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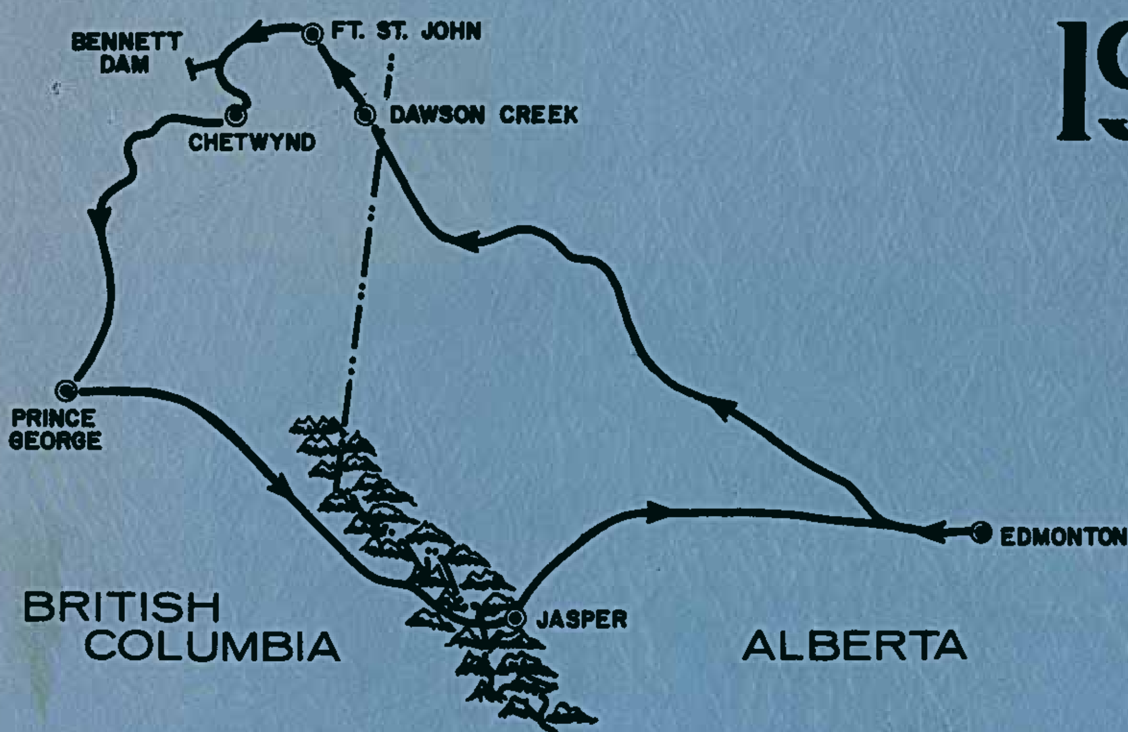
PEACE RIVER
PINE PASS
YELLOWHEAD
1970



FIELD CONFERENCE
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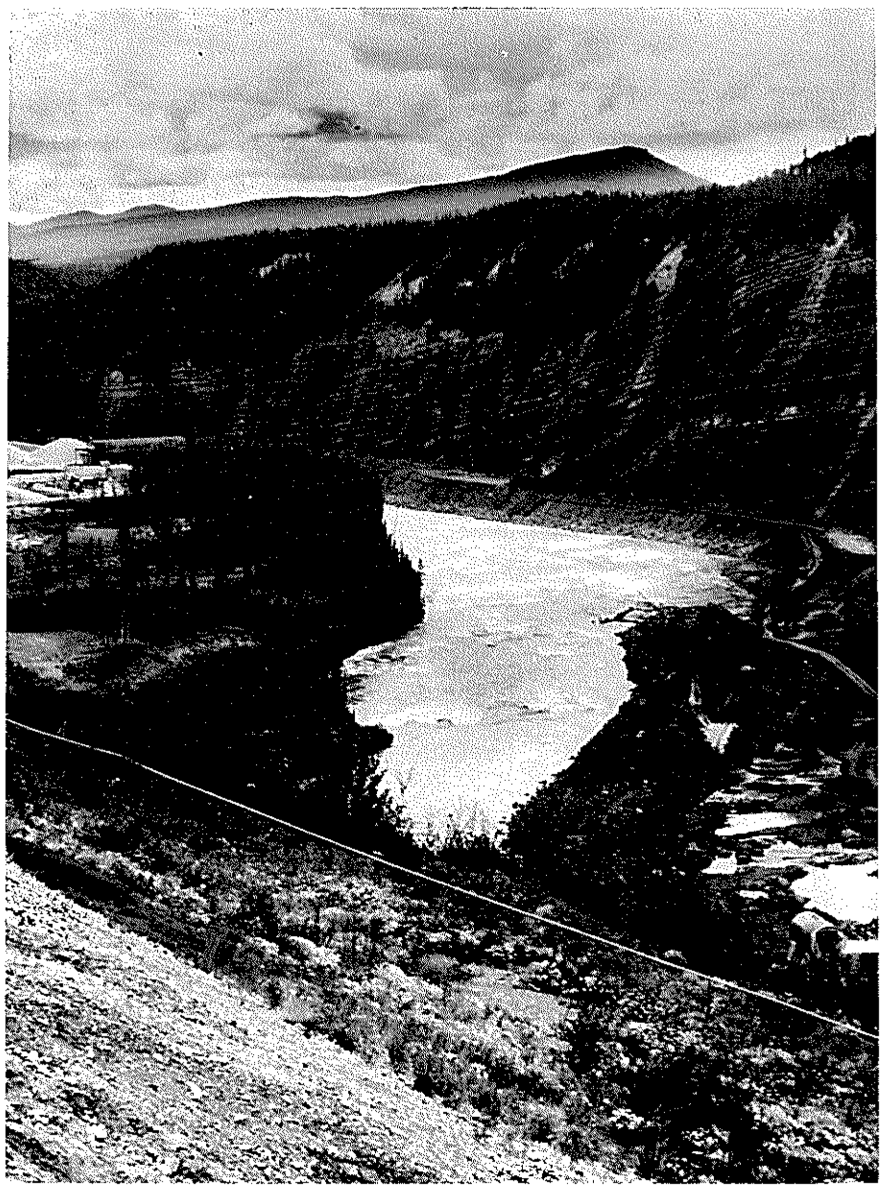

FRONTISPIECE

Gething Formation: exposed in canyon of the Peace River downstream from toe of W.A.C. Bennett Dam, Portage Mountain, British Columbia.

FIELD CONFERENCE

1970

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EDITORS

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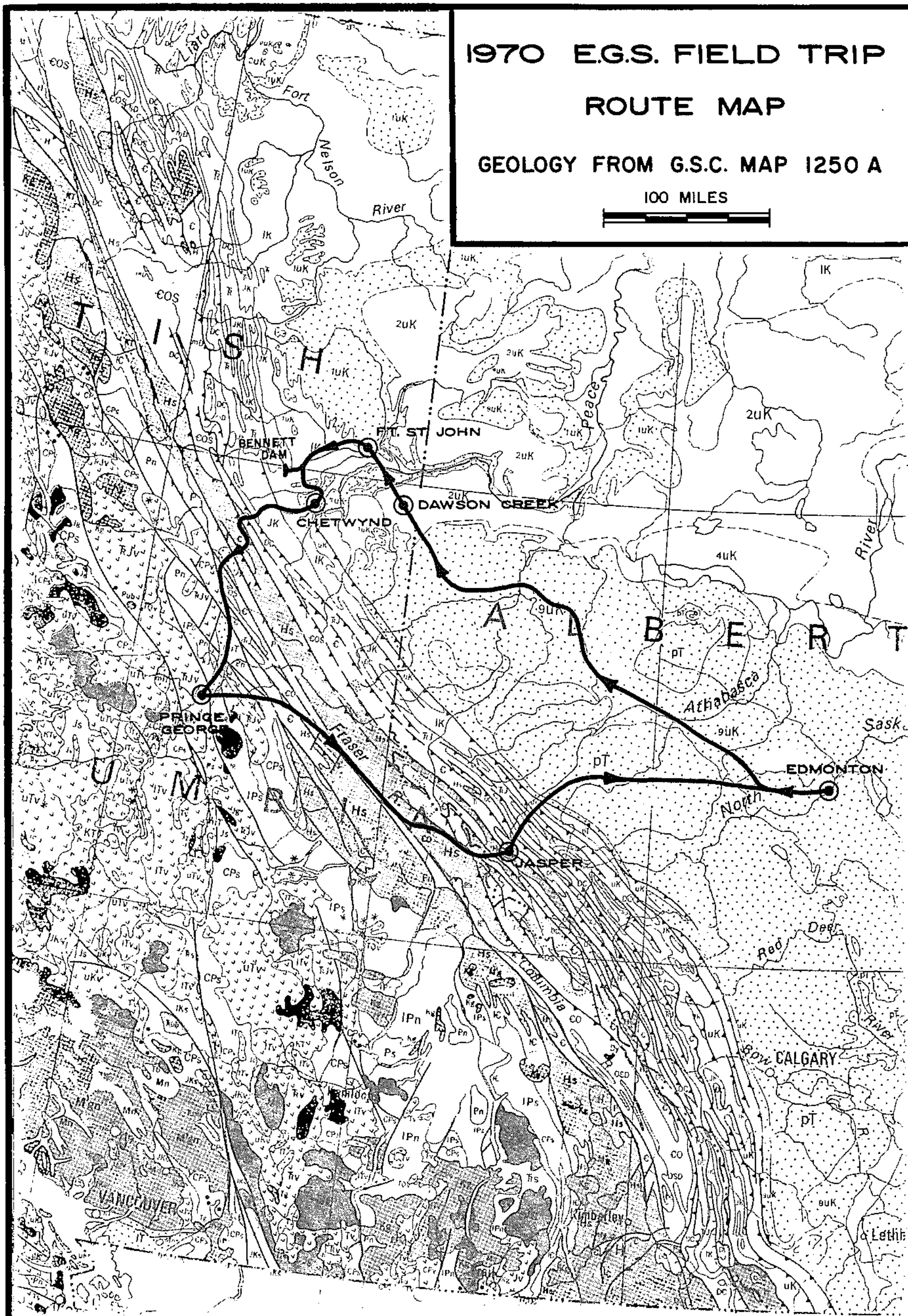
1970 E.G.S. FIELD TRIP
ROUTE MAP
GEOLOGY FROM G.S.C. MAP 1250 A
100 MILES
FT. ST JOHN
BENNETT DAM
DAWSON CREEK
CHETWYND
PRINCE GEORGE
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VANCOUVER
Kimberley
Fort
Nelson
River
Liard
Peace
River
Athabasca
North
Sask.
Fraser
Columbia
Red
Deer
River
Bow
ALBERTA

ITINERARY

Day 1 - September 10

Edmonton - Dawson Creek. Overnight Dawson Creek.

Day 2 - September 11

Dawson Creek - Chetwynd. Overnight Chetwynd.

Road outcrops between Fort St. John and the W.A.C. Bennett Dam and between Hudson Hope and Chetwynd will be examined. Time will be available for the B.C. Power and Hydro tour of the dam. Outcrops will be examined in the vicinity of the dam.

Day 3 - September 12

Chetwynd - Prince George. Overnight Prince George.

The day will be spent examining roadside outcrops between these points.

Day 4 - September 13

Prince George - Edmonton.

Outcrops will be examined on the route Prince George - Tête Jaune Cache - Jasper. Dinner near Jasper.

CHAIRMAN'S ACKNOWLEDGEMENTS

I should like to take this opportunity to express my thanks to the numerous organizations and individuals who assisted in the preparation of this field conference.

I am indebted to Dresser Atlas (Canada) for their generous sponsorship of a student member on this trip; to Cyanamid of Canada Ltd. for their kind donation of briefcases to delegates and to the British Columbia Power and Hydro Authority for their co-operation.

The considerable task of preparing the guidebook was supported by the major oil companies in Edmonton: Shell Canada Ltd. supplied typing facilities. Chevron Standard Ltd. and Shell Canada Ltd. undertook some of the drafting. Imperial Oil Enterprises Ltd. reproduced the guidebook. To the contributors and the organizations which permitted the publication of the various papers go my thanks for a very useful summation of the geology in the areas of our trip. The editors' task in assembling these has been most ably carried out and I am indebted to them.

Road logs were prepared by Drs. Henry Charlesworth (University of Alberta), Dick Campbell (G.S.C.; Vancouver), Don Stott and Gordon Taylor (G.S.C.; Calgary). These logs were edited and illustrated by Gil Graff of Shell Canada Ltd. To these men go my sincere thanks for their efforts and to Drs. Charlesworth, Stott and Taylor an additional acknowledgement for their contribution as guides.

To my Committee goes a special word of thanks for their willing help and numerous suggestions.

Finally, I welcome delegates to this, the 10th Annual Field Conference of our Society and hope that each of you finds something of value in what we have prepared.

G. J. Candy,
Field Conference Chairman.

A DISCUSSION OF THE STRATIGRAPHY AND STRUCTURE IN THE SUKUNKA AREA OF BRITISH COLUMBIA*

by L. Matwe and C. Bos

Central-Del Rio Oils Limited

INTRODUCTION

The Sukunka area is situated seventy-five miles southwest of Dawson Creek, British Columbia (see index map Figure 1). It is located in the Rocky Mountain Foothills, which have a differential relief of up to 4,000 feet. The terrain is rugged and poorly accessible.

Four exploratory wells have been drilled to test structures involving Triassic sediments. The result is one successful gas well (Triad B.P. a-43-B-93-P-5) and three abandonments. The shut in gas well has a calculated open flow in excess of 110 million cubic feet per day from approximately 300 feet of gross pay in the Triassic Pardonet and Baldonnel Formations. Secondary porosity and permeability was encountered because this well intersected the Triassic at the crest of a faulted and fractured anticline.

Acknowledgement is made to Triad Oil Company and staff for much of the information on the initial three wells in this area.

STRATIGRAPHY

General Discussion

Subsurface exploration in the Sukunka area has penetrated Lower Cretaceous and Jurassic strata in excess of 9,000 feet. A normal stratigraphic sequence would be approximately 5,700 feet (?). Thickening is due to tectonic deformation.

The subsurface stratigraphic correlations of the Cretaceous Bullhead, Cretaceous Jurassic Minnes, Jurassic Fernie and Triassic Schooler Creek Groups are based on the interpretation of the Gamma-ray sonic-logs, samples, and cores where available. The primary objective in exploration of the Sukunka area has been the Triassic Baldonnel Formation. The overlying Pardonet Formation is a secondary prospect. The Triassic has been encountered in the subsurface from drilling depths of 8,600 feet (Triad B.P. a-43-B-93-P-5) to over 11,000 feet (Triad B.P. b-10-A-93-P-5). The following geological discussion will briefly describe various stratigraphic intervals encountered in

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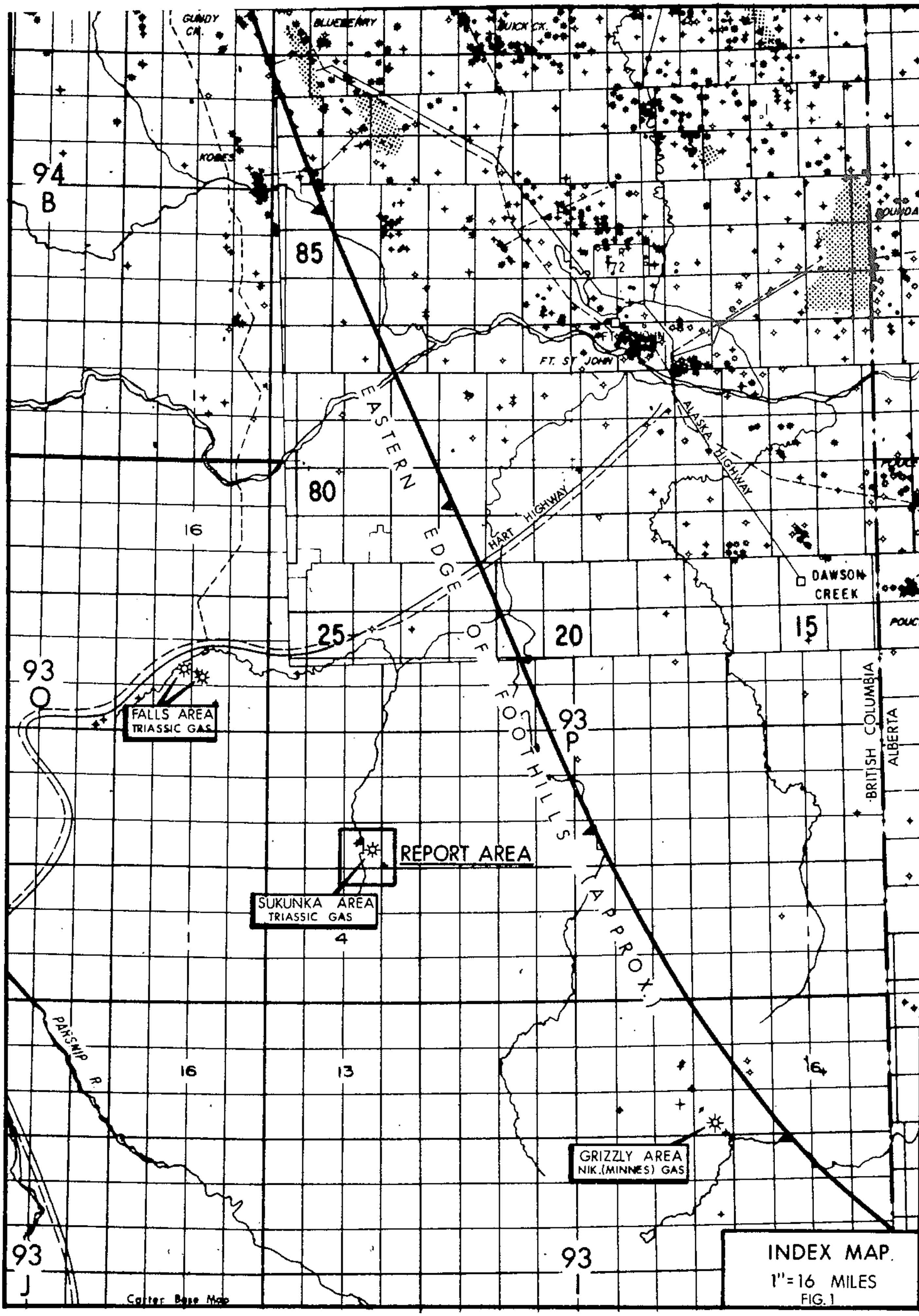


INDEX MAP.
1"=16 MILES
FIG. 1

the subsurface, and compare them to the type sections (see Figure 2).

Bullhead Group

The Bullhead Group is made up of the Gething Formation and underlying Cadomin Formation. In the Sukunka area some wells spud in the Gething Formation, which consists of interbedded carbonaceous sandstones, siltstones, shales, coals and some conglomerate beds. The Cadomin Formation is dominated by thick beds (up to 100 feet) of sandstones, cherts and conglomerates. This lithology is apparent in the basal 500 feet of the Bullhead Group in this area. A normal Bullhead Group section is from 1,300-1,600 feet thick. The CPOG et al Sukunka d-57-B-93-P-5 well encountered in excess of 2,900 feet, due to the fact that the borehole cuts this formation at an oblique angle.

Minnes Group

The Minnes Group is a thick series of sandstones, siltstones, shales and coals. Included within this group are the Brenot (?), Monach, Beattie Peaks and Monteith Formations. Only the Monteith Formation can be recognized in the subsurface. The three overlying formations are not readily distinct from each other. Coals and other non-marine deposits are prevalent throughout the interval. An undisturbed Minnes Group section is estimated to be from 3,000-3,600 feet thick. In the wells an apparent, tectonically disturbed thickness of 4,800-5,500 feet is encountered.

The top of the Minnes Group is picked on logs and samples where there is a sharp break from the overlying thick bedded sandstones and conglomerates of the Cadomin Formation to thinly bedded carbonaceous sandstones, siltstones and shales of the Brenot (?) Formation. The base of the Minnes Group is tentatively picked where thick bedded sandstones and quartzites of the Monteith Formation grade into a more thinly bedded series of sandstones, siltstones and shales of the Fernie Group. The subdivisions of the Minnes Group are shown in the Table of Formations (Figure 2).

Brenot (?) Formation

Cycles of thin bedded sandstone, siltstone, coal and shale are present, in several wells of the Sukunka area at the top of the Minnes Group. This section is probably correlative to the Brenot (?) Formation that was first defined by Hughes (1964) in the French Petroleum Company - Richfield Brenot Ck. No. 1 well, unit d-23-G-94-B-1, and is 343 feet thick. However, in a nearby surface exposure 750 feet thickness is estimated. The base of the section rests on the Monach Formation. Due to structural deformation a normal section of the Brenot (?) Formation in the Sukunka area is undetermined.

Monarch Formation

This section is not readily recognized in the subsurface of the Sukunka area. In the CPOG et al d-57-B-93-P-5 well, between the depths of 4,670? - ? a sandstone series is present. In several wells this particular lithology is noted to be present from about 2,200 - 2,600 feet above the top of the Monteith Formation. This zone may be the equivalent of the Monach Formation although coals are commonly present.

Beattie Peaks Formation

The top of the Beattie Peaks Formation is not recognized in the subsurface. The basal 300 - 400 feet of the Beattie Peaks Formation is a sequence of thinly bedded sandstones, siltstones, shales and coals.

Monteith Formation

The Monteith Formation consists of a section of thick bedded sandstones, quartzites, some siltstones and a few thin shale beds. No coals are present in the Monteith Formation in this area. The undisturbed subsurface section is calculated to be 600 - 700 feet thick.

Fernie Group

The Fernie Group is divided into three formations. They were described by Hughes (1964) as the Transition Beds (Passage Beds), Middle Shales, and Nordegg Beds. A normal thickness of 983 feet of the Fernie Group is present in the CPOG et al Sukunka d-57-93-P-5 well between the depths of 7,787 - 8,770 feet. Thickness of the subdivisions of the Fernie Group that are quoted in this report, are taken from this well. The Transition Beds (Passage Beds) are 233 feet thick and consist of interbedded siltstones, sandstones and shales. The Middle Shales are 681 feet thick, and consist of grey to dark grey shales, slightly dolomitic, very pyritic, with a few siltstone streaks and some scattered rounded, frosted quartz grains near the base.

The Nordegg Beds unconformably overlie the Triassic Pardonet Formation. They are 69 feet thick. The lithology is a highly calcareous shale with a few thin beds of micro-crystalline limestone and chert.

Schooler Creek Group

The Schooler Creek Group contains the Pardonet, Baldonnel, Charlie Lake and Halfway Formations. To date, only the upper 155 feet of the Charlie Lake Formation have been penetrated in the subsurface.

An undisturbed stratigraphic sequence of the Pardonet and Baldonnel Formations and the top of the Charlie Lake Formation is penetrated by the CPOG et al d-57-B well (see section B-B' Figure 4). The top of the Pardonet Formation was picked at 8,770 feet. The thickness of the Pardonet and Baldonnel Formations in the subsurface of the Sukunka area is derived from this well.

Pardonet Formation

The Pardonet Formation is 212 feet thick. The lithology can be subdivided into a) 50 feet of grey to dark grey, micro-crystalline, argill-

TABLE OF FORMATIONS

SURFACE AND SUBSURFACE

FIGURE 2.

AGE	GROUP	STRATIGRAPHIC UNITS	TYPE SECTION LITHOLOGY AND THICKNESS	ESTIMATED NORMAL SECTION FOR SUKUNKA AREA	MINIMUM THICKNESS IN THE SUBSURFACE OF THE SUKUNKA WELLS
CRETACEOUS	Bullhead	Gething Fm.	Sandstone, shales, siltstones, commonly carbonaceous, coals, few thin conglomerate beds present. 1,000'	Bullhead Group 1,300'	All wells spud in the Bullhead Group.
		Cadomin Fm.	Conglomerates of well-rounded, flattened pebbles, coarse grained sandstones, some shales. 70-600'	to 1,600'	2,900'+
	Minnes	Unnamed (Brenot Fm.)?	Thinly bedded carbonaceous sandstone, siltstone, and shales, some coals. 400'+	Minnes Group	Minnes Group, 4,800'.
		Monach Fm.	Cross-bedded sandstone, quartzites, some thin shales, few conglomerate lenses. 300-400'	3,000'	
		Beattie Peaks Fm.	Thinly bedded sandstones, shaly sands, siltstones, ironstone and dark grey to black shales. 600-1,200'	to 3,600'	Monteith Fm. 675' (Normal Section?)
JURASSIC		Monteith Fm.	Massive sandstone, quartzites, cross-bedded, some thin shales and shaly sandstone, also a few lenses of pebble conglomerates. 1,750'		
	Fernie	Transition Beds (Passage Beds)	Interbedded sandstones, siltstones, silty shales and dark grey shales. 75-150'	Fernie Group	Passage Beds, 23 Middle Shales, 680'
		Middle Shales	Dark grey to black fissile shales, minor amounts of argillaceous sandstone and, some clay ironstone banding. 500-600'	950' to 1,050'	Nordegg Beds, 70' Fernie Group, 98 (Normal Sections'

(Continued)

TABLE OF FORMATIONS

SURFACE AND SUBSURFACE

FIGURE 2.

AGE	GROUP	STRATIGRAPHIC UNITS	TYPE SECTION LITHOLOGY AND THICKNESS	ESTIMATED NORMAL SECTION FOR SUKUNKA AREA	MINIMUM THICKNESS IN THE SUBSURFACE OF THE SUKUNKA WELLS
JURASSIC	Fernie	Nordegg Beds	Black argillaceous microcrystalline limestone with interbeds of dark grey calcareous shale. Near the top are some beds of siltstone, sandstone and thin chert bands. 50-60'		
TRIASSIC	Schooler Creek	Pardonet Fm.	Limestones, silty, shaly, with beds of calcareous shales, siltstones, and traces of fine calcareous sandstone. 700'+	Pardonet Fm. 200'±	Pardonet Formation 185'
		Baldonnel Fm.	Limestone, fragmental, arenaceous, some local dolomitization. 500-550'	Baldonnel Fm. 200'±	Baldonnel Formation, 185' (Normal Sections?)
		Charlie Lake Fm.	Interbedded sequence of limestone, dolomite, anhydrite, sandstone and siltstones. 485'	Charlie Lake Fm. ?	Charlie Lake Formation - Not penetrated
		Halfway Formation	Dolomitic and calcareous siltstones and sandstones grading to arenaceous dolomites. 400'	Halfway Fm. ?	Halfway Formation - Not penetrated

Stratigraphy (modified) after D.F. Stott 1968, J.E. Hughes 1967.

aceous limestone. b) 80 feet of finely crystalline, light grey to brown dolomite with 30 feet of scattered vuggy porosity. The dolomite is silty, sandy, and in part cherty and siliceous. c) 82 feet of dark grey, pyritic, dolomitic shale. This basal shale is excellent for correlation purposes because it is developed in all the wells in the Sukunka area.

