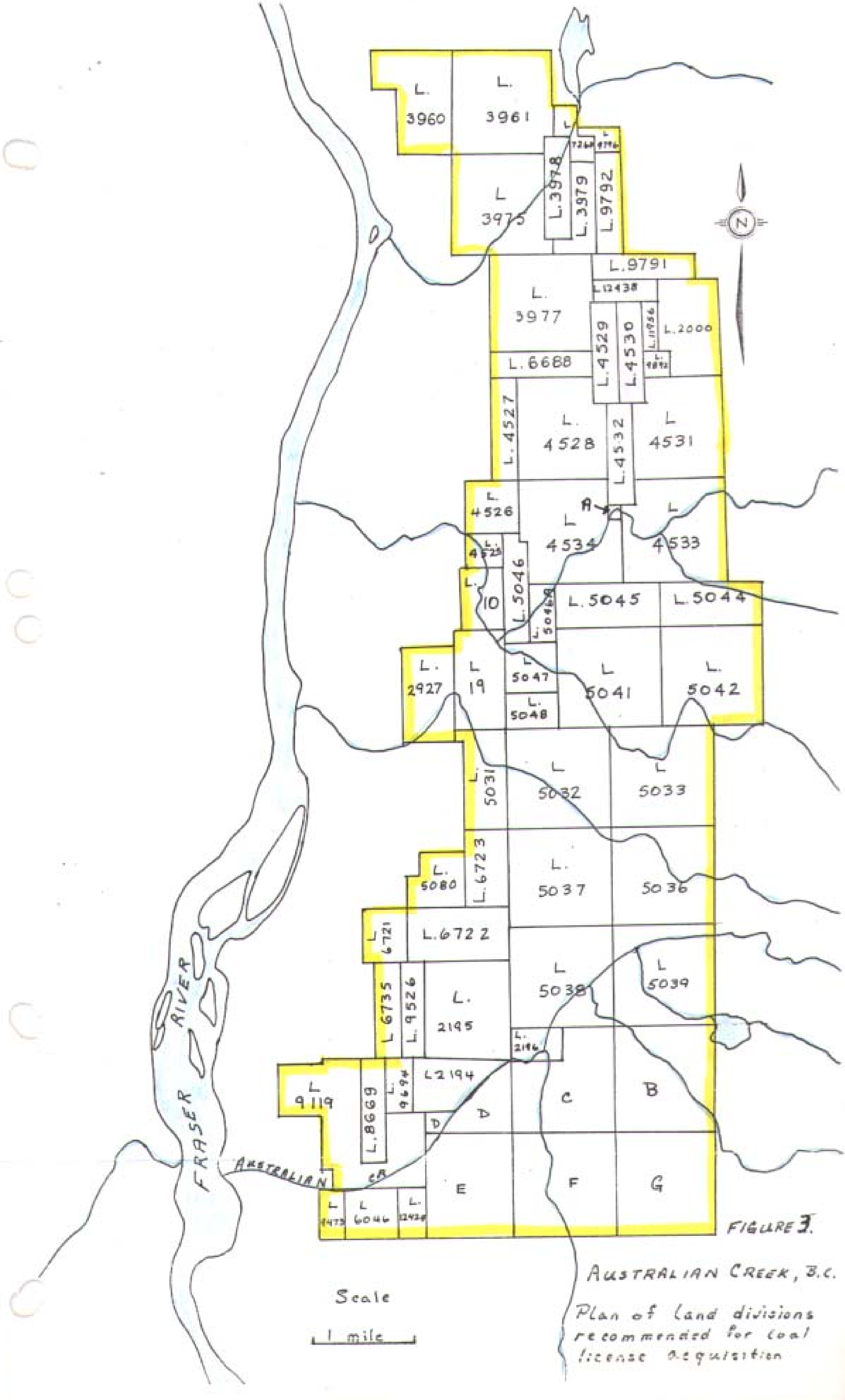

FIGURE 3.

AUSTRALIAN CREEK, B.C.

Plan of land divisions recommended for coal license acquisition

13-B-16

IMPERIAL OIL LIMITED

MEMORANDUM

May 19, 1977

File: C7-3.2

File copies to
1) Princeton
2) Quesnel
3) Groundhog

P. R. Vogt
Department

Re: Trip to Victoria May 11 - 13, 1977 to Discuss Some of the B.C. Intermontane Basins

Lou Kabatek and I spent considerable time talking to Bob Gilchrist, the Senior Government Coal Geologist and reading some of the reports on file. Several of the reports contain excellent reference material and we asked Bob to have them copied and sent to us. They will be sent to your attention along with the charge for duplication.

Lou will comment on what he found out about the Merritt Coal Field, and I will touch on Princeton, Quesnel, and Groundhog.

Princeton

Gravity lines run across the Basin in an east-west direction by C. Ager, Consultant, give a good approximation of basin shape and in addition lesser anomalies could be indicative of coal. These anomalies are based on similarities to Hat Creek anomolies and to results obtained over known coal bodies at Princeton.

The basin shallows to the north, but on a line (675N) which crosses the basin a few miles north of Princeton near Belfort several "lows" occur, one of which if real, would indicate thick coal at 400 - 600 ft. We have asked to have this report duplicated and when we receive it the data should be examined by Jim Hughson in the Minerals Group.

Quesnel

The report of drilling submitted by Manalta (Master Explorations) was studied but it is still not possible to make a good interpretation of the results as they do not seem to tie in to the surface work. Unexpected thicknesses of Quaternary material result in the coal being eroded out in some areas, but this does not explain everything. The report is being copied and

.../2

after it has been studied in more detail a field check will probably be desirable. Coal (lignitic) up to 14 feet thick is reported and if they occurs over any sizable area it could be an important resource.

Groundhog

We are getting three reports of this coal area copied for our files. These are good reports although unfortunately they primarily deal with the southern end of the basin rather than the Mt. Klappen area to the north where we have our main interest. I was unable to talk to Jim Fyles, the Deputy Minister, so do not have any new information on when a coal policy will be worked out with respect to coal lease or permit acquisition.

One point of real interest with respect to Groundhog which I think requires follow up is some planned work this summer by the G.S.C. Dr. Richardson of the G.S.C. of the Vancouver office will be doing field work in the area of our acreage application. He has invited Bob Gilchrist of the B.C. Department of Mines to spend some time with him and Bob is positive that if we desired we would be welcome. I believe it would be advantageous to discuss this with Dr. Richardson before he goes into the field (which may be soon) and if we have the manpower, attempt to co-operate with him. Possibly we could arrange to drill a few critical holes in support of the surface work using a helicopter for rig moving.

DBL:cb

DBLayer /per CBudel.
D. B. Layer

Misc. Reports

GEOLOGICAL SETTING

REGIONAL GEOLOGY

The south-central interior of British Columbia is distinctively underlain by irregularly shaped areas of generally flat-lying Tertiary rocks of sedimentary and volcanic origin. The northern half of the belt is essentially completely underlain by Tertiary volcanic rocks, beneath which local, small windows of underlying Tertiary sedimentary rocks have been exposed by valley erosion. The southern half of the belt is comprised of a very irregular scattering of areas of Tertiary rocks that range in size from a few square miles up to hundreds of square miles. Because many of these areas of Tertiary rocks occupy valleys (Hat Creek) or broad lowlands (Princeton) they have been referred to as Tertiary "basins" and often regarded as representing the stratigraphic record of separate, finite loci of Tertiary deposition. However, continuing exploration of these areas of Tertiary rocks indicates that the strata around the edges of the areas are almost everywhere truncated either by erosion surfaces or by boundary faults, thus it now appears more likely that the present scattered areas of Tertiary formations represent disconnected erosional remnants of one or more, but not many, continuous troughs of deposition that were filled during Tertiary time.

The hypothetical existence of such a continuous Tertiary continental sea in the interior of the province is further suggested by the fact that all of the explored and mapped Tertiary areas, or "basins", from Princeton to Prince George include all or part of a common stratigraphic succession, namely:

Top: (6) Volcanics - flat-lying sheet flows (Miocene-Pliocene)
(5) Sediments - commonly absent (Miocene)
(4) Volcanics - relatively flat-lying (Oligocene)
(EROSION, FOLDING, FAULTING)
(3) Sediments - continental, folded, faulted (Eocene)
COAL BEARING
(2) Volcanics - (Eocene and Oligocene)
(1) Sediments - confined to north end of belt (Paleocene)
COAL BEARING

Correlation of the stratigraphy of Tertiary sedimentary areas in south-central British Columbia, (Figure 2), indicates that the Paleocene basal formations are absent south of Bowron River; however, north of Prince George they are widespread and coal-bearing. In northern British Columbia from latitude 56° to 60° north, coal occurs in Paleocene rocks of the Sustut and Sifton Assemblages, which range in age from Upper Cretaceous to Eocene, and apparently is rarer in rocks of Eocene age. The broad distribution of Tertiary sedimentary rocks in the entire Interior Belt of British Columbia suggests that two major lineal basins were present from Upper Cretaceous to Eocene time in the northern half of the province. After some 10 million years of the Paleocene, one of these continental seas that was receiving deposition had extended southward to at least the 49th parallel and was host to volcanic and sedimentary deposition there by Eocene time.

It is of interest in such a regional concept of Tertiary deposition that recent seismological and off-shore drill data from the continental shelf off the west coast of Vancouver Island, (1972, D. L. Tiffin et al), indicate that bathyal deposition onto the shelf from the northeast occurred from the Eocene to the Pliocene of the Tertiary. This deposition included intercalated volcanics, as does the sequence in the Interior Belt on the northeast side of the Tertiary (coastal) landmass, and was interrupted by several periods of uplift and deformation before deposition was terminated in the Pliocene by the major uplift of the Coast Mountains. It is also of interest that the shelf rocks are mainly mudstones, as are most of the finer clastics in the Interior Belt.

If the Tertiary "basins" of the southern Interior Belt do represent the results of deposition into a continuous continental sea, and are therefore erosional remnants, rather than individual separated basins of deposition, the economic implications for the exploration for coal are important. The above-described hypothesis of the origin of the interior Tertiary formations thus implies far more continuity of the coal-bearing Tertiary formations throughout all of the areas underlain by Tertiary rocks than had heretofore been assumed. This possibility is further suggested by the fact that where erosion has stripped the overlying Tertiary volcanic cover coal has been discovered in the underlying strata in the Cariboo, Hat Creek, North Thompson, Nicola, Similkameen, and Okanagan "basins".

This concept of a continuous interior basin of Tertiary deposition, with its implication of possible continuous shoreline swamps in Eocene-Oligocene time, which subsequently developed into the known Interior Tertiary coal occurrences, has been derived from the study of the Tertiary deposits described in this report. The concept did not guide the study.

Tertiary sedimentation was interrupted by, and in part contemperaneous with, four periods of wide-spread volcanic activity. Vulcanism, initiated in the early Tertiary, was terminated in late Miocene-Pliocene times by the extrusion of extensive areas of plateau basalt and the uplift of the Coast Mountains. Frequent faulting, uplift, and rapid erosion accompanied the volcanic activity throughout the Tertiary and no doubt was the dominant cause of the post-depositional structural deformation of the various coalfields in south-central British Columbia.

COAL MEASURES

Coal accumulation occurred throughout the Tertiary in south-central British Columbia during three principal periods of sedimentary deposition; in the Paleocene from mid-Eocene to early Oligocene, and in the Miocene epochs.

The oldest coal-bearing sedimentary rocks are Paleocene in age. To date they are limited in areal extent to a local depression along the Bowron River east of Prince George. No evidence presently exists to indicate that the Bowron graben-like area was part of a much more extensive basin of coal deposition.

The most extensive and most economically-significant sedimentary rocks that contain coal are predominantly of Eocene age. Evidence also suggests that coal formation probably extended to the Oligocene. The Eocene (Oligocene) coal measures probably represent a lengthy locally sustained and locally cyclical period of accumulation within a relatively large scale environment of deposition, such as a series of interlocking littoral-lagoonal basins along the Tertiary sea shore(s). Extending from the 49th parallel northwestward to the Cariboo, it is conceivable that other deposits of this age underlie the extensive plateau lavas of west central British Columbia.

Miocene coaly accumulations have been exposed in the north end of the Interior Belt in valleys of present river systems, specifically the Fraser and its tributaries. Tectonically young, hence little deformed, these carbonaceous sediments generally occur as thin seams of poor quality lignite of limited areal extent.

The following portion of this report describes the geology and coal potential of each of the known coalfields or occurrences in the Southern Interior Belt of British Columbia. For convenience, these descriptions of coal occurrences that follow have been grouped by ages, namely: (1) Miocene, (2) Eocene and (3) Paleocene. Coal reserves and/or resources are included with each group when applicable.

II. HAT CREEK DEPOSIT: (Figure 6)

The Hat Creek coal deposit is described in detail in a separate report for this study of the thermal coal resources of British Columbia; however, it is important when assessing the possible coal potential of the remnants of Tertiary sedimentary rocks throughout the Southern Interior Coal Belt to appreciate that the coal reserve indicated in the relatively small Hat Creek "basin" is so large. The valley, entirely covered by overburden, totals about 60 square miles in area and only about 8 square miles at one end have been explored for coal, (Figure 6). Within the explored area an openpit deposit of subbituminous coal in excess of 500 million tons has been indicated by drilling; the remainder of the valley is presently being explored.

If some geological continuity of the coal measures in the Tertiary remnant areas in the Interior Belt can be established, then the exceptionally thick coal layers, (400-1600 feet), at Hat Creek may possibly be repeated elsewhere in the Tertiary sequence, i.e., in other areas of Tertiary rocks in the Interior Belt.

III. THOMPSON RIVER OCCURRENCES

Sedimentary rocks of Eocene age containing coal occurrences extend along the North Thompson River from Kamloops northward for approximately 60 miles. The deposits, occurring in a series of small, isolated, remnant basins, are in two groups; the southern group lies between Kamloops Lake and the city of Kamloops, and the northern group lies clustered along the North Thompson River near the village of Chu Chua.

Chu Chua: (Figure 7)

Coal, mined on a small scale for local consumption for 1921 to 1923, crops out on locally-named Coal Creek, approximately two miles south of Chu Chua. Apparently once part of a large and more extensive basin extending along the North Thompson River, several small remnant basins, including the one on Coal Creek, contain a sedimentary succession of conglomerate, arkose, shale and coal. Unconformably overlying a basement of older granitic and volcanic rocks and in turn capped locally by younger volcanic rocks, the sedimentary rocks are, in general, moderately folded along axes paralleling the river, although other structures are locally in evidence.

Data on the nature of coal occurrences in the Chu Chua area are restricted to the Coal Creek basin. At Coal Creek the sedimentary formation exceeds 2500 feet in thickness. The known coal measure, 600 feet in thickness, has its base 1650 feet above the basement; however coal seams may appear above or below the known coal section but few exposures of sedimentary rocks are available to determine this.

Within the indicated coal measure, three coal zones, which occur over 300 feet of stratigraphic section, have been partially developed and mined on a limited basis. The upper zone, 15'4" in thickness, contains two coal seams, (2'7" and 1'10" in thickness), separated by 10'11" of waste rock. The middle zone, 7'6" in thickness, also contains two seams (1'10" and 1'8" in thickness) which are separated by 4 feet of waste. A third zone, stratigraphically lower in the section, comprises a single seam 3'9" in thickness.

The coal on Coal Creek has been described as hard, black, lustrous, and thinly laminated. Samples selected from underground in 1923 and sent to the Mines Branch in Ottawa for analysis graded as follows:

	Moisture	Ash	Volatiles	Fixed Carbon	Calorific Value
Upper Zone					
top seam	3.6 %	13.8 %	37.9 %	44.7 %	12,040 Btu's/lb.
bottom seam	4.0 %	22.1 %	37.9 %	36.0 %	10,780
Middle Zone					
top seam	4.0 %	24.0 %	36.1 %	35.9 %	10,290
Lower Zone	3.7 %	37.3 %	29.4 %	29.6 %	8,230

The above samples were analyzed on an "as received" basis.

Coal seams in the Chu Chua area are relatively thin, do not lie close enough together to be considered as a mineable zone, and underlie Tertiary areas of very limited size. In addition, continuity of seams within each area is suspect because of suggested generally tumultuous depositional conditions during swamp formation. For these reasons, a thermal plant predicated upon coal from the Chu Chua region is not considered to be viable.

Kamloops: (Figure 7)

Coal occurs in sedimentary rocks of Eocene age near Kamloops. The sedimentary formation comprises conglomerate, shale, sandstone, and minor tuffaceous material. Located 2½ miles southwest of Kamloops, the thickest seam in the sequence is only a foot in thickness. A total thickness of 2½ feet occurs in 50 feet of stratigraphic section.

As the seams in the Kamloops area are known to be thin and occur in a few isolated Tertiary basins of limited areal extent, the coal is of no commercial interest.

IV. NICOLA COALFIELD: (Figures 8, 9 & 10)

Introduction:

The Nicola coalfield comprises several isolated Tertiary sedimentary areas which occur within an area 20 miles in diameter. Two, the Merritt and Quilchena area, are known to contain coal.

The Quilchena area was explored by the Diamond Vale Coal Co. from 1904 to 1906. However, other than by local ranchers for domestic production, no coal has been produced on a commercial basis from the area.

The Merritt area produced 2,660,000 tons of coal from 1906 to 1963. The bulk of this coal was produced by underground methods during the period 1908 to 1929 from two locations near the southwestern periphery of the "basin". Four other localities in the area were explored but produced only small tonnages.

The British Columbia Department of Mines drilled six holes (4508 feet) in the Merritt area in 1945 - 1946. Five holes were located east of the old Diamond Vale mine, situated near the centre of the "basin", and a sixth hole was drilled in the eastern part.

From 1960 to 1962 Imperial Metals and Power Ltd. carried out exploration in the Coal Gulley - Coldwater Hill areas southwest of Merritt in the general vicinity of the most extensive mine workings in the district. The program consisted of drilling 15 rotary holes and one diamond drill hole.

Geological Setting

The regional geology of the Nicola district is shown on Figure 8. Several irregularly shaped remnants of Eocene age sedimentary rocks lie unconformably on a basement of Upper Triassic volcanic rocks of the Nicola Group. The sedimentary rocks comprise shale, sandstone, conglomerate, and coal. Younger volcanic rocks locally cap the sedimentary sequence throughout the district.

The geology of the Merritt area, shown on Figure 9, because of its lengthy coal exploration and production history, is better known than any of the other areas. The Merritt "basin", for the most part occupying a depression in the basement volcanics, covers an area approximately 3 miles by 7 miles in extent. Although few exposures are available, several bore holes drilled in the area, coupled with more plentiful outcrops around the periphery, outline the geology in general terms. From the available data it is evident that the geology is complex. Marked changes in lithology and texture caused by relatively rapid deposition of sediments into the basin is indicated. The depositional structure has been further complicated by subsequent severe faulting and folding of the Tertiary sequence.

Coal Deposits: (Figure 9)

Several coal deposits are known to occur in the Nicola district. Six lie in the Merritt area; the other occurs in the Quilchena area. These coal areas are summarized as follows:

a) Quilchena Creek - One seam, approximately five feet in thickness, crops out on the eastern flank of the Quilchena Creek valley about two miles south of Nicola Lake. Although the Diamond Vale Coal Co. apparently carried out extensive drilling in the basin from 1904 to 1906 and reported their results to be satisfactory, no coal of economic significance was developed. Imperial Metals and Power Ltd. mapped and prospected the area on a reconnaissance basis in the early 1960's; however, no significant coal was indicated from this work. Because of the limited outcrop exposure, the Quilchena area cannot be viewed as having been adequately explored. A few widely-spaced reconnaissance drill holes would determine whether additional coal seams exist and would usefully assess the structure and lithology of the "basin".

b) Fairley Prospect - One seam of unknown thickness occurs a short distance north of the town of Merritt. The steeply-dipping seam was reported to comprise severly sheared, friable, and dirty coal. The Sunshine Mine established on the seam many years ago produced 247 tons of coal.

c) Normandale Prospect - Another seam, vertically-dipping and four feet in thickness, occurs 4½ miles east of Merritt near the edge of the "basin". The coal produced from this prospect is reported to have been 730 tons.

d) Glover Prospects - Several small prospect workings lie 4 miles east of Merritt, although no coal is presently visible at this locality. No record of coal production from the Glover area is known.

e) Coal Gulley Mines - Situated southwest of Merritt near the edge of the "basin", the Coal Gulley area has hosted several producing underground mines. Production ceased in 1929.

Exploration carried out by Imperial Metals and Power Ltd. in 1960 consisted of drilling four rotary holes. An additional five holes were drilled in the old river channel that separates the Coal Gulley area from Coldwater Hill. Three of the four holes intersected coal. Intersections ranged from 13 to 28 feet in one seam and 4 to 6½ feet in another seam.

The coal beds in the Coal Gulley area lie within tight folds along axes which trend northwest and plunge southeast. Seven seams, with a total coal thickness of 73 feet, are distributed throughout a stratigraphic interval of 770 feet. The seams vary in thickness from 2½ to 26 feet; six are in excess of 5 feet. Dips of seams range from 20 to 70 degrees.

f) Coldwater Hill Mines - Coal was produced up to 1929 from two seams on Coldwater Hill located a half mile east of the Coal Gulley area. Small tonnages were produced on a salvage basis for local consumption from 1953 to 1963.

Imperial Metals and Power drilled six short rotary holes in the area in 1960. Four holes intersected coal seams ranging in thickness from one to 3½ feet.

On Coldwater Hill six seams of coal ranging in thickness from 10 inches to 6 feet 8 inches occur within a stratigraphic interval of 450 feet. Total coal thickness is 21 feet; however, only two seams are over 5 feet in thickness. It is these two seams, presumably, from which production was achieved. The dip of the mineable seams is 30° to the northeast.

Because of the intervening old river channel, the differing structural geology, and marked variation in coal stratigraphy, correlation of coal seams between Coldwater Hill and Coal Gulley is not possible. The Coldwater Hill seams may occur within, above, or below the Coal Gulley coal section.

g) Diamond Vale Mine - Small scale underground production was attained from two seams located near the centre of the Merritt area just east of the town. A total of 46,398 tons of coal was produced intermittently from this operation until closure in 1945.

The coal in the Diamond Vale mine area occurs in five seams that extend over 307 feet of stratigraphic section. Coal seams, which dip to the southwest at 27° range in thickness from 1 foot 4 inches to 5 feet, with a total coal thickness of 17 feet 3 inches.

One half mile east of the mine workings, five holes were drilled in 1946 by the B. C. Department of Mines. The object of this program was to extend the productive Diamond Vale seams updip closer to the surface. As a result of this drilling it became evident that complex stratigraphy and structure prevent tracing seams beyond the mine workings by use of widely spaced drilling.

Coal Reserves

Imperial Metals and Power Ltd. have stated that sufficient mineable reserves have been developed in the Coal Gulley - Coldwater Hill areas to support an underground mining operation of 380,000 tons of clean coal per year for 20 years. Because of the complex geology and the lack of closely spaced drilling no established coal reserves have been defined elsewhere in the Nicola district.

Analytical data on coal sampled from various localities in the Merritt basin indicates that quality varies between deposits and seams. Analyses derived from five sources on an "as received" basis is summarized as follows:

a) Coal Gulley (1960): Moisture 4.4%-7.4%, Ash 7.9%-22.0%, Volatile matter 32.3%-34.2%, Fixed carbon 40.4%-54.9%, Sulphur 0.4%-0.6%, Calorific values 10,240 to 13,040 Btu per lb.

b) Coldwater Hill (1954): Moisture 5.6%, Ash 11.4%, Volatile matter 34.4%, Fixed carbon 47.6%, Sulphur 0.7%, Calorific value 12,060 Btu per lb.

c) Fairley Prospect (1926): Moisture 2.8%, Ash 4.6%, Volatile matter 37.5%, Fixed carbon 55.1%, Sulphur 0.4%, Calorific value 13,175 Btu per lb.

d) Diamond Vale (1910): Moisture 2.66%, Ash 4.36%, Volatile matter 37.84%, Fixed carbon 55.14%.

e) East Diamond Vale drilling (1946): Moisture 2.2%-2.9%, Ash 9.5%-28.6%, Volatile matter 27.8%-34.0%, Fixed carbon 38.9%-54.1%, Sulphur 0.33%-0.93%, Calorific value 9,651 to 13,400 (average 11,644) Btu per lb.

The rank of the coal in the Merritt basin is classified as a high volatile "B" bituminous coal with very low coking characteristics, (FSI=2).

Conclusions

It is evident that in the Nicola coalfield, particularly within the Merritt area, several coal seams exist that are in excess of five feet in thickness, (possibly seven to ten), and would be extractable by underground mining methods. For the most part the Merritt and Quilchena areas are largely unexplored.

Because of the possible complex nature of the basin geology and the restricted continuity indicated along coal seams, the development of substantial reserves in any given area would require relatively close spaced exploratory diamond drilling. Reserve blocks upon which underground mines might be developed would tend to be small and local in extent. Consideration of a large coal-fired thermal plant based on substantial reserves in the Nicola district are therefore not deemed to be practical.

V. SIMILKAMEEN COALFIELDS (Figure 11)

An evaluation of the Similkameen Coalfields, which include the Tulameen and Princeton basins, has been presented in a separate report as part of the overall study of the thermal coal resources of British Columbia. As in the case of Hat Creek, it is of possible significance when considering other Tertiary areas in the southern interior that the relatively small Tulameen and Princeton areas have been proven to contain major thermal coal resources.

VI. OKANAGAN OCCURRENCES (Figure 2)

Along the Okanagan Valley as far south as the international boundary and extending east to Arrow Lake are several small outliers of Tertiary rocks. Coal has been reported to occur as small lenses in the White Lake basin 8 miles south of Penticton and in a basin near Midway, B. C.

The White Lake basin contains coal in sedimentary rocks of Eocene age associated with conglomerate and sandstone. A single hole drilled in the centre of the basin failed to intersect coal.

Because of the restricted areal extent of these isolated Okanagan areas and the lensy nature of coal in two of them, it is concluded that they are not of economic interest as major thermal coal sources, hence do not warrant further exploration.

Regional stratigraphy and structural setting of the Kamloops Group, south-central British Columbia[1]

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The Kamloops Group is redefined as an assemblage of Lower to Middle Eocene volcanic and sedimentary rocks widespread in south-central British Columbia. In the type area west of Kamloops, the basal Tranquille Formation consists of 500 m of lacustrine and deltaic sediments, pillowed flows, and hyaloclastites. Elsewhere, basal coal-bearing nonvolcanic fluvial and lacustrine units occur, such as the Coldwater Formation at Merritt, the Chu Chua Formation at Barriere, and the Shorts Creek Formation west of Vernon. Overlying these formations are dominantly volcanic units. At the type area, the Dewdrop Flats Formation includes over 1000 m of interstratified basaltic andesite flows, andesitic flow-breccia sheets and cones, basaltic tuff rings, and an andesitic composite cone. Elsewhere, flat-lying basaltic andesite flows about 600 m thick with local flow breccias are common.