Baldonnel Formation

The Baldonnel Formation is 185 feet thick, and is a selectively leached, dolomitized bioclastic debris in a mud matrix, which is somewhat silty, argillaceous and siliceous. Scattered vuggy porosity is present.

Charlie Lake

The top of the Charlie Lake Formation is picked at the first occurrence of anhydrite below the Baldonnel Formation dolomite. The anhydrite occurs as beds of up to 20 feet thick, and is interbedded with thin beds of micro-crystalline dolomite in part similar to the Baldonnel Formation.

STRUCTURE

Regional Setting

The structures covered in this report are located in the Foothills Belt of the Rocky Mountains in the proximity of the Sukunka River North-eastern British Columbia, and are characterized by parallel northwest trending folds and southwest dipping reverse faults, (Figure 3 map).

The Foothills are bounded to the west by the Front Ranges, which are formed of a series of southwest dipping thrust plates, involving Triassic and Paleozoic sediments. The structures have the same general strike as the Foothills.

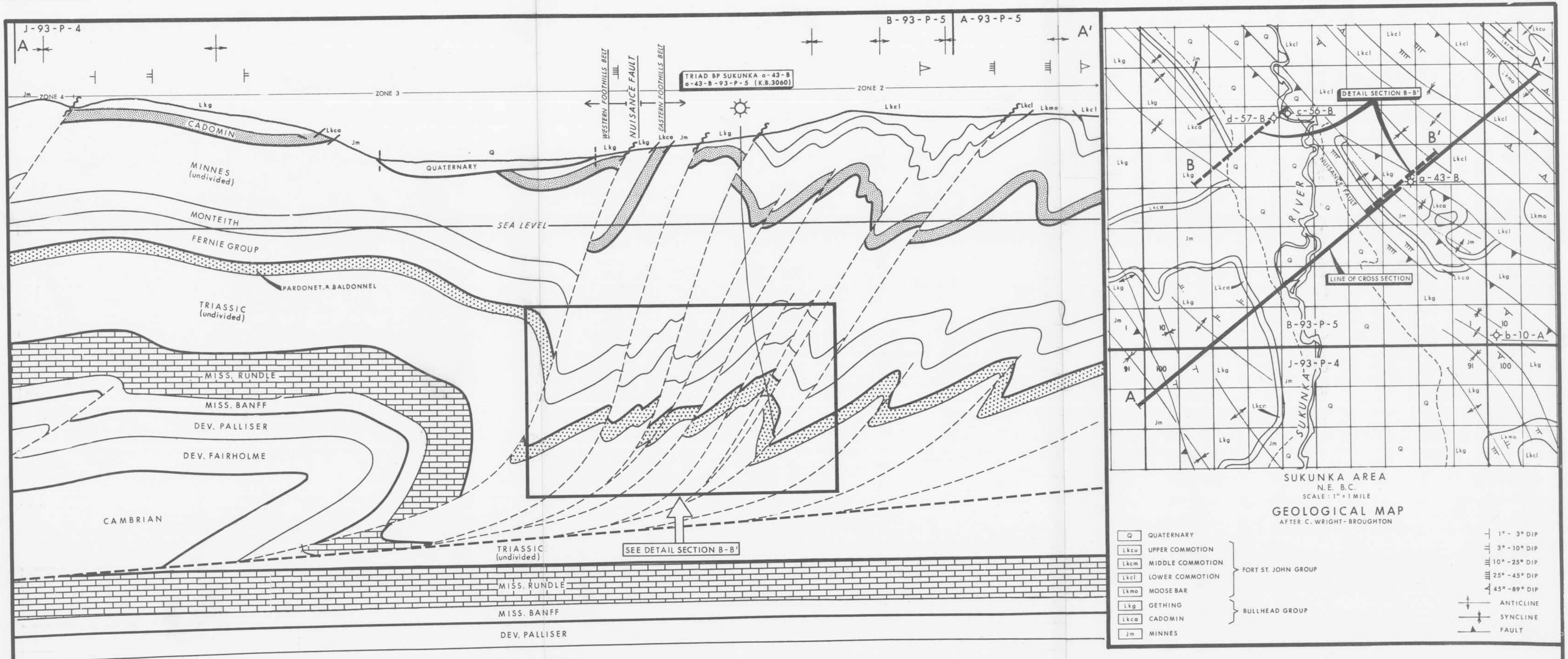
The Interior Plains lie to the east of the Foothills, and are underlain by relatively undisturbed gently west dipping Upper Cretaceous through to Paleozoic sediments which rest on the Precambrian basement.

The Foothills in this area can be divided in an Eastern Foothills Belt and a Western Foothills Belt. The division is made at the Nuisance Fault Zone (Figure 3).

Both belts can be subdivided in two zones. The Eastern Foothills Belt is composed of zone 1 and 2 and the Western Foothills Belt of zone 3 and 4. The map and cross-section A-A' (Figure 3) portray the middle zones 2 and 3. Zone 1 lies to the east of the area, and zone 4 is just included in the west. The structure at the surface of these four zones is shortly described below.

Eastern Foothills Belt: -

Zone 1: Broad open folds, low dips, little or no faulting.



STRUCTURE CROSS SECTION A-A'

SCALE

HORIZONTAL: 1" = 2,500' VERTICAL: 1" = 2,500'

JUNE, 1970

FIG. 3

C. BOS, R. AMSTUTZ, C.D.R. LTD.

Outcrops of Fort St. John Group (Note - The Upper Cretaceous Fort St. John Group in the Sukunka area is a 3,300 - 5,500 feet thick section composed of shales and sandstones overlying the Bullhead Group).

Zone 2: Tight folds, steep dips, little faulting. Outcrops of Lower Fort St. John Group and Bullhead Group. This zone is bounded to the west by the Nuisance Fault Zone.

Western Foothills Belt: -

Zone 3: Broad open folds, moderate dips, some faulting. Outcrops of Bullhead and Minnes Groups.

Zone 4: Tight folds, small scale chevron folding, steep and overturned dips, probably faulting. Outcrops of Minnes and Fernie Groups.

Subsurface Information

The Triad BP a-43-B well encountered a gas accumulation in the highly fractured, overturned limb of an anticline involving Upper Triassic carbonates. Subsurface information derived from this well, seismic data, and surface mapping indicated a rather simple, large asymmetric anticline in the Triassic, overlain by tightly folded Jurassic and Lower Cretaceous strata.

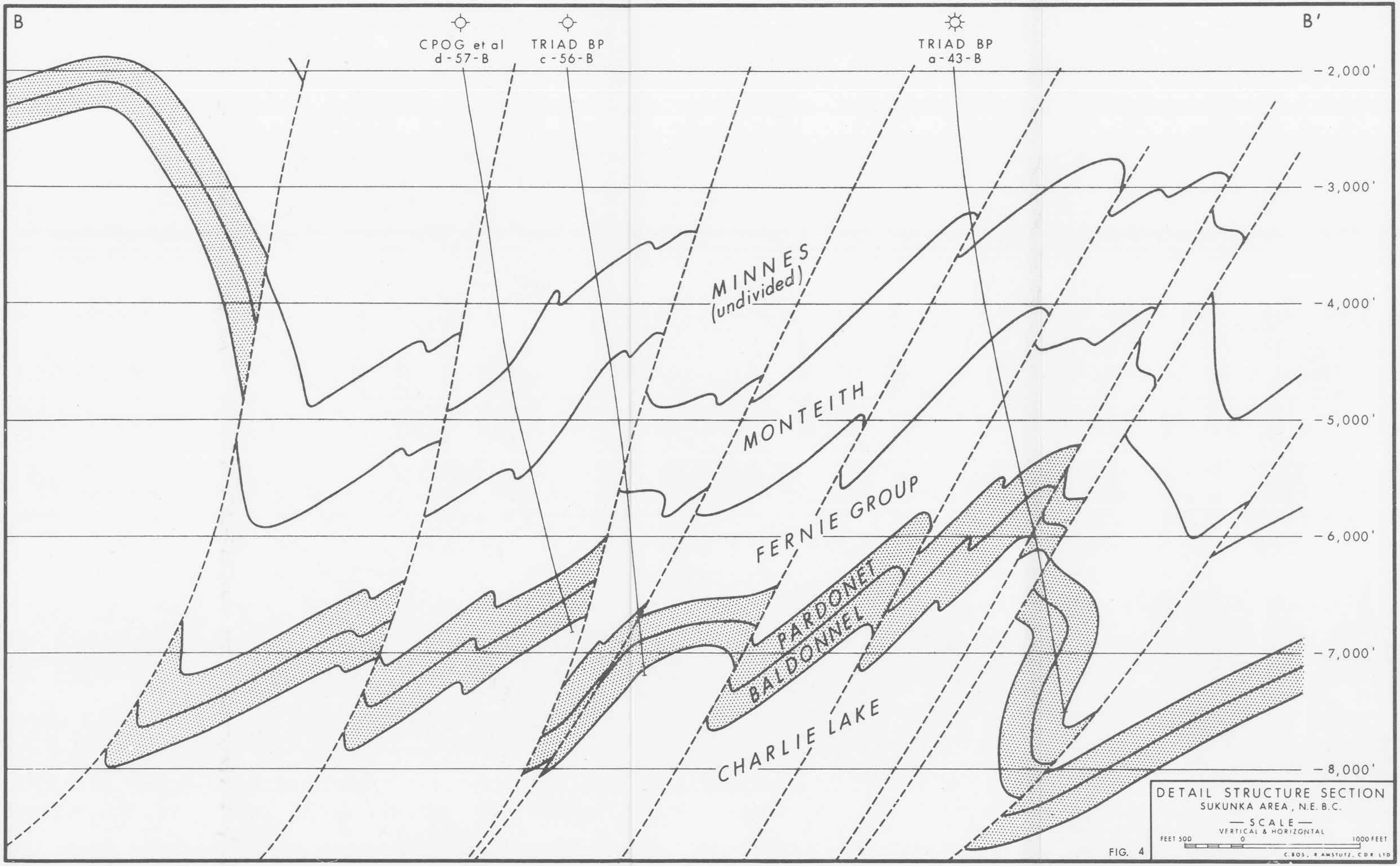
The subsequent wells (Triad BP c-56-B, Triad BP b-10-A, and CPOG et al d-57-B) proved this concept wrong, but contributed considerably to the understanding of the occurence and origin of the deformation in this area, and to the relationship of surface and subsurface structures.

The regional cross-section A-A' (Figure 3) is based on information derived from the detail, composite section B-B' (Figure 4). They show the following features:-

1) The shortening is mainly accomplished by concentric asymmetric folds, with steep southwest dipping axial planes.

2) With depth, faulting becomes prevalent to accommodate for volume and as a release of strain in the former folding compression, (see Figure 5). This reverse faulting is related to, and contemporary with the folding - both result from compression and uplift in the Rocky Mountain Orogeny. The occurrence of these faults indicate a sole fault or detachment plane at depth.

3) A major difference exists between the style of deformation east of the Nuisance Fault compared to that west of this fault. Paleozoic rocks are involved in the deform-



DETAIL STRUCTURE SECTION
SUKUNKA AREA, N.E.B.C.

— SCALE —
VERTICAL & HORIZONTAL
FEET 500 0 1000 FEET

C. BOS, R. AMSTUTZ, C.D.R. LTD.

FIG. 4

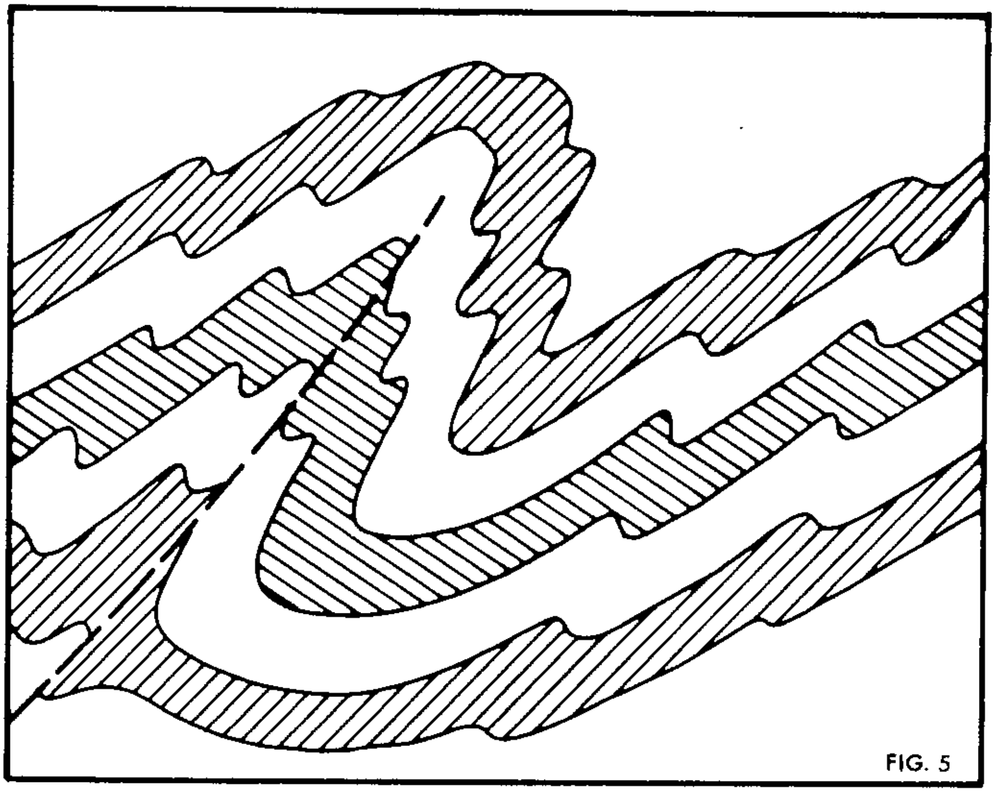


FIG. 5

Figure 5. Development of an Anticlinal Reverse Fault with depth, Sukunka area.

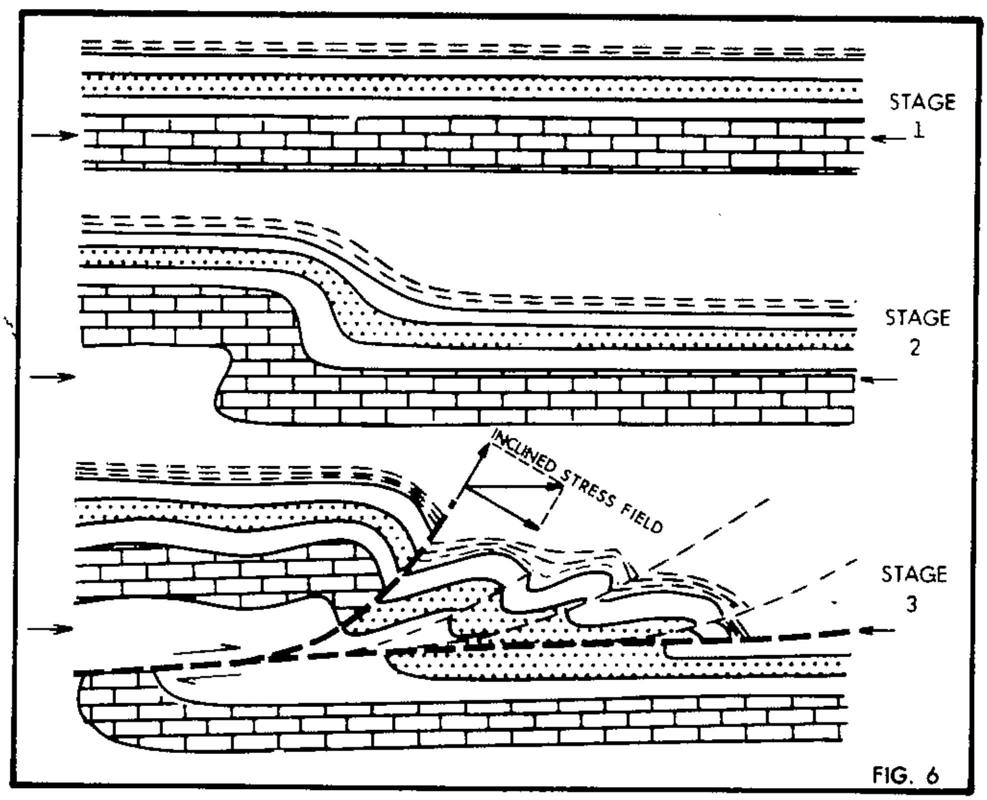


FIG. 6

Figure 6. Subsequent stages of structural deformation, Sukunka area.

ation west of the fault zone. Competent carbonates form the backbone for the structures and they determine the style of deformation. These competent rocks acted as a buttress against which the more easterly located Mesozoic clastics "crumbled" during subsequent shortening. Shortening of the underlying Paleozoics took place by underthrusting of at least three miles. An inclined stress field, was created which produced a fan shaped anticlinorium in the Mesozoic rocks of the Eastern Foothills Belt, (see Figure 6). The amount of shortening in zones 2 and 3 is 35% plus.

CONCLUSIONS

Structures drilled by wells in the Sukunka area involve Cretaceous, Jurassic and Triassic strata. The Triassic Pardonet and Baldonnel Formations have some secondary, leached porosity, with associated low permeability. An example is found in the CPOG et al d-57-B-93-P-5 well which encountered Upper Triassic dolomites above the calculated waterline, but had to be abandoned, due to a lack of porosity and permeability in the pay zone.

Future success for Triassic gas exploration in the Sukunka area, rests entirely on the ability to drill that part of the structure, where the reservoir qualities have been increased by extensive fracturing.

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GEOLOGY AND GENERAL FEATURES W.A.C. BENNETT DAM

by

Lisle T. Jory[1] and Alan S. Imrie[2]

INTRODUCTION

W.A.C. Bennett Dam, owned by B. C. Hydro and Power Authority, is located on the Peace River in British Columbia near the boundary between the Rocky Mountain Foothills and the Interior Plains (Figure 1). The site is near the head of Peace River Canyon and is approximately 14 miles upstream from the town of Hudson Hope.

The Peace River had long been recognized as a potential source of hydro-electric energy but not until 1957 were detailed site investigations initiated. These investigations culminated in the start of construction at W.A.C. Bennett Dam (then known as the Portage Mountain Dam) in 1962. The first fill was placed in 1964 and the embankment was completed in September 1967. In September of 1968, the first three of ten turbines went on line.

The dam develops the entire hydro-electric potential of the Peace River and its principal tributaries, the Parsnip and the Finlay, upstream from the site.

This paper describes briefly the reasons for the choice of the W.A.C. Bennett damsite and the geology of the site. Engineering data of general interest is given.

CHOICE OF SITE

Initial hydro-electric planning conceived the construction of two 300-foot high dams, one in Peace River Canyon and one upstream near Finlay Forks. In all, eleven sites were investigated (Figures 1 and 2). Although the foundation rocks at the upstream sites were competent limestones of Paleozoic age, drilling below the riverbed revealed a narrow, alluvium-filled slot at least 500 feet deep. Consequently, all upstream sites were rejected and attention was diverted entirely to Peace River Canyon.

Peace River Canyon is younger than the remainder of the Peace River channel. Upstream from the Canyon, the river flows in a broad, glaciated, U-shaped valley which cross cuts the formations. Prior to the period of Pleistocene glaciation, the river flowed from the head of the Canyon to the

1. Dolmage Campbell and Associates Ltd., Consultants, Vancouver, B. C.

2. International Power and Engineering Consultants Ltd., Vancouver, B. C.

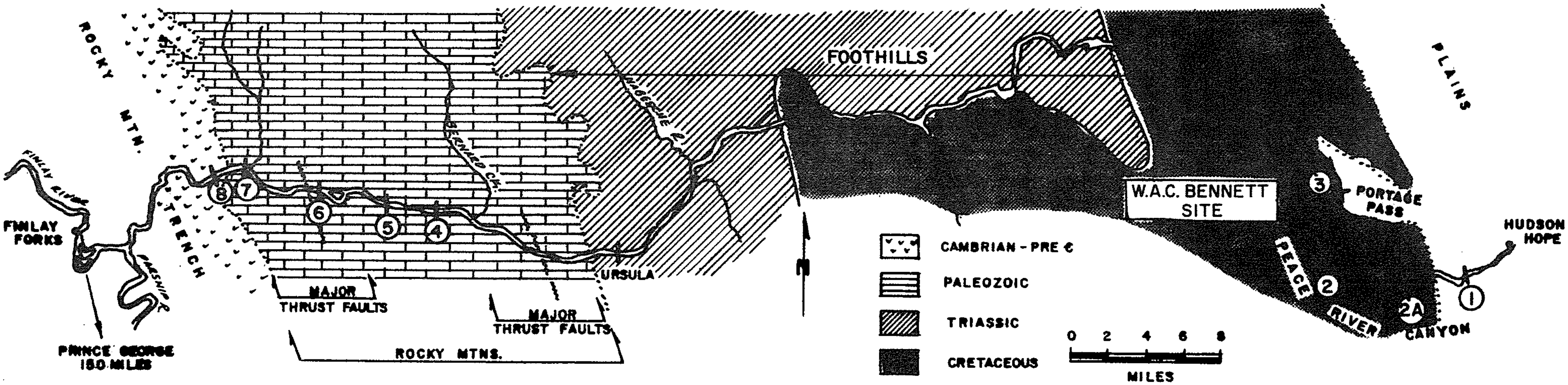
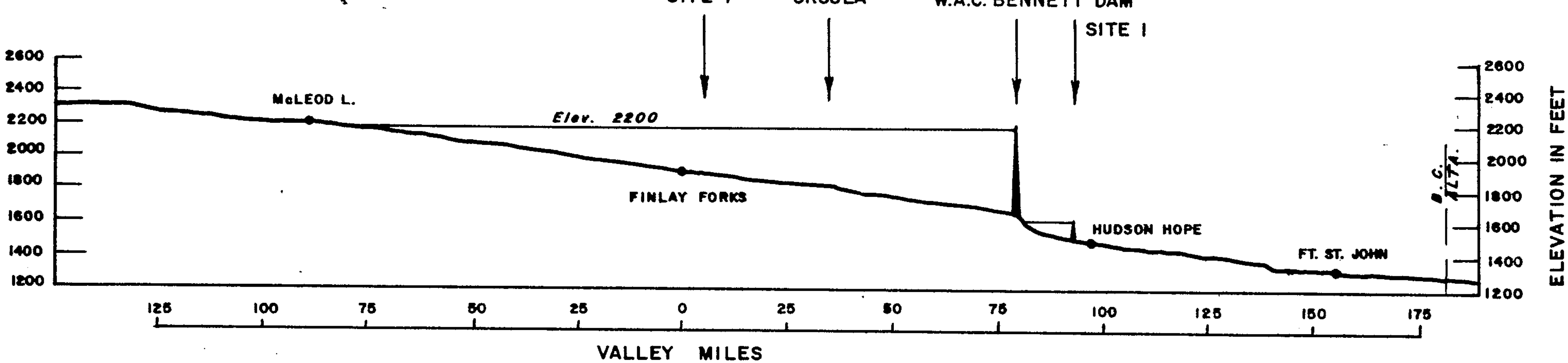


FIG. I GEOLOGY AND DAMSITES ALONG THE PEACE RIVER, FINLAY FORKS TO HUDSON HOPE
(after Dolmage & Campbell, 196



RIVER PROFILES ALONG THE PARSNIP & PEACE RIVERS

FIG. 2

vicinity of Hudson Hope along the route now known as Rocky Mountain Portage. (The dam access highway is close to this route.) At that time, sea-level was lower and the river cut its channel to a very low base. A 1738-foot deep drill hole in the Portage reached to within 480 feet of present sea-level without encountering bedrock.

During the Pleistocene, the terminus of a valley glacier stabilized for a period in Portage Pass between Portage and Bullhead Mountains (Figure 3). Terminal moraine and outwash completely blocked the valley. When the ice eventually rotted away, about 10,000 years ago, the impounded lake left behind spilled over a pass to the south. A new, arcuate channel south of Portage Mountain was established and erosion of Peace River Canyon began.

Thus, the glacial history of the area dictated the nature of the hydro-electric development of the Peace River. Glacial action not only provided an excellent rock-canyon foundation for a dam but also provided large quantities of quality construction gravels in the moraines only three miles from the site.