The basal sediments accumulated in separate fault-bounded basins initiated immediately before the onset of volcanism. These volcanic rocks filled the basin and formed a widespread volcanic blanket, which was disrupted by continued fault movement. The numerous basins are linked by a throughgoing fault network with up to 12 km of net right-lateral strike-slip displacement.

Le groupe de Kamloops est redéfini comme étant un assemblage de roches volcaniques et sédimentaires d'âge Eocène inférieur à moyen largement répandues dans le centre-sud de la Colombie Britannique. Dans la région type à l'ouest de Kamloops, la formation basale Tranquille est composée de 500 m de sédiments lacustres et deltaïques, de laves en coussins et de hyaloclastites. Ailleurs, apparaissent des unités fluviatiles et lacustres basales de roches non-volcaniques à charbon telles que dans la formation de Coldwater à Merritt, la formation Chu Chua à Barriere, et la formation Shorts Creek à l'ouest de Vernon. Des unités principalement de composition volcanique recouvrent ces formations. Dans la région type, la formation Dewdrop Flats comprend plus de 100 m de coulées interstratifiées d'andésite basaltique, de couches de brèche de coulée et de cônes de lave andésitique, d'anneaux de tuf basaltique et d'un stratovolcan andésitique. Ailleurs, se retrouvent fréquemment des coulées horizontales d'andésite basaltique d'une puissance d'environ 600 m accompagnées localement de brèches de coulée de lave.

Les sédiments de base se sont accumulées dans des bassins d'effondrement delimités par des failles dont l'origine remonte au début du volcanisme. Ces roches volcaniques ont rempli le bassin et formèrent une vaste nappe volcanique brisée par une action prolongée du mouvement des failles. Les nombreux bassins sont reliés entre eux par un réseau transversal de failles pouvant avoir jusqu'à 12 km de décrochement dextre.

[Traduit par le journal]

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Introduction

The existence of Tertiary volcanic and sedimentary rocks in south-central British Columbia has been known since the first geological reconnaissance studies (Selwyn 1872, Dawson 1879, 1895). Later regional mapping defined their areal extent in the Nicola (Cockfield 1948), Ashcroft (Duffell and McTaggart 1952), and Vernon (Jones 1959) map areas. Pioneer K–Ar dating by Mathews (1964) showed that the rocks previously mapped as the Kamloops Group comprised two series, one of Early to Middle Eocene age, and the other of Miocene age. This work implied that the two series should be separated, and that the Kamloops Group (dated as Eocene at Tranquille) should exclude the Miocene rocks; this usage has been followed by Campbell and Tipper (1971) in the Bonaparte Lake map area to the north, and is confirmed in this study.

Previous studies of the Kamloops Group did not attempt to unravel the regional distribution of lithologies and paleotectonic environments. This hindered investigation of Eocene tectonics in southern British Columbia. To remedy this, new studies of the stratigraphy and structure of the Kamloops Group were made at several areas, including the type area at Kamloops. This additional work allowed the compilation of a preliminary geological map of the Kamloops Group (Fig. 1), and an attempt to correlate stratigraphic terms. This, in turn, allowed an interpretation of the Eocene structural evolution of the region.

New studies of Kamloops Group geology

Kamloops–Tranquille area (Fig. 2 map and sections)

The Kamloops Group at its type locality can be divided into two formations: a lower, volcano-

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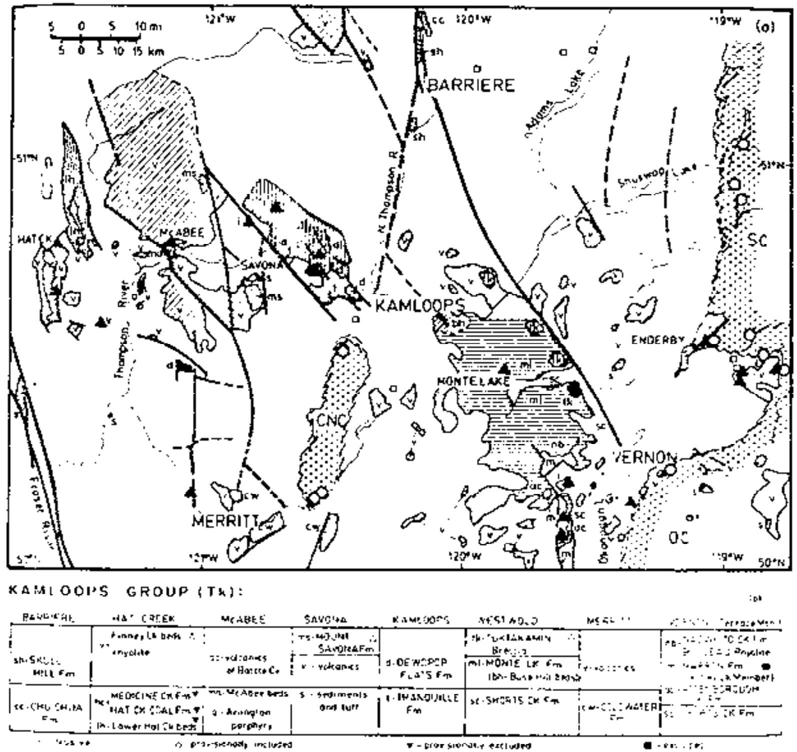

FIG. 1. (*a*) Geologic map of the Thompson Valley area, showing areas of preserved Kamloops Group rocks. Abbreviations: CNC = Central Nicola Complex; OC = Okanagan Complex; SC = Shuswap Complex. Circles = reset dates in metamorphic rocks, squares = significant nonreset dates, triangles = radiometric date localities from Table 2. Known Eocene faults are shown by solid bold lines, inferred faults by dashed lines. Mapping in part from MacMillan (1978), Church (1975, 1979*a*,*b*), Cockfield (1948), Duffell and McTaggard (1952), Jones (1959), and Campbell and Tipper (1971). (*b*) Chart showing nomenclature of the Kamloops Group and related units.

sedimentary Tranquille Formation (the "Tranquille beds" of Dawson 1895; Cockfield 1948), and an upper, volcanic Dewdrop Flats Formation. Type locations and thicknesses of the two formations and their constituent members are listed in Table 1. The small outcrops of "Coldwater beds" reported by Cockfield (1948) in the Kamloops area consist of well indurated red-brown sedimentary breccia similar to Mesozoic sediments that occur in the Afton mine area and farther west. They are a different lithology from either the Tranquille Formation or the type Coldwater beds near Merritt, and are shown as "Mzs" in Fig. 2.

The Tranquille Formation, up to 450 m thick, is divisible into lower, middle, and upper units in each of

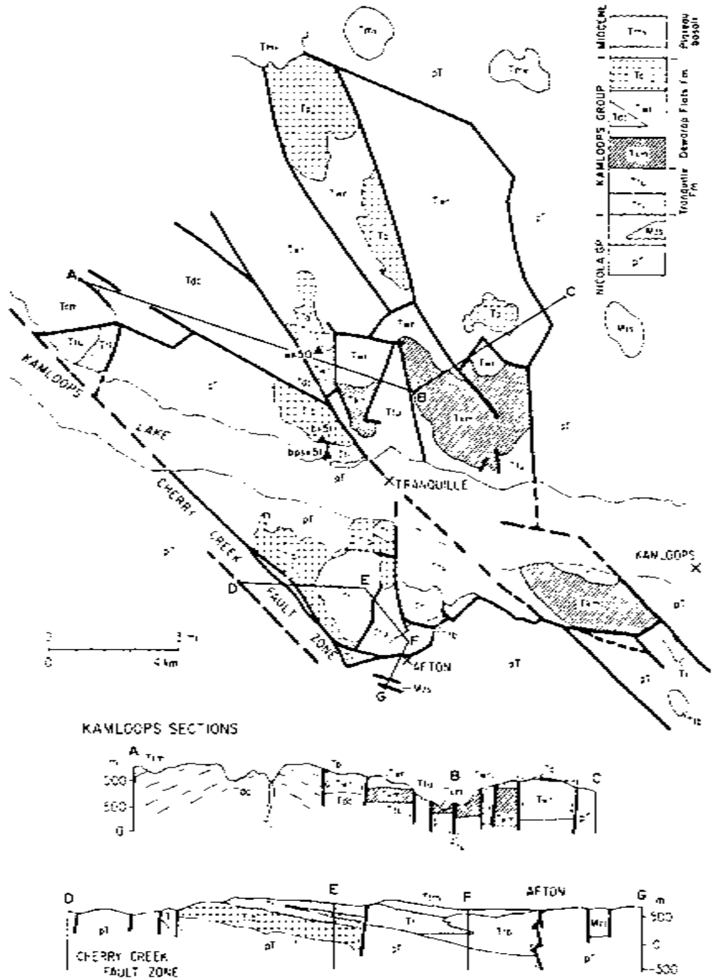

FIG. 2. Map and structural sections, Tranquille area. (a) Generalized geologic map, from Ewing (in press). (b) Section ABC across Tranquille Canyon graben and the Doherty Creek cone. (c) Section DEFG across homoclinal panels of the Tranquille Formation, and the Afton zone. For symbols see Table 1.

TABLE 1. Type localities and descriptions of newly defined units, Kamloops Group

Name	Type locality	Lat. N	Long. W	Lithologies	Thickness (m)	Symbol
Tranquille Fm	Tranquille area	50°43'	120°31'	Lacustrine, fluvial, hyaloclastic	0–450	Tt
Lower	Various			Lacustrine, tuffaceous	0–390	Ttl
Middle	Various			Pillowed flows, tuffs	0–230	Ttu
Upper	Various			Hyaloclastites, tuff	0–250	
Border	NE of Afton pit	50°40'	120°30'	Fluvial, deltaic, tuff	nd	Ttb
Dewdrop Flats Fm	Dewdrop Flats					
	SW of Tranquille	50°46'	120°35'	Volcanics	>1000	
Nipple breccia	W of Tranquille River	50°45'	120°29'	phb Ol basalt; tuff ring	0–100	
Kissick breccia	E of Tranquille	50°41'	120°29'	Flow breccia and phb cone	190	Tkm
Mara Hill member	W, S sides Mara Hill	50°44'	120°29'	Flat-lying andes flow + ftb	150–300	
Wheeler Mountain breccia	SW slope Wheeler Mtn.	50°46'	120°30'	Flow breccia and phb, sheet, cone	250	Twr
Red Plateau member	S side Red Plateau	50°46'	120°33'	Flat-lying andes flow + ftb	350–450	
Opax breccia	W side Opax Hill	50°48'	120°32'	Flow breccia, andes, sheet	>300	To
Castle Butte breccia	S side Red Plateau	50°46'	120°35'	phb, Pl-andes; large cone	0–550	Tdc
Doherty Creek member	Doherty Ck headwaters	50°47'	120°41'	Andes flow + ftb, tuff, etc.; stratocone	<600	
Rosseau Mountain breccia	N of Red Point	50°47'	120°43'	Basalt flow breccia + phb; cone	>100	Trm
Battle Bluff intrusions	W of Tranquille	50°44'	120°33'	Diabase sills, irregular intrusions		Tbb
Mt. Savona Fm	Crest of Mt. Savona	50°42'	120°49'	Boulder cgl, fgl; can resemble agglomerate; well bedded	>350	Tms
Battle Creek volcanics	E of Cache Creek	50°49'	121°10'	Andesite flow + ftb; flow breccia	>400	Tbc
McAbee sediments	McAbee, E of Cache Creek	50°48'	121°10'	Lacustrine, hyaloclastites	0–550	Tma
Monte Lake Fm	Monte Lake, NW of Westwold	50°29'	119°50'	Andesite flow + ftb, flat lying	450	Tml
Tuktakamin breccia	Tuktakamin Mountain, E of Westwold	50°28'	119°35'	Latitic breccia cone	>400	Ttk

NOTES: Lithology abbreviations: phb = phreatic breccia (palagonitic breccia); ftb = flow-top breccia; andes = andesite; Ol = olivine; Pl = plagioclase; cgl = conglomerate; fgl = fanglomerate.

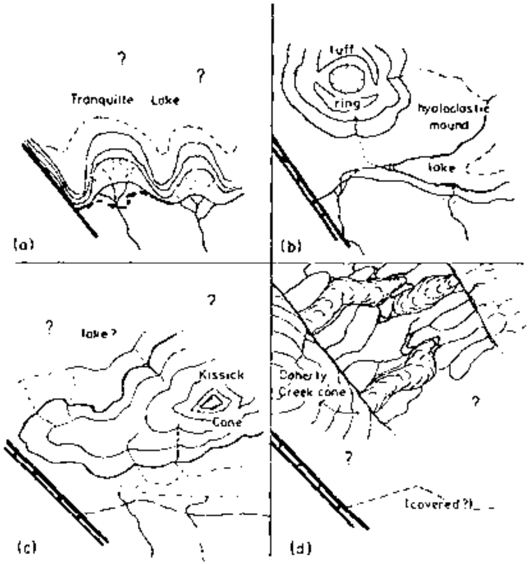

FIG. 3. Paleogeography of the Tranquille basin west of Kamloops at four times during Kamloops Group deposition: (a) lower Tranquille, (b) upper Tranquille; (c) Kissick; (d) Red Plateau.

its outcrop areas, but these units are not strictly correlative. The lower unit lies with inferred unconformity upon Triassic and Lower Jurassic rocks, and consists of lacustrine sediments and andesitic bedded tuffs. The unit becomes more tuffaceous upward; the basal lacustrine sediments show little trace of volcanic input. Slump blocks of Triassic basement rocks are locally present. This unit is extensively intruded near Tranquille by diabase sills of the Battle Bluff complex, and conformably overlain by middle and upper units consisting of andesite flows, andesitic and basaltic tuff, tuffaceous lacustrine sediment, and local phreatic breccia. North of the Thompson River valley, the upper unit consists of palagonite breccia mudflows, which formed a hyaloclastic mound or apron conformably overlying pillowed andesite flows. The hyaloclastic unit passes westward into the "breccia of the Nipple," a tuff ring deposit of olivine basalt.

A distinct facies of the Tranquille Formation is exposed along the southern margin of the outcrop area in and near the Afton mine. It consists of coarse arkosic-lithic wackes and interbedded grey–black shale, which show flaser bedding and local transported coal. This facies is inferred to mark one or more small fringing deltas that grew northward into the Eocene Tranquille Lake (Graham and Long 1979), as shown in Figs. 2c and 3. It is deformed by complex reverse faulting and slumping in the Afton structural zone (Carr and Reed 1976), which forms the southern margin of the Eocene basin.

Conformably overlying the Tranquille Formation is a volcanic sequence greater than 1 km thick, here called the Dewdrop Flats Formation. North of Tranquille, five members have been mapped. Lowest is the Kissick breccia, consisting of variably palagonitic basaltic andesite flow breccia; primary dips indicate at least one cone structure. Overlying is the Mara Hill member, consisting of red–brown thin-bedded basaltic andesite flows and flow-top breccias with local flow breccia; then the Wheeler Mountain breccia, consisting of andesite to basalt flow breccia, phreatic breccia, and mudflows; the Red Plateau member, consisting of thinly bedded

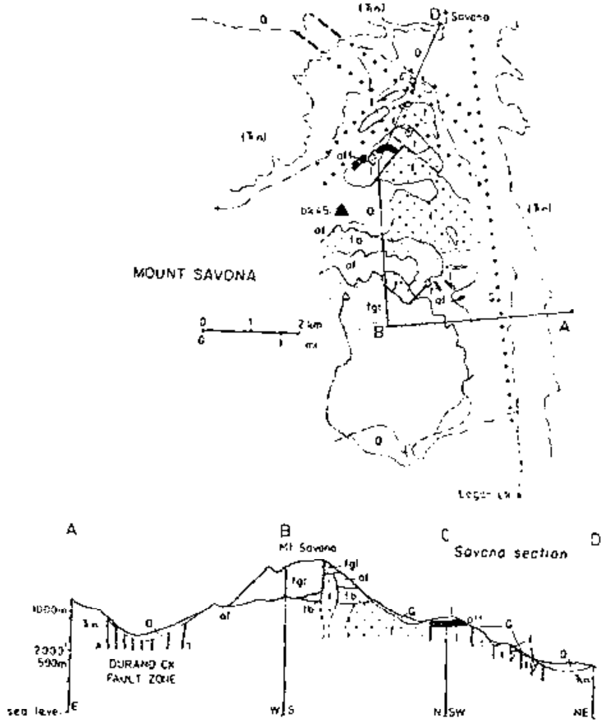

FIG. 4. Geologic map and section of the Mount Savona area. Abbreviations. t = tuff. f = felsic intrusive. af = andesite flows: fb = flow breccia; fgl = Mount Savona Formation. Bold dotted lines = concealed faults.

basaltic andesite flows and flow-top breccias; and the Opax breccia, consisting of glassy, often banded andesite flow breccia. This sequence forms an excellent, conformable stratigraphy, which helps to define the complex fault pattern of the Tranquille Canyon graben, as shown in Fig. 2. The Opax and Red Plateau members are overlain with marked unconformity by the Miocene Plateau basalts at the northern margin of the area.

Northwest of Tranquille, quaquaversal dips and facies changes indicate a large (9 km in diameter) structure, named the Doherty Creek composite cone (Figs. 2, 3). The rocks of this cone are divided into three members of the Dewdrop Flats Formation. Lowest is the Castle Butte breccia, consisting of palagonitic and transitional breccias of plagioclase-phyric andesite; at its base is a small exposed thickness of hyaloclastic debris. This member records the birth of the volcano as a tuff cone. Overlying with gradational contact is a thick succession of subaerial basaltic andesite flows with basaltic, andesitic, and dacitic ash, agglomerate, and small intrusive bodies, collectively referred to as the Doherty Creek member. Overlying this member on the west is the Rosseau Mountain breccia, a glassy basalt flow breccia. Faint bedding in this unit suggests a vent on the western side of the main volcano.

Correlation between the cone and canyon sequences

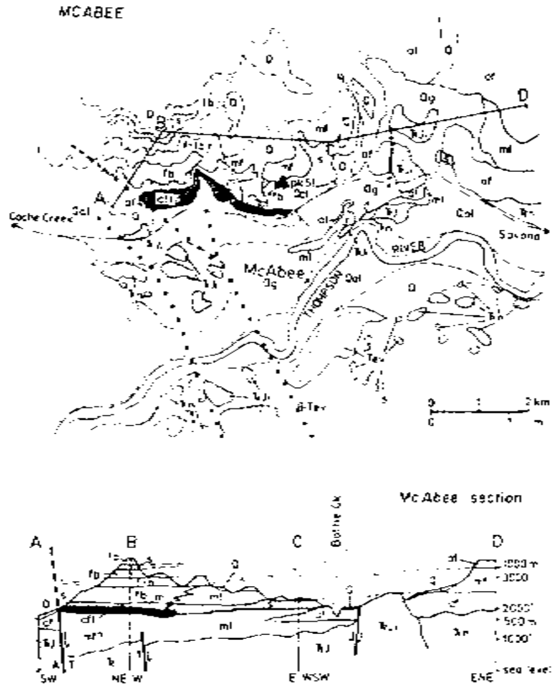

FIG. 5. Geologic map and section of the McAbee area. Abbreviations: TrJi = Guichon Creek intrusives; mf = mudflows and (or) hyaloclastites; af = andesitic flows; aft = ash-flow tuff (?); s = sedimentary rocks; fb = flow breccia; f + fb = flows and breccias, mixed.

is not certain. However, Castle Butte breccia underlies one section of Red Plateau basaltic andesite, suggesting that the latter is equivalent in part to the lithologically similar Doherty Creek member.

Mount Savona area (Fig. 4 map and section)

This area lies immediately to the east of the section described by Dawson (1895) and Rose (1914), and immediately south of the town of Savona. The lowest exposed unit is a tuffaceous complex of indeterminate thickness, which includes bedded and massive andesitic tuffs, rhyolite ash-flow tuff, and associated sediments. Neither the base nor the top is exposed; northwest- and northeast-trending shear zones bound the outcrop area. A unit of thinly bedded basaltic andesite flows and flow-top breccias, greater than 200 m thick, is inferred to overlie the tuffs. It is followed by about 150 m of andesite flow breccia and an equal thickness of basaltic andesite flows. All of these units are intruded by rhyolites, which are frequently banded and tuffaceous in appearance and bear abundant biotite, quartz, and feldspar phenocrysts.

Overlying all of the above units on a probable unconformity is the Mount Savona Formation (Table 1), which forms the upper, conspicuous cliffs of Mount Savona. This unit consists of well stratified and extremely coarse conglomerate to breccia, with boulders up to 3 m across. Local fine-grained interbeds approach a coarse sandstone. Clasts are predominantly Tertiary andesite and dacite. The unit is tentatively interpreted as

TABLE 2. Radiometric dates from the Kamloops Group, British Columbia

Identification	Mineral	% K	Ar*	%Ar*	Age (Ma)	Unit	Lat. N	Long. W	Analyst/collector/source
HAT161	Bio	6.87	1.39	90	51.2 ± 1.4	Hat Creek rhyolite	50 40.5'	121 34.5'	Harakal/Church/1
HA136	WR	3.15	0.554	77	41.7 ± 1.8	Finney Lake beds	50 46'	121 35'	Harakal/Church/1
WRD76-2	WR	2.27	0.445	85	49.8 ± 1.7	Cornwall Hills	50 40'	121 30'	Harakal/Danner/unpublished
AK636	Plag	0.98		59	52 ± 2	McAbee - 1 ash	50 48'	121 10'	Baadsgaard/Hills/3
AK628	Bio	5.13		85	51 ± 2	McAbee - 2 ash	50 48'	121 10'	Baadsgaard/Hills/3
AK629	Plag	0.515		74	49 ± 2	McAbee - 2 ash	50 48'	121 10'	Baadsgaard/Hills/3
AK117	Bio	5.79	1.05	78	46 ± 2	Savona flow	50 43.3	120 49.5'	Baadsgaard/Mathews/5
46-4	Bio	6.07	1.18	88	49.5 ± 1.7	Copper Creek pluton	50 51.6	120 48.0	Harakal/Ewing/7
9-2	WR	4.06	0.751	69	47.0 ± 1.6	Rhyodacite	50 54.3	120 42.9	Harakal/Ewing/7
AK118	Bio	5.64	1.17	86	51 ± 2	Battle Bluff sill	50 44.0'	120 33.2'	Baadsgaard/Mathews/5
AK640	Plag	1.30		84	52 ± 2	Tranquille ash	50 44'	120 33'	Baadsgaard/Hills/3
AK641	San	6.78		95	51 ± 2	Tranquille ash	50 44'	120 33'	Baadsgaard/Hills/3
AK642	Bio	6.34		86	51 ± 2	Tranquille ash	50 44'	120 33'	Baadsgaard/Hills/3
AK656	Bio	6.53		83	49 ± 2	Tranquille ash	50 44'	120 33'	Baadsgaard/Hills/3
TP32-3	WR	2.83	0.554	90	49.7 ± 1.7	Red Plateau flow	50 45.8'	120 33.4'	Harakal/Ewing/7
33-3	WR	2.45	0.490	90	50.5 ± 1.8	Monte Lake flow	50 29.6'	119 49.9	Harakal/Ewing/7
BC5	WR	2.69	0.500	68	42.5 ± 1.7	Brasch Creek flow	50 34.0'	119 3.0	Harakal/Mathews/6
TH3	WR	2.61	0.502	88	48.9 ± 1.7	Trinity Hills	50 31.4'	118 48.0'	Harakal/Mathews/6
TH3a	WR	2.58	0.495	84	48.8 ± 1.7	Trinity Hills	50 31.4'	118 48.0'	Harakal/Mathews/6
TH15	Bio	6.90	1.284	87	47.2 ± 1.6	Trinity Hills	50 29.5'	118 53.0'	Harakal/Mathews/6
TH16	Bio	6.47	1.076	77	42.3 ± 1.9	Trinity Hills	50 27.0	118 51.4'	Harakal/Mathews/6
74-11	Bio	6.81	1.341	82	48.7 ± 1.4	Nicola Valley dome	50 11.8	121 1.7	Harakal/MacMillan/4
	Hbl	0.63	0.123	54	48.3 ± 1.7	Nicola Valley dyke	50 12'	121 2'	Harakal/MacMillan/4
22498M	Bio	7.18	1.424	78	50.3 ± 1.8	Whiteman Creek stock	50 13'	119 37'	Harakal/Soregaroli/unpublished
TER-14	Bio	6.98	1.439	84	52.3 ± 1.8	Bouleau rhyolite	50 5.6'	119 37.5'	Harakal/Church/2
AK149	Bio	6.42	1.21	82	48 ± 2	Attenborough Creek ash	50 8.3	119 37.5	Baadsgaard/Mathews/5

NOTES: All ages are recalculated to $\lambda_\epsilon = 0.581 \times 10^{-10}$ year^{-1}; $\lambda_\beta = 4.963 \times 10^{-10}$ year^{-1}; $^{40}K/K = 0.01167$ at.%; Ar* in cm^3 g^{-1} × 10^{-5}; Bio = biotite; Plag = plagioclase; San = sanidine; Hbl = hornblende; WR = whole rock; sources: 1 = Church (1975); 2 = Church (1979b); 3 = Hills and Baadsgaard (1967); 4 = MacMillan (1978); 5 = Mathews (1964); 6 = Mathews (in press); 7 = this study.

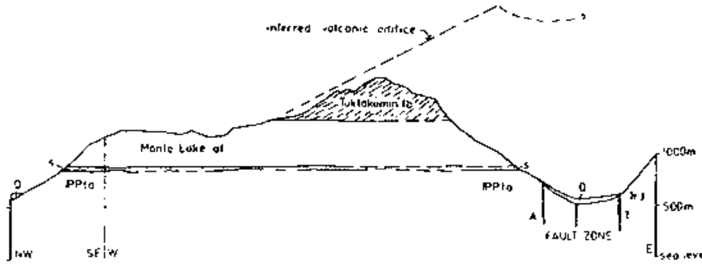

FIG. 6. Section through Tuktakamin Mountain east of Monte Lake. Abbreviations: s = Shorts Creek Formation; af = andesite flows; fb = flow breccia; PPta = Thompson Assemblage (Okulitch 1979).

a fanglomerate consisting of material reworked from earlier Kamloops Group deposits. The source may be the structurally high block east of the area of Durand Creek. Similar fanglomerate forms high bluffs on the west side of Deadman Creek some 30 km to the north-northwest, which are reported to be overlain by andesite flows (Cockfield 1948; Duffell and McTaggart 1952). Rose (1914) and Cockfield (1948) interpreted these deposits as volcanic agglomerates, but their excellent, although coarse, bedding and lateral continuity suggest a near-source sedimentary origin rather than formation from volcanic ejecta.