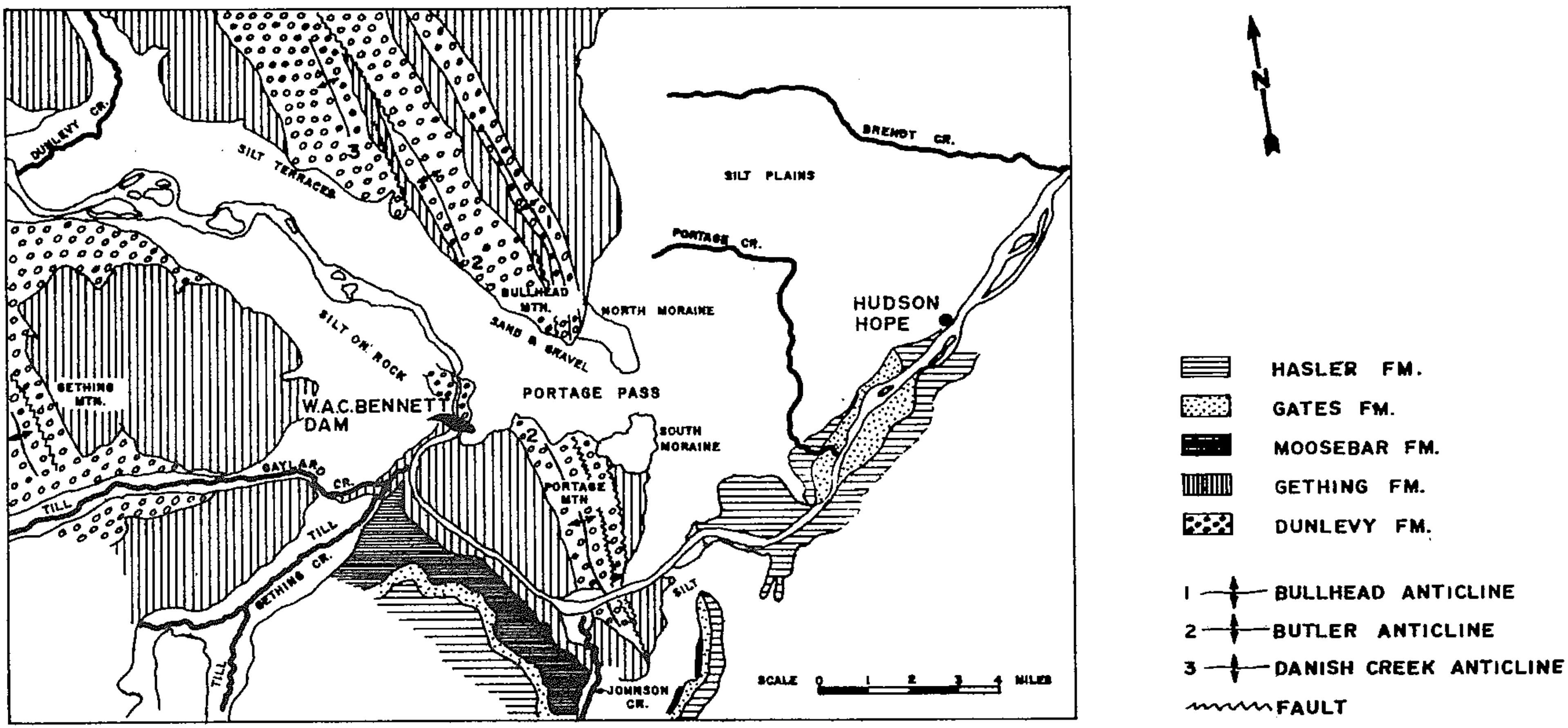
The W.A.C. Bennett site was selected for the major hydro-electric development to impound 600 feet of head. Utilization of the canyon's remaining 140 feet of head is expected to occur when circumstances warrant at Site 1, 12 miles downstream from the dam. Ultimately, additional low-head sites may be developed between Hudson Hope and Taylor, B.C.

SITE GEOLOGY

The foundation rocks of W.A.C. Bennett Dam are non-marine sandstones, siltstones, shales, and some coals of Lower Cretaceous age. Rock types grading between the above types are common. The beds are part of the Bullhead group which has been sub-divided into the Dunlevy formation (lower) and the Gething formation. The boundary between the formations is fixed at the Peace River coal seam. The seam, six to eight feet thick, is by far the thickest at the site and is the only one which has been economically exploited. Mining took place within the left abutment of the damsite and was limited in extent. However, during foundation preparation, it was necessary to re-open the mine workings, many of which had caved, and backfill them with gravel.

The beds are quite uniform in attitude. They strike northwest and dip 5° to 10° southwest (downstream) (Figure 4). Individual beds are remarkably persistent although there is some lensing due to facies changes.

The Dunlevy formation comprises massive, very competent sandstone beds up to 100 feet thick interbedded with relatively thin beds of shale, siltstone, and coal. About 60% of the section is sandstone. The shale contains an unusually high percentage of quartz. The highest part of the dam is founded on the Dunlevy formation and the major underground structures are excavated in it.



AFTER DOLMAGE & CAMPBELL (1963)

GEOLOGY of the PEACE RIVER CANYON

FIG. 3

The Gething Formation, which underlies only the outer ends of the wings of the dam contains a much larger percentage of shale and coal than does the Dunlevy. Shale and sandstone horizons are rarely more than 25 feet thick and individual beds are commonly a few inches thick. In physical characteristics, the various rock types are similar to those in the Dunlevy formation.

No faults are present within the site. Joints are relatively few in number and individual joints are usually restricted to a single bed. Within the foundation, a few thin soft seams of pulverized shale and coal, termed mylonite, are found along bedding planes.

Fossils found in the rocks during excavations included numerous impressions of leaves and ferns, outlines of logs, several impressions of dinosaur tracks, and one impression of a turtle. Casts of the shell and dinosaur track are on display at the Central Control Building.

THE DAM

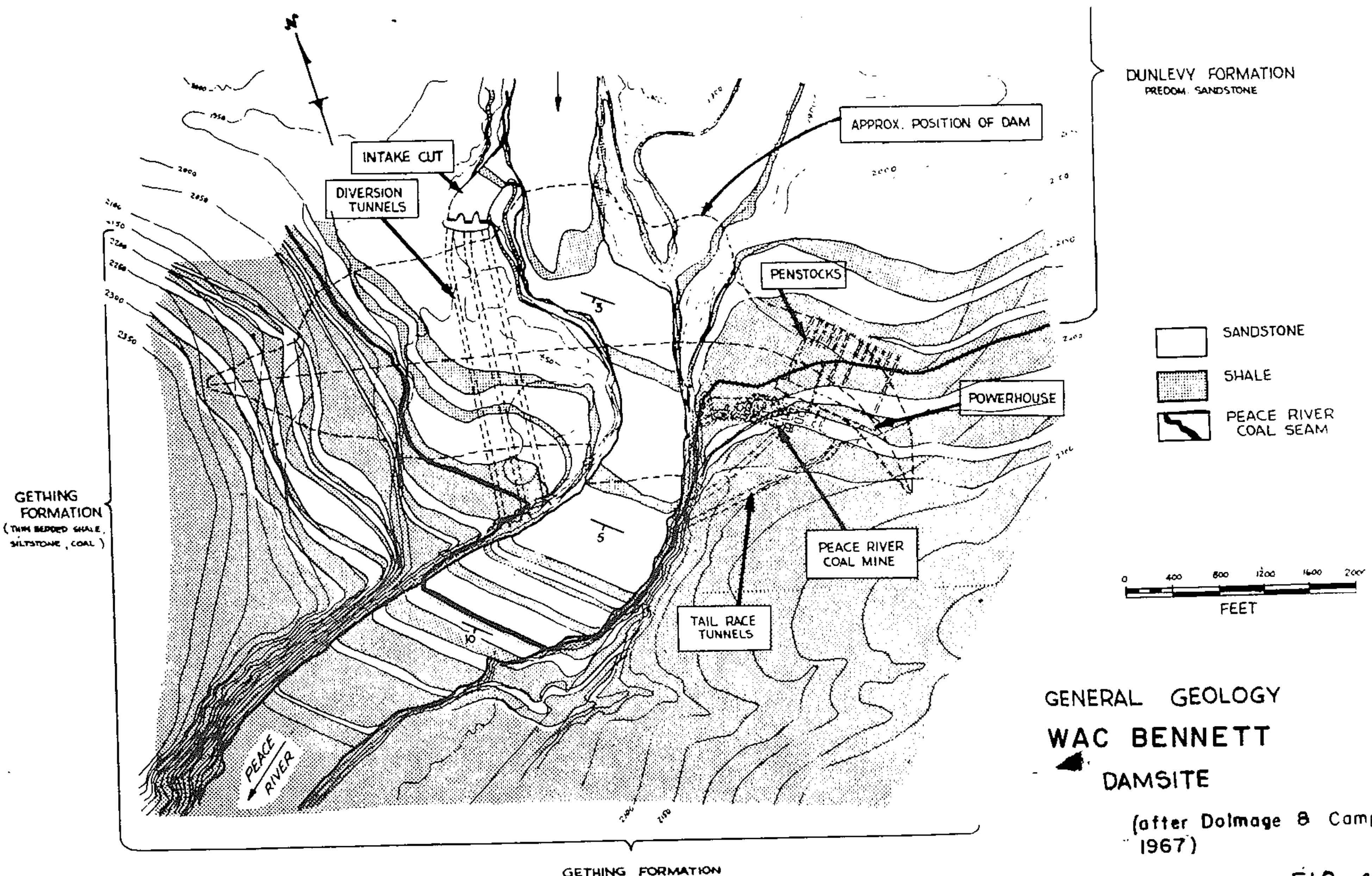
The dam is a zoned, rolled-gravel-fill embankment as depicted in Figure 5. Construction gravels were derived from the South Moraine 3 miles from the site. Silt was excavated at the site and mixed with processed moraine materials to form the impermeable core. Riprap to portect the downstream face and the upper portion of the upstream face was obtained by quarrying local sandstone.

A grout curtain under the dam core extends to a maximum depth of 350 feet and provides a water barrier comparable to that of the silt core.

Two mammoth tusks were discovered in the moraine gravels, one of which is on display at the Central Control Building. Carbon 14 dating of one tusk gave an age of 11,500 years B.P.

The powerhouse and its ancillary works (manifolds, penstocks, tailraces, low voltage lead shafts) are located within the left abutment of the dam. Most of the rock excavation required for the powerplant structures was carried out in the upper 450 feet of the Dunlevy formation (Figure 5).

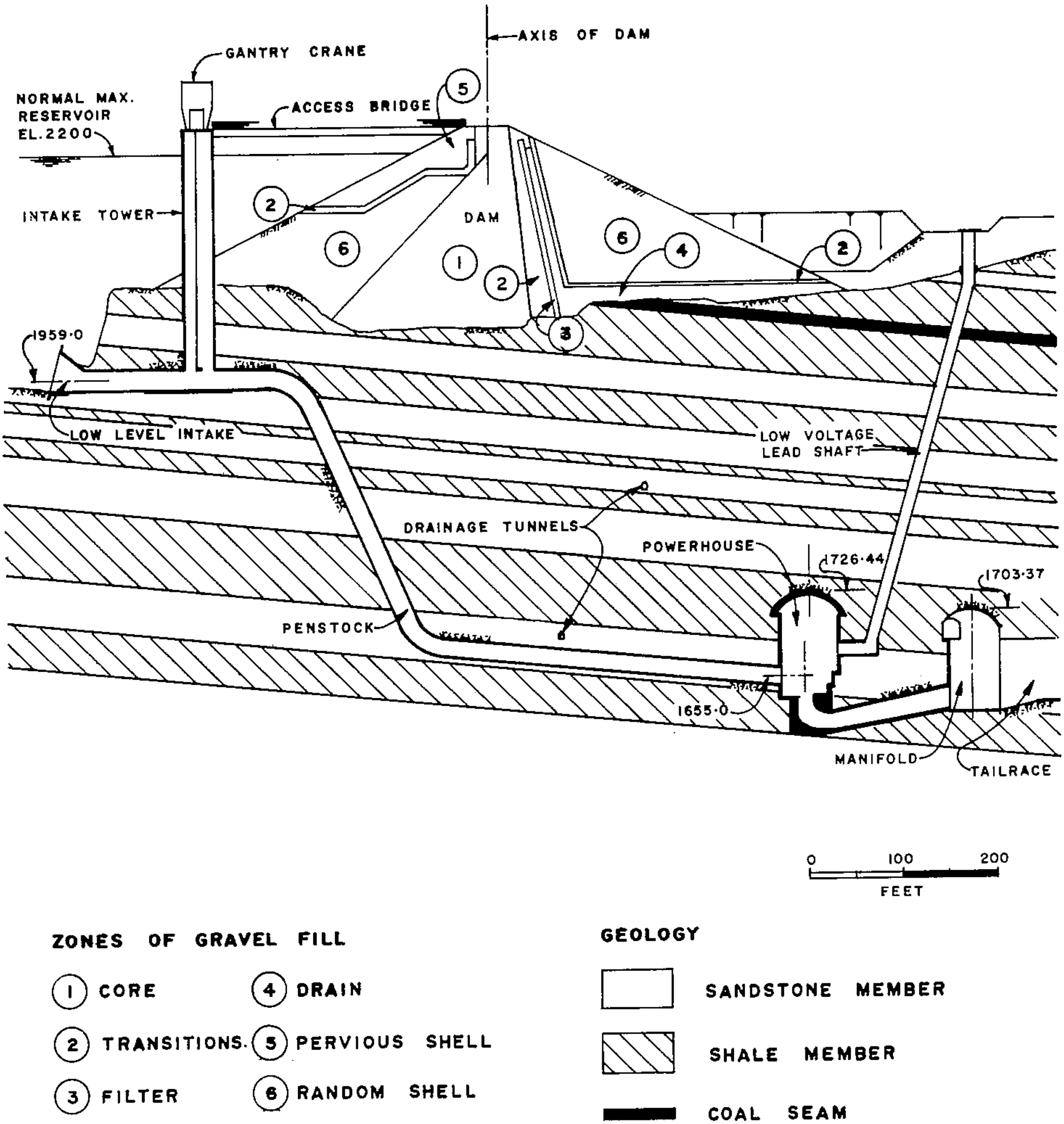
The University of Alberta has installed seismograph stations around the perimeter of the reservoir to monitor seismic activity due to the reservoir load.



GENERAL GEOLOGY
WAC BENNETT DAMSITE

(after Dolmage & Campbell, 1967)

FIG. 4



TYPCAL SECTION
LEFT ABUTMENT
(After Imrie, 1967)

FIG. 5

ENGINEERING DATA

Dam:	600 feet high, 6700 feet long, 3000 feet wide at the base. Volume - 57,000,000 cubic yards. Crest elevation is 2230 feet.
Conveyor Belt Capacity:	the conveyor belt transported construction gravels from the moraine at a rate of 12,000 tons per hour; belt length - 15,000 ft.
Installed Capacity:	2270 megawatts (Future at Site 1 - 700 megawatts).
Transmission Lines:	2 lines; each 550 miles long, 500,000 volts.
Reservoir:	27,000 square mile catchment; 680 square mile lake; 57,000,000 acre-feet storage.
River Flow:	36,500 cusecs (long term average)
Powerhouse:	890 feet long, 67 feet wide, 153 feet high.
Diversion Tunnels:	three, each 48 feet in diameter and 2500 feet long.
Spillway:	100 feet wide, 2300 feet long; capacity 341,000 cusecs.

LIST OF CONSULTANTS

Major engineering responsibility for design and construction supervision was held by International Power and Engineering Consultants Limited. Geological engineering consultants were Drs. V. Dolmage and D. D. Campbell. Soil consultants were Dr. R.B. Peck and Mr. C.F. Ripley.

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TRIASSIC STRATIGRAPHY, PINE PASS AREA, NORTHEASTERN BRITISH COLUMBIA

by D.W. Gibson

INTRODUCTION

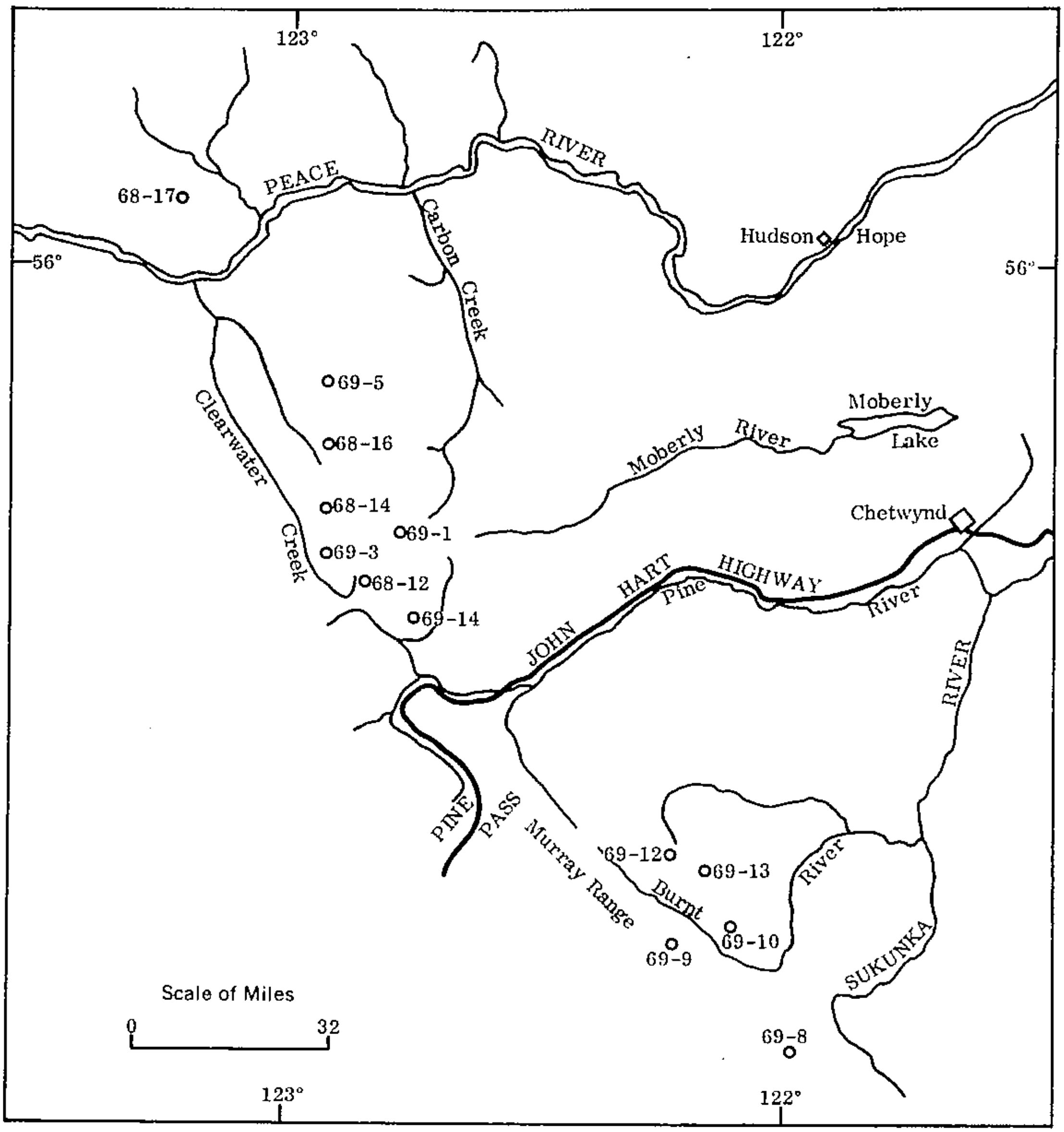
This paper is a brief account of the Triassic stratigraphy in the Rocky Mountain Foothills between Peace and Sukunka Rivers, northeastern British Columbia (Fig. 1). The report is based on field work carried out during the summers of 1968 and 1969, as a member of Operation Smoky, a regional geological mapping and stratigraphic investigation by officers of the Geological Survey of Canada.

STRATIGRAPHY

General

Triassic rocks in the Pine Pass area have been recognized and described in variable detail by McLearn and Kindle (1950), Colquhoun (1960, 1962), Muller (1961), Westermann (1962), Pelletier (1963), and Hughes (1967). Barss et al., (1964) synthesized all published Triassic stratigraphic information in Western Canada up to the end of 1961, including the region covered by this report. The present investigation by the writer in the Rocky Mountain Foothills, between the Sikanni Chief River of British Columbia and the Smoky River of Alberta, is an attempt to revise and establish a useful and meaningful surface nomenclature system, and to provide detailed information on the distribution, age and stratigraphic relationships of the Triassic rocks in northeastern British Columbia, and furthermore, to relate this study to a previous investigation of Triassic rocks in the Foothills and Front Ranges of central and southern Alberta, and southeastern British Columbia (Gibson 1965, 1968, 1969).

In 1969, field work south of Peace River revealed a noticeable difference between the physical appearance and composition of Lower and Middle Triassic rocks north of John Hart Highway and Pine Pass, and those to the south. Some of the lithostratigraphic units recognized north of the highway, cannot be reliably extended into the region to the south. Consequently, a different stratigraphic subdivision and nomenclature system is required for the southern sequence. The Lower and Middle Triassic rocks between Pine Pass and Sukunka River can be subdivided into units that have been established in the Jasper region of Alberta (Gibson, 1968). Therefore, it is proposed to modify part of the Triassic nomenclature used in the Jasper-Banff region of Alberta, and apply it to Lower and Middle Triassic rocks outcropping between Hart Highway and Sukunka River. The stratigraphic subdivision and nomenclature used in



LEGEND

1969		1968	
SECTION NUMBER	NAME	SECTION NUMBER	NAME
69- 5	Bocock Peak	68-17	Mount Greene
69- 1	Carbon Creek	68-16	Eleven Mile Creek
69- 3	Clearwater Creek	68-14	Peck Creek
69-14	Callazon Gap	68-12	Clearwater Lake
69-12	Brazion Creek		
69-13	North Burnt River		
69- 9	West Burnt River		
69-10	Watson Peak		
69- 8	Lean-to Creek		

Figure 1. Locations of Triassic sections between Peace and Sukunka Rivers, northeastern British Columbia

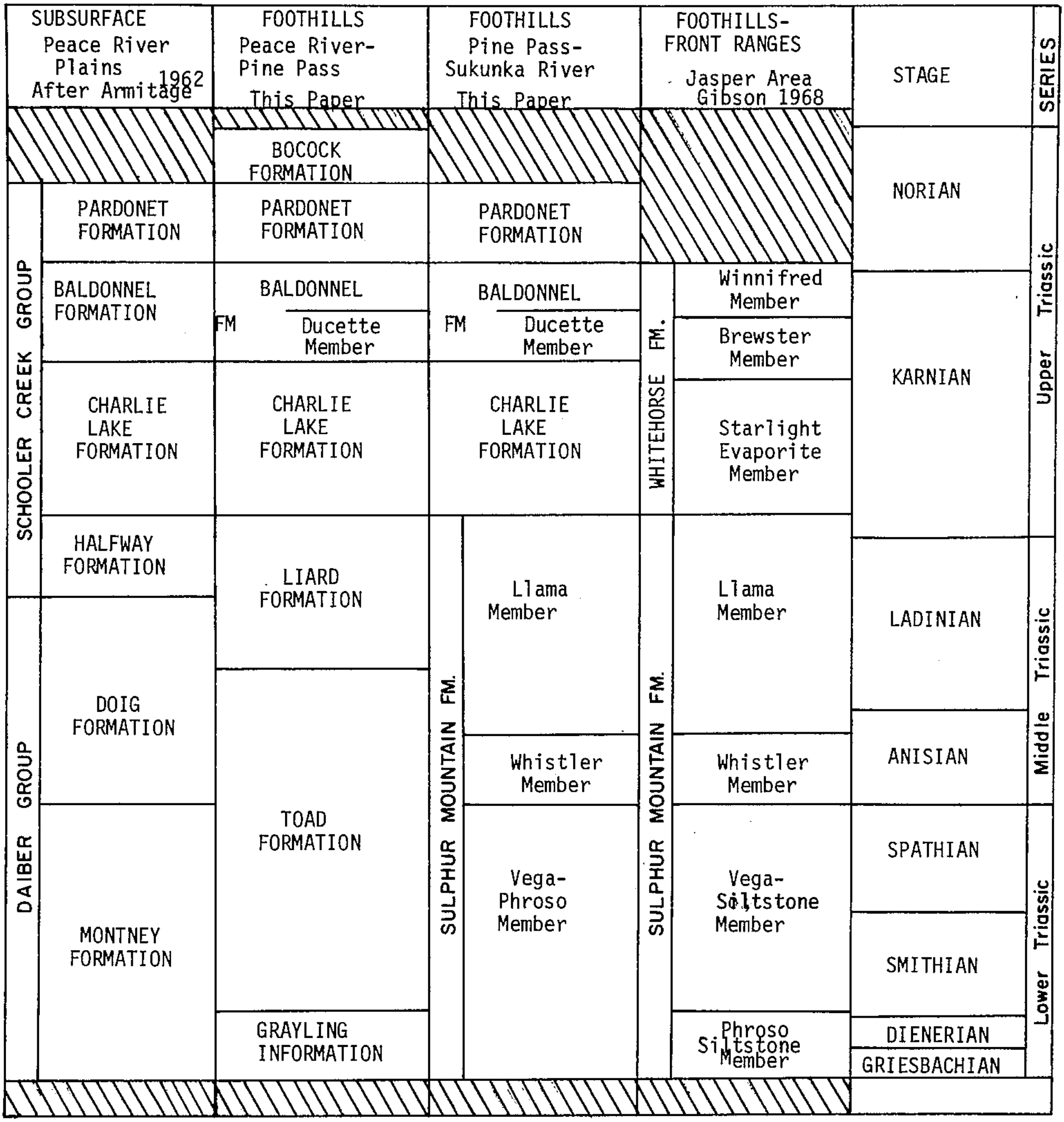


Figure 2. Nomenclature and correlation chart illustrating Triassic formations and members in the Peace-Sukunka River area, and their suggested correlation with formations and members in the subsurface Peace River Plains, and the Jasper area of Alberta.

the north for Upper Triassic rocks in the Peace River - Pine Pass area will be extended southward into the region south of Pine Pass, at least as far as Sukunka River (Fig. 1). It is expected that field work during 1970 will establish an area where it becomes more convenient and practical to abandon the Upper Triassic nomenclature of the Pine Pass area, and adopt the nomenclature and stratigraphic subdivision of the Jasper area.

The following discussion is presented in two parts, one dealing with the formations and members between Peace River and John Hart Highway, and the other dealing with the formations and members between the highway and Sukunka River. Where the lithologic units in the two areas have similar stratigraphic boundaries and nomenclature, only one description will be given.

Figure 2 illustrates the field units recognized, and the nomenclature used in this report. A more detailed account of the Triassic stratigraphy between Sikanni Chief River and Pine Pass has been submitted for publication by the Geological Survey of Canada. The following discussion contains information abstracted from the Geological Survey report.