McAbee area (Fig. 5 map and section)

Lower Tertiary rocks in this area are grouped into two informal formations with extensive lateral intertonguing. The lower, sedimentary unit, 550 m thick, is called the McAbee sediments after Hills (1965). It overlies Triassic and Lower Jurassic rocks on an unconformity with up to 200 m of relief. The dominant lithology of the McAbee sediments is a palagonitic mudflow and breccia complex similar to the upper unit of the Tranquille Formation. East of Battle Creek, this lithology interfingers with andesite flows. Near the bounding fault on the west are two cliffs of columnar-jointed andesite, tentatively interpreted as altered ash-flow tuffs; they pass eastward into a complex admixture of flow breccia, mudflows, and tuffs, including some 30 m of lacustrine sediments. Ash from this unit yielded K–Ar dates of about 51 Ma (Table 2; Hills and Baadsgaard 1967).

The upper unit is called the Battle Creek volcanics, after good exposures in Battle Creek canyon north of McAbee. In the northeastern part of the area, this unit consists of over 400 m of monotonous basaltic andesite flows and flow-top breccias. Westward the andesite flows give way to over 500 m of flow breccia, which thickens and becomes more uniform towards the western bounding fault (Fig. 5). West of the fault, andesite flows appear to directly overlie the basal unconformity, suggesting that the flow breccia was erupted along the fault zone and ponded in the downthrown eastern block.

Monte Lake area (Fig. 6 section; Fig. 1 map)

In the area northwest of Vernon three formations can be defined. At the base of the Tertiary is less than 30 m of nonvolcanic sand, silt, and shale, which is correlative with the Shorts Creek Formation mapped by Church (1979*a*,*b*) to the south. Overlying this is over 600 m of monotonous flat-lying basaltic andesite flows and flow-top breccias, which are here called the Monte Lake Formation (Table 1), after excellent cliff and roadcut exposures near Monte Lake. A reference exposure occurs at the south end of Monte Lake, on Highway 97. Overlying the Monte Lake volcanics is a cliff-forming sequence, over 400 m thick, of west-dipping latite flow breccia, here called the Tuktakamin breccia. It forms the summit of Tuktakamin Mountain, and is thought to underlie similar summits to the northwest (Fig. 1). Westerly dip is observed in each locality, suggesting a series of large volcanic edifices along the fault zone immediately to the northeast; one is sketched in Fig. 6.

Andesitic volcanics similar to the typical Monte Lake Formation are observed north and west of Monte Lake in the area east of Kamloops. Southeast of Kamloops, the flows pass into small cone structures of flow and mudflow material, the "Buse Hill beds" ("bh" in Fig. 1). This area has not been mapped in detail.

Proposals for stratigraphic usage

The detailed mapping of the Kamloops Group described above, together with similar mapping at Terrace Mountain west of Vernon (Church 1979*a*,*b*) and at Hat Creek (Church 1975), allows a redefinition and clarification of Kamloops Group nomenclature, shown in Fig. 1*b*. It is proposed here that the Kamloops Group be restricted to those volcanic and sedimentary rocks of Early to Middle Eocene age in south-central British Columbia that are generally similar to the type area at Kamloops. This sequence may contain local internal unconformities and nonvolcanic sediments. Specifically excluded from the unit are the Miocene–Pliocene Plateau basalts and Oligocene sediments of the Fraser River Formation (Graham 1978; Rouse and Mathews 1979). From K–Ar determinations (Table 2) and fossil evidence the Kamloops Group rocks are time equivalents of, although compositionally distinct from, the Princeton Group to the south, the Marron and White Lake sequences to the southeast, and the Ootsa Lake volcanics to the northwest.

The division of the Kamloops Group in the type area into two formations has been described above. The Tranquille Formation apparently accumulated in a local downdropped basin. Therefore, although similar basal successions are known elsewhere, they should bear separate formation names. Tranquille-type sediments can be referred to generally as "Tranquille facies." The Dewdrop Flats Formation, on the other hand, probably formed a semicontinuous blanket over much of the southern interior of British Columbia during its eruption. However, in view of the isolated outcrop patterns and difficulties in correlation, it is best to use local formation-level names in the major outcrop areas.

The stratigraphic relations of lower Tertiary rocks in the Hat Creek area are not firmly established. Volcanic rocks there yield Middle Eocene dates (Table 2), and are correlative with the Kamloops Group (Church 1975, Church *et al.* 1979). The thick sedimentary sequence at Hat Creek, divided by Church (1975) into lower, fluvial "Coldwater beds," the overlying Hat Creek Coal Formation, and the upper, lacustrine Medicine Creek Formation, were considered by Church to be prevolcanic (Early Eocene). Palynologic and other studies, however, have suggested to some workers (Kim 1979, quoting G. E. Rouse, unpublished) that the coal formation is Late Eocene and postvolcanic. Furthermore, the extensive outcrop area of fluvial sediments northeast of Hat Creek (shown in Fig. 1 as "lower Hat Creek beds") has not yet, to my knowledge, yielded any evidence of age.

Any final decision on the correlation of these sediments with other units in the region seems premature. If the sediments are Early Eocene, they could be correlative with the Tranquille Formation of the type area, and therefore, be considered part of the Kamloops Group. If, however, they are Late Eocene, they have no correlative units in the type area or elsewhere in known Kamloops Group rocks, and it would therefore be reasonable to exclude them from the Kamloops Group.

The term "Coldwater Formation" refers to the dominantly fluvial, coal-bearing sedimentary strata poorly exposed in the Merritt, lower Guichon Creek, and Quilchena basins (Cockfield 1948; MacMillan 1979). Its type area is at Merritt at the mouth of the Coldwater River, a reference section was described by Dawson (1895). Hills (1965) correlated these sediments with the Tranquille and McAbee sediments on palynologic grounds. This formation is similar to the newly recognized border deltaic facies of the Tranquille Formation at Kamloops. The Coldwater sediments should therefore be included in the Kamloops Group, following Cockfield (1948) and Hills (1965).

The Chu Chua and Skull Hill Formations of Uglow (1922) and Campbell and Tipper (1971) are found in the North Thompson Valley near Barriere. The lower formation, the Chu Chua, is a coal-bearing sedimentary sequence similar to the Coldwater Formation, fossils indicate an Early Eocene age. The overlying Skull Hill Formation consists mainly of hornblende andesite.

In the Monte Lake area, formation-level units have been described in a previous section. To the south, Church (1979*a*,*b*) has given informal names in the Terrace Mountain area west of Vernon. His basal Shorts Creek Formation and overlying Attenborough Creek Formation are typical Kamloops Group lithologies, as are the upper formations, the Bouleau rhyolite, and the Naswhito Creek Formation. These sequences are separated by a tongue of Kitley Lake trachyte, a member of the Marron Formation. I propose that the Shorts Creek, Attenborough Creek, Bouleau rhyolite, and Naswhito Creek units be included in the Kamloops Group. Definitely alkaline rocks that are correlative with the Marron Formation to the south (Church 1973) should be excluded from the Kamloops Group (Ewing 1981).

As defined here, the Kamloops Group rocks form a distinctive lithologic package in south-central British Columbia. Similar rocks are found in isolated outcrops east of the Barriere–Vernon fault zone, at Squilax, Mount Ida, Enderby, and the Trinity Hills (Daly 1915, Jones 1959; Okulitch 1979), which have not been studied by the author. Mathews (in press) reports Middle Eocene ages from the Trinity Hills and Enderby Cliffs sequences east of Enderby, as summarized in Table 2. They indicate a generally similar age and a possible equivalence to the Kamloops Group.

Tectonic setting

During Early to Middle Eocene time, small fault-bounded basins received thick accumulations of sediment. In some areas volcanism was simultaneously active, producing bedded tuffs, pillowed flows, and hyaloclastites (seen at Tranquille, McAbee, and Savona, also northwest of Savona, and in a concealed basin southwest of Savona (W. J. MacMillan, personal communication, 1979)). In other areas (Barriere, Hat Creek (following Church 1975), and Merritt) volcanism did not contribute to early sedimentation; these areas contain coal and lignite of economic interest. Active fault boundaries are seen at Tranquille, Savona, McAbee, and Hat Creek. At Tranquille and Hat Creek (Kim 1979), deformation continued during and after sedimentation.

At a slightly later time, the Tranquille Canyon graben received a volcanic fill of over 1 km, significantly thicker than elsewhere. This suggests that the graben developed during volcanic eruption, and ponded large amounts of basaltic and andesitic lava and breccia. Subsidence continued after eruption of all the exposed units.

The sedimentary and volcanic basins are not simple grabens. At Tranquille the southern basin margin is a jumble of faults and slumped blocks, which are the surface manifestations of high-angle reverse faults at depth (Carr and Reed 1976; also Fig. 2c). Its southwestern margin is a broad, braided, intrusive-lined fault zone, which is one of the throughgoing faults of the area. At Hat Creek, the sediments are moderately to tightly folded, cut both by dip-slip faults with alternating senses of displacement and by strike-slip faults (Kim 1979). Therefore, although these basins are subsidence structures, they are unlikely to have been formed by simple extension. Rather, they show some similarity in their evolution to some of the sedimentary basins of southern California (see Crowell 1974).

The small Eocene basins are linked together by large throughgoing faults (Fig. 1), which form prominent topographic furrows in the Thompson Valley region. Where they have been studied, these fault zones are 1–3 km wide, composed of numerous interweaving strands, and marked by complex secondary shearing. A typical example is the Cherry Creek fault zone west of Kamloops (Ewing, in press). Several prominent valley segments covered with Quaternary material may be localized by these faults (such as parts of the North Thompson Valley, the valleys between Barriere and Vernon, the valley west of Kamloops, and valleys northwest and south of Savona). Volcanic cone structures are aligned along these fault zones (Tuktakamin breccia; the Buse Hill cones; McAbee flow breccia) and some contain Tertiary intrusives and sediments not correlative with material outside the fault zone (Cherry Creek fault zone; and faults south of McAbee). Apparent dip-slip movement on these zones is locally over 500 m, but changes markedly along its length. Fault trends are dominantly north–south and northwest–southeast.

Dominant strike-slip motion on these major faults best accounts for the features outlined above. Dip-slip motion, although locally important, is probably secondary. The small sedimentary and volcanic depressions occupy niches within the throughgoing system of faults, either in triangular areas between splaying faults, along the side of a major fault bend, or in an area lying between offset faults as a pull-apart basin. These locations are consistent with those expected from networks of strike-slip faults (see Lensen 1958; Wilcox *et al.* 1973). The alternating tension and compression noted at Hat Creek and Tranquille are likewise consistent with a dominantly transcurrent regime (Crowell 1974). A right-lateral sense of motion is indicated by the direction of graben elongation (about north–south) and the northward-directed reverse faulting at Afton. Such motion agrees with the regional right-lateral shear inferred for the Canadian Cordillera during latest Mesozoic and Cenozoic time (Monger and Price 1979, Ewing 1980).

Another tectonic curiosity exists in the Thompson River region. Eocene-reset K–Ar metamorphic dates on Mesozoic igneous and metamorphic rocks have been obtained in two areas (Fig. 1): to the south and east of the map area in rocks of the Okanagan and Shuswap Complexes (Mathews 1976; Okulitch 1979), and from the Central Nicola Complex (the Central Nicola batholith of Cockfield 1948) between Kamloops and Merritt (Preto *et al.* 1979). These reset terranes have a regional distribution in broadly linear north-northeast-trending belts through southern British Columbia and the northwestern United States; they are inferred (Ewing 1980) to represent metamorphic core complexes (Coney 1979), which record roughly east–west crustal extension.

The Central Nicola Complex (Fig. 1) extends roughly north-northeast from a point east of Merritt to a point some 20 km south-southwest of Kamloops. It fits into the system of throughgoing faults described above, being nestled between an extension of the Cherry Creek fault zone on the north and a strong northwest–southeast furrow on the south. Thus, three large extensional or inferred extensional features of Eocene age—the Tranquille Canyon graben, the Central Nicola Complex, and the Merritt basin—form a broad arc from north to south in south-central British Columbia.

The tectonic features described above form a consistent pattern (Fig. 7). The region is divided into a number of blocks, separated either by faults or extensional structures. If we assume that the faults represent conservative block margins, across which no net crustal extension or shortening took place, it is possible to construct a displacement vector diagram (Fig. 8) by treating each fault boundary as an azimuth or horizontal displacement. The resulting diagram graphically shows the effect of Eocene-active tectonism on the study area: a net northwestward translation of the western end relative to the eastern end. The amount of Eocene displacement is unknown, as no laterally displaced features have been recognized. If, however, we assume a reasonable displacement of about 1 km across the Tranquille Canyon structures, total elongation is of the order of 12 km

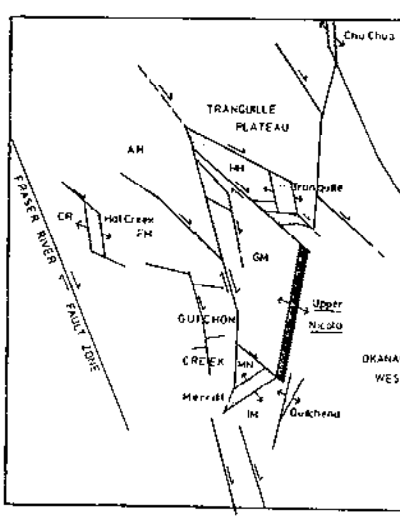

FIG. 7. Idealized sketch of major Eocene tectonic features in south-central British Columbia. Throughgoing faults, extensional grabens, and core complexes divide the area into many blocks. Abbreviations: HH = Hardie Hill; GM = Greenstone Mountain; AH = Arrowstone Hills; FM = Forge Mountain; CR = Clear Range; MN = Merritt North; IM = Iron Mountain.

northwest–southeast. This style and direction of elongation are consistent with Price's (1979) model for pervasive shear between diverging strike-slip faults.

Summary of geologic history of the Kamloops Group

At about 53 Ma, strike-slip movement began along a network of interconnected faults, some of which may have had a prior Mesozoic history of movement. As a consequence of local crustal extension, some blocks subsided and received up to 500 m of fluvial, deltaic, and lacustrine sediments. Volcanism began concurrently with subsidence within the Tranquille and McAbee areas, choking the sedimentary basins with ash, pillowed flows, and hyaloclastites (Fig. 3). Other basins to the northeast and southwest, more distant from early centres of volcanism, received more nonvolcanic sediment and developed locally significant coal zones. Increased volcanic activity filled the basins and formed a blanket over much of the region. Low basaltic andesite shield edifices were most abundant, but large andesite volcanic cones formed locally, with their centres often aligned by the throughgoing faults. More than 1400 m of Dewdrop Flats Formation volcanic rocks accumulated in the subsiding Tranquille Canyon graben. Coarse

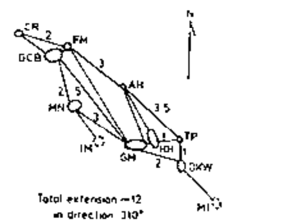

FIG. 8. Displacement vector diagram for south-central British Columbia Mesozoic–Tertiary strike-slip faulting. See text for assumptions and Fig. 7 for abbreviations. Numbers are on a relative scale.

fanglomerates developed along some of the fault zones. Simultaneously with faulting, sedimentation, and volcanism, metamorphic core complexes rose both locally and regionally as a deep-seated response to crustal extension in the strike-slip regime (Coney 1979).

The latest age of fault movement is not known. Most strike-slip movement on the major faults to the south appears to have ended by 42 Ma (Monger and Price 1979). The entire region was later eroded to a low-relief surface before the eruption of the Late Miocene to Pliocene Plateau basalts.

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53.

THE TRANQUILLE BEDS OF THE KAMLOOPS GROUP: A TERTIARY (MIDDLE EOCENE) COAL-BEARING SEQUENCE IN THE VICINITY OF KAMLOOPS LAKE, BRITISH COLUMBIA

Projects 760056 and 770047

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Graham, P.S.W. and Long, D.G.F., The Tranquille beds of the Kamloops Group: a Tertiary (middle Eocene) coal-bearing sequence in the vicinity of Kamloops Lake, British Columbia; in Current Research, Part A, Geol. Surv. Can., Paper 79-1A, p. 357-360, 1979.

Abstract

The probability that economic coal seams are present in the Tranquille beds of the Kamloops Group is considered remote. Deposition of most of the sequence in a protected lacustrine environment is indicated by the abundance of flat bedded mudrocks, presence of fresh water ferns, and absence of marine fossils. Massive sandstone and minor conglomerate in the sequence may have been deposited from mass sediment flows initiated on fan deltas at the margins of the lake. Coaly material in the sequence appears to be allochthonous. Thin seams might be expected in the subaerial parts of the fan deltas, but their locations cannot be accurately predicted using existing information.

Introduction

The Tranquille beds are one of several isolated Tertiary coal-bearing sequences in central British Columbia. The name was initially applied by Dawson (1896) to a sequence of conglomerate, sandstone, mudstone, and tuff within a predominantly volcanic sequence (Kamloops Group of Cockfield, 1948) which outcrops in structurally isolated blocks on the north and south shores of Kamloops Lake (Fig. 53.1) in map area 92I/9, 10, 15. The geological setting of the Tranquille beds has been described by Dawson (1896), Cockfield (1948), and Carr and Reed (1976). The initial purpose of this report is to discuss the coal resource potential of the Tranquille beds, based on observations of its stratigraphy, sedimentology, and structure. A supplementary study of the effects of contact metamorphism on low rank coaly material in the Tranquille beds was undertaken by Creaney (1979) who visited the area with the authors in May 1978.

Stratigraphic Age and Correlation

Sedimentary rocks assigned to the Tranquille beds are not limited to a single stratigraphic level within the Kamloops Group. North of Kamloops Lake, near Tranquille (Fig. 53.1), Dawson (1896) recorded the beds as a distinctive marker between the upper and lower volcanic sequences. Twenty kilometres west of Kamloops Lake, Hills (1965, p. 23) recorded similar tuffaceous sedimentary rocks which he interpreted, on the basis of palynology, to be at a lower level within the volcanic sequence. South of Kamloops Lake, in the vicinity of the Afton Mine, sedimentary rocks assigned to the Tranquille beds are unconformable with the orebody (Carr and Reed, 1976, p. 380). Radiometric (K-Ar) dating of volcanic rocks in the section north of Kamloops Lake (Rouse and Mathews, 1961; Hills, 1965; Hills and Baadsgaard, 1967) indicate a middle Eocene age for this section. This is supported by palynological observations by Rouse and Mathews (1961) and Hills (1965).

On a broader scale, some confusion exists in the correlation and relative ages of component units within the Kamloops Group. Rocks near Red Lake which Cockfield (1948) interpreted as Tranquille beds are now considered to postdate the Kamloops Group and have been referred to the (upper Miocene-Pliocene) Deadman River Formation (Mathews and Rouse, 1963; Campbell and Tipper, 1971). Traditionally, rocks of the economically important Coldwater beds (Group) have been interpreted as a basal part of the Kamloops Group (Dawson, 1896; Cockfield, 1948; Duffell and McTaggart, 1951) and hence older than the Tranquille beds. They occur in areas to the south (Cockfield, 1948) and west (Duffell and McTaggart, 1951; Church, 1975; Höy, 1975) of Kamloops Lake. As outcrops of the Coldwater Group are geographically separated from volcanic rocks of the Kamloops Group (except perhaps at Hat Creek; Church, 1975) the relationship of these beds to other units of Cockfield's (1948) Kamloops Group is not clear. Dawson (1896, p. 69b) suggested that an apparent absence of contemporaneous volcanic material, or derived volcaniclastic material (similar to volcanics of the Kamloops Group), along with a greater degree of deformation, supported his hypothesis that the Coldwater beds were older than volcanism in the Kamloops Group. Cockfield (1948) concurred with this interpretation, although he (p. 39) along with Duffell and McTaggart (1951) could find no positive evidence for this age assignment. In contrast Hills (1965) recorded volcanic rocks below the Coldwater Group near Princeton and Coalmont, and bentonites within the sequence at Quilchena and in coal seams at Coalmont. Church (1975) found tuff bands intercalated with coal in the Coldwater Group at Hat Creek and (p. 110) observed dacite lavas resting on top of the group in two localities, indicating that volcanic rocks of the Kamloops Group were partly coeval but mostly younger than the Coldwater Group. Hills (1965) suggested, on the basis of palynological observations, that rocks of the Coldwater Group, occurring south of Kamloops Lake, at Merritt, Nicola-Mamit and Quilchena, are younger than the Tranquille beds,

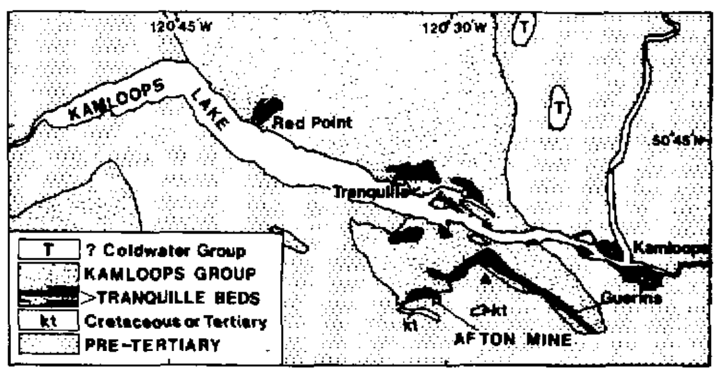


Figure 53.1. *Distribution of the Tranquille beds of the Kamloops Group, in the vicinity of Kamloops Lake and Afton Mine. Modified after Cockfield (1948) and Carr and Reed (1975).*

though are still assigned a middle Eocene age. Preliminary analysis of the palynology of Hat Creek may indicate a Late Eocene age for the coal-bearing sequence of the Coldwater Group in this area (W.S. Hopkins, pers. comm., 1978). This apparent conflict between earlier geological observations and palynological interpretations obviously necessitates further radiometric and palynological studies before the problem can be fully resolved.

Minor outcrops of conglomeratic rock near the Afton mine (unit KE and Carr and Reed, 1976, Fig. 3) may predate the Kamloops Group, and could be correlative with map unit 7 of Cockfield (1948) and map unit 21 of Duffell and McTaggart (1951). Rocks of the Chu Chua Formation, which underlie volcanic rocks in the Bonaparte Lake map area, were correlated with the Coldwater beds by Campbell and Tipper (1971). These beds may predate volcanism in the Kamloops Group, or may be equivalent to the Tranquille beds in the Kamloops area. Hills (1965) suggested that the Tranquille beds are correlative with middle Eocene rocks below the Princeton coal zone in the Allenby Formation at Princeton, and with the lower part of the succession in the Coalmont sediments near Tulameen.

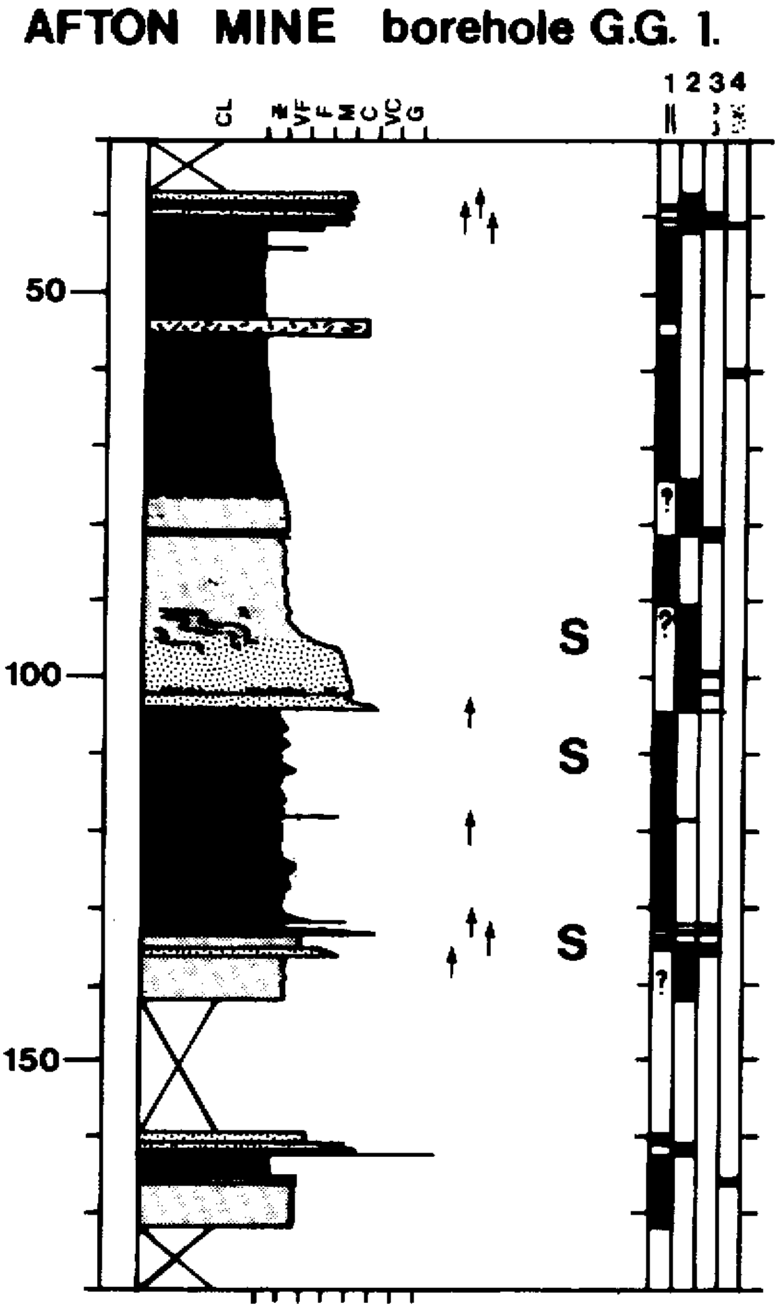
Structure and Thickness of the Tranquille Beds

The Tranquille beds outcrop in structurally isolated blocks north and south of Kamloops Lake. The preserved thickness of the sequence increases rapidly to the north of the Afton Mine where drilling has indicated in excess of 500 m of section (Carr and Reed, 1976). Thickness of the sedimentary sequence north of Kamloops Lake is probably in excess of 300 m (Dawson, 1896, p. 174b). In the Kamloops Lake area, dips within the Tranquille beds have been recorded from nearly horizontal to 35°. Drilling in the proximity of the Afton Mine (Carr and Reed, 1976, Fig. 10) has revealed three principal fault sets. Two of these sets (orientation west-northwest and east-northeast) are high angle reverse faults, which have thrust the orebody onto the Eocene strata. The third set (north-northeast) has the effect of displacing Eocene strata to the south (or down) relative to the main body of Eocene rocks. The net result of this faulting has been to produce several isolated blocks which include essentially monoclinal strata. Other minor deformation can be related to early (or syndepositional) faults (resulting in slumped beds), and the diastrophic effects of volcanism both during emplacement of parts of the Kamloops Group and during emplacement of later volcanic sequences. Minor isoclinal folds are present close to faults in the Afton Mine exposures, although evidence of major folds is uncommon.

Lithology

In outcrops to the north of Kamloops Lake, the Tranquille beds consist of yellow to buff weathering tuffaceous sandstone, siltstone, and mudstone, with minor tuffs and conglomerate (Cockfield, 1948, p. 35). In outcrops within the Afton Mine (2070 ft level) and in core from boreholes located to the north of the mine, the Tranquille beds appear to be dominated by finely laminated tuffaceous siltstone and mudstone, with lesser amounts of sandstone and conglomerate (cf. Fig. 53.2). Organic material in the form of coalified plant detritus, including a few logs, is present in minor amounts throughout the sequence.