PEACE RIVER-PINE PASS AREA

Grayling Formation

The Grayling Formation consists of recessive, shaly- to flaggy-weathering, dolomitic quartz siltstones, silty shales, and minor calcareous siltstones, silty limestones, dolomites, and very fine-grained sandstones. The formation is dark to brownish grey, commonly very carbonaceous-argillaceous*, slightly pyritiferous, and thin- to medium-bedded. The formation has a maximum measured thickness of 325 feet near Peck Creek (Section 68-14), and a minimum thickness of 225 feet near Clearwater Creek (Section 69-3).

The mineral composition of the Grayling Formation consists mainly of angular quartz and feldspar, dolomite, calcite, minor pyrite, illite, phosphate, and trace amounts of common heavy minerals. Dark grey to black, siliceous phosphate nodules and lenticles are sometimes found near the Toad Formation contact. This feature may be observed at road exposures west of Pine River Bridge crossing.

The Grayling Formation unconformably overlies dark grey chert, and siliceous mudstone of the Permian Fantasque Formation. The contact with the overlying Toad Formation is gradational, and sometimes difficult to distinguish. The contact is placed mainly on the basis of a change in carbonate composition, where the cement and matrix of the siltstones and shales of the Grayling Formation grade vertically, from a predominance of dolomite to calcite. This change commonly ranges over a thick sequence of strata.

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*Because of the colour-masking effect, and the intimate association of the organic carbonaceous matter with clay minerals, it was not possible to distinguish the organic and argillaceous constituents using a binocular or petrographic microscope. One or both constituents may be present in a given sample.

The Grayling Formation is sometimes characterized by the presence of large limestone concretions up to 1 foot in diameter, which commonly contain ammonites and pelecypods. Those collected from the report area include Prionolobus cf. P. lilangense (Krafft), Anakashmirites sp., Prosphingites sp., Arctoceras sp., and Posidonia mimer Oeberg. An Early Triassic Dienerian to Smithian age is suggested for the formation.*

Toad Formation

The Toad Formation comprises a thick sequence of dark grey, shaly- to flaggy-weathering, carbonaceous-argillaceous, very calcareous siltstones, silty limestones, silty shales, and lesser silty dolomites and calcareous sandstones. At some localities, the formation displays a distinctive alternation of resistant and recessive bedding which is related to the carbonate and carbonaceous-argillaceous concentration of the strata. This weathering characteristic can be observed in exposures west of Pine River Bridge crossing on the John Hart Highway. The thickness of the Toad Formation in the Peace River - Pine Pass region ranges from 520 feet at Mount Greene on Peace River, to more than 1,370 feet near Callazon Creek. Thickness values south of Peace River are variable, and may be due to an uneven basement on which sediments of the Grayling Formation were deposited, or the variation may be the result of gradational contacts with the underlying Grayling and overlying Liard Formations.

The mineral composition of the formation is similar to that of the Grayling Formation. The siltstones and minor sandstones are composed of angular, "corroded" grains of quartz, feldspar, micro-aggregates and crystals of pyrite, and black to dark brown, opaque carbonaceous-argillaceous matter, all cemented by recrystallized calcite and minor dolomite. The carbonate consists of calcite, lesser dolomite, and trace amounts of siderite. Phosphate occurs sparingly throughout the formation. However, near the Toad-Grayling Formation contact, black nodules, coarse grains, and lenticles are found through a stratigraphic interval of 100 to 200 feet. These nodular phosphates may be seen at Peck Creek (Section 68-14).

The contact of the Toad Formation with the Liard Formation in the Peace River-Pine Pass area is gradational. It is placed within a stratigraphic interval where the dark grey siltstones, silty limestones, and silty shales grade vertically into a sequence of predominantly lighter weathering, coarse-grained siltstones, very fine-grained sandstones, and subconchoidal fracturing limestones. The contact with the underlying Grayling Formation is gradational as previously discussed.

The Toad Formation as defined by the writer, encompasses a fauna ranging in age from Early Smithian to Late Ladinian. However, in the Peace River-Pine Pass area, the formation contains very few stratigraphically useful fossils. Those collected include Daonella sp., Daxatina sp.,

* All fossils collected in the field were identified and dated by E. T. Tozer of the Geological Survey of Canada.

Protrachyceras sp., which are all of probable Ladinian age.

Liard Formation

The Liard Formation consists of resistant, cliff-forming, very dolomitic to calcareous, fine- to coarse-grained sandstones, calcareous and dolomitic siltstones, and minor silty to sandy dolomites. Buff-weathering, sandy to silty, and bioclastic limestones are intercalated in the succession near Peace River. However, southward toward the Hart Highway, these limestones are dark grey-weathering, very finely crystalline, and display a subconchoidal fracture. These dark weathering limestones can be seen in exposures along Hart Highway, east of Silver Sands Creek. Here, the limestones contain dark grey chert lenses and nodules. The formation is thin- to thick-bedded, and is generally light to medium grey to yellowish grey, especially at localities near Peace River. Farther south, the formation is darker grey, reflecting a larger carbonaceous-argillaceous concentration. The Liard Formation thickens south of Peace River. At Clearwater Creek (Section 69-3), the formation is 1,370 feet thick, whereas at Peck Creek, a minimum thickness of 1,160 feet was recorded. In the Halfway River region to the north, the Liard Formation ranges in thickness from 92 feet to 540 feet.

Mineralogically, the Liard Formation is similar to the underlying Toad Formation, differing, however, in texture and relative concentration of the constituent minerals.

The contact with the overlying Charlie Lake Formation is gradational, but readily apparent at most localities. It is drawn where dark grey-brown-weathering sandstones and siltstones of the Liard Formation, change to light grey- to buff-weathering dolomites, and dolomitic sandstones and siltstones of the Charlie Lake Formation.

The Liard Formation south of Peace River contains good index fossils of Late Ladinian and Early Karnian age. In the region north of Peace River only indeterminate bivalves and lingulid brachiopods were collected. At Callazon Creek Gap (Section 69-14), Daxatina cf. canadensis Whiteaves, Clionitites cf. wheeleri (Johnston), Clionitites cf. reesidei (Johnston), Protrachyceras sp., Trachyceras obesum Tozer, Halobia sp., and Badiotites sp., were collected from the Liard Formation. This fauna represents the Early Karnian substage.

Charlie Lake Formation

Strata characteristic of the Charlie Lake Formation can be recognized in the Hart Highway-Sukunka River area, and will, therefore, be discussed with the Charlie Lake lithofacies north of Hart Highway. The formation comprises a buff to yellow, light grey- to orange-brown-weathering assemblage of dolomitic to calcareous sandstones, siltstones, sandy limestones and dolomites, and minor intraformational and solution breccias.

The sandstones and siltstones which predominate north of Hart Highway are quartzose, and are cemented by very fine to medium crystalline dolomite, and some calcite. The sandstones are fine to medium grained, thin- to thick-bedded, partly laminated and crossbedded, and in the region adjacent to and north of Peace River are friable and sometimes porous. The carbonates, which predominate south of Hart Highway, are often sandy to silty, and composed of recrystallized, very fine to medium crystalline mosaics of calcite and dolomite. The dolomites are thin- to medium-bedded, and are most common in the upper third of the formation both north and south of the highway. Limestones are similar in character to the dolomites, except in the area south of the highway, where they are sometimes bioclastic, containing fragmented brachiopod and/or pelecypod shells and crinoid material. The limestone interbeds are more common in the Pine Pass-Sukunka River area. The collapse or solution breccias are found mainly south of Hart Highway, and are composed of yellow to buff, angular clasts of silty to sandy dolomite and chalky limestone, up to 1½ inches in diameter, cemented by sandy to silty, medium to coarsely crystalline calcite and dolomite. Neither gypsum nor anhydrite have been observed in any surface exposures in northeastern British Columbia by the writer. Because of the sometimes gradational and interfingering nature of the Charlie Lake-Liard Formation contact, thickness values in some regions are variable. The formation ranges in thickness from a maximum of 940 feet near the north fork of Burnt River (Section 69-13) to a minimum of 490 feet on Clearwater Creek (Section 69-3). Exposures of the Charlie Lake Formation can be seen in road cuts on Hart Highway, east of Silver Sands Creek, and on the west side of Pine River Bridge crossing.

The contact of the Charlie Lake Formation with the overlying Baldonnel Formation is abrupt and distinct both north and south of Hart Highway. Typifying this contact relationship is Section 68-12, near Clearwater Lake (Fig. 1). The upper Charlie Lake Formation consists of buff- to light grey-weathering, sandy to silty dolomites, and dolomitic siltstones and sandstones, and is overlain in sharp contrast by dark greyish brown-weathering limestones, and dolomitic siltstones of the Ducette Member of the Baldonnel Formation.

The Charlie Lake Formation contains few fossils. Those collected include _Pleuromya_ sp., and indeterminate pectinid bivalves. In the western Foothills north of Peace River, a deeper water correlative facies of the Charlie Lake Formation contains a fauna of probable Karnian age.

Baldonnel Formation

The Baldonnel Formation Peace River-Pine Pass area is divided into two distinct facies. The upper and main facies occurs throughout most of northeastern British Columbia, whereas the lower unit, named the Ducette Member, is confined to the Foothills area between Peace and Sukunka Rivers. The description of the Ducette Member will follow as a separate heading.

The Baldonnel Formation comprises a light grey to brownish grey-weathering, resistant, cliff-forming sequence of limestones, dolomites, and minor siltstones. The carbonates are slightly silty, commonly carbonaceous-argillaceous, and commonly contain medium to dark grey chert lenses and nodules. The limestones are finely crystalline to aphanitic to bioclastic, and in part very dolomitic. The bioclastic limestone consists of abraded, fragmented crinoid columnals, and pelecypod and/or brachiopod shells. The dolomite is very calcareous, and displays textural parameters similar to those of the limestone. The siltstones are quartzose, very calcareous to dolomitic, often laminated, and sometimes crossbedded. The formation ranges in thickness from a minimum of 83 feet at West Burnt River (Section 69-9), to a maximum of 480 feet at the headwaters of Eleven Mile Creek (Section 68-16). The thickness range of the main and typical facies of the formation excluding the Ducette Member is between 40 feet at West Burnt River and 190 feet at Eleven Mile Creek.

The contact of the Baldonnel with the overlying Pardonet Formation ranges from conformable and distinct, to gradational. North of Hart Highway the contact is sharp and distinct, and is placed at the top of the light to medium grey-weathering carbonates of the Baldonnel Formation which underlie finely laminated, thin-bedded, carbonaceous-argillaceous limestones of the Pardonet Formation. South of Hart Highway the contact is gradational, and must be placed within a stratigraphic interval where the limestones of the Baldonnel Formation grade into the crenulated laminated limestones of the Pardonet Formation.

In the report area only Spiriferina abichi and Lima sp. were collected from the formation. These fossils are considered to be part of the Mysidioptera poyana faunal zone, (Tozer, 1967) of Karnian age.

Ducette Member

Between Peace and Sukunka Rivers, the lower part of the Baldonnel Formation consists of a distinctive dark grey-brown-weathering sequence of strata called the Ducette Member (Gibson, in preparation).

The Ducette Member consists of dark grey-brown, carbonaceous-argillaceous, siltstones, very fine-grained sandstones, limestones, and minor dolomites. The siltstones and sandstones are quartzose, very dolomitic to calcareous, dark grey to greyish brown, thin- to thick-bedded, and commonly display fine, regular to wavy laminations and colour banding. The limestones and minor dolomites, usually restricted to the lower half of the member are dark grey, slightly quartzose, carbonaceous-argillaceous, and finely crystalline to bioclastic. The member varies in thickness from a minimum of 43 feet west of Burnt River (Section 69-9), to a maximum of 390 feet near Clearwater Lake (Section 68-12) north of Hart Highway.

The contact between the Ducette Member and the main and typical facies of the Baldonnel Formation is gradational. It is placed within a small interval, where the dark grey-brown-weathering siltstones and silty limestones grade into more resistant and lighter-weathering limestones and dolomites of the typical lithology of the Baldonnel Formation.

Fossils are scarce. Near Clearwater Lake (Sections 68-12, 69-3), undetermined rhynchonellid brachiopods were collected.

Pardonet Formation

The Pardonet Formation consists of dark grey- to dark brownish grey-weathering, carbonaceous-argillaceous, limestones, silty limestones, calcareous and dolomitic siltstones, and minor shale. The limestone is commonly quartzose and dolomitic, finely crystalline to bioclastic, and emits a fetid sulphurous odour upon fracture. The bioclastic limestone consists of whole and fragmented pelecypod and brachiopod shells, which often form dense coquina interbeds. The limestone is thin- to medium-bedded, and weathers shaly to flaggy, commonly forming recessive, partially covered intervals. The dark grey siltstones are thin- to thick-bedded, quartzose, carbonaceous-argillaceous, and are cemented by finely crystalline calcite and minor dolomite. The formation ranges in thickness from a maximum of 450 feet near the headwaters of Eleven Mile Creek (Section 68-16), to a minimum measured thickness of 270 feet west of Burnt River (Section 69-9). The latter value is incomplete; however, only a minor amount of the formation is considered to be absent.

The Pardonet Formation north of Hart Highway is overlain, probably disconformably, by the Bocock Formation. The contact is placed where dark grey-brown, recessive limestones and minor siltstones of the Pardonet Formation, change abruptly into very light grey- to white-weathering limestones of the Bocock Formation. At Pine River Bridge crossing on Hart Highway, the Pardonet Formation is overlain unconformably by the Jurassic Fernie Formation.

The Pardonet Formation is one of the most fossiliferous units in the Triassic succession. However, in the Peace-Sukunka River region only a few collections were obtained which include *Guembelites* cf. *jandianus* Mojsisovics, *Malayites* cf. *dawsoni* McLearn, *Sirenites* sp., *Halobia* sp., *Monotis subcircularis* Gabb, and *Monotis* cf. *ochotica densestriata* Teller. These fossils indicate an age ranging from Early to Late Norian.

Bocock Formation

The Bocock Formation, a newly recognized stratigraphic unit (Gibson, in preparation), outcrops only in the area between Peace River and Hart Highway. It consists of a very resistant, light grey- to buff-weathering, medium- to thick-bedded sequence of limestone. The limestone is medium to medium light grey, aphanocrystalline to coarsely crystalline to bioclastic, and at some localities is slightly dolomitic to quartzose. The bioclastic limestone is restricted mainly to the most eastern exposures, and consists of fragmented pelecypod and brachiopod shells, and crinoid columnals, with the latter constituent forming medium to thick beds of encrinite with good intergranular porosity. The bioclastic limestones are sometimes permeated by black vitreous pyrobitumen residues, and emit a fetid odour upon fracture. The Bocock Formation ranges in measured thickness from a minimum of 65 feet near Bocock Peak (Section 69-5), to a maximum of 208 feet at the type locality on the east fork of Carbon Creek. The formation has not been observed north of Peace River, nor south of Hart Highway. At Pine River Bridge crossing, the formation is absent, and the Pardonet Formation is overlain by the Fernie Formation. The contact with the Jurassic is very distinct and probably unconformable. Near Eleven Mile Creek this contact was observed to have an estimated relief of 25 feet with the Fernie Formation.

The exact age of the Bocock Formation is unknown, because of the lack of diagnostic and identifiable fossils. The lithologic similarity to limestones and dolomites of the Baldonnel Formation, and the contrast between the dark weathering strata of the Jurassic System, suggest that the formation is part of the Triassic rock sequence, and possibly Late Norian or younger in age.

PINE PASS-SUKUNKA RIVER AREA

SULPHUR MOUNTAIN FORMATION

The Lower and Middle Triassic map units recognized in the Peace River-Pine Pass area cannot be extended with any degree of confidence into the area south of the Hart Highway, because of a facies change. Other more distinctive units are recognized which do not coincide with unit boundaries recognized north of the highway. These distinctive units are similar to those recognized in an earlier investigation in the Jasper-Banff area of Alberta (Gibson, 1968). The nomenclature of the southern rock units will, therefore, be applied to the Lower and Middle Triassic succession in the Pine Pass-Sukunka River area.

The Sulphur Mountain Formation in the Pine Pass-Sukunka River area is divided into three members which are in ascending order, the Vega-Phroso Member, the Whistler Member, and the Llama Member. The formation, up to 1,800 feet thick, comprises a relatively thick sequence of dark grey to orange-brown-weathering, dolomitic to calcareous, carbonaceous-argillaceous siltstones, bioclastic limestones, and minor silty shales and dolomites, and very fine- to fine-grained quartz sandstones. The formation unconformably overlies chert and cherty limestones of the Fantasque and Prophet Formations, and is overlain gradationally by light grey- to buff-weathering dolomitic siltstones and sandstones, silty dolomites and limestones of the Charlie Lake Formation.

Vega-Phroso Member

The name Vega-Phroso is a combination of two names representing two distinct Lower Triassic members found throughout the Jasper area of Alberta. However, in the Hart Highway-Sukunka River area, the gradational and interfingering nature of the contact between the two facies prevents a meaningful subdivision into mappable units. Therefore, the two facies have been combined and described as one member of the Sulphur Mountain Formation.

The Vega-Phroso Member consists of thin- to medium-bedded, shaly- to flaggy-weathering, carbonaceous-argillaceous, dolomitic to calcareous siltstones and minor silty shales and bioclastic limestones. The siltstones and shales are dark grey, and weather to a characteristic dull brownish grey. They are quartzose, and cemented by finely crystalline dolomite in the lower part of the succession, and by finely crystalline calcite and dolomite in the upper part of the member. The bioclastic limestones, consisting of slightly dolomitized and silicified fragmented pelecypod shells, occur as lenticular interbeds in the lower third of the member. The Vega-Phroso Member varies in thickness from a minimum of 394 feet at Watson Peak and Lean-to Creek (Sections 69-10, 69-8), to a maximum of 464 feet at Brazion Creek (Section 69-12).

The member unconformably overlies chert and cherty mudstones of the Permian Fantasque Formation in most of the area. However, at Brazion Creek (Section 69-12), the Triassic unconformably overlies cherty limestones of the Mississippian Prophet Formation. The contact with the overlying Whistler Member is generally conformable and distinct. It is placed where resistant, brownish grey-weathering siltstones of the Vega-Phroso facies change abruptly into recessive, dark grey siltstones of the Whistler Member. At both locations in the Murray Range to the west, the contact is gradational, ranging over an interval of 5 to 10 feet.

The Vega-Phroso Member contains few identifiable fossils. Collected from the lower third (Phroso facies) of the member were *Posidonia mimer* Oeberg, *Posidonia aranea* Tozer, *Arctoceras* sp., *Xenoceltites* sp., and *Paranorites* sp., all of which suggest ages ranging from Early Triassic Dienerian to Spathian.

Whistler Member

The Whistler Member comprises a dark grey, recessive sequence of very carbonaceous-argillaceous, calcareous and dolomitic siltstone, silty shale, and silty carbonaceous limestone. The carbonate cement of the siltstone increases in amount westward, such that some of the calcareous and dolomitic siltstones of the Whistler Member in the Murray Range may be actually classed as very silty limestones and dolomites. At some sections the siltstones in the lower 1 to 2 feet of the member are slightly phosphatic containing black, angular and well rounded grains and clasts of phosphate, up to 2 inches in diameter. The quartzose and sometimes dolomitic limestones are finely crystalline to bioclastic, with the latter consisting of thin, wavy to crenulated beds of compressed, whole and fragmented pelecypods and ammonites. Some of the limestone interbeds contain thin fractures and small vugs, lined and filled with black, vitreous, pyrobitumen matter. The Whistler Member ranges in thickness from a minimum of 280 feet at Lean-to Creek in the Murray Range, to a maximum of 280 feet at Watson Peak east of Burnt River (Fig. 1).

The Whistler Member is overlain by the Llama Member. This contact is gradational and is drawn where the dark grey recessive, thin-bedded siltstones of the Whistler Member, grade into thick-bedded, massive orange-brown-weathering siltstones of the Llama Member. This contact east of Burnt River is distinct and easily placed; however, along the Murray Range to the west, it is less distinct, and must be placed within a stratigraphic interval as much as 25 feet thick.

Fossils within the Whistler Member, although abundant are poorly preserved and generally indeterminate. At Lean-to Creek and Watson Peak (Sections 69-8, 69-10), Parapopanoceras selwyni McLearn, Gymnotoceras sp., Longobardites cf. canadensis McLearn, and Daonella sp. (americana or dubia) were collected, and indicate a Middle Triassic Anisian age.

Llama Member

The upper member of the Sulphur Mountain Formation consists of a thick, resistant, orange-brown to brownish grey-weathering sequence of siltstones, limestones, with some very fine- to fine-grained sandstones. The siltstones are very dolomitic to calcareous, slightly carbonaceous-argillaceous, and form the predominant lithology of the member. Limestone, which occurs as thin to medium, lenticular interbeds throughout the upper half of the member, is medium to light grey-weathering, quartzose, sometimes carbonaceous-argillaceous, and is very finely crystalline to bioclastic. The bioclastic limestone consists of whole and fragmented pelecypod and/or brachiopod shells, and crinoid columnals. The orange-brown-weathering sandstones are very quartzose, and cemented by finely crystalline dolomite and minor calcite. They are well indurated, medium- to thick-bedded, and are commonly found in the upper 200 feet of the member. The Llama Member is completely exposed only at West Burnt River (Section 69-9), and attains a thickness of 1,170 feet.

The contact with the overlying Charlie Lake Formation is gradational, and readily apparent at localities examined south of Hart Highway. It is drawn where the orange-brown-weathering dolomitic sandstones and siltstones of the upper Llama Member grade into yellowish grey-weathering, calcareous and dolomitic fine- to medium-grained sandstones, dolomites, limestones, and calcareous and dolomitic intraformational or solution breccias of the Charlie Lake Formation.

The Llama Member, the most fossiliferous facies of the Sulphur Mountain Formation, contains the following fauna: Progonoceratites poseidon Tozer, Protrachyceras sikanianum McLearn, Silenticeras sp., Megaphyllites sp., Lobites sp., Arcestes sp., Hungarites sp., Asklepioceras sp., Paratrachyceras sutherlandi McLearn, Daxatina canadensis McLearn, Nathorstites mcconnelli (Whiteaves), Daonella cf. longobardica Kittl, Daonella cf. subarctica Popov, Daonella nitanae McLearn, and Daonella elegans McLearn. The fauna ranges in age from Early to Late Ladinian.

CORRELATION

The correlation of Triassic strata in Western Canada has previously been outlined and discussed in variable detail by McLearn and Kindle (1950), Hunt and Ratcliffe (1959), Colquhoun (1960, 1961), Armitage (1962), and Barss et al., (1964). The following brief discussion will emphasize only the equivalence of stratigraphic units described in this paper, and how they correlate with units in the subsurface Peace River Plains. For a more complete and comprehensive discussion of Triassic correlation between the Peace River-Pine Pass area, and other regions of northeastern British Columbia and Western Alberta, the reader is referred to a Geological Survey of Canada Paper by the writer, to be published in early 1971. The following correlation is based on relative stratigraphic position, fossil content, and lithologic similarity.

The Grayling Formation in the Peace River-Pine Pass area is lithologically equivalent to the Phroso facies of the Vega-Phroso Member of the Sulphur Mountain Formation south of Hart Highway. In the subsurface the Grayling Formation is equivalent to the lower third of the Montney Formation as illustrated in Figure 2.

The Toad Formation as defined and used by the writer in the Peace River-Pine Pass region correlates with the upper two thirds of the Vega-Phroso Member, all of the Whistler Member and the lower third of the Llama Member of the Pine Pass-Sukunka River region. The Toad Formation is also equivalent to the upper two thirds of the Montney Formation and part of the Doig Formation in the subsurface of the Plains. The Vega-Phroso Member as shown in Figure 2 is equivalent to the subsurface Montney Formation. This stratigraphic equivalence is only apparent in the region south of Hart Highway, and is based on the occurrence of a distinctive phosphatic pebble horizon, found at the contact between the Whistler and Vega-Phroso Members of the Sulphur Mountain Formation and the Montney-Doig Formations in the subsurface. The Whistler Member and lower two thirds of the Llama Member correlate with the Doig Formation in the subsurface Peace River Plains. This relationship is based on relative stratigraphic position and lithologic similarity, as the fossil control between the two regions is poor.

The Liard Formation of the Peace River-Pine Pass region correlates with the upper two thirds of the Llama Member in the Foothills of the Pine Pass-Sukunka River region, and the upper third of the Doig Formation, and all of the Halfway Formation in the subsurface Peace River Plains.

The Upper Triassic Charlie Lake, Baldonnel, and Pardonet Formations can be recognized throughout the Foothills of the Peace-Sukunka River area, and most of the subsurface Peace River Plains. The Pardonet Formation appears to have a restricted distribution in the subsurface, being limited to the western part of the subsurface Plains. The correlation of these three formations with the members of the Whitehorse Formation in the Jasper area is uncertain until more field work has been undertaken south of Sukunka River. However, the Brewster Member near Smoky River contains fossils representative of the *Mysidioptera poyana* faunal zone (Gibson, 1968). In the Peace River area, the same fossils have been found in the Baldonnel Formation.

The Bocock Formation was recognized only in the Peace River-Pine Pass area, and has no known correlative in other regions of northeastern British Columbia or western Alberta.

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STRUCTURAL GEOLOGY, PINE RIVER AREA OF THE ROCKY MOUNTAIN FOOTHILLS

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The Rocky Mountain Foothills of the Pine River area are 37 miles wide, from Mount Wabi to Solitude Mountain. They expose strata of Triassic (Karnian, and older beds) to Late Cretaceous (Cenomanian). Older strata are uplifted westwards, and the scale of deformation increases from east to west.

The Foothills can be divided into two parts: the Outer (Eastern) Foothills, and the Inner (Western) Foothills. The divisions represent different styles of Laramide tectonism, and are reflected in land forms and terrain.

PHYSIOGRAPHY

In the east, the plateau masses and the wide flat floor of the Pine River dominate the landscape. The physiographic elements are the plateau belts along the structural trend, mesas formed on flat-lying strata, and escarpments and tributary valleys along the anticlines.