Sandstone contains abundant detritus of volcanic origin, presumably derived from underlying members of the Kamloops Group. Further volcanic material may have been derived from reworking of contemporaneous

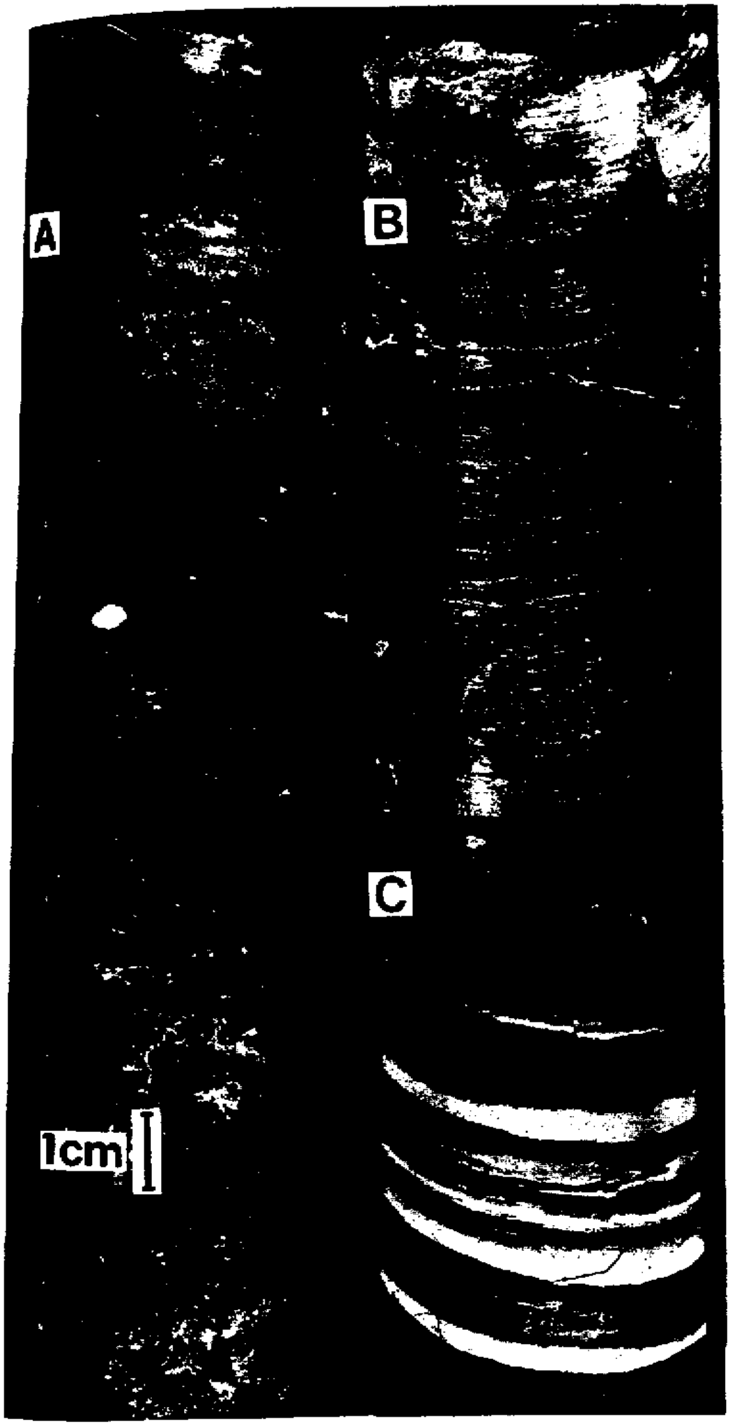


Claystone (CL) and siltstone (Z) in black;
very fine sandstone (VF) in light stipple;
fine to very coarse sandstone (F, M, C, VC) heavy stipple;
G = granule cong;
S,L small and large pebble conglomerate;

Sedimentary structures:
1. flat bedding;
2. no visible structures;
3. intraclasts, rip-up clasts;
4. detrital organic material

S = slumped beds;
Arrows indicate conspicuous graded beds.

Figure 53.2. *Partial log of borehole GG1 illustrating style of sedimentary rocks in the Tranquille beds near Afton Mine. Depth below surface in metres.*



A = *Rip-up clasts of mudstone (black) and volcaniclastic material (white) in very fine sandstone unit from the 81 m level of borehole GG1 (Fig. 53.2).*

B = *Finely laminated mudrock from the 165 m level of borehole GG1.*

C = *Graded laminated units of fine sandstone to claystone from the 214 m level of borehole GG6, located 750 m north of the Afton Mine.*

Figure 53.3

volcanic rocks. Grain size range is from very fine to very coarse sand grade, with medium and coarse varieties most abundant. Although some very poorly sorted sandstone units were observed, most beds appeared to be moderately well to moderately poorly sorted. The bulk of the sandstone is devoid of any visible structure. Minor horizontal bedding, wavy bedding and ripple cross lamination were observed in outcrops within the mine, as was graded bedding which is more conspicuous in the core (Fig. 53.2). Rip-up clasts (Fig. 53.3A) are common in the graded beds. The lack of visible structure in many of the sandstone beds may in part be due to homogeneity of grain size, or in outcrop to local weathering conditions (cf. Hamblin, 1962) or may be a primary depositional feature. Structure may have been obliterated in some beds during slumping, perhaps associated with contemporaneous faulting.

Typically, mudstone strata are well laminated, with fine lamination (less than 1 mm) being most common (Fig. 53.3B) although some strata appear homogeneous. Colour (fresh) ranges from nearly black in the more organic rich beds to a light greenish brown in beds containing abundant volcaniclastic material (ash?). Small scale composite rhythms, resembling varves, were observed in parts of the section (Fig. 53.3C).

The general flat-bedded character of the finer grained sedimentary rocks and their lack of abundant bioturbation indicate that deposition of much of the sequence occurred in a relatively still water lacustrine environment. Massive and graded sandstone units may be the products of mass sediment flows (including grain flows and turbidity currents) which were initiated in shallower water, perhaps in response to development of fan deltas at the lake margins. A lacustrine origin is supported by the palynological observations of Hills (1965, p. 53) who considered the presence of both macro- and micro-fossils of **Azolla primeava** to indicate deposition in the quiet waters of a lake. Coaly material (including logs and detrital plant remains) appears to be allochthonous.

Igneous rocks occurring within the Tranquille beds (andesites and dacites) may include both intrusive and extrusive varieties. Due to poor exposure it is not always possible to determine the relationships of these rocks to the enclosing sedimentary rocks. However observations of vitrinite reflectance by Creaney (1979) indicate that at least some units encountered in boreholes north of the Afton Mine are of intrusive origin.

Coal Occurrences

Dawson (1896) reported "a small bed of lignite" near Red Point (Fig. 53.1) which was found during the progress of the Government Railway survey in 1878. McEvoy (in Dawson, 1896) recorded several thin coal seams from an exploration adit near Guerins (Fig. 53.1). The aggregate thickness of seven seams at this locality amounted to only 77 cm in 180 cm of section of interbedded mudstone and sandstone. Individual seams did not exceed 30 cm. Quality of coal appears to have been variable, and shale partings discontinuous. These occurrences could not be relocated during our investigations. Additional occurrences of coaly material were observed in the Afton Mine and in cores from the north of the mine. However, coal seams appear to be very rare in the sedimentary sequence. Individual seams are commonly clean, although in outcrop they appear to be thin (maximum 8 cm) and discontinuous. Coalified detritus is common in the associated sandstone and mudstone. Maceral analysis is as yet unavailable. Observations by Creaney (1979) indicate that away from intrusive bodies the coals are of sub-bituminous A rank.

Coal Potential

The probability of major coal seams occurring within the Tranquille beds both north of Afton Mine and in the vicinity of Kamloops Lake is extremely remote. A subaqueous (lacustrine) environment is postulated for much of the sequence in which coaly material is predominantly allochthonous. Coal seams may be developed in proximal (subaerial) parts of fan delta complexes at the margins of the lake in which the Tranquille beds were deposited, but the location of such potential sites cannot be predicted using existing information.

Acknowledgments

We thank L.V. Hills, S. Creaney, and J.D. Hughes for their comments on an earlier version of this paper. Afton Mines Ltd. and Canex Placer Ltd. granted permission to examine their property and drill core from the Afton property. A.J. Reed provided an illuminating discussion and tour of the Afton Mine site.

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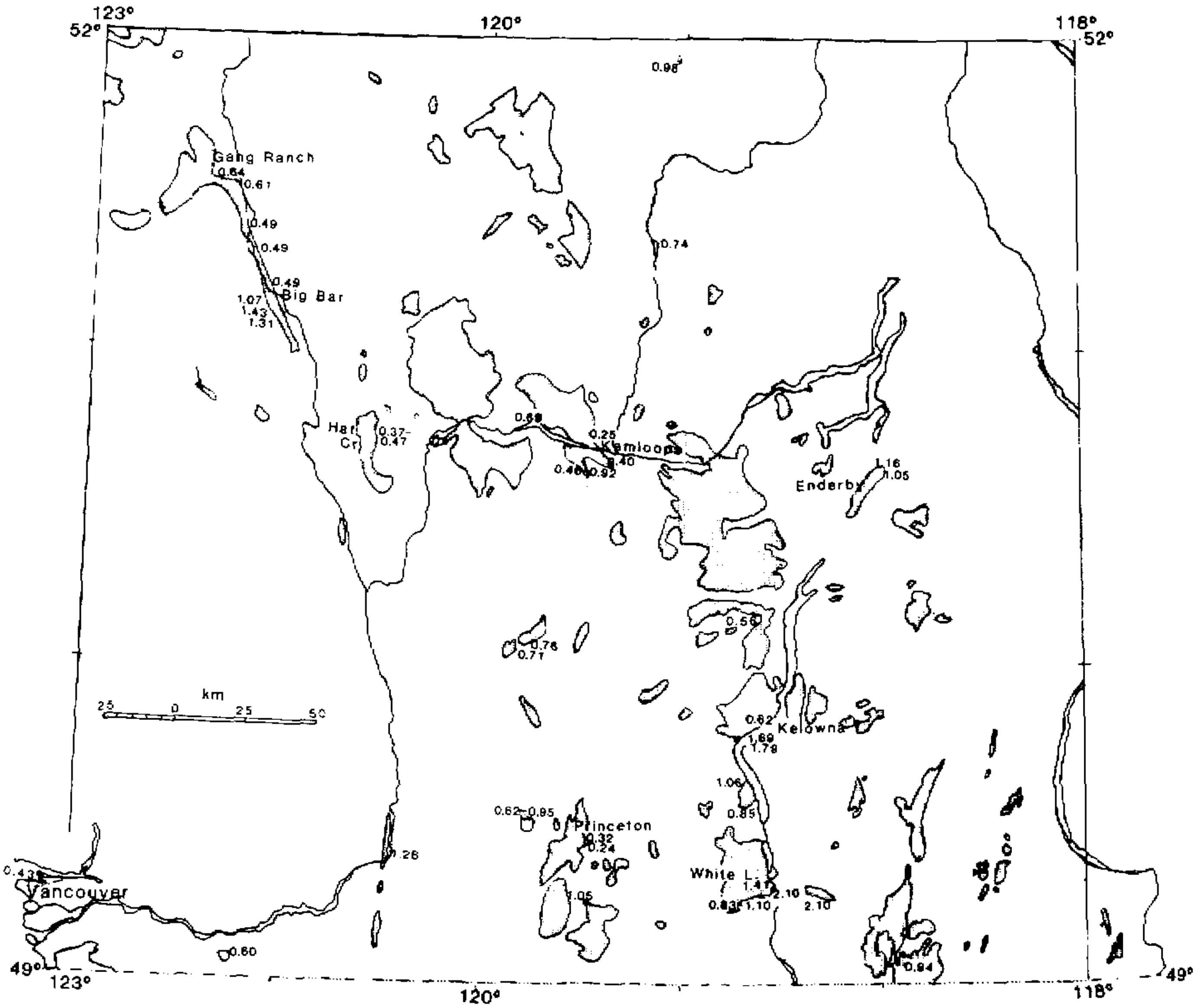


FIG. 1. Eocene bedded rocks (shaded) in southern British Columbia and their mean maximum vitrinite reflectance values.

FIG. 2. Histogram of mean maximum vitrinite reflectance values from Fig. 1.

of cover for the samples analysed here, let alone arrive at a burial history.

The vitrinite reflectance values are presented in summary form in Fig. 1 and in the accompanying histogram (Fig. 2). In the latter no more than two values from any one site have been used so as to avoid bias of the well-studied localities over the isolated sites where only a single sample is available.

Discussion

The greatest concentration of reflectances falls in the range 0.45–1.00%; this range may be considered "normal" for Eocene vitrinite in southern British Columbia. Departures from these values bear closer scrutiny.

Abnormally low values of reflectance are found near Kamloops (0.25%) from a sample very near the top of the succession at a site that may never have had any great depth of cover and at Hat Creek where, as already noted, sediments may be younger than Middle Eocene and may, therefore, have escaped any major thermal event. The Princeton Basin also contains vitrinite with low reflectances (0.28 and 0.32%), but here the explanations offered above cannot apply. The vitrinites in question are low in the sedimentary succession (~100 m above the Princeton–Black coal seam) and have been covered by as much as 1000 m of younger strata (McMechan 1983, p. 30). The Mid-Eocene age is, moreover, well established by K–Ar dating of the Princeton ash (Rouse and Mathews 1961) at 49 Ma (new constants). The anomalously low vitrinite reflectances at Princeton may be the result

(1)

M E M O R A N D U M

86 04 28

TO: Louise Klatzel Mudry

FROM: Brenda Wright

SUBJECT: B.C. RECONNAISSANCE EVALUATION

FILE: NTS 92H and 92I

PROJECT: B.C. Reconnaissance
Phase I
May 31 - June 30, 1982

LOCATION: East half of NTS Map Sheets 92H and 92I in the Princeton-Kamloops area

ACCESS: Majority of targets were road accessible.

APPROACH: Used target areas modelled after the Tertiary Princeton, Tulameen, Merritt and Hat Creek coal basins. Criteria for target selection:

- o Eocene sediments on basement rock
- o Eocene volcanics and sediments interbedded on basement rock
- o Eocene sediments under Eocene or younger volcanic (cap) rock
- o Eocene volcanics on basement rocks (previous misidentification or inliers of sediment not previously realized)
- o Miocene volcanics on basement (possible windows of sediments)
- o Topographic lows in basement rocks that could contain isolated occurrences

RESULTS: Of the 54 targets covered, 14 yielded Eocene sediments. These occurrences consisted primarily of conglomerate and medium-grained sandstone. Three outcrops displayed coalified logs. There were no shales or mudstones found. This would be indicative of a higher energy environment.

ADDITIONAL WORK REQUIREMENTS

1) Target 11 - located near Similkameen Flats south of Princeton
- inadequate coverage due to obstructed roads
- mapped by G.S.C. as Princeton Group andesite and basalt
- might be associated with coal-bearing sediments as is the case in the Princeton coalfield

.../2

2) Taret 31 - located north of Kamloops Lake and straddling the Tranquille River
- report recommends more work could be done
- area is fairly large and has been mapped as Kamloops Group volcanics
- coal-bearing Tranquille sediments have been reported interbedded with the lavas
- work should be concentrated to the north on the Bonaparte Lake map sheet

RECOMMENDATIONS:

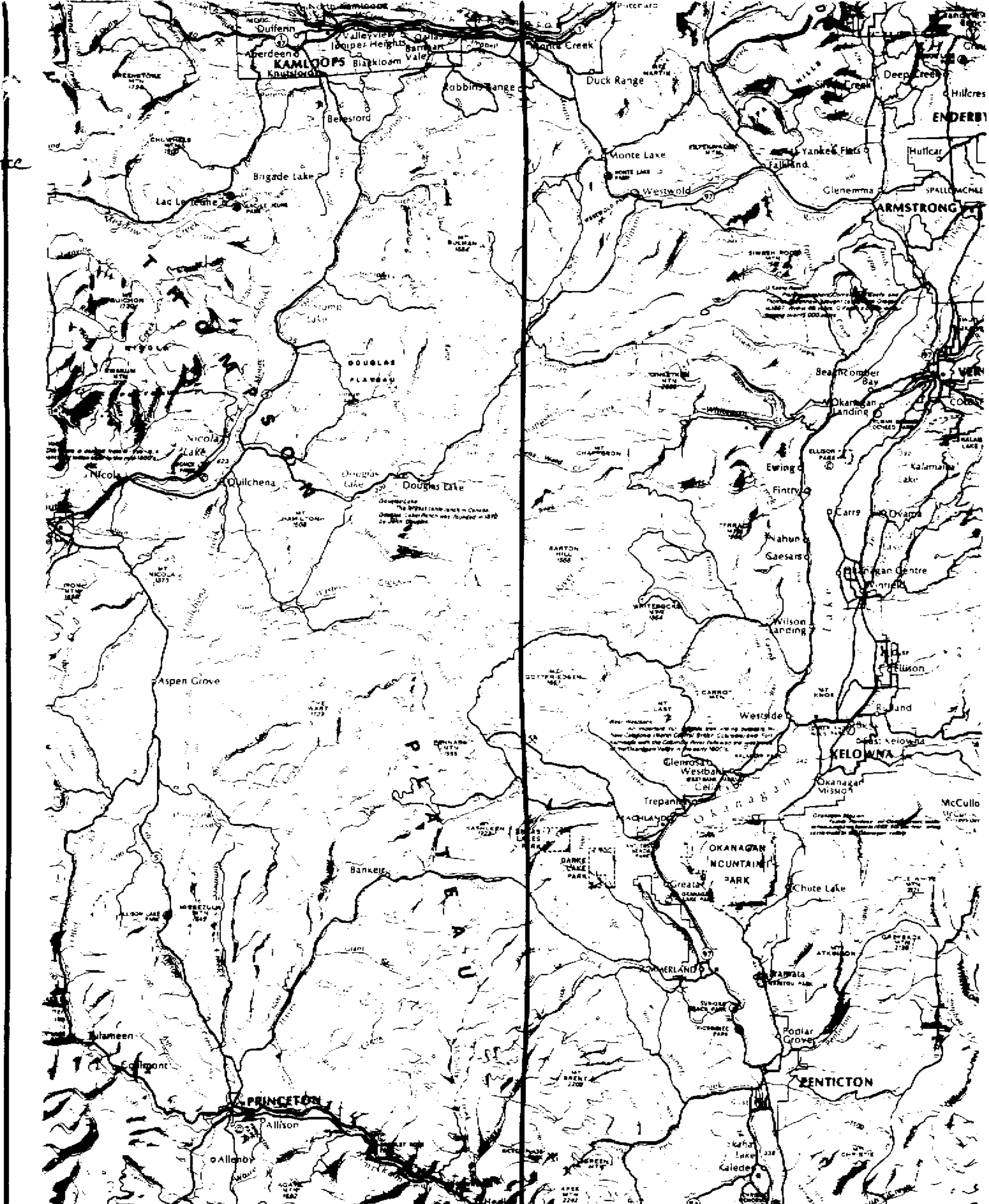
The above areas are what I would consider the most likely coal-bearing targets by virtue of their size and their relationship to previously discovered coals. I believe that most of the rest of the project area has been adequately covered with no success and therefore no further work is recommended. The targets that I have indicated could both be explored in under two weeks. I would consider the entire area as low priority due to the fairly extensive mapping coverage in the past, both by this department and by the G.S.C.

Brenda

BMW:jlg
Attachment
0367k:95-94

2
Reconnaissance
PHASE
I

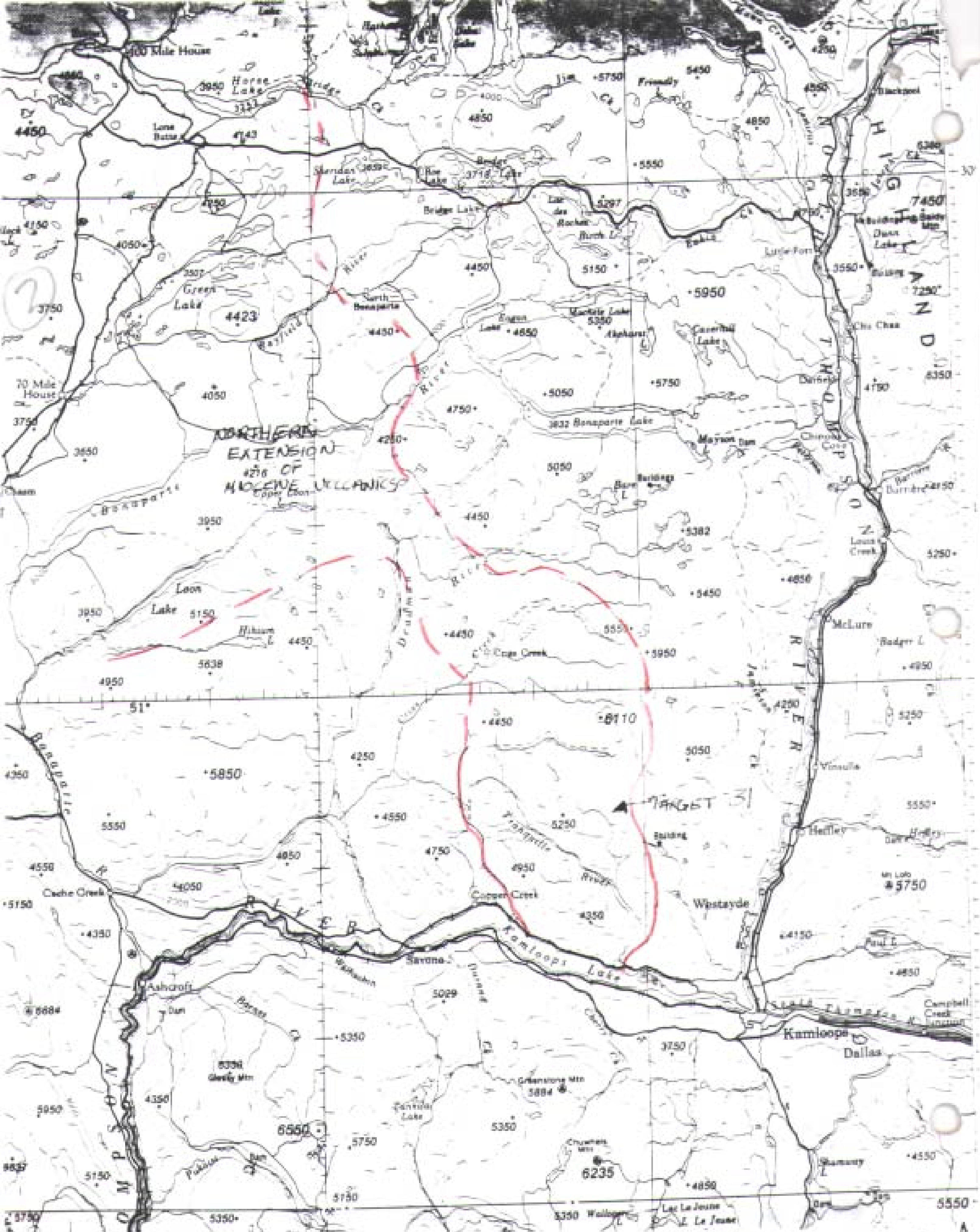
1



TARGET II

Scale 1: 750,000

N



Scale 1:500,000

N

BMW.

M E M O R A N D U M

86 05 27

TO: File - NTS 92 H 8

FROM: B.M. Wright

SUBJECT: PRINCETON COALFIELD DATA

Location

- encompasses the town of Princeton, B.C. and lies in a northeast/southwest trend along the Similkameen and Tulameen rivers (see attached map).

Stratigraphy

- Tertiary Princeton Group which overlies an early Paleogene unconformity.
- Princeton Group consists of a lower Volcanic Formation and the upper Allenby Formation (mid-Eocene Age).
- Allenby Formation is 1700 m thick, coal-bearing, and consists of non-marine terrigenous clastics and lesser volcaniclastic rocks.

Structure

- basin is a half graben with a major normal fault zone bounding the eastern margin.
- dips within the basin are to the east (10-25^{o}), therefore some movement has post-dated sedimentation.
- broad, open, east to southeast trending folds are present.
- faulting is common along the basin margins.
- normal faults with offsets of a few metres are present in old mine workings.

Coal Development

- most coal zones are confined to the upper part of the Allenby Formation whose base is arbitrarily placed at the base of the Princeton - Black - Blue Flame coal zone.
- four zones of economic coal lie within a 530 metre stratigraphic interval (see Figure).
- Princeton seam has historically been 5-7 m thick, the upper 2 m of which were exploited (see attached map).
- thickness are quite variable and correlation is difficult.
- for the most part, coal seams of the Allenby Formation have been only mildly deformed.

.../2

Depositional Environment

- northern part of the Princeton Basin may be of braided stream/alluvial fan origin and therefore not stable enough for coal development.
- southern portion has better developed seams but these near surface coals have, for the most part, been already mined out.
- volcanism may be responsible for the high ash content.

Coal Quality

- ash content is high (13-35%) with numerous bentonite partings within the seams
- high moisture content (up to 25%)
- volatile matter ranges from 28-33% (AR basis?)
- sub-bituminous 'A' in rank (6000 - 10,000 BTU/lb)
- sulphur values are less than 1%

Mineability

- weak strata encloses the seams which is bad for underground mining as well as slope stability within open pits.
- rapid lateral variations within the seams make the prospect of underground mining unattractive.
- coal piles have the tendency to combust spontaneously.

Resources

- historical coal production of 1.8 Mt is thought to represent less than 1% of the total in situ resources.
- total potential resource is 10.1 Mt (Dolmage Campbell and Assoc. Ltd., 1975), all underground.