West of Fisher Creek, the relief increases and the physiography alters to hill-and-mountain ranges and alternating valleys of northwest trend. The ranges are developed on steep dipping beds in anticlines and overthrusts. They attain elevations of 5,500 to 7,000 feet, comparable to the summit levels of the Rocky Mountains about the Pine Pass.

The Pine Valley was over-deepened by glaciation, or by down cutting in the late Tertiary, or by these combined mechanisms. Glacial erratics are present to 6,000 feet elevation, and cirques occur above timberline, about 4,750 feet elevation. A lake filled the Pine Valley to about the present elevation of 2,450 feet on the retreat of the Cordilleran ice, and accumulated clays, varved clays, silts and sands. The bedrock floor of the pre-glacial valley stands at 930 feet elevation or less at Commotion Creek. In the final stages of deglaciation, the old course of the Pine was changed from north-northeast to the present course, southwards from Chetwynd to the confluence with the Sukunka River. The underfit valley of Centurion Creek, along the Moberly-Chetwynd road, contained the pre-glacial course of the Pine River.

THE OUTER FOOTHILLS

The Outer Foothills contain broad, shallow synclines of simple form, alternating with narrow anticlinal belts. The synclines are 5 to 8 miles wide. Their strata are relatively undeformed, and about flat-lying in wide axial zones. Synclines are downthrown in step-wise form from west to east. Anticlines are 1 to 2 miles wide, folded in concentric forms of low amplitude. Their folding is asymetric with axial planes dipping west, and with thrust faults breaking the east flank.

THE INNER FOOTHILLS

The Inner Foothills contain a series of closely folded anticlines and synclines, reverse faults, and a few large thrusts. Fold amplitudes of anticlines and synclines are about equal, and greatly exceed those of the Outer Foothills. Fold forms are angular and concentric, and modified by faulting; asymetry is common, and axial planes dip west. Structures in the west part of the Inner Foothills assume a pattern: (1) thrust, or thrust faulted anticline: (2) closely folded syncline: (3) a rear anticline forming the footwall of the succeeding thrust, or fault on the west.

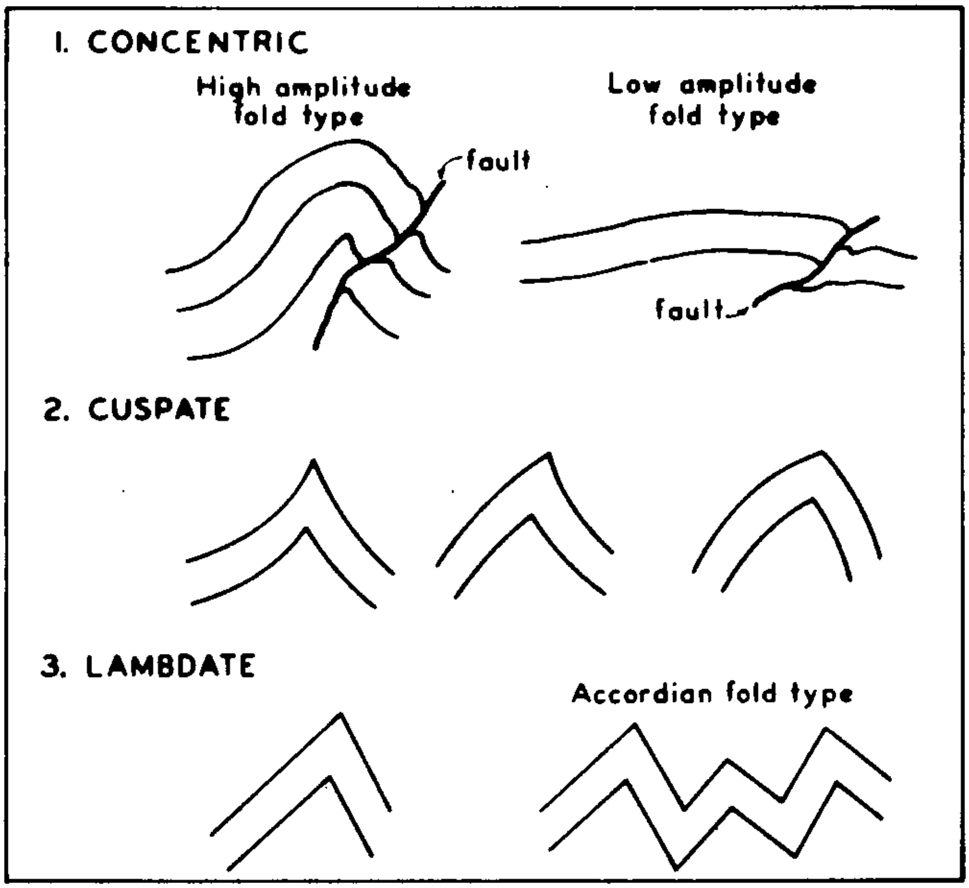
The major thrusts, the Pyramis thrust, and the Solitude thrust marking the boundary with the Rocky Mountains, have stratigraphic displacements more than 3,000 feet and extensive translations.

Structural Relations of the Inner and Outer Foothills

Structural patterns of the Outer and Inner Foothills are distinct. Locally, they are separable along the Pine River anticline (Crassier to Fisher Creek). In adjacent areas, the westerly synclines of the Outer Foothills are partly modified by folding and faulting of the Inner Foothills type, eg. the Carbon syncline north of the Moberly River, and the Chamberlain syncline at the Sukunka River. Anticlines of the Outer Foothills north of the Moberly River include compound, concentric, and angular folds of high amplitude, and in one instance, a thrust (the McAllister thrust) replacing the syncline.

The essential structure of the Outer Foothills, the little deformed synclines, major deformation restricted to the anticlines, dissimilar fold amplitudes in synclines and anticlines, and the step form depression of synclinal strata, is characteristic of orogenic forelands. A similar pattern of structure, but with reduced vertical displacements continues into the west margin of the Plains. Structures of the Outer Foothills can be ascribed to faulting and displacements of the basement; there is no contrary or conclusive evidence.

Structures of the Inner Foothills indicate major lateral compression and uplift, and widespread dislocation of the sedimentary cover. They belong to the orogenic zone of the Rocky Mountains and Foothills.



CLASSES OF PARALLEL FOLD FORMS

Figure 1

FOLD FORMS

Folding in the Foothills is of parallel tvpe, and expressed in concentric and angular forms (Figure 1).

Concentric folds of low and high amplitude forms are distinguished by θ, the dip of strata at the point of contraflexure between anticline and syncline, and by related parameters for faulted parts of structure.

Low amplitude concentric folds have θ less than 15^{o}, and in the Pine Valley are confined to the Outer Foothills. The Commotion anticline typifies this class. Its characteristics are: a limited fold compression; and disharmonic structure with the overlying sector of the anticline separated and extended over the core and fold centre.

High amplitude concentric folds have θ more than 15^{o}; they occur in the Inner Foothills, and in parts of the Outer Foothills outside the Pine Valley. The folding is mostly continuous about relatively shallow centres, and the west limbs are faulted. Box form anticlines, eg. the Big Boulder anticline, represent an extreme form of this fold class.

Angular folds are common in the Foothills, and occur in the west part of the Pine Valley. They include cuspate, lambdate, and serial lambdate forms (= zig-zag = accordion folds). The general term angular describes folds for which the distinction lambdate, cuspate, is uncertain. Angular folds have high fold amplitude and great vertical extent in large structures - the Bickford anticline is an example. Structures in the Peace, Moberly, and Pine River areas indicate progressive sequences in the development and replacement of concentric folds by angular folds. Faults in angular folds are parallel, and adjacent or close to the axial planes. Lambdate folds seem less common, and occur in fault zones, and above thrusts and detachment planes, eg. minor folds in the Bickford anticline, and subordinate folds in the east limb of the Coyote syncline.

TECTONIC ENVIRONMENT

The Rocky Mountains and Foothills form a continuous system with different alignment of their southern and northern divisions. These divisions north and south of Latitudes 56°00' and 54°15' are joined and hinged about the Foothills of the Peace, Moberly, and Pine River areas in the foreland, and about Mount Averil in the Rocky Mountain Trench. The hinge reflects the influence of a Pre-Laramide geofracture of northeast trend.

The old geofracture followed the axis of the Peace River embayment, which originated in early Carboniferous time after the subsidence of the Peace River arch. The embayment trended northeast, transversely to the former miogeosyncline of the Rocky Mountains. The Peace River embayment underwent differential subsidence and sedimentation to the last stratigraphic record in the Cenomanian stage. It contained and preserved about twice the thickness of sediments occurring in the adjacent margins on the cratonic shelf.

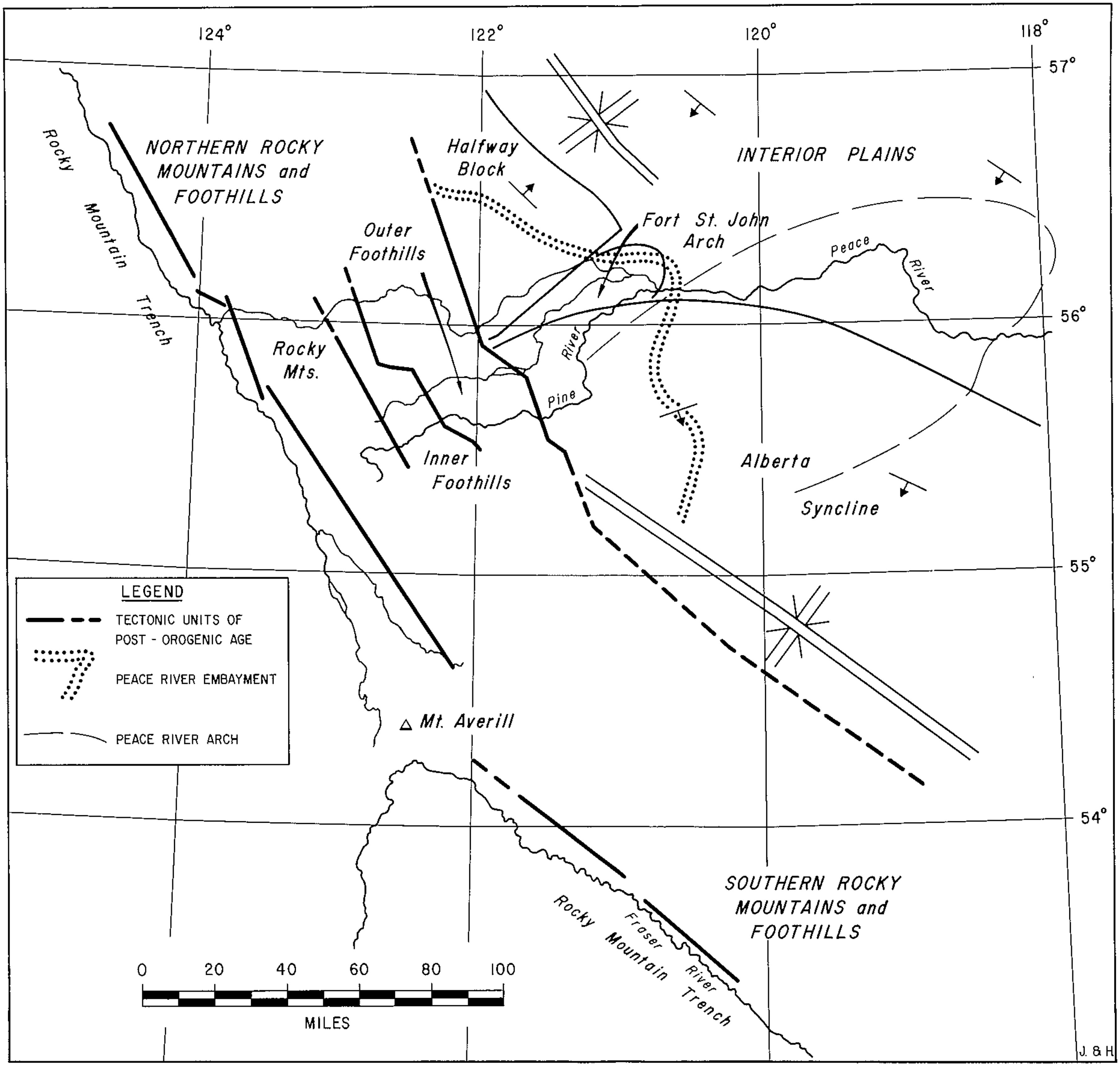


FIGURE 2 TECTONIC FRAMEWORK OF THE PINE RIVER AREA

The major tectonic elements of the orogenic foreland in the Plains, the Halfway block north of the Peace River, and the Alberta syncline to the south, were divided along the axis of the former Peace River embayment. Laramide structures were impressed on these foreland units in the Outer Foothills and in the west margin of the Plains.

Structures of the Outer Foothills, both anticlines and synclines, plunge southeast. The plunge is a regional feature, representing a tilt or depression averaging about 125 feet per mile between the Peace and the Pine Valleys (measurements on the base of the Fort St. John Group). The regional depression, reconstructed to a relict preorogenic surface, corresponds to the terminal closure and southeast plunge of the Alberta syncline.

Major structures trending S 18 to 24°E, a characteristic trend of the Northern Rocky Mountains and Foothills, cross the extension of the Alberta syncline in the Outer Foothills of the Pine River area. Structures in the Inner Foothills here have trends in the range S 28 to 42°E; these trends are common to adjacent parts of the Northern and Southern Rocky Mountains and Foothills.

ILLUSTRATIONS

Figure 1. Classes of parallel fold forms.

Figure 2. Tectonic Framework of the Pine River Area.

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PALEOZOIC STRATIGRAPHY OF PINE PASS, NORTHEASTERN BRITISH COLUMBIA

by G.C. Taylor and E.W. Bamber[1]

ABSTRACT

The Paleozoic succession of the Pine Pass area consists of shallow marine carbonates, sandstones, and shales of Cambrian, Ordovician, Devonian, Early Carboniferous (Mississippian), and Permian age. Several major facies changes and unconformities occur within this sequence, which is intermediate in nature between those to the north and south, and is therefore important for the establishment of regional correlations between the Jasper area and the northern Rocky Mountains and Foothills.

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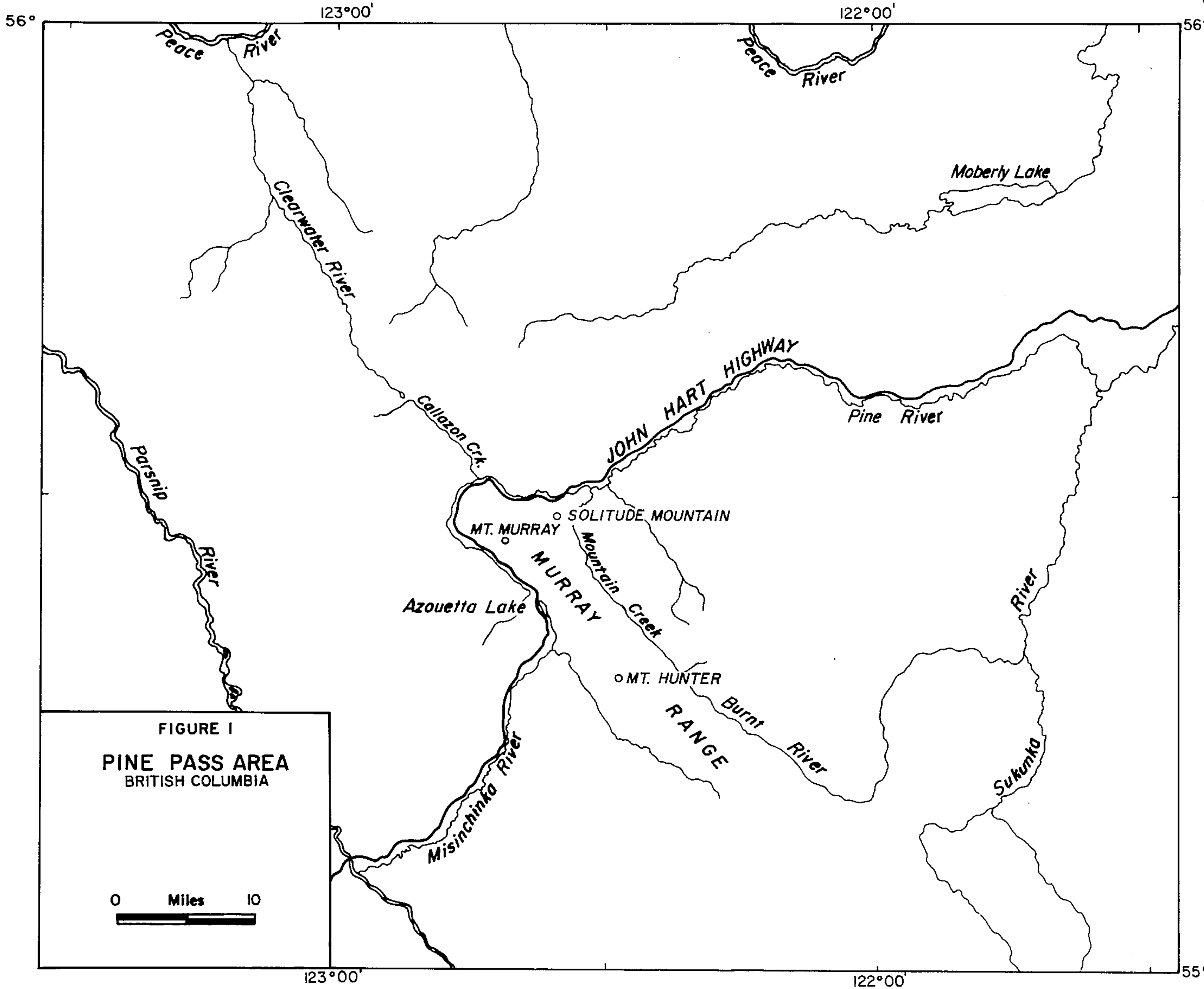

FIGURE I

PINE PASS AREA
BRITISH COLUMBIA

INTRODUCTION

Within the Paleozoic succession of the Pine Pass area there are several stratigraphic units typical of the more northerly part of northeastern British Columbia, and others that are typical of the Rocky Mountains and Foothills of the Jasper region (Fig. 2). The area displays several major unconformities and facies changes, thus providing an important link between the northern and southern successions. This summary paper is based mainly on field studies by the authors during the summers of 1968 and 1969, carried out as part of an extensive reconnaissance study by the Geological Survey of Canada in the Rocky Mountains and adjacent Plains of northern British Columbia. The Cambrian to Devonian succession was dealt with by G.C. Taylor, and the Carboniferous and Permian , by E. W. Bamber. Previous work in the Pine Pass and adjacent areas, which is incorporated in the paper, includes the studies by Muller (1961, 1967), on the Pine Pass map-area; Norford (1965), on the Lower Paleozoic succession at Mount Hunter and near the Clearwater River; Irish (1970) on the Halfway River map-area to the north; Slind and Perkins (1966), on the Lower Paleozoic between Jasper and the Pine River; and McGugan (1967), on the Permian of the Peace River area.

STRATIGRAPHY

Cambrian

The Cambrian succession of the Pine Pass area has been subdivided into three mappable units, which approximately correspond to the Lower, Middle and Upper Cambrian. Within this succession seven formations are recognized, following the usage of Slind and Perkins (1966); the Lower Cambrian Gog Group consisting of the McNaughton, Mural, and Mahto Formations; the Middle Cambrian Tatei-Chetang, Titkana, and Arctomys Formations; and the Upper Cambrian Lynx Formation.

Lower Cambrian

Gog Group

Quartz sandstone and minor dolomitic units of the Gog Group form a prominent, resistant-weathering map unit overlying the Precambrian Miette argillites along the east flank of the Murray Range above the Murray Thrust. At Mount Murray the total thickness of the group is only 530 feet and no subdivision of the sequence was attempted. Sixteen miles south, at Mt. Hunter (Fig. 1), a thickness of 1,790 feet was measured for the Gog Group, with 1,065 feet assigned to the McNaughton Formation, 120 to the Mural, and 605 feet to the Mahto Formation.

The McNaughton Formation consists of orthoquartzite, quartz sandstones, and dolomitic, quartz sandstones with minor shale, dolomite, and conglomerate beds. These rocks are of very shallow water, possibly fluvial origin. The quartz grains are generally in the fine to medium

TABLE OF FORMATIONS

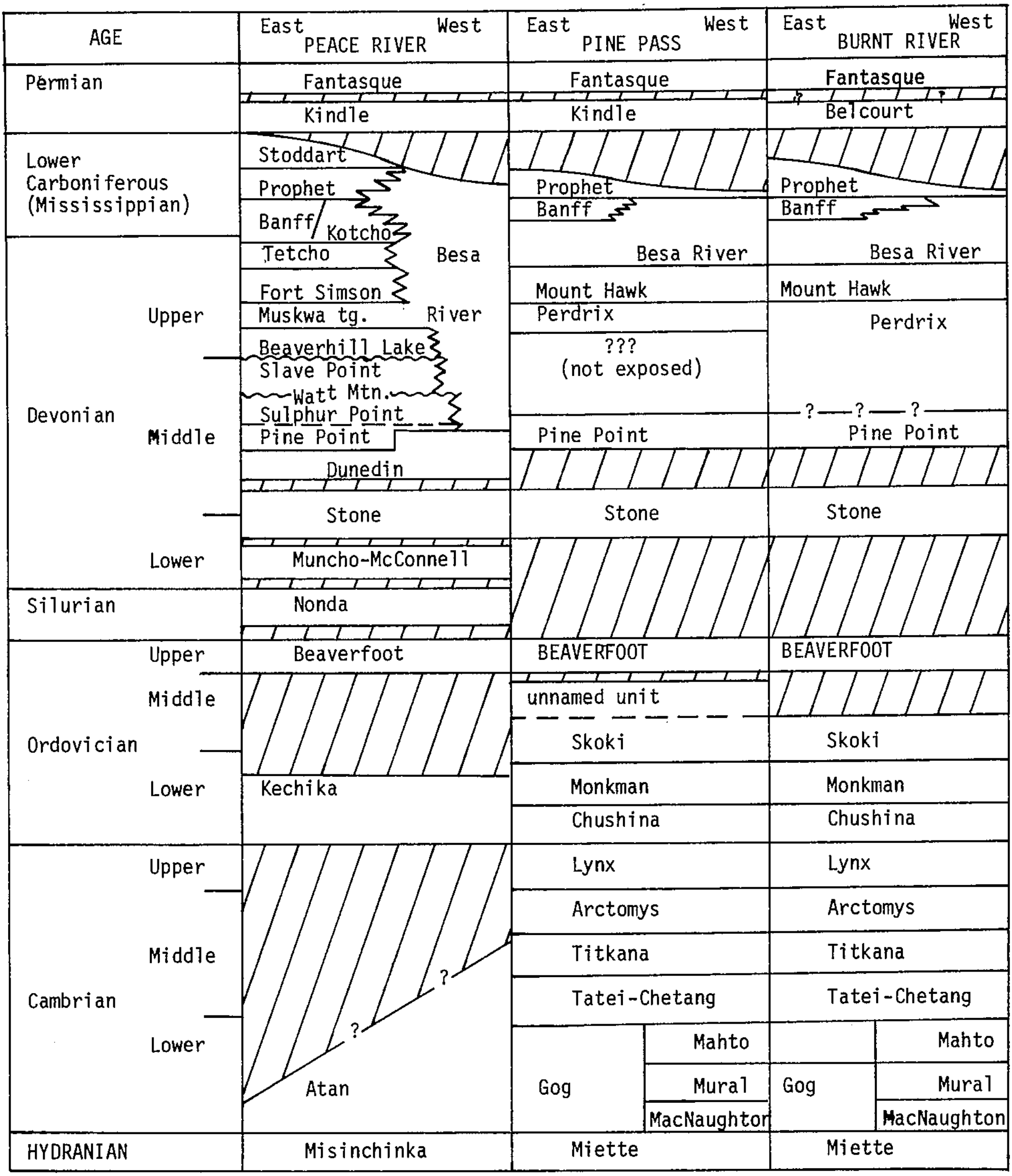

Figure 2.

size range and are well rounded. Locally the quartz sandstones may contain up to 20% feldspar, which is dominantly microcline. Glauconite is the most abundant accessory mineral. The contact of the McNaughton Formation with the underlying Miette phyllite is sharp and unconformable. No fossils were found in the McNaughton.

The Mural Formation consists of dolomite with minor red and green dolomitic and arenaceous shales, and represents the first definite marine sedimentation in the area. The contact with the underlying McNaughton Formation is sharp and apparently conformable. No fossils were found in the Mural. Lower Cambrian trilobites occur 6 miles west of Mount Hunter in a dolomite unit described by Street (1966) and considered here to be representative of the Mural Formation.

The Mahto Formation is similar in lithology to the McNaughton Formation, but is commonly somewhat finer grained, and is distinguished by the presence of minor purple and maroon quartzite and shale. Feldspar is generally absent from the Mahto, and few accessory minerals are present. Crossbedding, desiccation cracks, and ripple marks are common, as are Scolithus tubes, which occur in the fine-grained rocks. The contact with the overlying Tetei-Chetang Formation is conformable and gradational. No fossils were found in the Mahto Formation.

Middle Cambrian

A succession of vari-colored dolomites and minor shales of very shallow marine origin, has been assigned to the Middle Cambrian mainly because of stratigraphic position. No fossils have been collected from these rocks. The unit forms a distinctive and valuable marker for mapping purposes occurring above the Gog quartzites in the hanging wall of the Murray Thrust and in several minor splays to the west. Three formations are present and can be distinguished mainly on the basis of color difference - the red-weathering Tatei-Chetang Formation, the grey-weathering Titkana Formation, and the light yellowish brown-weathering Arctomys Formation. All these formations thicken rapidly in a southerly direction.

The Tatei-Chetang Formation consists of about 290 feet of white and maroon dolomites and dolomitic shales. The dolomites are finely crystalline, and locally sandy and/or cherty. Sedimentary structures are prominent and include desiccation cracks, ripple marks, rain drop impressions, and salt crystal casts, all indicating deposition in very shallow water.

The Titkana Formation is represented by approximately 105 feet of light and dark grey, fine to medium crystalline dolomite and limestone, with local development of chert lenses. The contact with the overlying Arctomys Formation is sharp and conformable.