.../3

Potential

- the northern portion of the basin is largely unexplored
- all of the potential appears to be underground
- good access and close to port
- high ash, high moisture, non-coking, low rank coal
- outcrop exposure is < 1%; what there is is usually slumped
- poor roof and floor and is definitely a problem with bentonite partings
- rapid lateral variation in the seams
- recommend that this area is of little interest

Brenda

BMW:jlg
Attachments
0453k:4-5

xc: J. Horgan
L. Klatzel-Mudry

Reference: Geology of the Princeton Basin; BCMEMPR Paper 1983-3, R.D. McMechan

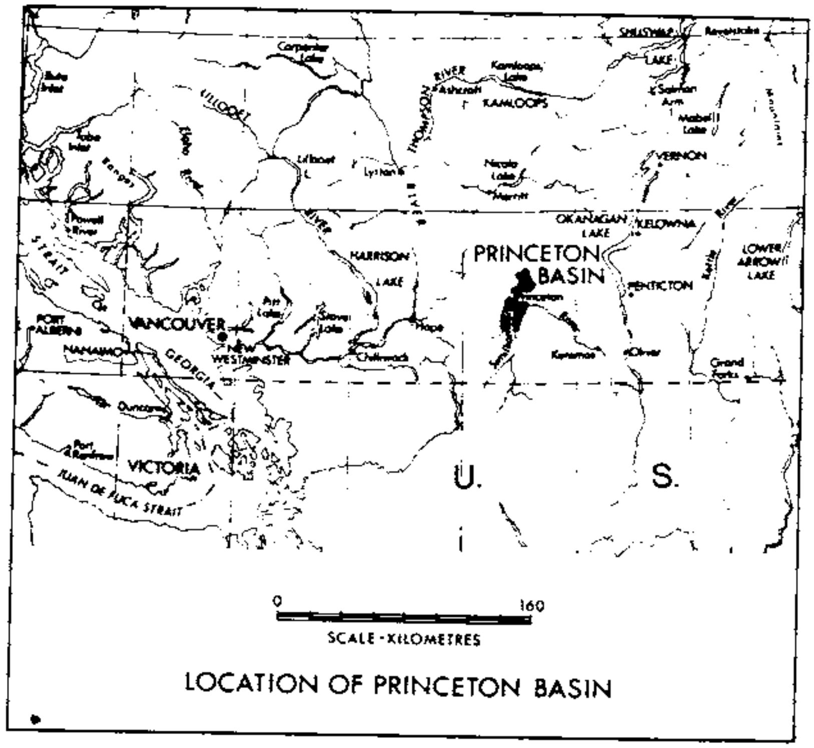


Figure 1. Location map of the Princeton Basin.

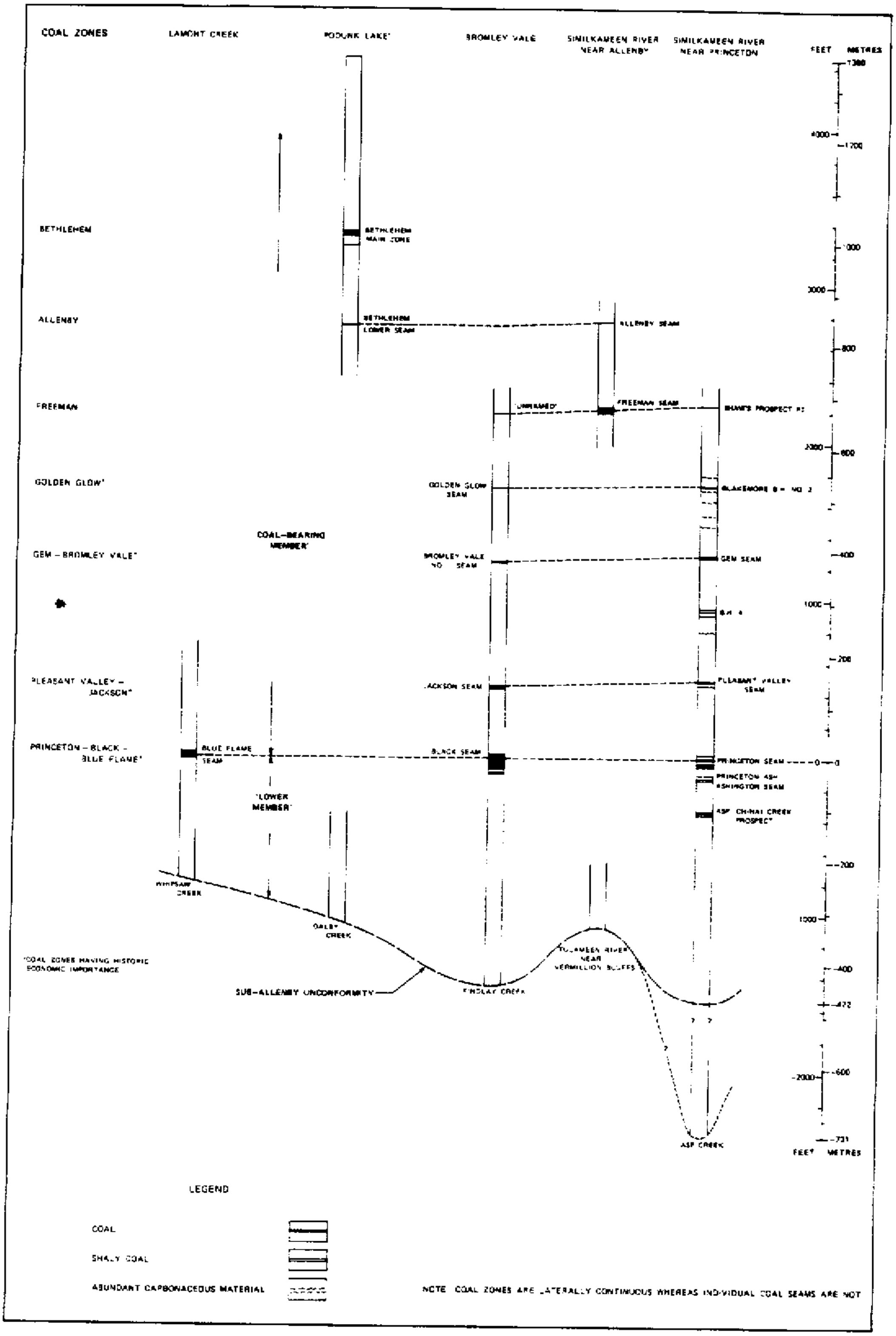


Figure 12. Correlation chart of coal zones in the Allenby Formation, Princeton Basin.

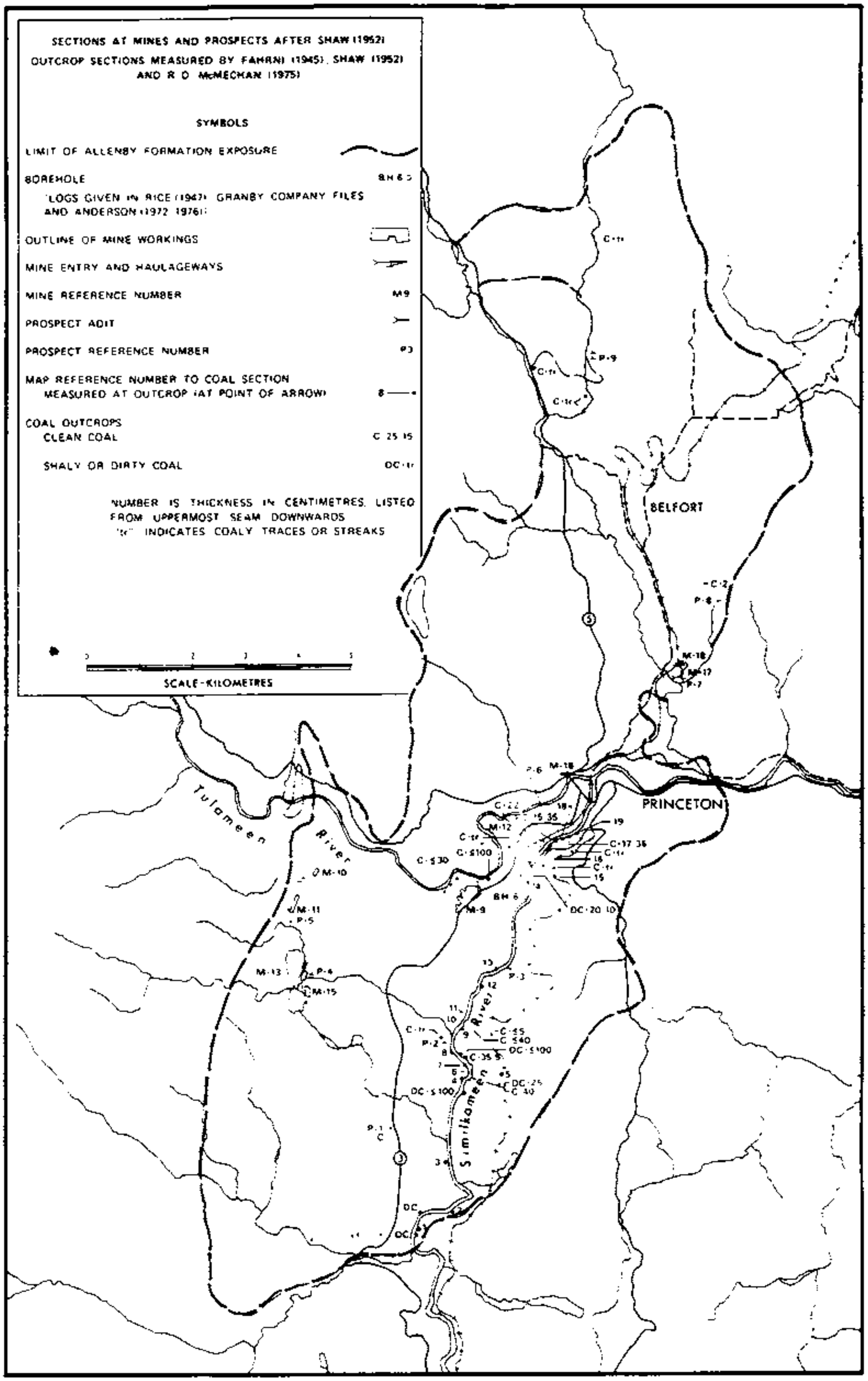


Figure 13a. Coal outcrops, mines, and prospects, Princeton Basin (excluding Princeton-Black-Blue Flame coal zone); for index, *see* Figure 13b.

MEMORANDUM

86 05 06

TO: Louise Klatzel Mudry

FROM: Brenda Wright

SUBJECT: B.C. RECONNAISSANCE EVALUATION

FILE: NTS 92 O 1

PROJECT: B.C. Reconnaissance
Chilcotin
June - July 1983
May - July 1984

LOCATION: NTS Map Sheets 92 O, 92 N E 1/2, 92 J E 1/2, 92 I W 1/2

ACCESS:
- poor quality and few access roads
- required helicopter use and fly camping
- 200-320 kilometres one-way distance from closest helicopter base

TARGET FORMATIONS:

1. Jackass Mountain Group (L. Cret.)

   - the 1200 metre thick basal sedimentary section of the group was targetted
   - no coal has been reported, however, carbonaceous wood and plant fragments are present

2. Kingsvale Group (U. Cret.)

   - the group consists mainly of a series of volcanic rocks unconformably overlying the Spences Bridge Group, with a 60-300 metre sedimentary zone at its base in places

.../2

1983 RECONNAISSANCE:

- attempted to build a stratigraphic section of the Jackass Mountain Group in order to determine the marine/terrestrial boundary which was thought to hold the greatest potential for coal deposition
- found the lower quarter of the section to contain carbonaceous plant fragments and thin coal stringers

1984 RECONNAISSANCE:

- this program was designed to further explore those areas delineated in the 1983 program
- six target areas
- three areas were underlain by Kingsvale Group sediments
- three areas were underlain by sediments of the Jackass Mountain Group Division A
- some coaly material and plant fragments were observed, but no coal occurrences of economic value were found

ADDITIONAL WORK REQUIREMENTS:

- no further work is recommended for the areas covered in 1983-84
- however, these formations present promising targets for areas to the northwest
- I would suggest that this be considered a prime target area for B.C. reconnaissance utilizing the same approach as the 1984 Chilcotin program

Brenda

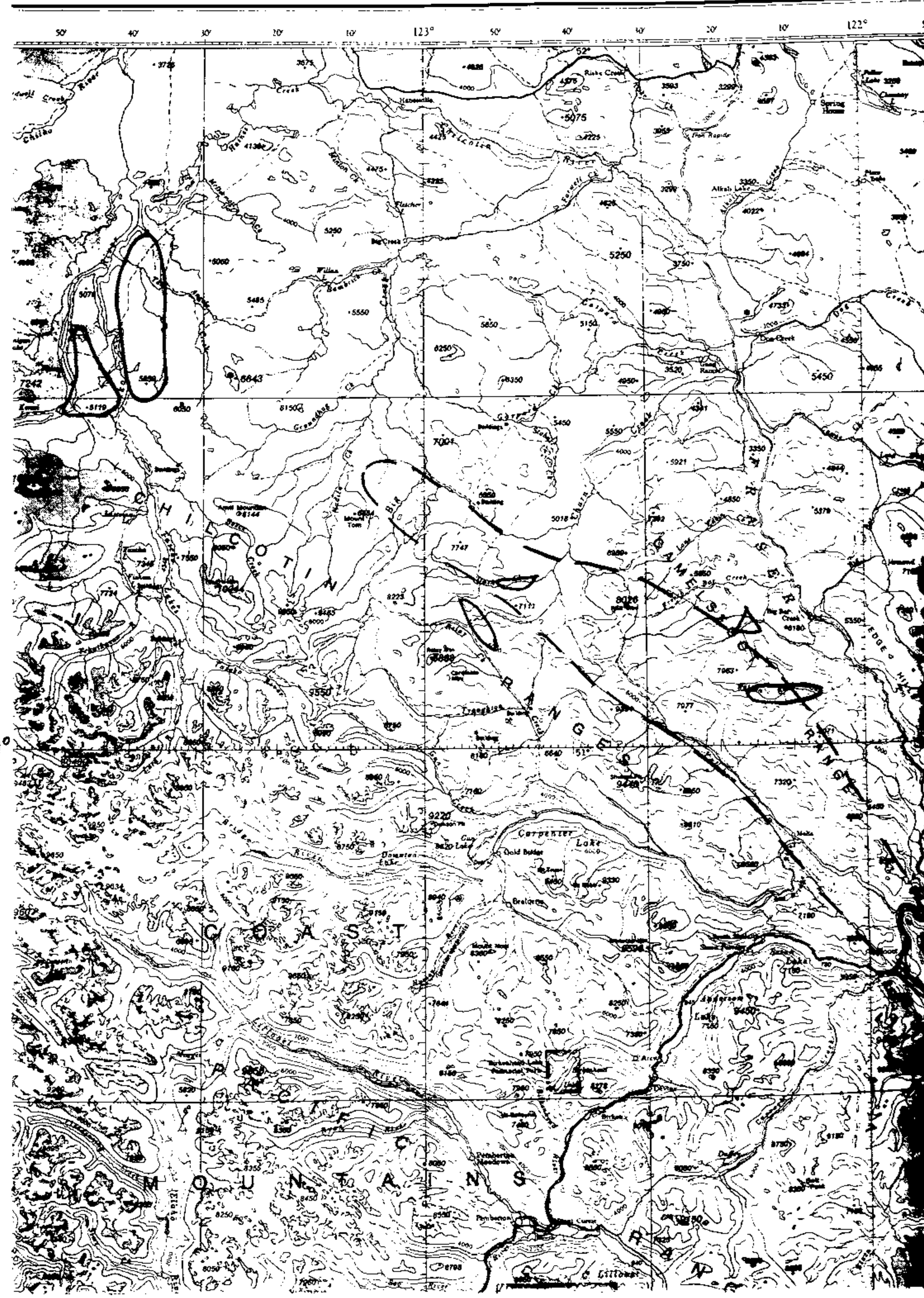
BMW:jlg
0419k:16-17
Attachment

xc: J. Horgan

ERA	PERIOD	92 N	92 O	92 J	92 I	
	Miocene or Younger	Unnamed		Unnamed	Unnamed	Vesicular basalt, andesite, rhyolite, with related breccia and tuff.
	Oligocene or Older	Unnamed		Unnamed	Kamloops Gp	Andesite, dacite with related breccia and tuff.
	Paleocene			Unnamed	Coldwater Beds (Kamloops Gp.)	Sandstone, shale, siltstone and conglomerate.
	U. Cret.	Coastal Intrusives		Scuzzy Pluton	Coastal Intrusives	Quart diorite, granodiorite diorite, albite syenite, and hornblendite.
	U. Cret.		Division D			Andesitic and basaltic tuffs and breccias.
			Division C			Volcanic conglomerates, greywacke, conglomerate and shale.
		Division B	Division B		Division B	Andesite, Basalt with related agglomerate, breccia and tuff.
		Division A	Division A	Division A	Division A	Siltstone, greywacke, arkose, shale and conglomerate.
	L. Cret.				Spences Bridge Gp.	Andesite, dacite, basalt and ryolite with related breccias and tuffs; sandstone and conglomerate.
	L. Cret.	Taylor Creek Gp.	Taylor Creek Gp.	Taylor Creek Gp.		Shale, banded limey shale, siltstone, greywacke, chert pebble conglomerate.
	L. Cret.	Jackass Mountain Gp.	Jackass Mountain Gp.	Jackass Mountain Gp.	Jackass Mountain Gp.	Greywacke, argillite, arkose, and conglomerate.
	M. Jur. To L. Cret.	Relay Mountain Gp.	Relay Mountain Gp.	Relay Mountain Gp.	Relay Mountain Gp.	Shale, siltstone, mudstone, greywacke, conglomerate minor minor volcanics, minor limestones.
	L. Cret.				Coast Intrusions West of Fraser R.	Granodiorite
	L. Cret.				Lilloet Gp.	Argillite, volcanic conglomerate tuffaceous sandstone, conglomerate.
	L. Cret.				Brew Gp.	Argillite, quartzite, conglomerate.
	U. Jur.				Mount Lytton Batholith	Granodiorite, quartz diorite and gabbro.
	M. Jur.			Unnamed	Unnamed	Shale, conglomerate, siltstone and sandstone.
	L. Jur.				Guichon Creek Batholith	Granite, granodiorite, diorite
	U. Triassic				Nicola Gp.	Basalt, andesite, limestone, sandstone, schist and gneiss.
	U. Triassic				Unnamed	Ultrabasic Rocks
	U. Triassic	Unnamed		Hurley Fm. Pioneer Fm. Noel Fm.	Unnamed	Shale, greywacke, siltstone, conglomerate, limestone, greenstone, tuffs, breccia schist and gneiss.
	M. Triassic			Bridge River		Argillite, phyllite, greenstone
	Palaezoic				Unnamed	Phyllite, quartzite, limestone slate, schist and gneiss.
	Permian				Cache Creek Gp.	Greenstone, argillite, minor limestone and quartzite shist (Marble canyon limestone).
		(Tipper, 1968)	(Jeletzky and Tipper, 1967)	(Roddick and Hutchison, 1973)	(Duffell and McTaggart, 1952)	

KINGSVALE GROUP

1281K



↑ N

51°

NTS 92 NE

1983 Recon. Area

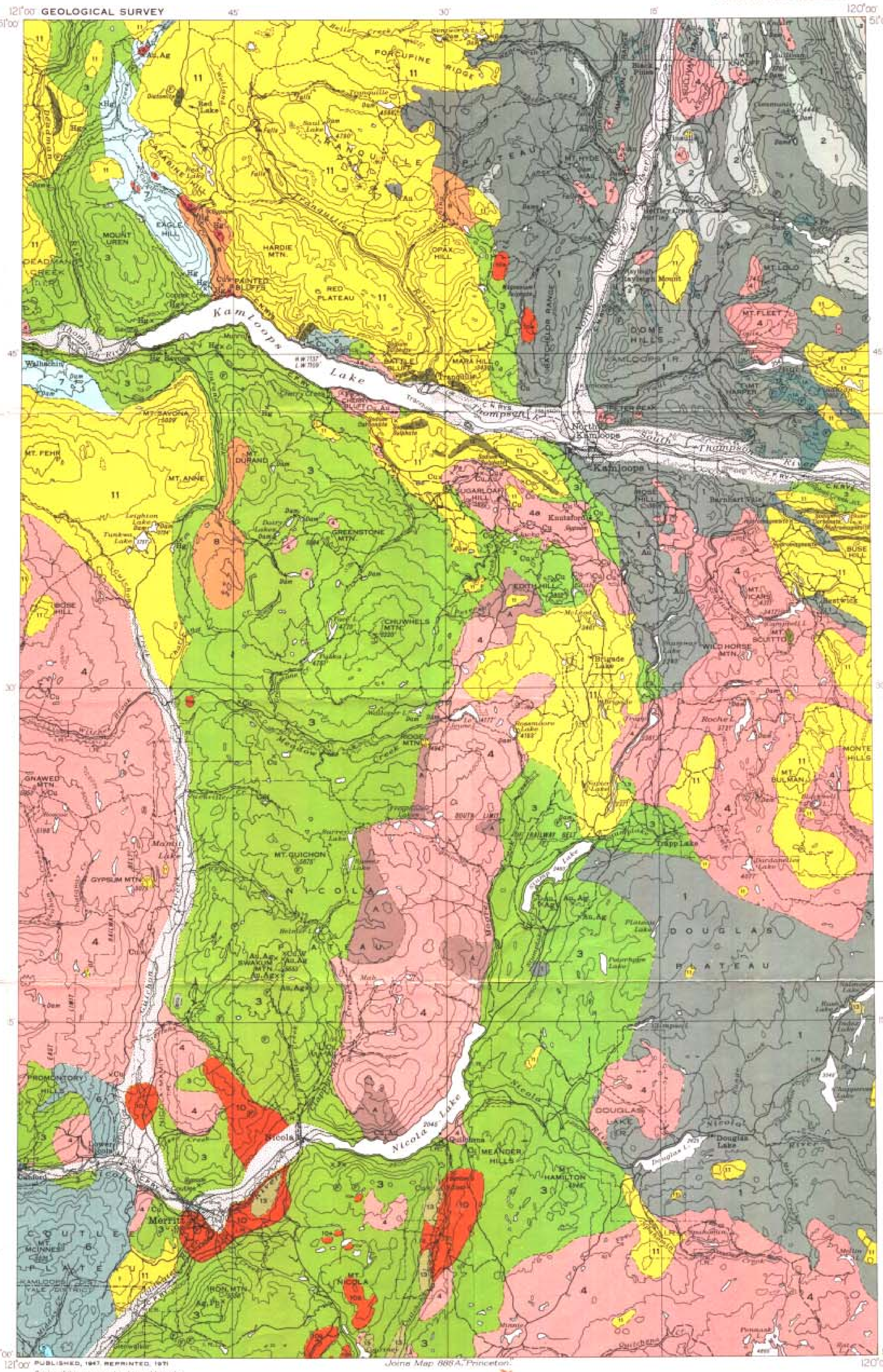
1984 Recon. Area

Geology Maps

CANADA
DEPARTMENT OF MINES AND RESOURCES
MINES AND GEOLOGY BRANCH
BUREAU OF GEOLOGY AND TOPOGRAPHY

SHEET 92 I (East Half)

GEOLOGICAL SURVEY



PUBLISHED, 1947. REPRINTED, 1971
Copies of this map may be obtained from the Geological Survey of Canada, Ottawa

Joins Map 888A, "Princeton."

MAP 886A

NICOLA

KAMLOOPS AND YALE DISTRICTS
BRITISH COLUMBIA

Scale, 1/253,440 or 1 Inch to 4 Miles
Miles

Approximate magnetic declination, 24°30' to 27° East.

LEGEND

CENOZOIC

TERTIARY
MIOCENE OR LATER

13 — *Valley basalt: mainly vesicular basalt*

MIOCENE OR EARLIER
KAMLOOPS GROUP

11, 12 — 11. *Rhyolite, andesite, and basalt; associated tuffs, breccias and agglomerates. May include some younger basalts*
12. *TRANQUILLE BEDS: conglomerate, sandstone, shale, tuff; thin coal seams*

10 — *COLDWATER BEDS: conglomerate, sandstone, shale, and coal;* 10a, *similar to* 10, *but may include younger beds*

MESOZOIC OR CENOZOIC

CRETACEOUS OR TERTIARY

9 — *COPPER CREEK INTRUSIONS: granite, granodiorite, granite porphyry*

8 — *Andesite, basalt, picrite, agglomerate, breccia, and tuff; minor conglomerate and sandstone*

7 — *Conglomerate, sandstone, and shale*

MESOZOIC

CRETACEOUS
LOWER CRETACEOUS
KINGSVALE GROUP

6 — *Rhyolite, andesite, and basalt; associated tuffs, breccias, and agglomerates; arkose, conglomerate*

SPENCE BRIDGE GROUP

5 — *Hard, reddish lava*

JURASSIC AND (?) LATER

4 — *COAST INTRUSIONS: granite, granodiorite, gabbro;* 4a, *Iron Mask batholith; syenite, monzonite, diorite, gabbro;* 4b, *pyroxenite and peridotite. Probably not all of the same age, and may be in part post-Lower Cretaceous*

TRIASSIC
UPPER TRIASSIC
NICOLA GROUP

3 — *Greenstone; andesite, basalt; agglomerate, breccia, tuff; minor argillite, limestone, and conglomerate*

PALÆOZOIC

CARBONIFEROUS AND PERMIAN
CACHE CREEK GROUP (?)

2 — *Greenstone, generally slightly sheared. May include some Triassic rocks* (3)

1, 1A — *Argillite, quartzite, hornstone, limestone, sheared conglomerate, breccia, greenstone, and serpentine;* 1A, *limestone*

A — *Chlorite schist, quartz-mica schist, amphibolite, and granitic intrusions, commonly gneissic and largely of Palæozoic age*

Heavily drift-covered area
Fault
Synclinal axis
Fossil locality
Mineral occurrence

SYMBOLS FOR METALS

Silver	Ag
Gold	Au
Copper	Cu
Iron	Fe
Mercury	Hg
Lead	Pb
Tungsten	W

Road
Road (not well travelled)
Trail
Post Office
Forestry lookout
Land District boundary
Limit of Railway belt
Indian Reserve boundary
Intermittent lake and stream
Marsh
Sand bar
Contours (interval 500 feet)
Depression contour
Height in feet above mean sea-level

Geology by W. E. Cockfield, 1939, 1940, 1941, 1943

For Mineral Localities, see Map 887A, "Nicola"

Base-map compiled by the Topographical Survey, 1937, from information obtained from published Federal Government maps. Cartography by the Drafting and Reproducing Division, 1946.

SCALE, 1 INCH TO 200 MILES

DESCRIPTIVE NOTES

The map-area lies east of Cascade Mountains within the belt of Interior Plateaux, and the topographic features comprise broad upland areas separated by deeply cut valleys. Thompson River and its main tributaries, the North and South Thompson, and Nicola River occupy the master valleys. A considerable part of the area consists of the open, sage-brush country characteristic of the "dry belt" of British Columbia. Forest growth on the lower slopes of the hills consists of widely spaced trees forming open, park-like areas. On the upper and northern slopes forest growth is dense, and large amounts of windfall in places render travel difficult.

A group of foliated rocks (A) is shown separately on the map. They are believed to be largely of Palæozoic age, but Triassic members may be present, and the assemblage also includes much granitic material.

The Palæozoic rocks of the Cache Creek group (1,2) comprise formations of both Carboniferous and Permian age, but are so greatly deformed that their succession could not be determined. The more prominent bands of limestone (1A) were mapped separately in the hope that they would serve as horizon markers, but were found in many instances to occur as single, discontinuous masses or pods. In the northeastern part of the area greenstones are prominent and have been mapped separately (2). They are fine- to medium-grained, altered, generally sheared rocks, and are believed to be interbedded with Palæozoic sedimentary strata, but the possibility of some of them being intrusive is not precluded.

The Triassic period is represented by the Nicola group (3), which here consists largely of volcanic rocks (greenstone). These vary from fine-grained or nearly aphanitic to coarsely porphyritic types. They are predominantly green, but also occur in various shades of purple, red, brown, or grey, and include some with a dark or nearly black groundmass. The rocks are chiefly andesites, but include basaltic types as well as feldspar porphyries with phenocrysts ranging from minute size to half an inch in length. Much breccia and tuff is associated with the lavas. The latter are partly altered to chlorite, epidote, and calcite, and boundaries of individual flows are generally difficult to detect. Minor amounts of sedimentary rocks are associated with the volcanic members and have provided marine fossils of Upper Triassic age. Limestone is the most abundant type, but argillite and conglomerate occur sparingly. The limestone bands generally consist of a series of lenses rather than continuous beds.

Many plutonic rocks are included with the Coast intrusions (4). They are invariably intrusive into Triassic rocks (3) with which they come in contact, but were not found cutting the Lower Cretaceous rocks (6). They are considered to be largely Jurassic, but younger members may be present. The rocks are mostly medium-to coarse-grained granodiorites or quartz diorites, but locally include more acidic or more basic types. The common ferromagnesian minerals are biotite and hornblende. Of special interest is the Iron Mask batholith (4a), which contains copper deposits and veins of magnetite. The plutonic mass west of Guichon Creek also serves as host rock to a number of copper deposits.

Rocks correlated with the Spence Bridge group (5) were identified only at one locality in the extreme southwest part of the area, where they are continuous with similar rocks occurring in the Princeton map-area to the south.

The rocks of the Kingsvale group (6) are co-extensive with considerable areas of similar rocks to the south and west, some of which carry fossil plants. They show a wide range of colours, red, green, purple, buff, brown, grey, white, and black, and possess many characters similar to the Kamloops volcanic rocks, though feldspar porphyries are much more common. The agglomerates carry boulders of the granitic rocks of the region.

Small bodies of Copper Creek intrusions (9) appear along Carabine and Criss Creeks cutting both sedimentary and volcanic rocks (7,8). The latter are of either Cretaceous or Tertiary age, but no fossil evidence was obtained on which to base an age determination.

The Kamloops group includes a considerable thickness of volcanic and sedimentary rocks (10, 11, 12). The Coldwater beds (10) occur at the base of the group and in places appear to underlie the volcanic rocks unconformably. They contain, so far as is known, no intercalated flows or tuffaceous material, and probably antedate the period of vulcanism. However, fossil evidence shows no distinction in age between these and the Tranquille beds. They consist of conglomerate, sandstone, and shale, with commercial coal seams. The volcanic rocks (11) are chiefly dense, fine-grained, basaltic lavas. They exhibit a wide range of colours and are intercalated with considerable thicknesses of breccias and agglomerate. Interbedded with these volcanic rocks and grading upwards into the agglomerates are the Tranquille beds (12). These consist of conglomerate, shale, sandstone, and tuff, with thin coal seams.

Flat-lying basalts (13) are found along benches in some of the valleys and are probably the most recent consolidated rocks of the area.

Pleistocene and Recent deposits cover much of the bedrock. These are thickest in the valleys, but long, drift-covered slopes with few outcrops characterize many of the hills. The larger valleys are lined in many places with marginal terraces of sand, gravel, and clay. Terraces of white silt are prominent in the valley of South Thompson River, but also occur elsewhere in the area.

Data on the structure of the Triassic rocks are scanty, but those obtained appear to indicate that in the southern part of the map-area the folds have northerly trending axes. The emplacement of some of the plutonic rocks is also along a general northerly direction and is at variance with the general northwesterly regional trend. In the vicinity of Kamloops Lake, however, the folds appear to strike northwest, a trend that is followed by the Iron Mask batholith.

The Kingsvale rocks have in general a gentle dip southwestward, but locally are highly disturbed.

The Coldwater beds are not well exposed, but appear to occur in open folds, except near the margins of the basins where dips approach the vertical. At the western margin of the Merritt coal basin the beds form a series of sharp folds with the axes striking northwest and plunging southeast. The Tertiary lavas have in general gentle dips, and some of the flows are nearly horizontal.

The mineral deposits of the map-area represent a number of diverse types and have provided several productive mines, but the total production is small in comparison with nearby districts.

Placer gold deposits have been mined, generally on a small scale and with low returns, on the lower reaches of Tranquille River and Jamieson and Criss Creeks, and along Thompson River below Deadman River.

Vein deposits containing gold and silver, with lead, zinc, and copper minerals, occur in the Triassic greenstones at Stump Lake, and similar veins occur with replacement deposits in the greenstones and limestones of Swakum Mountain. Much work has been done on the Stump Lake deposits, which were among the early lode discoveries of the province, and shipments of ore and concentrates have been made. The veins are commonly less than 2 feet wide, but have been followed for long distances.

Quartz veins are numerous in Palæozoic sedimentary rocks of the northeastern part of the area, and in small bodies of granitic rocks that cut them. They have been explored chiefly for their gold and silver content, but production to date has been small.

Copper deposits have been discovered at many places in the plutonic rocks west of Guichon Creek. The copper minerals occur as veins and in shattered zones associated in many places with molybdenite and in some with tourmaline. Copper deposits are also abundant in and around the Iron Mask batholith, where they occur as veins, impregnations in the country rock, and as stockworks. Only a few carry important gold values. A pronounced alteration of the rock to pink albite and epidote is common near the deposits, but very little quartz is present. Veins of magnetite and apatite also occur with the Iron Mask batholith.

Many veins and disseminations of copper minerals have been found in the rocks of the Nicola group.

Mercury showings are widely scattered in the northwest corner of the map-area from near Tunkwa Lake to Criss Creek. They occur in the rocks of the Nicola group and in Cretaceous or Tertiary sedimentary and volcanic rocks. The cinnabar is associated mainly with veins and stringers of dolomite, but some occur with chalcedonic quartz replacing the rock. The production from these deposits is less than 150 flasks, made chiefly prior to 1900.

The ore contains a variety of industrial mineral deposits, from among which a limited production of gypsum, sodium sulphate, and sodium carbonate has been made.

Coal has been mined for many years at Merritt from a basin of Tertiary sedimentary rocks, and is known to occur with similar strata on Quilchena Creek.

CANADA
DEPARTMENT OF MINES AND RESOURCES
MINES AND GEOLOGY BRANCH
BUREAU OF GEOLOGY AND TOPOGRAPHY

SHEET 92 H (East Half)

LEGEND

CENOZOIC

TERTIARY
MIOCENE OR LATER

19 — *Valley basalt: vesicular, varicoloured basalt*

18 — *Plateau basalt: amygdaloidal, brown basalt*

MIOCENE OR EARLIER
PRINCETON GROUP

16, 17 — 16, *Mainly shale, sandstone, and conglomerate; coal*
17, *Varicoloured andesite and basalt*

CRETACEOUS OR TERTIARY
UPPER CRETACEOUS OR LATER

14, 15 — 14, *OTTER INTRUSIONS: pink and grey granite and granodiorite*
15, *LIGHTNING CREEK INTRUSIONS: grey quartz diorite*

MESOZOIC

CRETACEOUS
LOWER CRETACEOUS
KINGSVALE GROUP

12a-b, 13 — 12a, *mainly volcanic breccia;* 12b, *mainly andesite and basalt porphyry*
13, *Andesite and basalt porphyry and volcanic breccia*

PASAYTEN GROUP

11 — *Mainly grit and shale;* 11a, *mainly purple lava, tuff, and breccia*

SPENCE BRIDGE GROUP

10 — *Hard, reddish andesite and basalt*

JURASSIC (?) AND CRETACEOUS
UPPER JURASSIC (?) AND LOWER CRETACEOUS
DEWDNEY CREEK GROUP

9 — *Tuff, volcanic breccia, grit, argillite;* 9a, *mainly conglomerate*

JURASSIC OR LATER

8 — *COPPER MOUNTAIN INTRUSIONS: syenogabbro, augite diorite, pegmatite*

5, 6, 7 — *COAST INTRUSIONS:* 5, *grey, slightly gneissic granodiorite;* 6, *mainly reddish, coarse-grained, siliceous granite and granodiorite;* 7, *light coloured granodiorite, quartz diorite, and gabbro*

4 — *Peridotite, pyroxenite, gabbro*

TRIASSIC
UPPER TRIASSIC
NICOLA GROUP

3 — *Varicoloured lava; argillite, tuff, limestone; chlorite and sericite schist*

PALÆOZOIC

CARBONIFEROUS OR LATER

2 — *BRADSHAW, INDEPENDENCE, SHOEMAKER, and OLD TOM FORMATIONS: cherty and slaty argillite, green andesite, limestone; quartz-mica schist and gneiss*

HOZAMEEN GROUP

1 — *Chert, green andesite, limestone*

Fault
Fossil locality ... ⓕ
Mineral occurrence ... ×

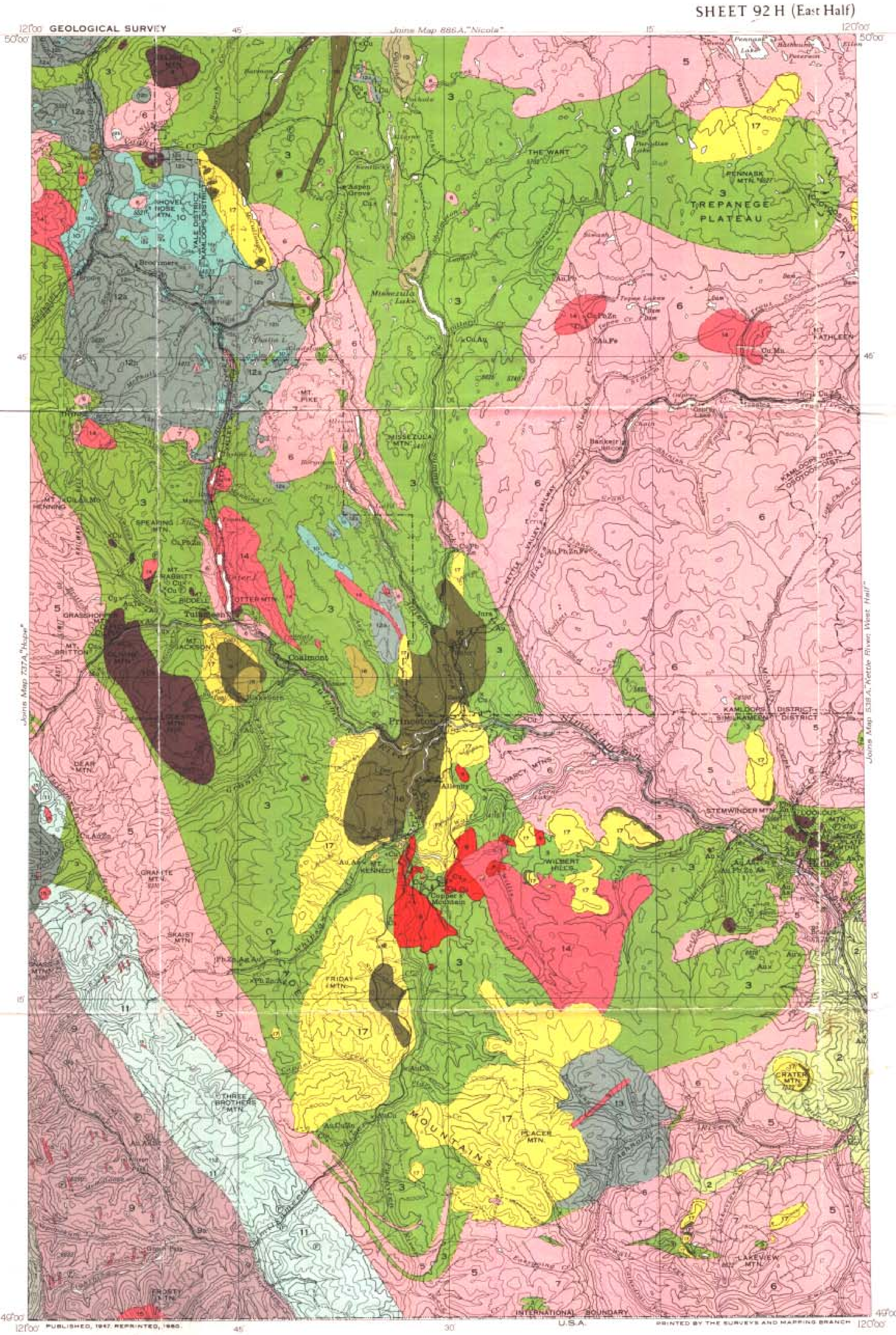
SYMBOLS FOR METALS

Silver	Ag
Arsenic	As
Gold	Au
Cobalt	Co
Chromium	Cr
Copper	Cu
Iron	Fe
Manganese	Mn
Molybdenum	Mo
Lead	Pb
Platinum	Pt
Antimony	Sb
Tellurium	Te
Zinc	Zn

Geology by H.M.A. Rice, 1939, 1941, 1944.

Approximate magnetic declination, 23° 15' East

For Mining Properties, see Map 889A, "Princeton"



DESCRIPTIVE NOTES

Most of the map-area lies in the Interior Plateaux, with its west and south boundaries in the Cascade Mountains. The plateau topography consists of relatively flat-topped hills and ridges, separated by deep and, in places, steep-walled valleys. The main drainage is along the east-west valley occupied by Tulameen and lower Similkameen Rivers, into which tributary streams flow from north and south. The area is heavily forested except at the northern boundary east from Aspen Grove and along lower Similkameen Valley, which are in open, sage-brush country typical of the "dry belt".

The Nicola group (3) is a large and varied assemblage consisting mainly of many-coloured volcanic rocks ranging from porphyritic and non-porphyritic dacite to basalt. Some types are similar to, and difficult to separate from, members of the Kingsvale group (12b), particularly in the northwest corner of the map-area and along Allison Creek north of Princeton, where, as a result, the identity of the two types is not wholly established. Interbedded with the lavas are belts and lenses of sedimentary and pyroclastic rocks. The largest of these, in the vicinity of Hedley, is host to the most important gold mines in the area. Most of the Nicola rocks are not strongly metamorphosed, but they are sheared into chlorite and sericite schists along a belt as much as 4 miles wide paralleling the east margin of the Eagle granodiorite body (5, in part).

The age of the Dewdney Creek group (9) and its relation to the Pasayten group (11) are not definitely established. Fossils of Lower Cretaceous age have been found in Dewdney Creek beds, but the group may be, in part, as old as Upper Jurassic. The two groups are in fault contact, and although the Pasayten is relatively younger it is not known whether or not it grades downward into Dewdney Creek strata. There is, however, a considerable difference in lithology between the groups, and no marine fossils have been found in the Pasayten.

The Spence Bridge group (10) has a very limited development in the area. Along Nicola River to the west it appears to underlie the Kingsvale group conformably, but in Princeton map-area there is evidence of an erosional unconformity between the two.

The Kingsvale (12) is a thick series of volcanic rocks, with discontinuous patches of greywacke, volcanic breccia, and conglomerate at the base. Fossil plants found near Kingsvale are considered to be of uppermost Lower Cretaceous age, and somewhat younger than those found in the Spence Bridge group near Spences Bridge. Two isolated bodies (13), one on Podunk Creek and one on Young Creek, are correlated with the Kingsvale on lithological grounds. They may, however, be correlative with the Spence Bridge, to some members of which they bear resemblance.

Tertiary sedimentary rocks (16) occur mainly in Princeton and Tulameen coal basins. They are overlain and underlain conformably by lavas (17) that elsewhere occupy considerable parts of the map-area. Together they form the Princeton group, which is correlative with much at least of the Kamloops group of Nicola map-area to the north. Fossil plants are plentiful in the sedimentary measures, and their age is believed to be Lower Miocene. The group may, however, be in whole or in part somewhat older.

Flat-lying basalts are found along benches (18) and valleys (19). They are younger than the Princeton group, and the valley basalts are believed to be the youngest consolidated rocks in the map-area. Outcrops of the latter have been glaciated, but in Nicola map-area to the north they have been found overlying unconsolidated sediments, so that they may be of interglacial age.

The ultrabasic rocks (4) are believed to be the oldest intrusive bodies of any size in the map-area; they are, however, probably closely related to, and may be an early phase of, the Coast intrusions. The principal body, in the vicinity of Olivine Mountain, is composed of several distinct rock types, but it was not found possible to map these separately.

The Coast intrusions (5, 6, 7) are believed to represent a protracted and, in part, intermittent period of intrusion continuing possibly from Middle Jurassic to Upper Cretaceous time. Three types are recognized and have been mapped separately. In places they cut one another, but in other places the contacts appear to be gradational. All three types are characteristically acidic, with plenty of visible free quartz, and the composition of granodiorite or quartz diorite.

The age of the Copper Mountain intrusions (8) is uncertain. All that has been determined definitely is that they cut the Nicola group and are overlain by the Princeton group. Accordingly they may belong with either the older or the younger series of intrusive rocks, but differ markedly from both in the almost entire absence of free quartz.

The Otter intrusions (14) appear very different from the Coast intrusions. For the most part they resemble syenites, with a pink to liver colour, and with quartz, if visible, restricted to well formed phenocrysts. Actually they have the composition of granodiorite or granite, but the quartz of the groundmass is in microscopic intergrowths with feldspar and is rarely visible to the naked eye. Everywhere they, or feldspar porphyries abundantly associated with them, cut the Lower Cretaceous formations, but not the Princeton group, so that their age is either Upper Cretaceous or early Tertiary.

The Lightning Creek intrusions (15) are also younger than the Lower Cretaceous rocks, and although they resemble certain phases of the Otter intrusions they are less clearly distinguishable from the Coast intrusions. Except for the Castle Peak stock on the south edge of the map-area most of the Lightning Creek intrusions are in the form of dykes and sills many of which carry needle-like amphibole crystals.

Rocks of the Nicola group and older formations have been folded into tight, north- to northeast-trending anticlines and synclines. The Cretaceous rocks in the southwest have a similar trend, but to the northwest they show open folds and strike easterly. From the vicinity of Princeton a spray of three or more faults radiates to the north, but could not be traced to the south. Another series of large faults, with a northwest trend, crosses the southwest corner of the area, and several small but economically important faults have been recognized in the vicinity of Hedley. The faults seem to have originated before the Coast intrusions were emplaced, but later movements along them have fractured these intrusive rocks and even members of the much younger Otter group. No evidence, however, is available to indicate that the faults have affected the known Tertiary formations.

The area first became important when, in the early 'sixties, gold and platinum placer deposits were discovered along Tulameen and Similkameen Rivers and their tributaries. In later years placer mining has dwindled in importance with the exhaustion of the easily discoverable deposits.

Gold ore is being mined at Hedley. The orebodies are chiefly deposits of arsenopyrite and lesser amounts of other sulphides occurring in beds of highly altered limestone. The principal ore deposits are those being mined by Kelowna Exploration Company, Limited, and Hedley Mascot Gold Mines, Limited.

Bornite-chalcopyrite deposits occur mainly at four localities. The most important is Copper Mountain, where many orebodies are known and some are being actively mined by the Granby Consolidated Mining, Smelting and Power Company. Copper deposits also occur within a belt running south from the edge of the map-area, north of Aspen Grove, to the foot of Missezula Lake; in a group of prospects at Law's camp, north of Grasshopper Mountain; and at the Independence mine, close to the edge of the map-area north of Mount Henning, where molybdenite is also an important constituent. Bornite and chalcopyrite are the principal ore minerals, although chalcocite ore was mined at one prospect near Missezula Lake. Pyrite and, much more rarely, galena and sphalerite occur in some of the deposits. The sulphides replace Nicola volcanic rocks in zones of considerable shearing and alteration. Quartz is not prominent as a gangue mineral. At Copper Mountain the ore is believed to be related to the Copper Mountain stock, a composite intrusion ranging from gabbro to syenite. The source of the ore at Aspen Grove is not so clearly indicated. It is perhaps significant that the Copper Mountain camp lies near the point of convergence of a radiating group of faults, and that the Aspen Grove camp is situated along the line of two northerly branches of this group.

Gold-telluride deposits have been found on Grasshopper Mountain; the two principal occurrences consist of brecciated zones in sheared Nicola rocks partly occupied by quartz and irregularly mineralized with small amounts of chalcopyrite and pyrite. Native gold and gold telluride have provided high but erratic assays.

Lead-zinc deposits have been found on Similkameen River and Whipsaw Creek near the northeastern edge of the Eagle granodiorite. They occur as quartz veins carrying galena, sphalerite, pyrite, and minor amounts of other sulphides in the belt of highly sheared Nicola rocks that borders this granodiorite. Galena and sphalerite also occur in sheared Nicola volcanic rocks west of Otter Lake.

Lead-zinc deposits occur in a series of parallel shear zones in or close to the small stock of Otter granite on Siwash Creek.

The principal non-metallic deposits in the area are the coal seams in Tertiary sedimentary rocks of the Princeton group, particularly those in the Tulameen and Princeton basins. The name of Vermilion Forks, by which the settlement of Princeton was originally known, was given in reference to a small but conspicuous deposit of ochre that occurs in the same rocks near the railway about 2 miles west of Princeton. Beds of bentonite are also found in these Tertiary rocks near Princeton.

MAP 888A

PRINCETON

YALE, KAMLOOPS, SIMILKAMEEN, AND OSOYOOS DISTRICTS
BRITISH COLUMBIA

Scale, $\frac{1}{253,440}$ or 1 Inch to 4 Miles
Miles
4 0 4 8 12

COPIES OF THIS MAP MAY BE OBTAINED FROM THE DIRECTOR, GEOLOGICAL SURVEY OF CANADA, OTTAWA

minerals

From 92-H-8
Princeton O.F.

LEGEND

Road
Road not well travelled
Trail
School
Post Office
Land District boundary
Limit of Railway belt
Indian Reserve boundary
Stream (flow disappearing in places)
Contours (interval 500 feet)
Height in feet above mean sea-level

Base-map compiled by the Topographical Survey, 1937, from information supplied by the British Columbia Department of Lands. Cartography by the Drafting and Reproducing Division, 1946.

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CANADA
DEPARTMENT OF MINES AND TECHNICAL SURVEYS
GEOLOGICAL SURVEY OF CANADA

GEOLOGICAL SERIES

SHEET 92 I (West Half)

LEGEND

CENOZOIC

TERTIARY

MIOCENE OR EARLIER

KAMLOOPS GROUP (23, 24)

- 24 — *Basalt, andesite, and rhyolite; associated tuffs and breccias*
- 23 — *COLDWATER BEDS (?):* sandstone, shale, and conglomerate; coal

EOCENE

- 22 — *Conglomerate, breccia, arkose, and shale; basaltic lava and breccia (relations to Kamloops group unknown)*

CRETACEOUS OR TERTIARY

- 21 — *Conglomerate, sandstone, and shale*

MESOZOIC

CRETACEOUS

LOWER CRETACEOUS

KINGSVALE GROUP

- 19, 20 — 19. *Arkose, conglomerate, shale, and greywacke*; 20. *Basalt and andesite; agglomerate, tuff, and breccia*

SPENCES BRIDGE GROUP

- 18 — *Andesite, dacite, basalt, and rhyolite; tuff, breccia, and agglomerate; conglomerate, sandstone, greywacke, and arkose*

JACKASS MOUNTAIN GROUP

- 15, 16, 17 — 15. *DIVISION A: greywacke, argillite, and siltstone; arkose and conglomerate*; 16. *DIVISION B: conglomerate, greywacke, and argillite*; 17. *DIVISION C: greywacke, argillite, conglomerate; arkose*

LILLOOET GROUP

- 14 — *Argillite, volcanic conglomerate, and tuffaceous sandstone*

BREW GROUP

- 13 — *Argillite, quartzite, and conglomerate*

JURASSIC

MIDDLE AND UPPER JURASSIC

- 12 — *Shale, conglomerate, and sandstone*

TRIASSIC

UPPER TRIASSIC

NICOLA GROUP

- 11 — *Basalt and andesite; tuff and agglomerate; limestone, quartzite, argillite, greywacke, and arkose*

TRIASSIC OR EARLIER

- 8–10 — 8. *Phyllite, quartzite, limestone; greenstone; schist*; 9. *Argillite, slate, phyllite, quartzite, greywacke, chert, limestone; greenstone; schist*; 10. *Phyllite, argillite, conglomerate, greywacke. May be in part of late Mesozoic age*
- 7 — *Schist and gneiss*

PALÆOZOIC

PERMIAN AND (?) EARLIER

CACHE CREEK GROUP

- 5, 6 — 5. *Greenstone; chert, argillite, minor limestone and quartzite; chlorite and quartz-mica schist*; 6. *MARBLE CANYON FORMATION: limestone*

INTRUSIVE ROCKS

MESOZOIC — COAST INTRUSIONS

CRETACEOUS OR LATER

LOWER CRETACEOUS OR LATER

- 4 — *Quartz diorite, albite syenite*

CRETACEOUS

LOWER CRETACEOUS

- 3 — *Granodiorite*

JURASSIC OR CRETACEOUS

LOWER CRETACEOUS OR EARLIER

- 2 — *MOUNT LYTTON BATHOLITH: granodiorite, quartz diorite, and diorite*

JURASSIC

LOWER JURASSIC

- 1 — *GUICHON CREEK BATHOLITH: granite, granodiorite, quartz diorite, diorite*

JURASSIC (?)