The Arctomys Formation consists of 200 feet of silty, light yellowish brown-weathering, finely crystalline dolomite with thin partings and beds of red and black shale. The contact of the Arctomys with the overlying Lynx Formation is sharp and possibly disconformable.

Upper Cambrian

The Lynx Formation at Mt. Hunter consists of 1,435 feet of dark and medium grey, medium crystalline dolomite and limestone. Minor limestone-pebble conglomerates are common near the base and the top of the formation. The lower part of the formation is predominantly dolomite, in which pisolitic and possibly oolitic textures are preserved. This interval also contains thin, varve-like laminations of dolomite and silty dolomite. In the upper part of the formation, the predominant rock-type is limestone, which occurs mainly as thick, nodular units separated by thin, coarse-grained beds containing macerated trilobite debris. The carbonates of the Lynx apparently represent marine sedimentation under slightly deeper marine conditions than had previously existed in the area during Cambrian time. The contact with the overlying Chushina Formation is sharp and apparently conformable.

Ordovician

Over 4,600 feet of strata are included in the Ordovician succession of the Pine Pass area. The terminology extended into the area from the south by Slind and Perkins (1966) has been applied, with minor changes, in this paper. North of the Pine Pass the structural configuration of the Rocky Mountains is such that there is a large area in which Ordovician rocks are not exposed. Further north where Ordovician strata are again exposed, immediately south of Peace River, the succession of formations described by Slind and Perkins (ibid), can no longer be recognized, and the succession is better ascribed to the Kechika Group.

The Chushina Formation at Mount Hunter is 1,800 feet thick and consists mainly of argillaceous limestones of shallow water origin. At the base of the Formation there is a color change from the more somber greys of the underlying Lynx Formation to the silver grey of the lower limy shales and argillaceous limestones of the Chushina. This contact is marked by an abrupt step in the weathering profile caused by the recessive nature of the lower part of the Chushina, as opposed to the more resistant nature of the Lynx Formation. The middle part of the Chushina Formation is more resistant and weathers light grey, whereas the upper part of the Formation is strongly resistant and displays a distinctive brown weathering aspect. The Chushina Formation is of Early Canadian age. Its upper contact with the overlying Monkman Quartzite is sharp, but apparently conformable.

The Monkman Quartzite is 1,350 feet thick near Pine Pass and apparently thins toward the south. It consists of light and medium grey-weathering orthoquartzite and dolomitic quartz sandstone. The sand grains are fine-to medium-grained and well rounded. Bedding is generally massive to indistinct, although local units are well bedded, with some cross-bedding, and local channelling.

No fossils other than Scolithus tubes and indeterminate brachiopods have been found in the Monkman.

The Skoki Formation was deposited under very shallow water conditions and consists of 700 feet of finely crystalline, medium and dark grey dolomites with minor argillaceous and sandy dolomite beds in the lower part of the formation. Thick pisolitic beds and rare desiccation conglomerate beds occur locally.

Fossils of early Middle Ordovician (Whiterock) age have been identified from the Skoki Formation.

Unnamed quartzite-dolomite unit. The usage by Slind and Perkins (1966) of the Skoki Formation to include all rocks lying between the Monkman Quartzite and the Beaverfoot Formations represents an expansion of its application in the type area (Norford, 1969). In the Mount Hunter section approximately 120 feet of white orthoquartzite with about an equal amount of very dark grey, argillaceous dolomite overlies the typical Skoki succession with apparent conformity. The stratigraphic relationships of this unit are not precisely known. It may equate with the upper member of the Skoki of Slind and Perkins (1966, p. 459), or it may be a new unit that is locally preserved beneath the sub-Beaverfoot unconformity. No fossils were obtained from this unit.

The Beaverfoot Formation consists of about 560 feet of monotonous, medium and dark grey, fine and medium crystalline cherty dolomites. The Formation weathers dark grey, and is resistant. It stands out in strong contrast to the light grey-weathering Skoki Formation below, and the tan-weathering Stone Formation above. The Beaverfoot Formation is of relatively open-marine origin, and contains a diversified, silicified fauna of solitary and colonial corals, nautiloids, gastropods, and brachiopods of Richmond age. It overlies the Skoki Formation with marked disconformity, truncating that formation in a southerly direction.

Devonian

Two formations of Middle Devonian and three of Late Devonian age are recognized in the Pine Pass area. The Middle Devonian Stone and Pine Point Formations apparently onlap the western edge of Peace River Arch, whereas the Late Devonian Mount Hawk Formation apparently extends from the southeast across the Arch and into the margin of the Besa River basinal facies to the northwest.

The Stone Formation consists of approximately 1,530 feet of very finely crystalline dolomites, sandy dolomites, and sandstones of very shallow marine to supratidal origin. Minor collapse breccias indicating the former presence of evaporites are common throughout the unit, as are floating sand grains. The formation thins rapidly to the south, mainly because of onlap, with only the upper members of the Formation being present near the headwater of Misinchinka River. In the Pine Pass area the Formation exhibits a very characteristic tan-weathering color. The Stone Formation rests with profound unconformity on the underlying Beaverfoot Formation. Locally the unconformity is evidenced by as much as 150 feet of well-rounded dolomitic sandstone and orthoquartzite at the base of the Formation. The Stone Formation lacks fossils in the Pine Pass area, as is the case with many very shallow water - to supratidal successions. The age of the formation is presumed to be Eifelian on the basis of outcrop continuity with dated sections north of Peace River.

The Pine Point Formation consists of approximately 1,000 feet of medium crystalline, very dark grey dolomites and limestones. Dolomitic sandstone, orthoquartzite, and red-weathering shales are locally common at the base of the formation. The formation exhibits a very dark grey weathering color and has a pronounced recessive interval near the base.

A significant unconformity marks the base of the Pine Point. Rocks equivalent to the Dunedin Formation of the northern areas are absent beneath this unconformity because of onlap onto the Peace River Arch.

Fossils are very common in the Pine Point Formation. *Stringocephalus* and *Amphipora* are the most characteristic. The Formation is of Givetian age.

The Perdrix Formation is not exposed in the immediate vicinity of Pine Pass because of structural complications. Its presence is presumed because of the occurrence of Mount Hawk carbonates immediately beneath the Murray Thrust at the John Hart Highway. The formation is exposed near the big bend of the Sukunka River (43 miles southeast of Pine Pass), where approximately 1,000 feet of dark grey-weathering shales overlie the Pine Point Formation and are in turn overlain by the Mount Hawk Formation.

The Mount Hawk Formation consists of fine-grained, argillaceous limestones that are exposed in the footwall of the Murray Thrust where it intersects the Hart Highway. A.E.H. Pedder (pers. comm.) has identified a typical Frasnian Mount Hawk fauna from this locality.

Carboniferous

The Carboniferous of Pine Pass is represented by a sequence of marine shale and carbonate rocks similar to that occurring in the more northerly part of the Foothills of northeastern British Columbia. It begins with the thick, non-calcareous, cherty mudstone and shale of the Besa River Formation, grades upward through the calcareous shale and argillaceous limestone of the Banff Formation into the fine-grained, silty, argillaceous limestone and dolomite of the lower Prophet Formation, and is capped by dolomite and skeletal limestone of the upper Prophet. This lithological succession represents a gradual change from open marine, relatively deep-water sedimentation during the Tournaisian (Early Mississippian) and early Visean (early Late Mississippian), to shoaling and carbonate bank development during the Middle and early Late Visean (Late Mississippian). Carboniferous rocks younger than early Late Visean are not found in Pine Pass. The Prophet Formation is disconformably overlain by Lower Permian rocks.

The Besa River Formation, which overlies the Frasnian Mount Hawk Formation, is a recessive, poorly exposed sequence of dark grey-weathering shale, mudstone, and chert. Its total thickness is unknown. A maximum of 450 feet is present in incomplete sections through the upper part of the formation on the east side of the Murray Range, southeast of Azouzetta Lake (Fig. 1). The Besa River underlies the broad valley lying immediately east of the Murray Range. On the east side of this valley, the Besa River grades upward into yellowish brown-weathering, calcareous shale and limestone of the Banff Formation. The Banff is absent on the east side of the valley, however, and its lateral equivalents are within the cherty shale and mudstone of the upper Besa River, which is directly overlain by cherty carbonates of the Prophet Formation in sections southeast of Pine Pass near the headwaters of Mountain Creek (Fig. 1). No diagnostic fossils have been found in the Besa River of this area. Upper Paleozoic plant fragments have been reported north of Pine Pass by Muller (1967, p. 80). The lower age limit of the formation is given by the occurrence of a Frasnian fauna in the underlying Mount Hawk Formation, and the age of overlying Banff Formation is probably Tournaisian (Early Mississippian). Thus, the Devonian-Carboniferous boundary apparently lies within the Besa River Formation.

The Banff Formation consists of several hundred feet of light yellowish brown-weathering, argillaceous, silty limestone and calcareous shale, which forms a recessive interval beneath the cliff-forming carbonates of the Prophet Formation in the mountain range extending southeast from Solitude Mountain (Fig. 1). It is gradational with both the underlying Besa River Formation and the overlying Prophet Formation, and passes westward into the upper part of the Besa River exposed on the east flank of the Murray Range (see above). Because of the poor exposure and unfossiliferous nature of the Banff in the area, neither the thickness nor the age of the formation has been determined. A Tournaisian age is indicated for the Banff of Pine Pass by the presence of late Tournaisian to early Visean (late Osage to early Meramec) corals in the lower part of the overlying Prophet Formation. To the southeast, the Banff can be traced into beds with a fauna of Early to Middle Tournaisian (late Kinderhook to early Osage) age.

The Prophet Formation is a sequence of resistant carbonates exposed mainly in the mountain range extending southeast of Solitude Mountain and northwest along the east side of Callazon Creek and Clearwater River (Fig. 1). In an incomplete section on the south side of the John Hart Highway at the north end of Solitude Mountain, approximately 400 feet of the formation is exposed (lower part covered). The lower 204 feet of this section is mainly moderately resistant, dark grey, silty, argillaceous limestone and dolomite containing scattered skeletal grains. Some lensing beds and nodules of dark grey chert and thin beds of calcareous shale are also present. In the overlying 111 feet, these fine-grained carbonates are interbedded with cliff-forming, light greyish brown, cherty, coarse-grained skeletal limestone. The upper 85 feet of the Prophet is dominated by resistant, light to medium grey, medium- to coarse-grained, dolomitic skeletal limestone showing well developed crossbedding in part. Numerous lenses and beds of chert, and minor micritic-skeletal limestone and dolomite are interbedded with the coarse-grained carbonates. The contact with the overlying, less resistant Kindle

Formation is sharp and disconformable, showing up to 3 feet of local relief. An irregular, nodular, discontinuous chert bed up to 2 inches thick marks this contact. The gradational change within the Prophet, from fine-grained, dark grey carbonates and shale at the base to coarse-grained skeletal limestone and dolomite at the top, is consistent along this range toward the northwest into the Peace River area and to the southeast approximately 35 miles, into the Burnt River area (Fig. 1). Beyond this, in the Dawson Creek and Monkman Pass map-sheets, massive skeletal limestone occurs at the base as well as at the top of the succession, and the name Rundle is applicable. The Prophet changes facies westward toward the east flank of the Murray Range, where chert and dolomite are dominant. There the lower half of the formation contains thick intervals of shale and mudstone typical of the underlying Besa River Formation. A similar facies change takes place across the Foothills between the Peace River and the Alaska Highway to the north (Bamber, et al., 1968, pp. 7, 8; Irish, 1970, p. 43), where the Prophet Formation passes laterally into the Besa River Formation by a westerly increase in chert, shale, and mudstone, and a decrease in skeletal and other limestones of shallow marine origin.

McGugan (1967, pp. 85-87) has shown that the Carboniferous clastic rocks (Stoddart Group) overlying the Prophet Formation north of Pine Pass are truncated toward the south beneath a sub-Permian unconformity, such that Permian rocks rest directly on the Prophet in Pine Pass. It can also be demonstrated that the upper part of the Prophet Formation has been truncated beneath the sub-Permian unconformity. Corals collected near the top of the Prophet in the Solitude Mountain section are slightly older than those occurring in the upper part of the formation in more easterly sections near the John Hart Highway, and in the area north of Pine Pass.

On the basis of coral faunas collected from several sections in Pine Pass, the Prophet Formation ranges in age from Late Tournaisian or Early Visean (late Osage or early Meramec) to early Late Visean (late Meramec).

Permian

The Permian sequence of Pine Pass consists of an upper chert unit, the Fantasque Formation, and a lower unit dominated by siltstone and limestone, the Kindle Formation. These units can be traced southward along the mountain front from their type areas in the southeastern Yukon (Fantasque Formation) and the Toad River area of British Columbia (Kindle Formation), through the Peace River area to Pine Pass (Bamber, et al. 1968, pp. 10-13; Irish, 1970, pp. 45-53). McGugan (1967) proposed the informal name Mount Greene beds for the rocks representing the Kindle Formation from Pine Pass north to the Peace River area, and extended the name Ranger Canyon Formation from the south to include the overlying chert unit. The chert unit, however, has been removed beneath the sub-Triassic unconformity between the Sukunka and Murray Rivers, an area between approximately 35 and

65 miles southeast of Pine Pass, and thus cannot be traced directly into the chert and sandstone of the Ranger Canyon Formation, which occurs further to the south in the central and southeastern part of the Monkman Pass map-sheet. Because of the physical continuity and lithologic similarity between the Permian units of Pine Pass and those to the north, the northern terms Kindle and Fantasque are applied in this paper.

The Kindle Formation, which disconformably overlies the Prophet Formation in Pine Pass, is a recessive, poorly exposed, greyish brown-weathering unit composed of medium to dark grey, very fine-grained argillaceous, silty limestone, calcareous siltstone, and minor calcareous shale. Its total thickness is unknown. An incomplete thickness of 159 feet is present in the Solitude Mountain section on the John Hart Highway, (Fig. 1), and McGugan (1967, p. 87) reported 40 feet of phosphatic siltstones and carbonates belonging to the lower part of the unit in a railway cut approximately 1¼ miles to the northeast. The Kindle thins to the southeast, along the east side of Mountain Creek and Burnt River, and is absent in sections approximately 30 miles southeast of Solitude Mountain. To the west, along the east flank of the Murray Range, the chert of the Fantasque is underlain by approximately 450 feet of fine-grained, cherty, dolomitic limestone with some beds of medium-to coarse-grained, skeletal limestone. This Permian carbonate unit rests disconformably on the Prophet Formation, contains Lower Permian brachiopods and fusulinid foraminifers, and appears to be the northern extension of the Belcourt Formation, which is well developed in the Monkman Pass map-sheet to the south. The stratigraphic relationships between the Belcourt and the Kindle Formation have not been established. A sparse, poorly preserved brachiopod fauna of Early Permian (Wolfcampian or Leonardian) age occurs in the Kindle of Pine Pass.

The Fantasque Formation is incompletely exposed in Pine Pass, where it consists of resistant, dark grey, bedded chert with minor lenses of cherty, phosphatic dolomite. McGugan (1967, p. 85, Fig. 2) reported 125 feet of rocks belonging to this formation in a railway cut less than 1 mile north of Solitude Mountain. Southeast of Solitude Mountain the unit thins beneath the Triassic and, as stated above, is absent between the Sukunka and Murray Rivers, 35 to 65 miles from Pine Pass. In sections on the east flank of the Murray Range, southeast of Azouzetta Lake, the Fantasque ranges from 102 feet to 109 feet in thickness and has approximately the same lithology as in Pine Pass, with thin interbeds of siliceous shale and mudstone. Neither the upper nor the lower contact of the formation has been observed in the area and no fossils other than spicules were found. The Fantasque overlies Lower Permian rocks, contains Permian fossils near its type area to the north (Bamber, et al., 1968, p. 13), and is consistently overlain by Lower Triassic rocks. A widespread unconformity occurs between the Fantasque and Kindle Formations north of Pine Pass (ibid., pp. 11, 12).

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JURASSIC AND CRETACEOUS ROCKS OF PINE RIVER REGION, BRITISH COLUMBIA

by D.F. Stott[1]

INTRODUCTION

Jurassic and Cretaceous rocks in northeastern British Columbia include a thick succession of marine shales and sandstones interbedded with continental, coal-bearing strata. Although the composite thickness of the succession totals well over twenty thousand feet (Figure 1), it is unlikely that so much sediment was ever present at any one locality. Rather, it would appear that a series of depositional troughs developed with the axis of each successively younger one occurring progressively farther east.

Jurassic Fernie and basal Cretaceous Minnes strata of Pine River region outcrop only in the Foothills, where the major exposures occur between Clearwater River and the eastern rim of Carbon Creek basin. Bullhead strata occur along the axes of several major synclines, particularly the Carbon Creek syncline, and in folds as far east as the lower end of Peace River canyon. Successively younger beds outcrop eastward with Lower Cretaceous Fort St. John beds appearing east of Crassier Creek in Pine River valley and east of the canyon of Peace River. The Upper Cretaceous Dunvegan Formation is involved in the folding along the eastern Foothills and extends eastward into the Plains. The younger marine succession of the Smoky Group appears south of John Hart Highway along an escarpment extending from Murray River eastward toward Dawson Creek. The overlying continental Wapiti strata form the bedrock surface of most of the Plains region south of the highway.

Previous Work

The early history of geological investigations in this region is summarized by Stott (1967a, 1968)[2]. The pioneer work of McLearn (1918, 1923) outlined the Cretaceous stratigraphy in the vicinity of Peace River and studies by Wickenden and Shaw (1943) established the succession in Pine River valley. The comprehensive summary by McLearn and Kindle (1950) established a firm base for future geological investigations in northeastern British Columbia. Lowermost Cretaceous marine rocks in the Peace River region were first recognized by Mathews (1947) and more recently were described by Hughes (1964). A summary of Jurassic stratigraphy was given

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2 Reference to every report concerning Jurassic and Cretaceous stratigraphy in the region of Pine and Peace Rivers is not possible in this type of summary. The interested reader may compile a more complete bibliography by consulting those references listed.

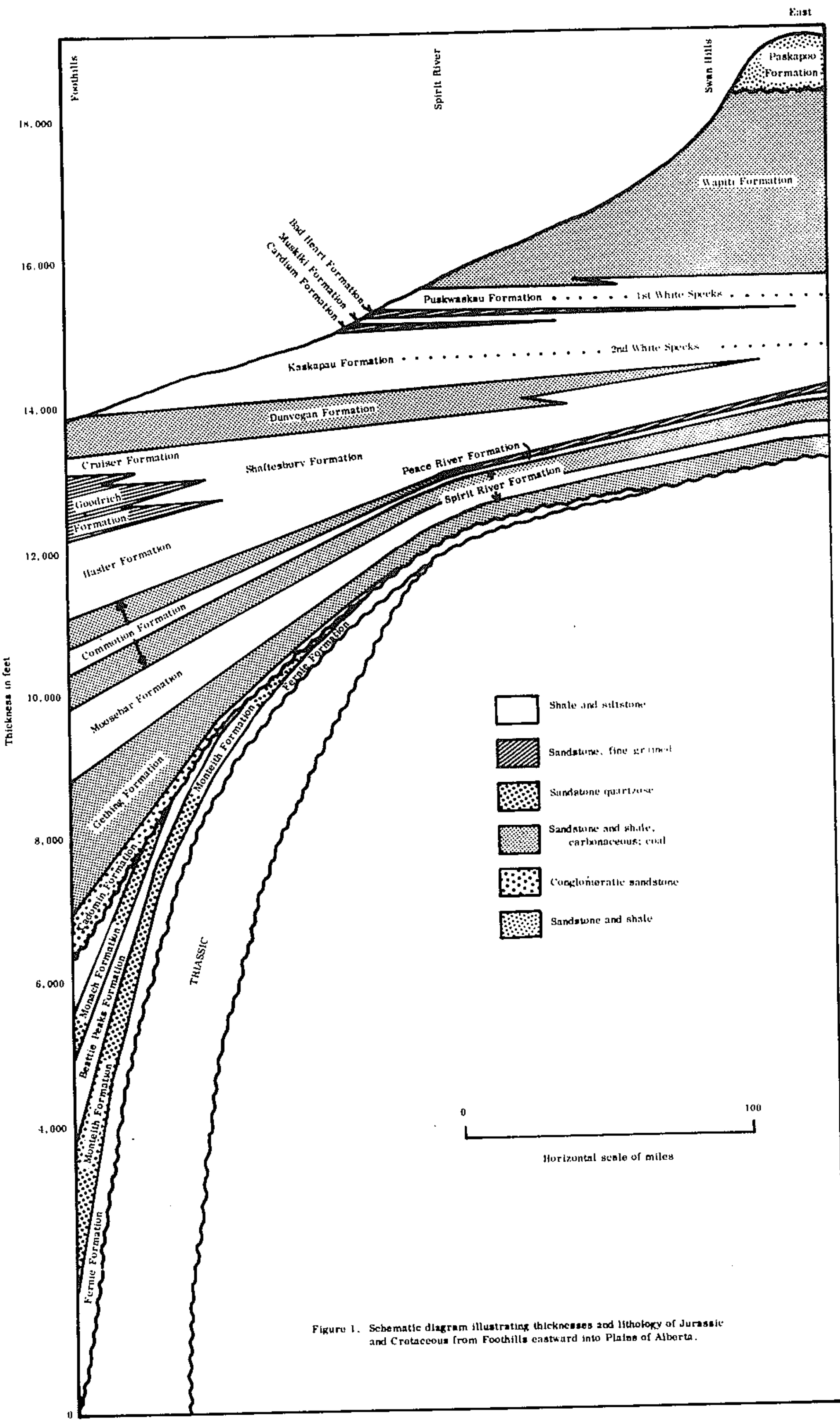

Figure 1. Schematic diagram illustrating thicknesses and lithology of Jurassic and Cretaceous from Foothills eastward into Plains of Alberta.

by Springer et al. (1964) and similar summaries of Cretaceous stratigraphy were presented by Rudkin (1964) and Williams and Burk (1964). Considerable new information from this region has become available in recent years. The lowermost Cretaceous Minnes succession north of Peace River was outlined by Stott (1967a, 1969a); the Fort St. John Group between Smoky and Peace Rivers was described in detail (Stott, 1968) and the Upper Cretaceous Smoky Group between Smoky and Pine River was described also (Stott, 1967b). In addition, the Halfway and Charlie Lake map-areas were mapped by Irish (1958, 1970); Dawson Creek map-area, by Stott (1961); the Pine Pass map-area by Muller (1961). The Pine valley was mapped by Hughes (1967). Currently, the mapping and stratigraphy of much of this region is being revised as part of a detailed geological study, Operation Smoky, being undertaken by the Geological Survey of Canada.

JURASSIC

Fernie Formation

Jurassic strata lie unconformably on Triassic beds as a result of uplift related to the development of the Omineca geanticline to the west and also to general epeirogenic uplift of the craton to the east. Thin euxinic shale, siltstone, and limestone beds are characteristic. During Jurassic time, subsidence was slight within the Alberta trough and sedimentation was disrupted by minor regressions. No Middle Jurassic Bathonian or upper Bajocian rocks are recognized (Frebold and Tipper, 1970) and non-deposition during that time may be attributed to an orogeny in the Cordilleran region. A thin glauconitic unit of Oxfordian age apparently represents another regression within the Alberta trough and may be related to uplift of the margin of the craton. During latest Jurassic, the Omineca geanticline, uplifted during the initial phase of the Columbian orogeny, began to contribute large quantities of sand.

The most complete exposures of the Jurassic Fernie Formation in this region are north of Peace River (Stott, 1967a, 1969a). There, a basal unit 56 to 209 feet thick, consists of phosphatic, calcareous, and cherty shale with minor limestone and siltstone. Although that unit was correlated on the basis of lithologic and paleontologic similarities with the Sinemurian Nordegg Member of the central Alberta Foothills, a recent revision of the fauna by Hans Frebold (1970) indicates that most of it is of late Pliensbachian age and therefore younger than the type Nordegg. A few feet of Sinemurian beds are present at some localities. The younger Pliensbachian beds may be correlated with the Red Deer Member recently defined by Frebold (1969). That succession is overlain by black, calcareous, papery shale which almost certainly represents the Paper Shales. The middle succession of 65 to 273 feet of rusty weathering sideritic marine shale with a persistent glauconitic siltstone marker, is equated (Stott, 1967a), on the basis of lithology and of microfauna identified by T.P. Chamney, with the Rock Creek, Grey Beds, and Green Beds of more southerly regions (see Frebold, 1967; Frebold and Tipper, 1970). Interbedded sandstone and shale grade upward into fine - to coarse - grained, quartzose sandstone of the Monteith Formation, which spans the boundary between the Jurassic and Cretaceous.

Table of Formations
(thickness in feet)

	Group	Formation	Member	Description
Upper Cretaceous		Wapiti (0-1,500)		Conglomerate; fine- to coarse-grained sandstone; carbonaceous shale and coal.
	Smoky Group (1,250-3,900)	Puskwaskau (375-1,200)	Nomad (0-159)	Rusty weathering rubbly shales, greenish grey shales and fine-grained, thin-bedded sandstones.
			Chungo (12-194)	Fine-grained, thick-bedded, brown weathering sandstones and dark grey siltstone.
			Hanson (115-176)	Dark grey, rusty weathering, blocky to rubbly shales.
			Thistle (100-600)	Dark grey to black, calcareous, platy to fissile shales.
			Dowling (50-200?)	Dark grey, rubbly to platy shales, weathering rust.
		Bad Heart (0-85)		Fine-grained, thick- to thin-bedded sandstone, weathering brown. In some regions, includes brackish and non-marine carbonaceous, greyish and greenish shales.
		Muskiki (115-381)		Dark grey, rubbly to platy shales, weathering rust and having banded appearance.
		Cardium (15?-225)	Baytree (0-37)	Massive to thick-bedded conglomerate of chert and quartzite pebbles in coarse-grained sandstone matrix.
			Moosehound (0-143)	Greyish green to brown, carbonaceous, rubbly shales; fine- to coarse-grained carbonaceous sandstones; thin coal beds, minor conglomerate.
			Ram (40-84)	Fine-grained, thick-bedded sandstone, weathering rusty brown.
		Kaskapau (850-2,800)	Opabin (175-325)	Dark grey, rusty weathering, blocky to rubbly shales.
			Haven (100-620)	Dark grey to black, rubbly to platy shales, weathering rust, with yellow efflorescence and fetid odour.
			Vimy (250-800)	Dark grey to black, calcareous, platy to fissile shales. Includes much fine-grained, thick- to thin-bedded sandstone in northwestern part of region.
			Sunkay (100-1,000)	Dark grey, rubbly to platy shales, weathering rust; sandstone, fine-grained, thick- to thin-bedded and siltstone, argillaceous; sideritic concretions.
		Dunvegan (350-1,200)		Fine- to coarse-grained sandstone; conglomerate; carbonaceous shale and coal.
Lower Cretaceous	Fort St. John (2,000-5,000)	Cruiser Fm.[1] (350-800)		Dark grey marine shale with sideritic concretions; some sandstone
		Goodrich Fm.[1] (50-1,350)		Fine-grained, crossbedded sandstone; shale and mudstone.
		Hasler Fm.[1] (500?-1,500)		Silty, dark grey marine shale with sideritic concretions; siltstone in lower part.
		Commotion (1,080-1,600)	Boulder Creek Member (240-560)	Fine-grained, well sorted sandstone; massive conglomerate; non-marine sandstone and mudstone.
			Hulcross Member (0-450)	Dark grey marine shale with sideritic concretions.
			Gates Member[2] (220-900)	Fine-grained, marine and non-marine sandstones; conglomerate; coal; shale and mudstone
		Moosebar (100-1,000)		Dark grey marine shale with sideritic concretions; glauconitic sandstone and pebbles at base.
	Bullhead (300-2,500)	Gething (75-1,800)		Fine- to coarse-grained, brown, calcareous, carbonaceous sandstone; coal, carbonaceous shale, and conglomerate
		Cadomin (45-700)		Massive conglomerate containing chert and quartzite pebbles
	Regional erosional unconformity; bevels rock of succeedingly older age northward and eastward			
	Minnes (0-6,500)	Unnamed (0-1,400?)		Sandstone, fine-grained and silty shale; carbonaceous in part
		Monach (0-1,000)		Sandstone, fine-grained, argillaceous; massive, fine- to coarse-grained quartzose sandstone.
		Beattie Peaks (0-1,300)		Interbedded fine-grained sandstone and silty shales.
		Monteith (0-2,000)		Sandstone, fine grained; white, quartzose fine- to coarse-grained sandstone
Jurassic		Fernie (0-1,900)		Calcareous and phosphatic shales; rusty weathering shales; glauconitic siltstone; sideritic shales, thinly interbedded sandstone, shale, and siltstone.

[1]The Hasler, Goodrich, and Cruiser Formations are recognized in the Foothills. Equivalent shales in the Plains are included in the Shaftesbury Formation.
[2]Gates sandstones in Peace River Region are considered as a formation; farther south, they are included in Gates Member of Commotion Formation.

To the south between Peace and Pine Rivers, Jurassic rocks form a narrow recessive interval between more resistant Triassic and Cretaceous rocks and are poorly exposed. In most places, only parts of the formation occur in isolated outcrops and no complete description has been obtained of all the members. The Fernie Formation was determined to be more than 1,900 feet thick in its most westerly exposures in the vicinity of Bocock Peak. The basal Nordegg Member, containing lower Sinemurian Arietitidae, Oxytoma cygnipes Phillips, Gryphaea, and Furcirhynchia striata (Quenstedt), identified by Frebold, is exposed in the railraod cut at Pine River bridge and consists of 39 feet of limestones and calcareous shales. Only the basal part of an overlying unit of phosphatic chert and shale is present at that locality but, to the north, the unit is about 50 feet thick. This unit is probably equivalent to the beds containing late Pliensbachian fauna in the Halfway region. No accurate measurement was obtained of the interval between that unit and a distinctive marker bed of glauconitic mudstones, but it is in the order of 400 to 500 feet. That interval presumably represents the Paper Shales, Rock Creek, and Grey Beds of the southern Alberta Foothills (see Frebold, 1957; Frebold and Tipper, 1970). An extra-ordinarily thick unit of concretionary mudstone, glauconitic pebble mudstone and interbedded sandstone, siltstone, and mudstone, probably equivalent to the Green Beds and Passage Beds, is in the order of 1,500 feet (Plate I). Hughes (1967) reported the occurrence in these upper beds of Buchia mosquensis (Buch) and Buchia piochii (Gabb) for which Jeletzky (1968; see also Jeletzky and Tipper, 1968) suggested a Portlandian age. These beds can be correlated with the Passage Beds of the Southern Alberta Foothills and with the lower part of the Nikanassin Formation.

UPPERMOST JURASSIC - LOWER CRETACEOUS

Minnes Group

Sedimentation in the rapidly subsiding Alberta trough was continuous from the Jurassic into earliest Cretaceous time. Large quantities of debris, derived from the rising Omineca geanticline to the west, were deposited in a narrow marine embayment. Warren and Stelck (1958a) and Jeletzky (1968a) postulate a connection with Tyaughton trough on the western side of the geanticlinal welt, but there is some possibility that the embayment extended from the Yukon region. That embayment persisted through Berriasian and most of Valanginian time but apparently had disappeared by Hauterivian time. Continental deposition was followed subsequently by active erosion of the earliest Cretaceous succession.

Two new groups were proposed by Hughes (1964); the Beaudette Group contained the Monteith, Beattie Peaks, and Monach Formations; the Crassier Group included two new formations and the Gething Formation. Recent work by the writer demonstrated that no major faunal break occurs at the top of the Monach Formation, and that the major lithologic change occurs at the base of conglomeratic sandstones assigned to the Cadomin Formation. Those upper Jurassic to lowermost Cretaceous sediments are included in the Minnes Group (Ziegler and Pocock, 1960; Stott, 1967a, 1969a). The succession (Plate II), dominantly marine in the vicinity of Pine River and transitionally overlying the Jurassic Fernie Formation, has a maximum thickness of more than 6,500 feet along the western Foothills between Pine and Peace Rivers but decreases eastward to an erosional edge. The sequence is bevelled by a major regional unconformity and throughout the region is overlain unconformably by the Lower Cretaceous Bullhead Group.

Monteith Formation

The Monteith Formation (Mathews, 1947, p. 10) consists dominantly of marine sandstones. The formation extends around Carbon Creek basin where a prominent quartzose sandstone unit forms a high rim on the eastern side. The formation is recognized as far north as Besa River and at least as far south as Goodrich Peak. The thickest sections occur along a line between Mount Rochfort and Mount Le Moray, being in the order of 1,800 to 2,000 feet thick. The formation thickness decreases eastward and northeastward, being about 1,000 feet along the eastern rim of Carbon Creek basin and only 500 feet in eastern sections near Halfway River. The lower part of the formation and the transitional contact with the underlying Fernie Formation are well exposed just west of Le Moray Lodge on John Hart Highway.

Much of the Monteith consists of fine-grained, grey, siliceous, massive to flaggy, argillaceous sandstones, with thin intervals of silty shale. Fine-to-coarse-grained quartzose sandstone is most common at the top of the formation in the eastern Foothills but occurs throughout the succession at Mount Rochfort.

Ammonites comparable with Pavlovia s. lato., Buchia piochii (Gabb) and Buchia cf. B. fischeriana (D'Orbigny), collected by Muller and Irish from sandstones occurring either at the top of the Fernie or at the base of the Monteith, were dated by Jeletzky as late Tithonian or Purbeckian (latest Jurassic) and may be correlated with fauna in the lower part of the Nikanassin Formation to the south. Buchia, which according to Jeletzky may represent some part of the Buchia fischeriana zone of latest Tithonian age or the Buchia okensis zone of earliest Berriasian age and Buchia cf. okensis of early Berriasian age were collected by Hughes (1964, p. 18; see also Jeletzky, 1968) from lower Monteith beds on Le Moray Mountain. Tollia (Subcraspedites) cf. T. payeri (Toula), T. (S.) cf. T. stenomphala (Pavlow), T. (S.) cf. T. suprasubdita (Bogoslovsky), Buchia uncitoides (Pavlow), B. aff. B. unschensis Pavlow, Buchia volgensis Jeletzky, B. aff. B. keyserlingi (Lahusen), collected by the writer from the middle and upper Monteith beds were identified and assigned by Jeletzky to the Buchia uncitoides subzone of late Berriasian age. Tollia (S.) cf. T. tòlli and Buchia cf. B. keyserlingi found either in the upper Monteith or in the lowermost Beattie Peaks have been recently dated tentatively as of early Valanginian age by Jeletzky (pers. com.). The Monteith Formation of Pine Pass region, therefore, appears to range in age from Tithonian (latest Jurassic) to earliest Valanginian.

Beattie Peaks Formation

The Beattie Peaks Formation (Mathews, 1947) represents delta-front to mid-basin deposition associated with some enlargement of the basin in Valanginian time. Beattie Peaks strata are most typically developed at the type locality at Beattie Peaks and in other exposures along the eastern rim of the Carbon Creek basin. To the west and south, the interval becomes much sandier and the formation is less readily distinguished from the enclosing strata. The formation is 1,270 feet thick at Beattie Peaks, decreasing to 935 feet at Mount McAllister.

The dominant lithology in the type region is silty, brownish grey-weathering mudstone alternating with numerous lenticular and thin-bedded argillaceous sandstone, and a few thin coquinas, consisting mainly of Buchia with some belemnites. The sandstones are grey, finely and uniformly laminated, and are generally siliceous. These sandstones range from flaggy to thin-bedded, and many have the characteristic features of channel-fill.

Fauna obtained from the basal Beattie Peaks includes Buchia cf. B. uncitoides (Pavlow) that Jeletzky assigned to either the late (latest ?) Berriasian zone of B. uncitoides or the early Valanginian zone Tollia tolli. Other early Valanginian forms reported by Hughes (1964) from the Beattie Peaks include Polyptychites cf. P. keyserlingi and Buchia keyserlingi (Lahusen). Collections from higher in the formation include Buchia sp. aff. B. inflata (Toula), B. cf. B. keyserlingi (Lahusen), B. bulloides (Lahusen), Polyptychites and B. aff. B. crassicollis, which according to Jeletzky are representative of the Buchia n. sp. aff. inflata zone of mid- to late Valanginian age (see Jeletzky, 1968).

Monach Formation

The Monach Formation (Mathews, 1947), about 400 feet thick, comprises flaggy to massive, fine-grained, argillaceous sandstones overlain by a unit of thick-bedded, fine-grained to conglomeratic quartzose sandstone. The Monach is mapped within the Carbon Creek basin but elsewhere grades laterally into sediments similar to those of the Beattie Peaks Formation and cannot always be recognized as a distinct unit. Although the quartzose sandstone unit was not found in the vicinity of Goodrich Peak south of Pine River, a prominent succession of sandstone strata at that locality is assigned to the formation. An extremely thick unit of quartzose sandstone occurs within the Monach Formation north of Gold Bar (Plate II) and it now appears probable that beds included by the writer (Stott, 1967a, 1969a) in Unit 2 of the Beattie Peaks and (?) Younger Beds in the Halfway River region are equivalent.

Buchia bulloides (Lahusen), B. n. sp. aff. inflata (Toula), and B. cf. B. crassicollis Keyserling) were collected by the writer from the type Monach and Polyptychites cf. P. polyptychus (Keyserling) was collected by Hughes from the formation in Pine River valley. This fauna is assigned by Jeletzky to the mid- to late Valanginian zone of Buchia n. sp. aff. inflata.

Unnamed Formation

In previous years (Stott, 1962, 1967a), the writer pointed out that the Monach Formation was separated from Cadomin conglomeratic sandstones by a succession of interbedded fine-grained, brown, laminated sandstone and silty shale. Hughes (1964) attempted to extrapolate that unit into the subsurface in the French Petroleum-Richfield Brenot Creek No. 1 well, defining a new formation, Brenot, based on an interval within that well. Until current studies are completed, the writer still prefers to hold in abeyance the application of Brenot to the outcrop unit (see also Stott, 1967a, p. 20).

This upper, unnamed unit contains fine- to medium-grained sandstone, dark grey silty shales, in part carbonaceous and, at some localities, a few thin seams of coal. In most places, only the thicker sandstones are exposed and the recessive beds are covered. The thickness ranges from about 800 feet along Fisher Creek, northeast of Mount Bickford, to possibly as much as 1,400 feet in the most westerly sections.

Fauna obtained from these upper beds of the Minnes Group include Buchia n. sp. aff. B. inflata (Toula), B. aff. B. crassicollis var. solida (Lahusen), and B. cf. B. bulloides (Lahusen). This fauna, similar to that of the underlying Monach Formation, is assigned by Jeletzky to his zone of B. n. sp. aff. B. inflata and dated as mid- to late Valanginian.

Pre-Bullhead Unconformity

The withdrawal of the Neocomian sea from the Alberta trough resulted finally in widespread erosion. Lowermost Cretaceous and Jurassic strata are bevelled by a regional erosional unconformity in an easterly and northerly direction and successively older Mesozoic and Paleozoic strata appear toward the craton. The unconformity represents a major erosional interval in Neocomian to (?) Aptian time.

LOWER CRETACEOUS

Bullhead Group

As the uplift associated with the Columbian orogeny continued in the Cordilleran region to the west, coarse clastic material spread eastward across the Alberta trough. Renewed subsidence within the Alberta trough permitted the gradual advance from boreal regions of the Aptian (?) to early Albian sea and once again marine environments extended toward Peace River. The seaway was bordered on the south by a broad, low-lying alluvial plain. The sediments deposited in that alluvial environment are included in the Cadomin and Gething Formations of the Bullhead Group as recently modified by Stott (1968).

Cadomin Formation

The Cadomin Formation (McKay, 1929; see also Stott, 1968), consisting of massive conglomerate and conglomeratic sandstone, occurs along the axes of several major folds between Crassier Creek and Mount Le Moray. It lies on Minnes strata in the western Foothills but, as Minnes strata are truncated in a northeasterly direction, the Cadomin lies unconformably on Fernie shales in the Plains to the east.

The Cadomin beds are present in several folds between Pine River and Bullmoose Mountain (Plate III) and are well developed within the Carbon Creek basin. The Cadomin beds were well exposed before construction of the power dam on Peace River and some of the upper beds are still visible at the toe of the dam.

The formation is 96 feet thick south of Beaudette Creek and increases to over 700 feet in the vicinity of Peace River.

The conglomerates are composed mainly of rounded pebbles of quartz, chert, and quartzitic sandstone, embedded in a matrix of coarse- to fine-grained sandstone. The sediments are extremely well indurated and fractures commonly cut through rather than around the pebbles. The sandstones occur in massive 5 to 20-foot beds that weather reddish brown to grey. They range from fine- to coarse-grained. Bedding is not always apparent but both planar and crossbedded units are present. Some thin beds of dark grey shales, silty mudstones and coal are interbedded with the conglomeratic sandstones.

The Cadomin Formation is not definitely dated. However, in the Pine Pass region, it lies on rocks containing fossils dated by Jeletzky as middle to late Valanginian. Ziegler and Pocock (1960) suggested that underlying beds in the region of Mount Minnes, some 125 miles to the south, might be as young as Barremian. As the Cadomin is overlain by the Gething Formation which can be no younger than early Albian, the Cadomin can be tentatively dated as late Neocomian to possibly earliest Albian. As suggested by Jeletzky and Tipper (1968, pp. 88-89), the Cadomin conglomerate appears to be contemporary with coarse conglomerates of the Frenchman Barr Formation which lies along the western flank of the Omineca geanticline.

Gething Formation

The Gething Formation (McLearn, 1923) is a coal-bearing succession that is extremely well exposed at Peace River canyon (Plate IV). To the south, complete sections are rare and only isolated exposures are found. The thickness of the formation at the canyon was shown to be at least 1,600 feet (Stott, 1969b). A re-examination of the section in 1969 convinced the writer that no fault occurs within the succession so the total thickness of the Gething there approaches 1,800 feet. This maximum thickness represents the depocentre of a lobe of sediments whose axis parallels the ancient Peace River arch and trends northeastward from the canyon toward Fort St. John.

The Gething Formation consists of alternating units of sandstone, carbonaceous shale or mudstone, with some coal and conglomerate. The finer sandstones contain a moderate to high percentage of clay matrix with considerable quantities of carbonate and lithic detritus. The coarse sandstones, containing a high percentage of chert, contain little or no carbonate detritus and only minor amounts of matrix. Although numerous beds of coal are present in the Peace River canyon, the maximum thickness is in the order of only 5 to 6 feet. Thicker seams have been uncovered near Cleveland Creek along the John Hart Highway. Coal mines were in operation on Hasler Creek and near Peace River but mining activity has now ceased.

The Gething Formation can be dated by its stratigraphic position as Hauterivian to early Albian. It is equivalent to that part of the Blairmore Group extending downward from just above the Ostracod Zone. It is probably equivalent to much of the McMurray sandstone of the lower Athabasca River.

Fort St. John Group

During Albian time, variations in the rate of subsidence, the rate of deposition and the rate of uplift of the source region resulted in major marine transgressions which alternated with major regressions marked by alluvial and epineritic sediments. The non-marine facies do not extend far beyond a north-east trending hingeline that more or less parallels the axis of the Devonian Peace River arch. The initial deposits of the Fort St. John Group are those of the first major Albian marine transgression to extend southward beyond Peace River. The group includes the Moosebar, Commotion, Hasler, Goodrich, and Cruiser Formations.

More than 4,800 feet of Fort St. John strata occur on Dokie Ridge (Plate V; see Stott, 1968), about 5 miles north of Willow Flats on John Hart Highway. The Group thins northeasterly toward the Plains and the axis of maximum accumulation trends northeasterly, from upper Pine River.

Moosebar Formation

The Moosebar Formation, defined by McLearn (1923) on Peace River, extends southward at least to Kakwa River and equivalent marine beds are present at Cadomin, 125 miles to the south (Mellon and Wall, 1963). The formation is about 950 feet thick at Peace River and decreases southward, being 675 feet at Bullmoose Mountain and only 140 feet at Mount Torrens. The Moosebar consists of marine shale and siltstone. The basal shales are dark grey, rubbly to blocky and commonly contain reddish brown-weathering sideritic concretions. Highly glauconitic, argillaceous siltstone occurs near the base in many places and a thin bed of pebbles marks the contact with the Gething Formation.

Arcthoplites (Freboldiceras) irenese (McLearn), obtained from upper Moosebar shales south of Peace River, is considered by Jeletzky to represent the lower part of the generalized Arcthoplites or Beudanticeras affine zone and is believed by him to be of late lower Albian age. A characteristic microfaunal assemblage of Marginulinopsis collinsi, was reported by Stelck et al. (1956, p. 11) from the Lower Moosebar of the Pine River area. In addition, a similar assemblage was obtained from Moosebar shales near Mount Torrens (Mellon et al., 1963, p. 67; Chamney in Stott, 1968, p. 55). On the basis of its fauna, the Moosebar is correlated with the lower Buckinghorse Formation of the Sikanni Chief region, with the Clearwater Formation of Athabasca River, and with the Wilrich Member of the subsurface Spirit River Formation of the Peace River Plains.

The Commotion Formation records two major regressions and a major, although short-lived, marine transgression. The lower and upper members, Gates and Boulder Creek respectively, include the alluvial, deltaic, and epineritic sediments of the regressive phases and the middle Hulcross Member contains marine shales of the transgressive phase. The regressive marine sandstones rise stratigraphically as the formation is traced northward from Kakwa River toward Peace River. Those sandstones formed the seaward edge of continental deposits. Thus, in the south, a thick succession of carbonaceous sediments with coal accumulated but, farther north, only marine sandstones are present. The latter reached their maximum development near Pine River; farther north they grade laterally into finer and siltier offshore sandstone.

The Commotion Formation was defined in the Pine River valley by Wickenden and Shaw (1943, p. 5). Although the formation can be traced north of Moberly River, only the lower sandstone member retains its identity at Peace River and it is mapped there as the Gates Formation. The Commotion Formation is, however, a mappable unit in the Foothills as far south as Kakwa River. The formation is 1,311 feet thick at Dokie Ridge (Plate V), increasing to a maximum of about 1,600 feet in vicinity of Bullmoose Mountain and Wolverine River.

The Gates Member increases from 226 feet at Steamboat Island to a maximum of 873 feet near Belcourt Lake. It contains a cyclic succession of sandstones, mudstones, coal, and some conglomerate. In the southern part of the region, most of the member was deposited in a continental alluvial environment but in the region of Pine and Peace Rivers much of it is marine. Basal marine sandstones are fine-grained, laminated, brown, and calcareous. Coal is more abundant in the Kakwa-Belcourt region. This member contains an extensive fossil flora considered by D.C. McGregor and the late W.A. Bell to be equivalent to the Lower Blairmore flora (see Bell, 1956), which, until studies in this region were completed, had been considered to be most likely Aptian. However, the underlying Moosebar shales can be definitely dated as late early Albian. The Gates Member at Peace River contains fauna of the generalized zone of Beudanticeras and Lemuroceras (McLearn and Kindle, 1950; Stelck et al., 1956; Stott, 1968) considered by Jeletzky to be of late early Albian age.

The middle shales, or Hulcross Member, extend southward from Peace River at least to Wapiti River and possibly beyond. Equivalent beds on Starfish Creek are 435 feet thick and the member decreases to zero at Kakwa River. These marine shales are silty and dark grey but weather rusty and commonly grade upward into interbedded siltstone and mudstone. The Hulcross Member, at Moberly River, contains Pseudopulchellia pattoni Imlay and Gastroplites kingi McLearn var. flexicostatus Imlay. This fauna is considered to represent the lower part of the generalized late middle Albian Gastroplites zone (see Jeletzky, 1968b).

The Boulder Creek Member contains transitional, deltaic, and flood-plain facies. In the Pine Pass region, it is readily divided into three parts: a lower unit of thick-bedded to massive, fine-grained well sorted sandstone; a middle massive conglomerate (the Boulder Creek conglomerate of Spieker, 1921); and an upper coal-bearing succession of interbedded carbonaceous shales and argillaceous sandstone. To the south of Pine River, the tripartite division is not so evident. Conglomerate may occur throughout the upper part and coal-bearing beds range into the lower part of the member. The member is 556 feet thick on Dokie River amd decreases to 204 feet at Wapiti River.

Wickenden and Shaw (1943) obtained angiosperms from the Boulder Creek beds in the Pine Valley (see Bell, 1956). A flora containing several species of angiosperms was reported by Mellon et al., (1963) from the upper Commotion at Mount Belcourt. Additional specimens were obtained from the member at Bullmoose Mountain and Commotion Creek by the writer (Stott, 1968).

Pseudopulchellia pattoni Imlay and Gastroplites kingi McLearn var. flexicostatus Imlay occur either just below or in the basal beds of the Boulder Creek Member in the Moberly River valley. This fauna is dated by Jeletzky as middle Albian. The Hulcross and Boulder Creek Members are equivalent to the Peace River Formation of the Peace River Plains (see Stott, 1968, Figs. 3, 4, 5).

Hasler Formation

The Hasler Formation (Wickenden and Shaw, 1943) comprises marine shales, siltstones, minor sandstone, and a few thin beds of pebble conglomerate. No complete section of the formation is known in Pine Valley but parts of the formation are well exposed in road cuts west of Boulder Creek and along Hasler Creek. The formation is 868 feet thick on Dokie Ridge (Plate V; Stott, 1968).

Two main facies occur; the basal one is predominantly argillaceous siltstone with interbedded shale, and the upper one is rubbly shale. Several tens of feet of beds of both facies are exposed in the road cuts along John Hart Highway. Thin beds of conglomerate or pebbly mudstone occur in the upper facies on Hasler Creek.

On Peace River between Hudson Hope and the lower end of the canyon (Starfish Creek), beds equivalent to the upper two members of the Commotion Formation are predominantly marine shale and siltstone and, for mapping purposes (Stott, 1968), were included in the Hasler Formation. Those beds are continuous with shales occurring at The Gates east of Hudson Hope.

In its type region, the Hasler Formation lies above Commotion strata containing the middle Albian Gastroplites kingi fauna and below beds containing the late Albian Neogastroplites fauna. The lower shales on

Starfish Creek and neighbouring gullies have yielded Gastroplites kingi McLearn, G. kingi McLearn var. flexicostatus Imlay, Inoceramus cf. cadottensis McLearn, I. ex gr. I. anglicus Woods, and Lophidiaster cf. L. silentiensis McLearn. This fauna is assigned by Jeletzky (unpubl. interdept. rpts., 1969-1970) to the lower part of the generalized Gastroplites zone of middle Albian age. The shales and siltstones on Starfish Creek can be correlated with the Hulcross and Boulder Creek Members at Moberly River, the shales immediately above the Gates sandstone at The Gates east of Hudson Hope, and the Harmon Member of the Peace River Formation of the Plains. The Hasler Formation is equivalent to upper Buckinghorse shales of the northern Foothills and to the Lepine Formation of Liard River.

Goodrich Formation

The Goodrich Formation (Wickenden and Shaw, 1943) includes sandstone beds lying between the Hasler and Cruiser shales. Only 463 feet of the formation are exposed at the type locality (Plate VI) on Boulder Creek but some 1,320 feet were measured on Dokie Ridge (Stott, 1968).

The Goodrich sandstones grade eastward into shale and lose their identity as a mappable unit north of Moberly Lake and south of Hudson Hope. The Goodrich Formation extends southward from Pine River along the western flank of a broad syncline east of Bullmoose Mountain. As in the north, the sandstones grade eastward into shale and in the exposures south of Wolverine River, the Goodrich consists only of a few thin sandstone units.

In general, the Goodrich sandstones are fine-grained and occur in 5- to 80-foot units separated by recessive intervals of mudstone. On a hill west of Hasler Creek, 30 feet of coarse-grained massive sandstone lies about 60 feet below a massive conglomerate, 25 feet thick.