- A — *Hornblende diorite and related rocks*
- B — *Serpentinized ultrabasic rocks*

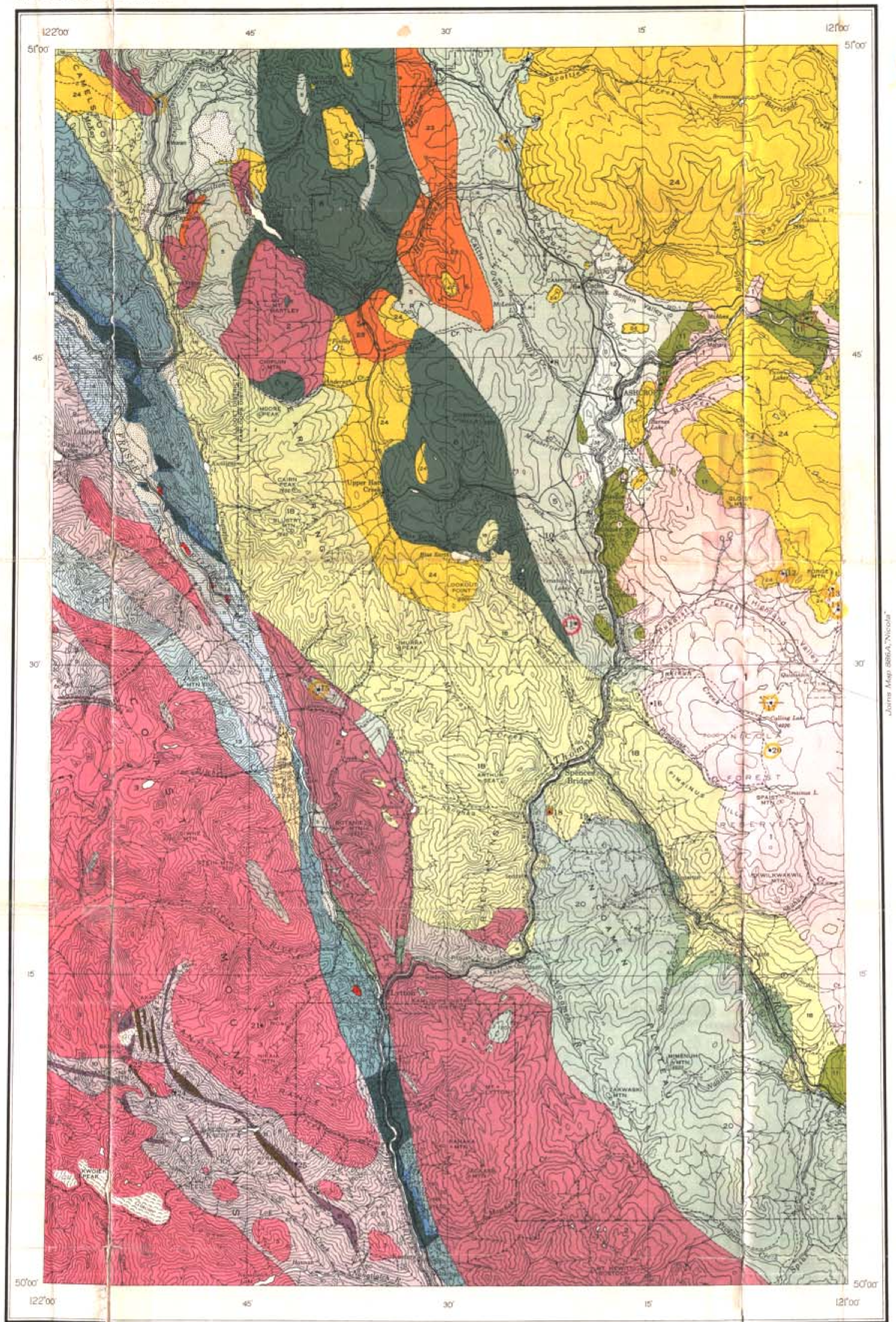
Heavily drift-covered area
Bedding (horizontal, inclined, vertical, overturned)
Schistosity (inclined, vertical)
Foliation (inclined, vertical)
Glacial striæ (direction of ice-movement known, direction unknown)
Fault
Fossil locality
Mining property 23

INDEX TO MINING PROPERTIES

1 Big Slide (Grange) mine (Gold, silver, copper)
2 Scottie Creek deposits (Chromium)
3 Ferguson Creek deposits (Chromium)
4 Maggie mine (Copper, silver, lead, zinc)
5 Hat Creek coal (Coal)
6 Cache Creek occurrence (Chromium)
7 Fairview group (Zinc)
8 Cornwall Creek (Chrome Pit) occurrence (Chromium)
9 Coronation group (Silver, lead, zinc)
10 Basque epsomite deposits (Magnesium sulphate)
11 Martel mine (Gold, molybdenum)
12 Glossy group (Copper)
13 Transvaal group (Copper)
14 Highland group (Copper)
15 Victory claim (Copper)
16 Toketic deposit (Iron)
17 O.K. mine (Chataway group) (Copper)
18 Spences Bridge coal (Coal)
19 Soap Lake deposit (Sodium Carbonate)
20 Kathleen claim (Copper)
21 Lytton Gold prospect (Gold)
22 Clarke prospect (Antimony)
23 Green Gold Jade claims (Vesuvianite)
24 Glacier group (Gold, silver)
25 Paystreak group (Silver)
26 Serpentine and Summit groups (Gold)

Geology by S. Duffell and K.C. McTaggart, 1945-46, and K.C. McTaggart, 1947

Cartography by the Geological Mapping Division, 1951



PUBLISHED, 1951

Joins Map 737A, "Hope"

MAP 1010A

ASHCROFT

KAMLOOPS, LILLOOET AND YALE DISTRICTS
BRITISH COLUMBIA

Scale: One Inch to Four Miles = 1/253,440

Miles 4 3 2 1 0 4 8 12

Approximate magnetic declination, 24° 15' East

803

DESCRIPTIVE NOTES

West of Fraser River, the map-area occupies part of the Coast Mountains of British Columbia, and the high ridges southeast of Lytton mark the northern extremity of the Cascade Mountains. Elsewhere the area forms part of the Interior Plateau, and its vegetation and climate are largely characteristic of the 'dry belt' of this region.

The Cache Creek group (5, 6) constitutes a thick succession of mainly chert, argillite, altered volcanic rocks, and crystalline limestone, much of which is deformed and largely altered to talc, chlorite, and sericite schists. The distinctive crystalline limestone of Marble Canyon and Pavilion Mountains is mapped separately as the Marble Canyon formation (6).

Lenses and patches of metamorphosed rocks (7) within the Coast intrusions consist in part of chlorite, hornblende, and quartz-mica schists, and in part of granitic gneiss. Some parts of the large area of these rocks on Scarped Mountains are identifiable as Cache Creek (5), but other lenses may include strata of Mesozoic age.

Unfossiliferous, metamorphosed rock groups of uncertain identity (8-10), west of Fraser River, probably comprise strata of both Palæozoic and Mesozoic age. One group of mainly micaceous and graphitic phyllite (8) is probably of late Palæozoic age, but may include younger formations. Another varied assemblage of sedimentary and volcanic rocks (9), at least 7,500 and probably 10,000 feet thick, is probably in part Cache Creek. Still another group, comprising many thousands of feet of grey to black phyllite, grey argillite, conglomerate, and greywacke (10), extends southeast into Hope map-area, where it appears to include rocks of the Upper Jurassic (?) or Lower Cretaceous Ladner group. It also affords points of resemblance with the Lower Cretaceous Brew group (13).

Nicola group rocks (11) consist mainly of medium-grained, basaltic and andesitic lavas, largely altered to greenstones, greenish grey tuff, and agglomerate. Argillite, chert, greywacke, and limestone, associated with volcanic rocks near Basque, have yielded marine fossils of Upper Triassic age. The group has been metamorphosed by the Guichon Creek batholith (1) and occurs as small roof pendants within, or as relatively small bodies along, the border of the batholith.

Conglomerates, shales, and sandstones of Jurassic age (12) occupy a narrow synclinal belt near Ashcroft. The sandstones, commonly arkosic, and the conglomerates are greenish grey. The black shales, commonly carbonaceous, have yielded ammonites of Middle and Upper Jurassic age. East of Basque, conglomerate at the base of the succession rests unconformably on granitic rocks (1).

The Brew group (13) consists mainly of banded argillite, impure quartzite, and boulder conglomerate, and contains marine fossils of early Lower Cretaceous age.

The Lillooet group (14) and the Jackass Mountain group (15-17) form a belt of folded and deformed Lower Cretaceous sedimentary rocks along Fraser River, and are in faulted contact with all adjacent rock groups.

The Spences Bridge group (18), consisting of about 5,000 feet of varicoloured volcanic rocks, mainly lavas, and minor continental sediments, has yielded fossil plant remains of mid-Lower Cretaceous age. The lavas are generally much decomposed, and are commonly traversed by thin stringers of pink and white calcite. The group is gently folded, much of it lying horizontally or nearly so.

Sedimentary rocks (19) and volcanic rocks (20) of the Kingsvale group unconformably overlie the Spences Bridge group along Nicola River. The light-coloured sedimentary strata at the base of the group reach a thickness of 800 to 1,000 feet on Shakan Creek, but may be missing elsewhere. Fossil plant remains collected from them are of late Lower Cretaceous age. Small areas of sedimentary rocks on Botanie Creek and Fraser River near Stein River were mapped with the Kingsvale group on the basis of fossil evidence. The volcanic rocks, which constitute the bulk of the group, are largely of andesitic and basaltic composition and flows are commonly amygdaloidal.

Evidence obtained in Nicola map-area to the east suggests that certain local accumulations of conglomerate and sandstone (21) may be either of Cretaceous or Tertiary age. The conglomerate contains boulders and pebbles of Cache Creek and Nicola group rocks as well as of granite.

A succession of sedimentary and volcanic rocks (22) 4,500 feet thick has yielded fossil leaves of Eocene age. Coarse conglomerates in the exposed sections contain easily recognized boulders of Lower Cretaceous rocks (13-17). These Eocene strata form one of the many fault blocks along Fraser River, and the steep dips and close folds are mainly the result of fault movements.

Most of the Kamloops group consists of volcanic rocks (24), but with them are included several small areas of Tertiary sedimentary beds (23), which at upper Hat Creek and south of Spences Bridge are coal bearing. The sedimentary strata are probably the equivalent of the Coldwater beds of the adjoining Nicola map-area. The volcanic rocks exhibit a wide range of colours; they are mainly dark, dense, fine-grained basalts, but include thick beds of agglomerate, minor breccia, and tuff. Thin beds of argillaceous material yielded poorly preserved leaves of Tertiary age.

All of the map-area was covered by ice during Pleistocene time except perhaps some of the higher peaks of the Coast Mountains. Pleistocene and Recent drift mantles most of the plateau region. White silt deposits are prominent along Thompson River east of Spences Bridge. Alluvial fans, and ice-contact and glacial outwash deposits are common, and the major valleys are lined with marginal terraces of sand, gravel, and clay.

Batholithic rocks of the Coast intrusions consist mainly of granite, granodiorite, quartz-diorite, and diorite. The Guichon Creek batholith (1) intrudes Upper Triassic rocks (11) and is overlain by Middle and Upper Jurassic rocks (12). The Mount Lytton batholith (2) is overlain by lavas of the Spences Bridge and Kingsvale groups (18-20) and may be of early Lower Cretaceous age, but is probably more nearly contemporaneous with the Guichon Creek mass. The widespread granodiorite (3) of the Coast Mountains is believed to be of mid-Lower Cretaceous age.

Elongate bodies of ultrabasic rocks (B), with which are associated bodies of hornblende diorite and related rocks (A), are exposed in the Coast Mountains. The rocks of the main serpentine belt in the southwest corner of the map-area are, apparently, about in line with those of the serpentine belt to the southeast in Hope map-area, and are probably of Cretaceous age. Small undifferentiated bodies of serpentine associated with Cache Creek rocks along Bonaparte River carry significant chromite deposits.

Several minor intrusions (4) cut rocks of the Fraser River Lower Cretaceous belt (14-17).

The belt of Lower Cretaceous rocks along Fraser River may be regarded as a series of fault blocks or slices involved in a major zone of faulting along which rocks to the west have been relatively elevated. From the south border of the map-area to Cinquefoil Creek the Cretaceous rocks appear to occupy a graben. Farther north, rocks to the west of the Cretaceous belt appear to be elevated, and those to the east relatively depressed, with respect to the Lower Cretaceous rocks.

Albitization and, to a lesser extent, prehnitization are features of many of the rocks in and adjacent to the Fraser River Cretaceous belt. The abundant albite of some of the intrusive rocks is a product of metasomatism, a process that is believed also to have affected the older bedded rocks (14) of the Cretaceous belt; the albite of the younger formations is probably of detrital origin.

The map-area contains a variety of metallic and industrial mineral deposits, several of which have been productive. Placer gold has been mined on all major streams, but only in small amount since early years of the present century. Stibnite is found in irregular quartz veinlets along a fault zone in granodiorite near the headwaters of Stein River. Plutonic rocks of the Guichon Creek batholith are host to copper deposits near Highland Valley, and contain hematite deposits in shear zones near Toketic. The copper minerals occur in veins and shattered zones associated with tourmaline and hematite, and the wall-rocks are commonly highly sericitized. The greatest production came from the O.K. mine, which during the period of its activity mined and concentrated 10,000 tons of ore containing 3.6 per cent copper. The Maggie mine on Bonaparte River was prospected underground as a copper deposit. Fifty tons of selected ore yielded 2 ounces of silver a ton, 8 per cent copper, and low assays in lead and zinc. Chromite occurs in ultrabasic rocks along Bonaparte River, the principal discoveries having been made on Scottie Creek and the creek south of it. Gold and silver have been reported from quartz veins in the schist, argillites, and batholithic rocks in the southwest corner of the map-area. The Big Slide (Grange) mine has produced gold, copper, and silver from narrow quartz veins in diorite. Considerable exploration work has been done at the Martel property on narrow lenticular quartz veins in Cache Creek rocks that contain molybdenum and gold. Narrow quartz veins carrying sphalerite, galena, and chalcopyrite occur in Triassic rocks east of Ashcroft.

Coal has been mined with limited success from the deposit at upper Hat Creek. Occurrences of gypsum, jade, vesuvianite, magnesium sulphate, and sodium carbonate have been recorded, and some magnesium sulphate has been produced from the deposit at Basque. Much of the Marble Canyon formation is composed of very pure limestone.

REFERENCE

Main highway with route number
Other roads
Trail
Church
Post Office
Land District boundary
Forest Reserve boundary
Indian Reserve boundary
Intermittent stream
Glacier
Contours (interval 500 feet)
Contours (position approximate)
Height in feet above mean sea-level

Base-map compiled by the Bureau of Geology and Topography from surveys and from information supplied by the Department of Lands and Forests, British Columbia.

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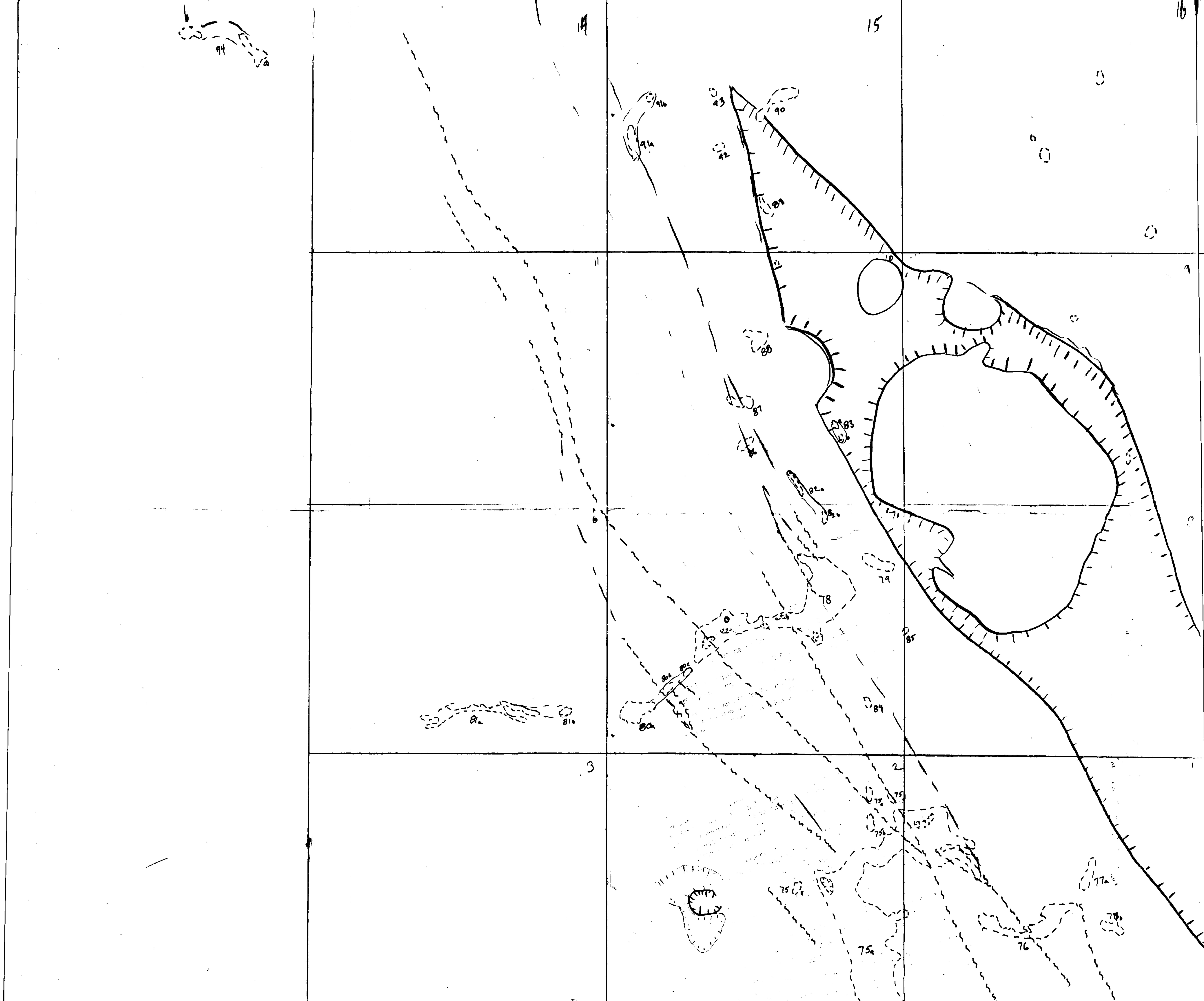

from 1982 program

PRINCE GEORGE
MAP SHEET
GEOLOGY
OVERLAY
TARGET
PHASE III

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(6)

93 G — 1:250,000 — CANADA — EDITION 1 — 93 G

Refer to this map as: 93G EDITION 1 ASE SERIES A 502

Compiled April '86
L. Klatzel Mudry

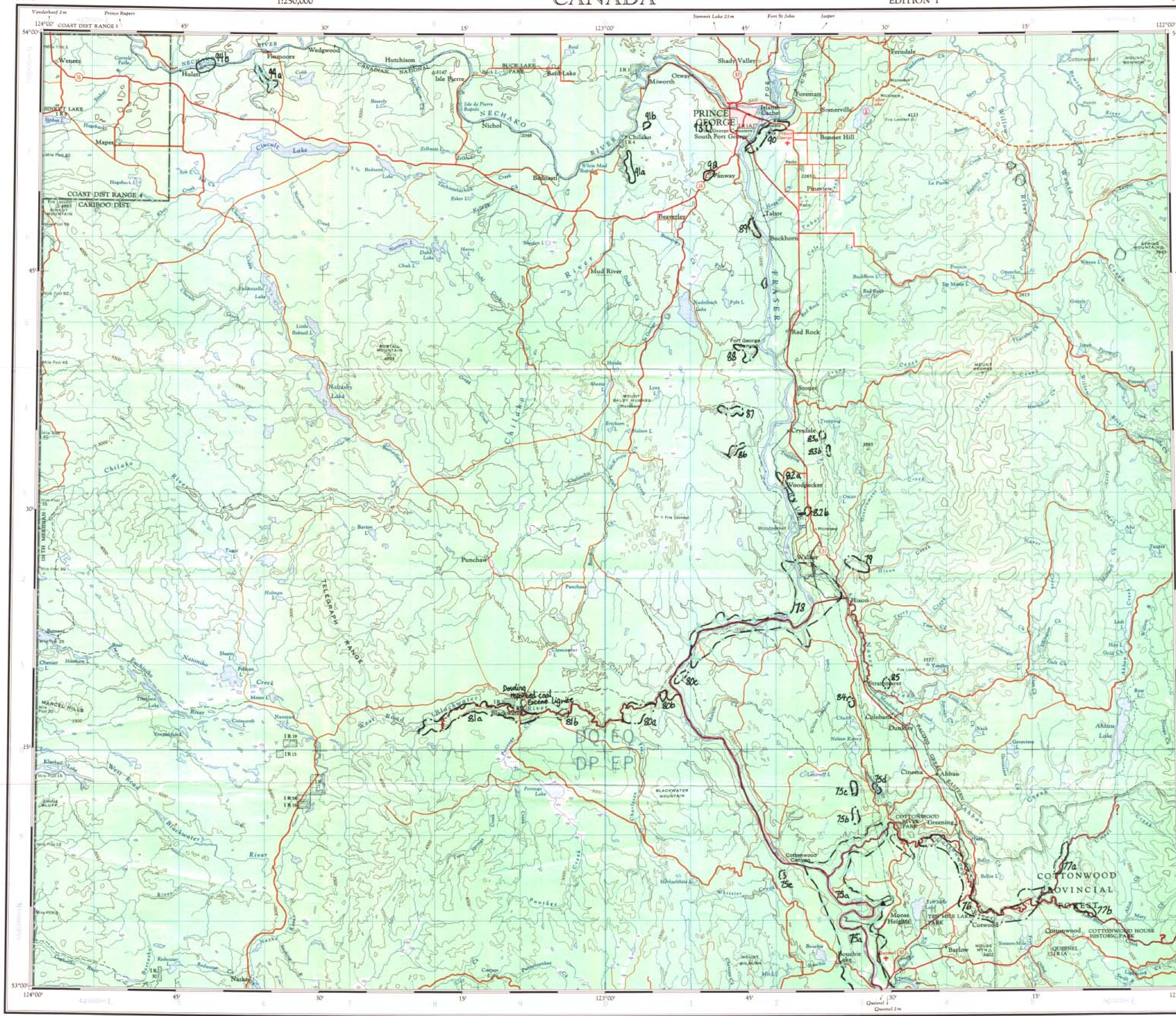
1982 Reconnaissance

— flown with helicopter to check sediments

Target covered

Target not covered sufficiently

Target not coverd at all



TEN THOUSAND METRE
UNIVERSAL TRANSVERSE MERCATOR GRID
ZONE 10

CARTER MAPPING LIMITED
510 - 5 Street S.W., Calgary, Alberta
T2P 1V6 264-1230

RELIABILITY DIAGRAM · CROQUIS D'EXACTITUDE

PRINCE GEORGE

BRITISH COLUMBIA

93G

"TO FILE"

00803
(7)

Scale 1:250,000 Échelle

Transverse Mercator Projection
North American Datum 1927
Contour interval 500 feet
Elevations in feet above Mean Sea Level

Projection Transverse de Mercator
Niveau de référence nord-américain 1927
Équidistance des courbes 500 pieds
Élévations en pieds au-dessus du niveau moyen de la mer

PRINCE GEORGE
93 G
EDITION 1

803

NATIONAL TOPOGRAPHIC SERIES

CANADA
DEPARTMENT OF MINES AND TECHNICAL SURVEYS

FIRST EDITION

CANADA SHEET 93 B

Refer to this map as:	93B EDITION 1 ASE SERIES A 502

Compiled April '86
L. Klatzel Mudry

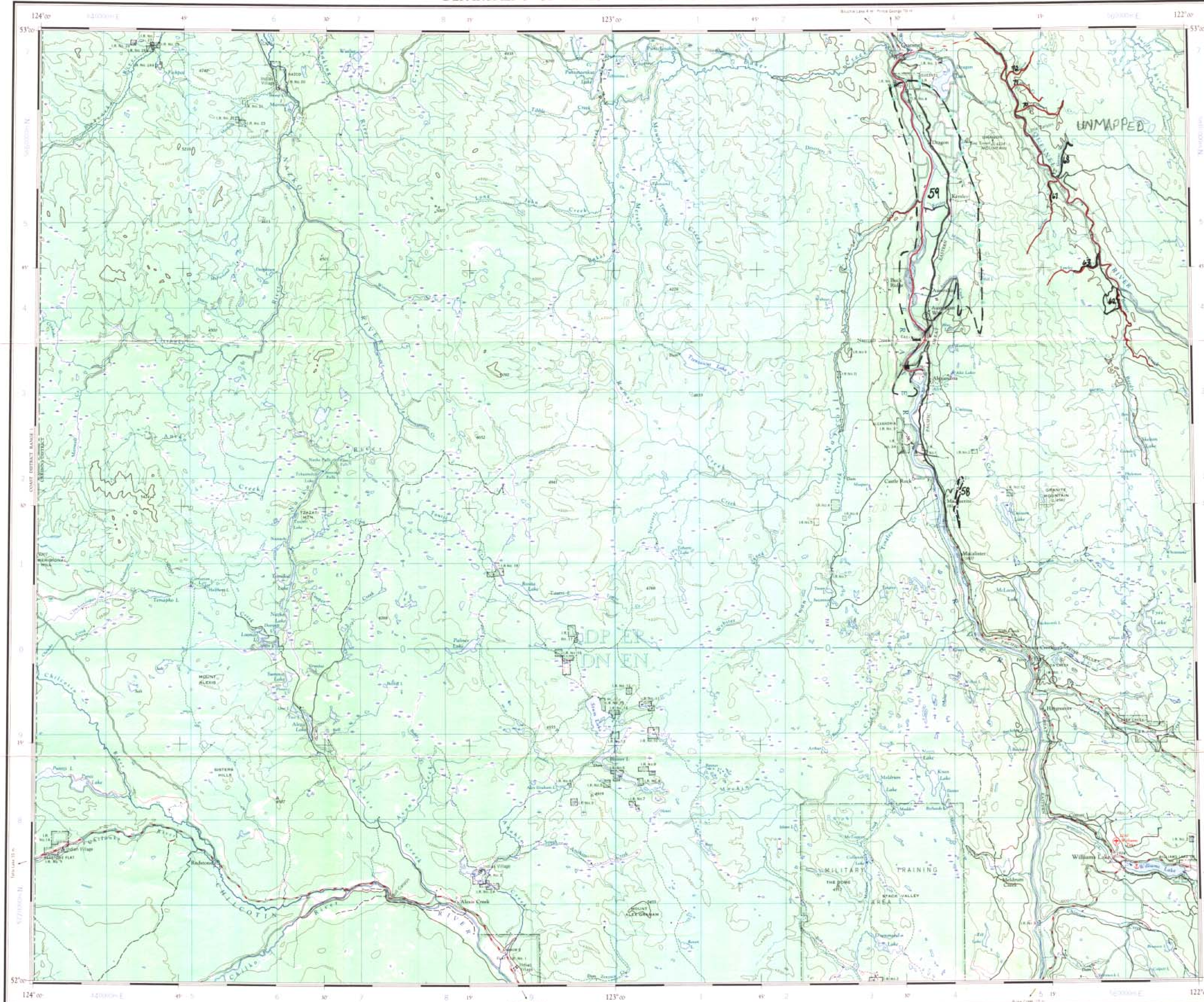
~ Flown with helicopter to check sediments

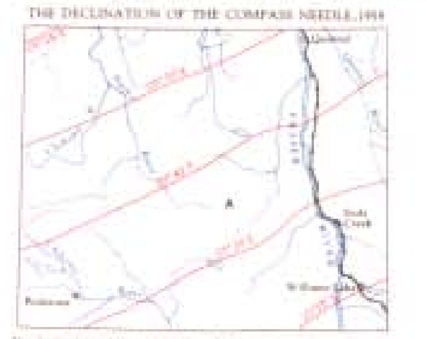
traverse driven or walked

Target covered

Target not covered sufficently

Target not covered at all





Universal Transverse Mercator Projection

QUESNEL

BRITISH COLUMBIA
CARIBOO DISTRICT

Scale 1:250,000
1 Inch to 4 Miles Approximately

Contour interval 500 Feet
Elevations in Feet above Mean Sea Level
North American Datum 1927

REFERENCE

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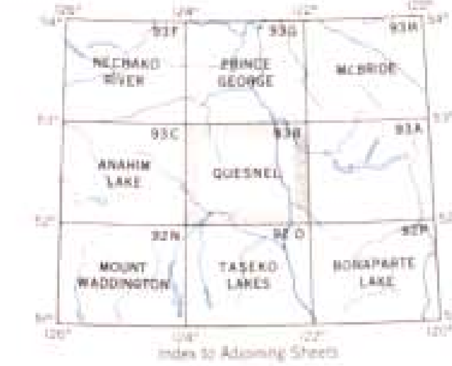

TEN THOUSAND METRE
UNIVERSAL TRANSVERSE MERCATOR GRID
ZONE 10

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(8)

GEOLOGICAL SURVEY OF CANADA

STRATIFIED AND HIGH-LEVEL PLUTONIC ROCKS

PLEISTOCENE AND RECENT

22	Unconsolidated alluvial, fluvial, and glacial deposits

PLIOCENE TO RECENT

21	GARIBALDI GROUP: Basalt to rhyodacite flows and pyroclastics, minor intercalated sediments; 21a, olivine basalt flows of Pleistocene age

MIOCENE OR YOUNGER(?)

20	Rhyolite and dacite breccia, tuff, and flows, minor sediments; 20a, andesitic volcanic breccia and conglomerate, lesser basalt; 20b, REXMOUNT PORPHYRY: dacitic porphyry (intrusive equivalent of 20?)

MIOCENE

19	Quartz monzonite, minor granite; 19a, miarolitic granodiorite and syenodiorite
18	Basalt flows; minor dacite

MIOCENE(?) AND OLDER(?)

17	Andesitic to basaltic flows and breccia, minor dacite; 17a, basalt flows with interbedded conglomerate and siltstone

EOCENE(?)

16	Shale, siltstone, sandstone, arkose, and conglomerate
15	Miarolitic granite; 15a, dacitic volcanics and porphyries (possibly equivalent to 19a?)

MID TO UPPER CRETACEOUS

14	KINGSVALE GROUP: 14a, arkose, greywacke, shale, minor conglomerate; 14b, andesitic flows and pyroclastics

LOWER CRETACEOUS

13	TAYLOR CREEK GROUP: Chert-pebble conglomerate, black limy shale, green tuff, volcanic breccia, andesite and basalt
12	JACKASS MOUNTAIN GROUP: 12a, interbedded carbonaceous argillite and greywacke, minor conglomerate and coal; 12b, greywacke, pebble conglomerate, argillite and gritty sandstone; 12c, argillite, conglomerate, and greywacke; 12d, massive greenish greywacke, argillite, gritty sandstone and pebble conglomerate
11	GAMBIER GROUP: Andesitic to dacitic tuff, breccia, agglomerate; andesite, argillite, conglomerate, lesser marble, greenstone, and phyllite
10	FIRE LAKE GROUP: Greenstone, chlorite schist, conglomerate, andesite, greywacke

UPPER JURASSIC AND LOWER CRETACEOUS

9	RELAY MOUNTAIN GROUP: Greywacke, siltstone, argillite

UPPER TRIASSIC TO MIDDLE JURASSIC

8	TYAUGHTON GROUP: Shale, siltstone, greywacke

UPPER TRIASSIC

7	CADWALLADER GROUP (undivided; includes Hurley, Pioneer and Noel strata, may include older and younger rocks): andesitic breccia, tuff, and flows, greenstone; lesser slate, argillite, phyllite, conglomerate, limestone, rhyolitic breccia and flows
6	HURLEY FORMATION: Thin-bedded argillite, phyllite, limestone, tuff, conglomerate, andesite, minor chert
5	PIONEER FORMATION: Greenstone, andesitic to basaltic flows and pyroclastics; 5a, BRALORNE INTRUSIONS (in part): augite diorite, gabbro, greenstone (intrusive and dioritized equivalents of 5)
4	NOEL FORMATION: Thin-bedded argillite, chert, conglomerate and greenstone

TRIASSIC AND JURASSIC AND OLDER(?)

ub	Ultramafic rocks: Serpentine, harzburgite, periodítite, diorite
3	BRIDGE RIVER (FERGUSSON) GROUP: Greenstone, basalt, chert, argillite, phyllite; minor limestone, serpentine, and serpentinized perdotite; 3a, more metamorphosed equivalents of 3, mainly biotite schist

PALEOZOIC(?)

2	Metasedimentary rocks, mainly micaceous quartzite, biotite-hornblende schist; minor garnet and staurolite schist; 2a, horn-blende-biotite-garnet schist, amphibolite, quartz diorite, garnet-cordierite gneiss, and migmatite
1	Granitoid gneiss, migmatite complexes, amphibolite, quartz diorite, and schist

PLUTONIC ROCKS
(mostly of unknown age)

qm	Quartz monzonite
gd	Granodiorite
qd	Quartz diorite
di	Diorite; dioritic complexes containing diorite, quartz diorite, amphibolite, greenstone, and dyke swarms
gb	Gabbro

MAP SYMBOLS

Geological boundary (defined, approximate, assumed)

Bedding (horizontal, inclined, vertical)

Foliation, schistosity (inclined, vertical, dip unknown, absent)

Fault (defined, approximate, assumed)

Fossil locality

Radiometric ages

● Age in millions of years
System: k=potassium-argon, u=uranium-lead
Minerals: b=biotite, h=hornblende, m=muscovite, w=whole rock, z=zircon
Laboratory: (u)=U.B.C. All others are G.S.C.

◆ Whole-rock K-Ar age determination (age given in years) for Garibaldi Group rocks. Data from N.L. Green (Ph.D. thesis in preparation) and Anderson (1975)

GEOLOGY BY

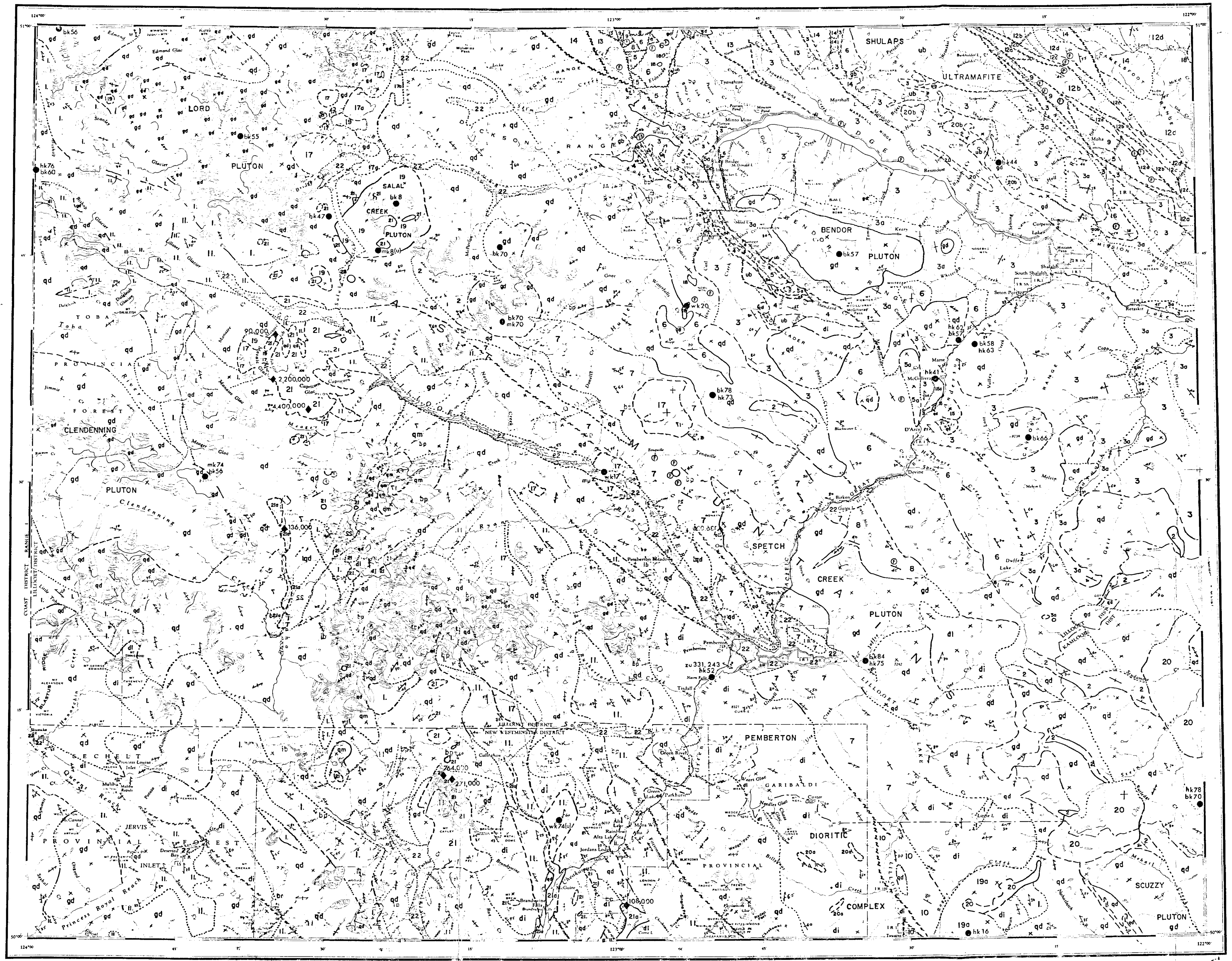
J.A. Roddick and G.J. Woodsworth (1970, 1974), W.W. Hutchison (1970), and from earlier reports (see references)

ADDITIONAL DATA FROM

J.A. Jeletzky (Camelsfoot Range), H.W. Tipper (Gun Creek), and N.L. Green (Cheakamus River area).

COMPILED BY

G.J. Woodsworth (1977)



GEOLOGY

PEMBERTON (92J) MAP-AREA

Scale 1:250,000 Échelle

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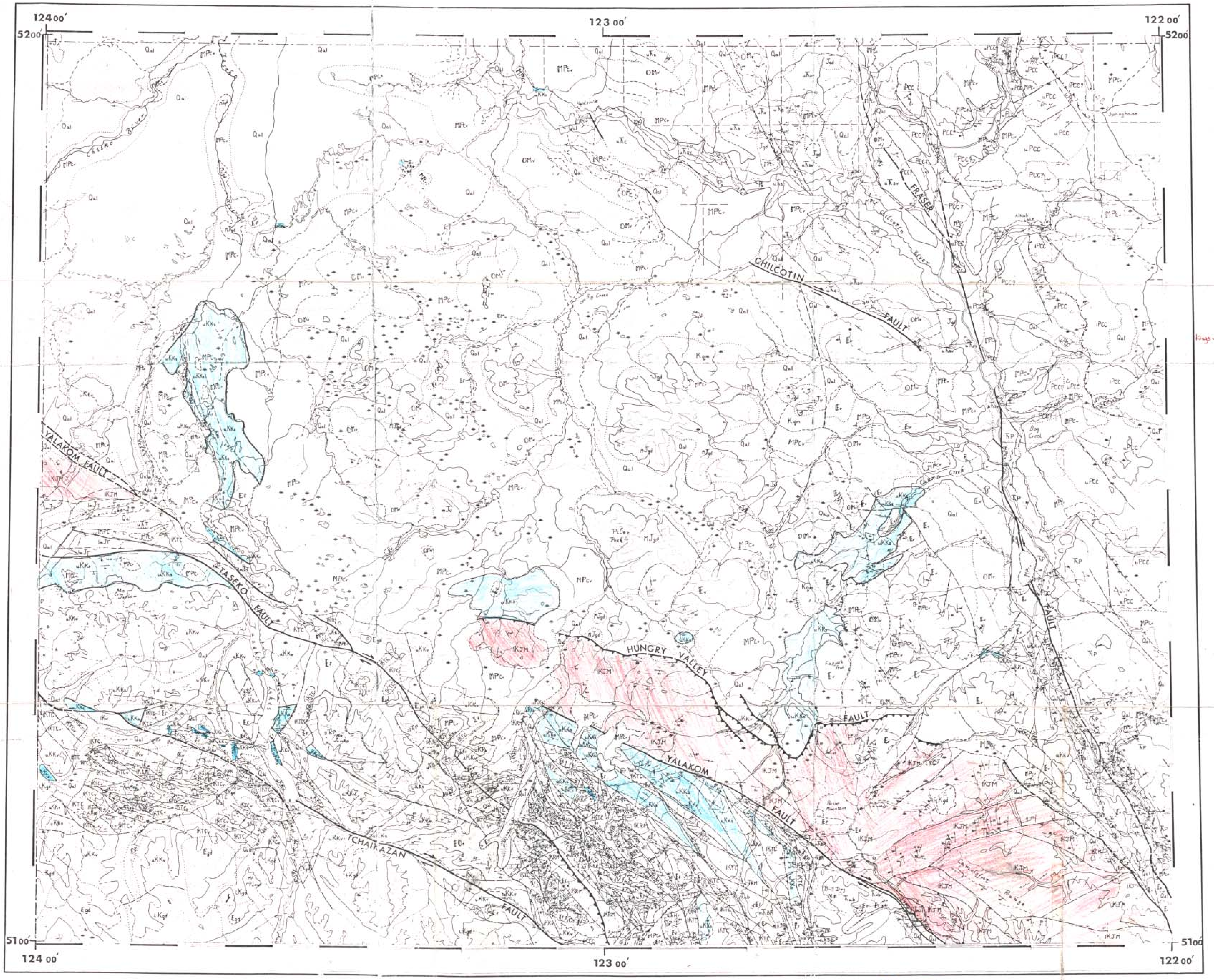

TASEKO LAKES (92 O) MAP – AREA

SEDIMENTARY AND VOLCANIC ROCKS

CENOZOIC

QUATERNARY

PLEISTOCENE AND RECENT

Qal — Till, gravel, sand, clay, and silt

TERTIARY

PLIOCENE AND/OR YOUNGER

Pc — greywacke, siltstone, pebble conglomerate

UPPER MIOCENE AND/OR PLIOCENE

CHILCOTIN GROUP

MPCv — Olivine basalt, andesite; minor related tuff and breccia

MPCs — Buff to grey siltstone, diatomite, clay and silty sand, coarse reddish brown conglomerate, minor ash beds and lignite

OLIGOCENE AND (?) LOWER MIOCENE

OMv — Grey to brown, fine-grained to porphyritic and amygdaloidal andesite and basalt tuff, breccia, and flows, includes minor Ev

OMs — Friable buff greywacke and siltstone

EOCENE?, OLIGOCENE?

THEBA GROUP

EOv — Buff, mauve, brown dacitic and rhyolitic tuffs, breccias and flows.

EOCENE AND YOUNGER (?), OLDER (?)

Ev — Rhyolitic and dacitic tuff, breccia, and flows; minor andesitic to basaltic rocks; may include minor OMv, includes small areas of Es along Fraser River

Es — Conglomerate, volcanic arenite, minor siltstone, plant seams.

MESOZOIC / PALEOZOIC

S.W. of YALAKOM FAULT	N.E. of YALAKOM FAULT	EAST of FRASER FAULT
CRETACEOUS UPPER CRETACEOUS (CENOMANIAN) KINGSVALE GROUP uKKv — Varicoloured andesitic, dacitic and basaltic pyroclastics; minor flows and volcanic sediments uKKs — Interbedded siltstone, greywacke and conglomerate LOWER CRETACEOUS (APTIAN AND ALBIAN) TAYLOR CREEK GROUP lKTC — Dark grey to black shale and siltstone, chert pebble conglomerate; minor ... sandstone lKTCv — Dark green to grey andesitic to basaltic flows, tuff and breccia LOWER CRETACEOUS (APTIAN AND ALBIAN) JACKASS MOUNTAIN GROUP lKJM — Buff to green greywacke, light grey shale, and pebble conglomerate; massive boulder conglomerate LOWER CRETACEOUS (HAUTERIVIAN) lKv — Reddish to purplish andesitic breccia and tuff JURASSIC AND CRETACEOUS MIDDLE JURASSIC TO LOWER CRETACEOUS RELAY MOUNTAIN GROUP Interbedded grey to greenish grey siltstone, shale, greywacke, minor cobble conglomerate and limestone Dark grey to green greywacke, siltstone, shale and minor conglomerate (CALLOVIAN AND L. OXFORDIAN) Dark grey shale argillite, greywacke, grey-brown pebble conglomerate TRIASSIC AND JURASSIC UPPER TRIASSIC TO MIDDLE JURASSIC TYAUGHTON GROUP lmJT — Dark grey to black shale and argillite, grey greywacke uTT — (NORIAN TO HETTANGIAN) Massive limestone, red conglomerate, limy greywacke, grit and shale TRIASSIC UPPER TRIASSIC (CARNIAN AND (?) NORIAN) CADWALLADER GROUP uTH — HURLEY FORMATION Grey to black argillite, minor conglomerate, limestone and volcanic rocks uTP — PIONEER FORMATION Massive fine grained to porphyritic dark-green basalt flows, minor pyroclastics and argillite MIDDLE TRIASSIC AND (?) OLDER BRIDGE RIVER GROUP mTBR — Interbedded chert and argillite, andesitic to basaltic flows and pyroclastics, and lenses of grey limestone	CRETACEOUS UPPER CRETACEOUS (CENOMANIAN) KINGSVALE GROUP uKKv — Varicoloured andesitic, dacitic basaltic pyroclastics; minor flows and volcanic sediments uKKs — Interbedded siltstone, greywacke, conglomerate LOWER CRETACEOUS (BARREMIAN TO ALBIAN) JACKASS MOUNTAIN GROUP lKJM — Buff to green greywacke, grey shale and pebble conglomerate; massive boulder conglomerate JURASSIC MIDDLE (BAJOCIAN) AND (?) LOWER JURASSIC mJv — Green porphyritic andesite breccia, tuff and flows, minor argillaceous tuff TRIASSIC UPPER TRIASSIC uTc — (NORIAN) Massive grey limestone; minor pebble conglomerate, shale uTsv — (CARNIAN AND/OR NORIAN) Interbedded shale, greywacke, andesitic to basaltic volcanics uTv — (CARNIAN AND/OR NORIAN) Dark grey andesitic to basaltic tuff and breccia, feldspathic flows, greywacke	CRETACEOUS (?) KINGSVALE GROUP (?) uKKs — Grey to dark grey siltstone and greywacke TRIASSIC MIDDLE AND/OR LOWER TRIASSIC AND (?) LOWER PAVILION GROUP TPv — Tuff, greywacke, volcanic flows, chert argillite, limestone TP — Chert argillite; minor tuff, limestone, lithic sandstone, volcanic flows PERMIAN AND (?) OLDER CACHE CREEK GROUP Pcc? — Chert, argillite, shale, greywacke; minor limestone lenses UPPER PERMIAN (?) uPcc — MARBLE CANYON FORMATION Massive grey limestone, minor shale LOWER PERMIAN (?) lPcc — Interlayered chert and argillite, basic volcanic flows and tuff, limestone

PLUTONIC ROCKS

CEN.

TERTIARY

EOCENE

Ef — Felsite, feldspar porphyry, biotite feldspar porphyry

Tgd — Granodiorite, minor quartz diorite

MESOZOIC

CRETACEOUS

LATE CRETACEOUS

lKgd — Granodiorite; lesser quartz diorite and diorite

lKqd — Quartz diorite, lesser diorite

Kqm — Quartz monzonite, minor granodiorite

JURASSIC

MIDDLE (?) JURASSIC

mJgd — Granitic granodiorite, diorite and quartz diorite

JURASSIC AND/OR OLDER

Jgd — Granodiorite, diorite, inclusions of basic volcanic rocks

TRIASSIC (?)

Tub — Peridotite, harzburgite, dunite, serpentinized peridotite

PAL.

PERMIAN (?)

Pub — Peridotite

GEOLOGICAL CONTACT (defined, approximate, assumed)

BEDDING (inclined, vertical)

SYNCLINE

ANTICLINE

FAULTS (sense of movement not indicated)

FAULT (right lateral transcurrent defined, approximate)

FAULT (thrust or high-angle reverse)

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Compilation by H.W. Tipper 1978

Sources of information: Field work by H.W. Tipper 1961-63, 1974, 1976, by C.E. Cairnes, 1937 and C.W. Drysdale, 1916 in Tyaughton Creek area, by G.B. Leech in Shulaps Range, 1947-48, by Hans Trettin along Fraser River, 1957-59, and by G.J. Woodsworth in the Coast Mountains, 1976

SCALE 1 250,000

4 2 0 2 4 6 8 MILES

5 0 5 10 KILOMETRES

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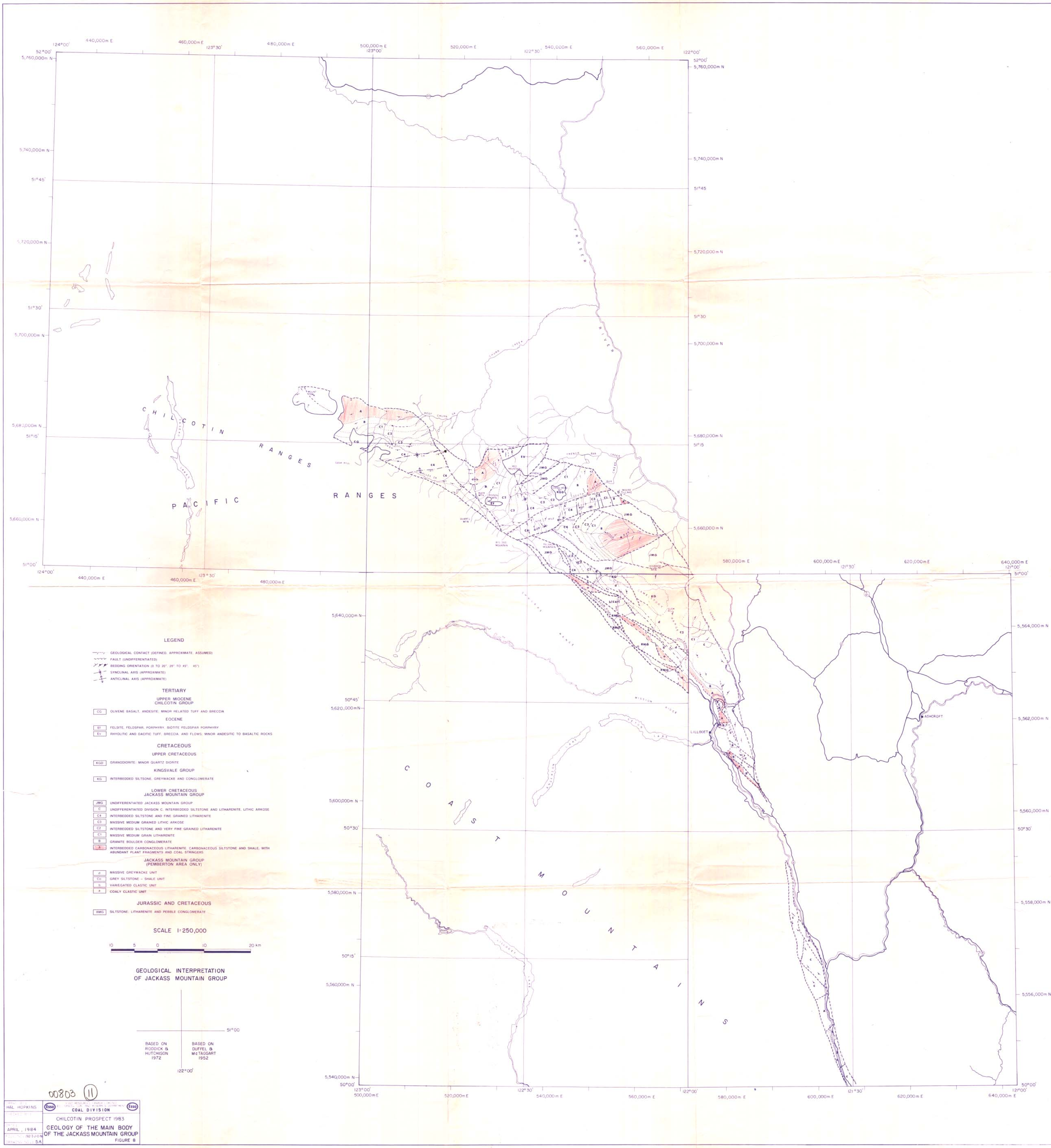
CHILCOTIN RANGES
PACIFIC RANGES
COAST MOUNTAINS
FRASER RIVER
LILLOOET
ASHCROFT
LEGEND
GEOLOGICAL CONTACT (DEFINED, APPROXIMATE, ASSUMED)
FAULT (UNDIFFERENTIATED)
BEDDING ORIENTATION (0 TO 20°, 20° TO 45°, 45°)
SYNCLINAL AXIS (APPROXIMATE)
ANTICLINAL AXIS (APPROXIMATE)
TERTIARY
UPPER MIOCENE
CHILCOTIN GROUP
CG OLIVENE BASALT, ANDESITE; MINOR RELATED TUFF AND BRECCIA
EOCENE
Ef FELSITE, FELDSPAR, PORPHYRY, BIOTITE FELDSPAR PORPHYRY
Ev RHYOLITIC AND DACITIC TUFF, BRECCIA, AND FLOWS; MINOR ANDESITIC TO BASALTIC ROCKS
CRETACEOUS
UPPER CRETACEOUS
KGD GRANODIORITE; MINOR QUARTZ DIORITE
KINGSVALE GROUP
KG INTERBEDDED SILTSONE, GREYWACKE AND CONGLOMERATE
LOWER CRETACEOUS
JACKASS MOUNTAIN GROUP
JMG UNDIFFERENTIATED JACKASS MOUNTAIN GROUP
C UNDIFFERENTIATED DIVISION C, INTERBEDDED SILTSTONE AND LITHARENITE, LITHIC ARKOSE
C4 INTERBEDDED SILTSTONE AND FINE GRAINED LITHARENITE
C3 MASSIVE MEDIUM GRAINED LITHIC ARKOSE
C2 INTERBEDDED SILTSTONE AND VERY FINE GRAINED LITHARENITE
C1 MASSIVE MEDIUM GRAIN LITHARENITE
B GRANITE BOULDER CONGLOMERATE
A INTERBEDDED CARBONACEOUS LITHARENITE, CARBONACEOUS SILTSTONE AND SHALE, WITH ABUNDANT PLANT FRAGMENTS AND COAL STRINGERS
JACKASS MOUNTAIN GROUP
(PEMBERTON AREA ONLY)
d MASSIVE GREYWACKE UNIT
Co GREY SILTSTONE – SHALE UNIT
b VARIEGATED CLASTIC UNIT
a COALY CLASTIC UNIT
JURASSIC AND CRETACEOUS
RMG SILTSTONE; LITHARENITE AND PEBBLE CONGLOMERATE
SCALE 1:250,000
10 5 0 10 20 km
GEOLOGICAL INTERPRETATION
OF JACKASS MOUNTAIN GROUP
51°00
BASED ON
RODDICK &
HUTCHISON
1972
BASED ON
DUFFEL &
McTAGGART
1952
122°00
00803 (11)
HAL HOPKINS
APRIL, 1984
921-J-O-N
5A
COAL DIVISION
CHILCOTIN PROSPECT 1983
GEOLOGY OF THE MAIN BODY
OF THE JACKASS MOUNTAIN GROUP
FIGURE 8
803