Neogastroplites haasi Reeside and Cobban is reported by Warren and Stelck (1969) 350 feet above the base of the Goodrich, and N. cornutus (Whiteaves) from the top of the Goodrich on lower Pine River. The Neogastroplites fauna, including Posidonia nahwisi (McLearn) var. goodrichensis (McLearn), occurring in the Goodrich sandstone, is considered by Jeletzky (1968) to be representative to the generalized Neogastroplites zone of late Albian age. The Goodrich Formation correlates with part of the Shaftesbury Formation on Peace River, and with the Sikanni Formation of the Foothills between Peace and Liard Rivers.

Cruiser Formation

Shales occurring between the fine-grained Goodrich sandstone and the coarse-grained and carbonaceous sediments of the Dunvegan Formation were assigned to the Cruiser Formation by Wickenden and Shaw (1943).

The Cruiser Formation is exposed in road cuts west of Chetwynd and the largest exposure is on a small tributary south of Pine River where 742 feet were measured (Stott, 1968, p. 101). The Cruiser varies greatly in thickness, both as a result of differences in rates of sedimentation and also as a result of lateral facies changes. The Cruiser shales are silty, dark grey to black, and weather into blocky or rubbly fragments. Sideritic concretions are common.

The Cruiser Formation of the Foothills is dated by its stratigraphic position between the late Albian Goodrich sandstone and the late Cenomanian Dunvegan Formation. The Cruiser, therefore, is dated as latest Albian to earliest Cenomanian. It is correlated with the upper Shaftesbury shales of the Plains, is approximately equivalent to the Sully Formation of the Foothills between Peace and Liard Rivers and is equivalent to the lower part of the type Sunkay Member of the Blackstone Formation.

Shaftesbury Formation

In the Plains, the interval between beds equivalent to the Commotion and the Dunvegan Formation consists entirely of marine shales. The Goodrich Formation grades laterally into shales inseparable from those of the Hasler and Cruiser Formation. The whole succession is assigned to the Shaftesbury Formation (McLearn and Henderson, 1944). The main area in which the Shaftesbury is recognized is north and east of Moberly Lake and along the lower reaches of Pine River.

The Shaftesbury shales are dark grey, flaky to fissile, and weather rusty. Some sandy siltstone and fine-grained sandstone occur in the upper part of the formation which grades upward into the overlying Dunvegan Formation.

Gastroplites kingi McLearn var. nov., cf. G. kingi McLearn var. flexicostatus Imlay, and Gastroplites spiekeri McLearn, occurring above the type Gates sandstones in basal shales of the Shaftesbury Formation, are assigned to the generalized Gastroplites zone of late middle Albian age. Gastroplites? (Paragastroplites?) liardense (Whiteaves), occurring about 3 1/2 miles west of Halfway River, is considered by Jeletzky to be early upper Albian. Neogastroplites cornutus (Whiteaves), Posidonia? nahwisi McLearn var. goodrichensis occur on Peace River between Bear Flat and Tea Creek. Stelck (1962) and Warren and Stelck (1969) report the occurrence of Neogastroplites muelleri and N. americanus from beds below the fish-scale marker bed and Neogastroplites mclearni Cobban and Reeside in fish-scale sandstones of the Shaftesbury Formation. In the Plains northeast of Pine River, Warren and Stelck (1958b; see also Stelck, 1962) reported the occurrence in upper Fort St. John beds of Pleurobema cruiserensis Warren and Stelck, Beattonoceras beattonense Warren and Stelck, and Irenicoceras bahani Warren and Stelck which are considered to be of early Cenomanian age. The Shaftesbury Formation, therefore, ranges from late middle Albian to earliest Cenomanian.

The Shaftesbury Formation of the Foothills and adjacent Plains is correlated with the Cruiser, Goodrich, and Hasler Formation of the Pine River region. Equivalent beds farther north are found in the Sully and Sikanni Formation and upper beds of the Buckinghorse Formation.

UPPER CRETACEOUS

Upper Cretaceous sediments, mostly sandstone and shale, were derived mainly from late Columbian and early Laramide uplifts in the Cordilleran geosyncline; a small amount of detrital material was probably contributed by the Shield. The rocks of Cenomanian to Santonian age are, except for the deltaic deposits of the Dunvegan Formation, almost entirely marine and constitute the Smoky Group. Extensive alluvial sediments deposited after mid-Campanian time are found in the Wapiti Formation.

Dunvegan Formation

The Dunvegan Formation contains sediments of deltaic and nearshore environments. It records the most major advance of those environments into the present Plains region since the previous widespread continental deposition of middle Albian time.

The Dunvegan Formation (Dawson, 1881), a succession of sandstone and interbedded shale, lies conformably on the Fort St. John shales. In the southern part of the region, the upper boundary is gradational. The formation is in the order of 500 feet thick in the vicinity of Torrens River and more than 900 feet of Dunvegan strata occur at Mount McAllister.

In general, the sandstones are fine- to coarse-grained, commonly crossbedded (Plate VII), laminated and weather brown. The interbedded mudstones are olive-brown to green, are carbonaceous in part, and contain some thin coal seams. Some indication of a coarsening westward is found north of Pine River. Dunvegan sandstones in the vicinity of Moberly Lake are predominantly fine grained with only thin beds of coarser sandstones with disseminated pebbles. Farther west at Mount McAllister, sandstones are medium grained and some 1- to 15-foot units of conglomerate are present.

The Dunvegan Formation contains the *Inoceramus dunveganensis*, *I. rutherfordi*, and *Unio (Pleurobema) dowlingi* fauna which Jeletzky (1968) tentatively considers to be contemporaneous with the late Cenomanian *Acanthoceras* fauna. A flora, described by Bell (1963), is also assigned a Cenomanian age.

Smoky Group

The Smoky Group, consisting mainly of marine shales, extends from the Foothills to its type section on lower Smoky River northeast of Grande Prairie. Within it, the Kaskapau and Puskwaskau shales are separated by arenaceous epineritic and shoreline deposits of the Cardium and Bad Heart Formations.

Kaskapau Formation

The Kaskapau Formation (McLearn, 1926, p. 119) is well exposed only in the vicinity of Murray River south of East Pine. More than 2,240 feet are present there, and comparable thicknesses occur in (Phillips) Puggins No. 1 and Canadian Southern and Associate Kelly Lake No. 1 wells.

The Kaskapau Formation consists of dark grey marine shales, divided into four members by the calcareous or sideritic content and by the occurrence of concretions (Stott, 1967b). A prominent facies change occurs in the vicinity of Tuskoola Mountain where several distinct sandstones appear in the middle part of the formation. Two of the more prominent ones were named Wartenbe and Tuskoola by Stelck (1955). Farther east beyond Dawson Creek, three other sandstones occur; Doe Creek and Pouce Coupe (Warren and Stelck, 1940) and Howard Creek (Stelck and Wall, 1954). These sandstones may be related to a broadening of the uplift of central part of the Omineca geanticline to the west which resulted in the development of the Dunvegan delta. The last three sandstones probably grade into Dunvegan strata in the region of Murray and Sukunka Rivers and the Wartenbe and Tuskoola equivalents may also grade laterally westward into carbonaceous sediments that would be included in the Dunvegan.

Fossils collected from the Kaskapau Formation include Dunveganoceras, Prionocyclus (Collignoniceràs) cf. P. (C.) woollgari Mantell, Inoceramus labiatus Schlotheim, Scaphites cf. S. patulus Cobban, and Inoceramus cf. I. lamarcki (Parkinson). The formation lies above the Cenomanian Dunvegan Formation and below beds containing the presumably latest Turonian zone of Scaphites preventricosus Cobban and, therefore, is considered to be of late Cenomanian to late Turonian age. Foraminifera of the formation were discussed by Stelck and Wall (1954, 1955), Wall (1960) and the Dunveganoceras succession, by Warren and Stelck (1955).

Cardium Formation

The Cardium Formation (Hector, in Whiteaves, 1895) consists of marine sandstone with some non-marine sediments. It is 125 to 140 feet thick in the bicinity of Wapiti River. More than 85 feet outcrop on the escarpment near Mount Puggins. Eastward from the Foothills, the Cardium grades laterally into siltstone and shales, its thickness decreases and the formation is represented on lower Smoky River by only a pebble bed. Part of the formation is well exposed in a quarry south of Pouce Coupe and some of the upper beds appear on the escarpment east of Dawson Creek.

The basal sandstones, included in the Ram Member are fine grained, generally uniformly laminated, but may exhibit small-scale, fine cross-laminations. Beds are commonly thick. The sandstones, consisting mainly of quartz and chert, are generally clean and well sorted. The porosity of those sandstones is lost through siliceous cementation.

From Wapiti River southward, a succession of carbonaceous mudstone, argillaceous sandstone, and siltstone occurs above the basal sandstones and is included in the Moosehound Member. The member is more than 50 feet thick at Wapiti River. It contains an angiosperm flora.

Coarse-grained sandstone and conglomerate occurring in the upper part of the Cardium Formation are included in the Baytree Member (Gleddie, 1949). The thickest section of 37 feet occurs southeast of Bay Tree, Alberta. Similar conglomeratic beds can be traced eastward to Cutbank Lake and westward along the escarpment south of Dawson Creek to Mount Puggins. In the Pouce Coupe quarry, about 20 feet of coarse-grained massive sandstone contain pebbles as much as 2 inches in diameter. At the type locality, pebbles, composed mainly of chert and quartzite, average about 1/4 to 1 inch although cobbles as much as 3 inches in diameter are present. The matrix consists of well-indurated, coarse-grained sandstone.

Muskiki Formation

The Muskiki Formation forms a thin, recessive unit between the prominent Cardium and Bad Heart sandstones. The formation is not well exposed along Murray River but is believed to have a thickness in the order of 125 to 150 feet. These transgressive deposits, marked by siderite and glauconite, represent shallow offshore environments and mildly oxidizing to mildly reducing bottom condition.

The Muskiki Formation is composed of rusty weathering, silty shales that weather platy to rubbly. Sideritic concretions are small but scattered throughout. On Tupper Creek north of Swan Lake, the basal beds contain disseminated chert pebbles.

Basal beds of the Muskiki Formation lie within the latest Turonian to earliest Coniacian zone of *Scaphites preventricosus* Cobban and *Inoceramus deformis* Meek (*see* Jeletzky, 1968). Much of the remainder of the formation lies within the zone of *Scaphites ventricosus* Meek and Hayden and *Inoceramus involutus* Sowerby (*see* Jeletzky, 1968b) and the upper beds may extend into the zone of *Scaphites depressus* Cobban. The microfauna of those beds were discussed by Wall and Germundson (1963, p. 339).

Bad Heart Formation

The Bad Heart Sandstone (McLearn, 1919, p. 4C) was originally defined on lower Smoky River where it consists of 10 to 25 feet of very glauconitic fine- to medium-grained sandstone. Although the sandstone may not be continuous, a prominent sandstone in the Foothills occupies a stratigraphic position equivalent to the type Bad Heart. That sandstone is 80 feet thick at Wapiti River and can be recognized along Murray River as far north as Mount Puggins. These deposits represent a minor regression in which barrier and offshore bars with associated lagoons formed along the margin of the basin.

In the Foothills, the formation consists of two members, a basal sandstone and an overlying succession of non-marine beds. The basal sandstone is fine to medium grained, uniformly laminated and bedded, well sorted, clean, well cemented with silica, and weathers rusty to reddish brown. The non-marine unit contains brown mudstones, greenish siltstones and sandstones, thin layers of coal and some angiosperm leaves.

The Bad Heart Formation lies within the zone of *Scaphites depressus* Cobban which Jeletzky (1968) considers to be early Santonian age. The angiosperm flora was considered by D.C. McGregor to have more in common with the uppermost Cretaceous floras than with the older Dunvegan flora.

Puskwaskau Formation

The upper shales of the Smoky Group are included in the Puskwaskau Formation (Wall, 1960, p. 6). The Puskwaskau Formation extends westward from its type locality on lower Smoky River to the Foothills. Its erosional edge lies on the escarpment between Dawson Creek and Murray River and it occurs on the east side of Murray River as far south as Flatbed Creek. In the type region, the Puskwaskau Formation contains concretionary and calcareous shales which are divided into five members. The formation is estimated to be about 700 feet thick in the vicinity of Murray River.

The Dowling Member, consisting of concretionary shale, is overlain by calcareous shales assigned to the Thistle Member. The Hanson Member includes concretionary mudstone that grades upward into siltstone and sandstone of the Chungo Member. The Chungo sandstone is marine, generally thick-bedded, fine-grained, and well sorted. It is exposed east of Kiskatinaw River and also east of Swan Lake. The uppermost marine shales, included in the Nomad Member, are interstratified westward with arenaceous sediments, grading laterally into non-marine strata included in the Wapiti Formation.

The Puskwaskau Formation contains the zones of *Scaphites vermiformis* to *Desmoscaphites bassleri* which are dated by Jeletzky (1968) as Santonian. Diagnostic fossils have not been collected from the Nomad Member in this region but those beds may be as young as early Campanian. The microfauna from the lower part of the formation was discussed by Wall (1960).

Wapiti Formation

Coarse clastic material included in the Wapiti Formation was produced by tectonic movements related to the early phases of the Laramide orogeny. The formation was defined by Dawson (1881) in the vicinity of Wapiti and Smoky Rivers. According to Jones (1966) the formation is 5,380 feet thick in the C.F.P. Regent Nose Mountain well (lsd. 15, sec. 20, twp. 65, rge. 11, W6) and he suggested that some 1,200 to 1,900 feet of Wapiti beds remain at Saskatoon Mountain in the Beaverlodge district.

The Wapiti Formation was divided into five members by Allan and Carr (1946). The lower part of the formation, which they did not examine, consists of conglomerates, thick units of fine- to coarse-grained sandstone, carbonaceous siltstone and shale, and most of the rocks have a greenish to brownish colour. Allan and Carr described Member B as containing about 500 feet of soft bentonitic, light coloured sandstone and shale; Member C, about 1,000 feet thick, as massive sandstone with some shale; Member D, as about 500 feet of shale and thin sandstone; and Member E, as 1,000 feet of massive sandstone, shale, and minor pebble conglomerate. Coal was said to occur most abundantly in Members B, C, and E. The equivalent of the Kneehills Tuff, a widespread time and stratigraphic marker, was considered by Williams and Burk (1964) to occur near the base of the uppermost member.

The formation is correlated with the Belly River, Bearpaw and Edmonton Formations of the southern and central Plains of Alberta.

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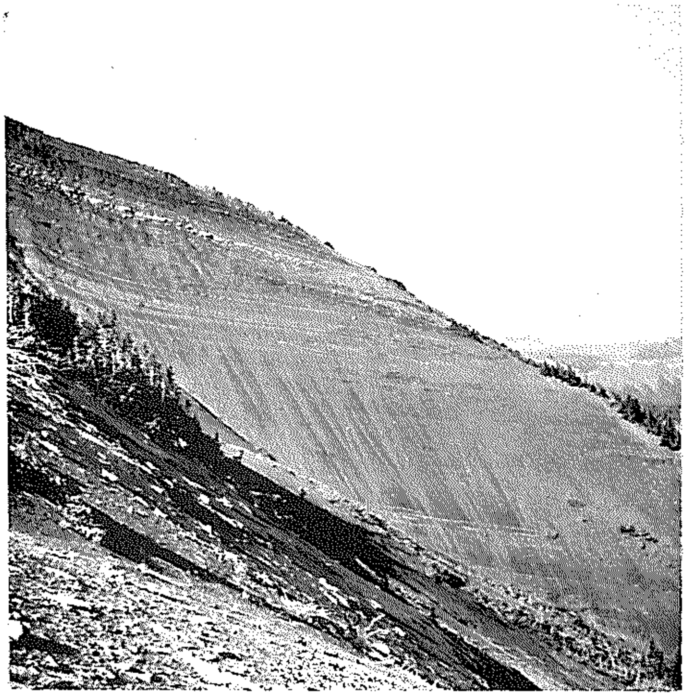

Plate I: Upper beds of Fernie Formation, southeast of Bocock Peak, Pine Pass map-area.

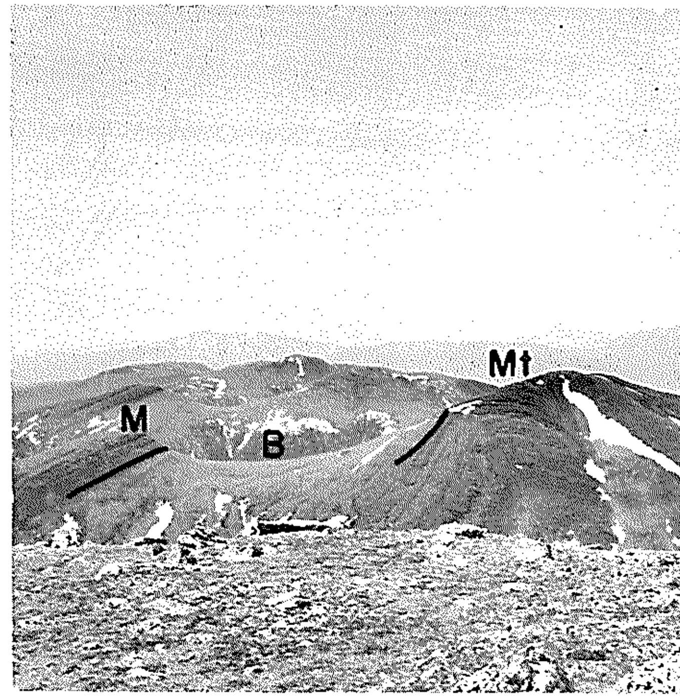

Plate II: Minnes Group, headwaters of Aylard Creek, Halfway River map-area. Anticline on right is formed by beds of Monteith sandstone (Mt). Recessive beds are those of Beattie Peaks Formation (B) and prominent ridge on left is formed by quartzose sandstones of Monach (M) Formation.

Plate III; Conglomeratic sandstones of Cadomin Formation, west of Cleveland Creek.

Plate IV: Gething Formation, on west bank of Peace River, looking south from dam-site.

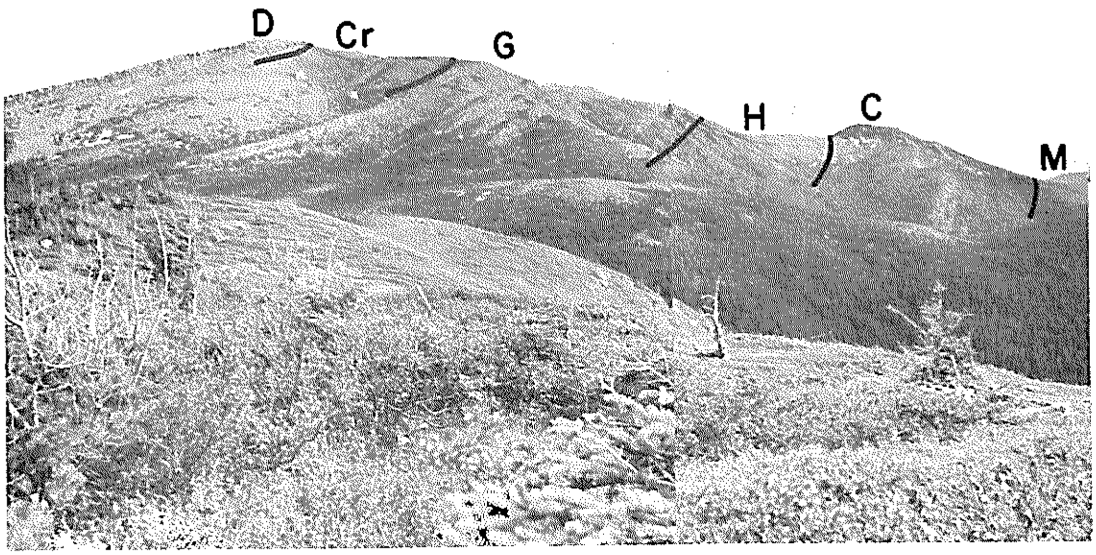

Plate V: Fort St. John Group, southward to main part of Dokie Ridge, Pine Pass map-area. Sandstones of Dunvegan Formation (D) lie at top of ridge to left. Prominent ridges of Goodrich sandstone (G) lie between recessive Cruiser shale (Cr) and Hasler shale (H) below. Prominent ridge on right is formed by upper conglomeratic beds of Boulder Creek Member in Commotion Formation (C). Moosebar Formation (M) lies on extreme right.

Plate VI: Goodrich Formation, type section in gully off Boulder Creek near Pine River, Dawson Creek map-area.

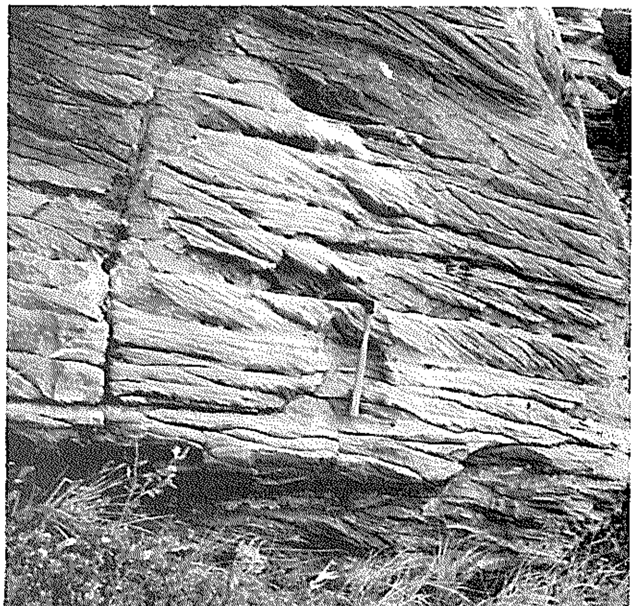

Plate VII: Cross beds in Dunvegan sandstone, Cruiser Mountain, Dawson Creek map-area.

GEOLOGY OF THE REGION BETWEEN PRINCE GEORGE AND JASPER

by

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Physiographically, the first 50 miles of the route traverse part of the Interior Plateau, which at this latitude merges to the northeast with the Rocky Mountain Trench, and skirts the northern end of the Cariboo Mountains (Holland, 1964). The Cariboo, Monashee, Selkirk and Purcell Mountains comprise the Columbia Mountains which extend southeastwards along the southwestern side of the Trench opposite the Rocky Mountains. The Plateau is underlain by Upper Paleozoic and Mesozoic rocks, covered locally by Tertiary deposits dominantly volcanic in nature. The Columbia Mountains contain mainly Precambrian and Lower Paleozoic rocks with some Upper Paleozoics, and these extend into the Plateau beyond their northern boundary.

From mile 50, the route follows the Fraser River upstream in a southeasterly direction along the Trench between the Cariboo and Rocky Mountains, until at about mile 170 it leaves the Trench to enter the Rocky Mountains. At this latitude the Rockies are divisible into Main Ranges with Precambrian and Lower Paleozoic rocks, Eastern or Front Ranges with Paleozoic and Mesozoic rocks, and Foothills with Upper Paleozoic, Mesozoic and Tertiary rocks. Within the Main Ranges, the route follows the Fraser River almost to the Continental Divide at Yellowhead Pass, and then the Miette River to its confluence with the Athabasca River near Jasper town. Although the geological part of the field-trip will end just northeast of Jasper, at the boundary between the Main and Eastern Ranges, the buses will then follow the Athabasca River across the Eastern Ranges and Foothills en route to Edmonton.

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A
A'
B
B'
C
C'
D
D'
10,000'
S.L.
10,000'
MT. SIR ALEXANDER
Jasper
Valemount
McBride
Prince George
Blue River
Wells
R O C K Y
M O U N T A I N S
C A R I B O O
M O U N T A I N S
I N T E R I O R
P L A T E A U
FRASER
FRASER RIVER
QUESNEL LAKE
Bowron R.
Willow R.
Raush R.
Canoe R.
Columbia R.
Blue R.
Torpy R.
Kenneth Cr.
Slim Cr.
16
5
122°
54°
52°
SCALE IN MILES
0
10
20
30
F.D.
Legend
PLEISTOCENE AND RECENT
Glacial deposits and alluvium
LATE CRETACEOUS OR PALEOCENE
Sandstone, shale, breccia, coal
JURASSIC TO TERTIARY
Intrusive granitic rocks
UPPER TRIASSIC TO MID JURASSIC
Andesitic and basaltic volcanic-clastics; breccia, tuff, volcanic aranite. agglomerate; minor argillite, limestone, greywacke and conglomerate.
UPPER TRIASSIC
Dark phyllite, argillite, shale, schist, minor limestone and sandstone
MISSISSIPPIAN IN PART
Slide Mountain Group: local basal cherty breccia, cherty argillite, quartzite (Black Stuart Fm.); local conglomerate, greywacke, greenstone, and Early Mississippian limestone (Guyet Fm.); pillow basalt, basalt breccia and flows, greywacke, argillite (Antler Fm.)
ORDOVICIAN, SILURIAN, POSSIBLE LOWER DEVONIAN
Limestone, shale, quartzite, (formations undivided, all or mainly Silurian adjacent to Trench in Rockies)
LATE LOWER TO UPPER CAMBRIAN
Limestone, shale, quartzite, siltstone in Rocky Mountains (undivided Fms include upper Gog Group Mahto Fm.); shale, siltstone, minor limestone in Cariboo Mts. (upper Cariboo Group Dome Creek Fm.)
LOWER CAMBRIAN
Mural Fm; limestone, shale, dolomite, quartzite (archeocyathids common)
In Rocky Mts.: McNaughton Fm. (bottom of Gog Gp.); quartzite in Main Rg. shale, phyllite, and siltstone above quartzite near Trench: In Cariboo Mts.: Midas Fm., siltstone, shale and phyllite; Yanks Peak Fm., quartzite; Yankee Belle Fm., shale, phyllite, limestone, siltstone, minor quartzite (undivided)
WINDERMERE (HADRYNIAN)
Cunningham Fm. in Cariboo Mts. Byng Fm. in Rocky Mts.; limestone, dolomite, shale, marble, phyllite and schist
Isaac Fm. in Cariboo Mts. (bottom of Cariboo Gp.), Upper Miette Gp. in Rocky Mts.; phyllite, argillite, shale, grit, limestone and schist
Kaza Gp. in Cariboo Mts., Middle Miette Gp in Rock Mts.; feldspathic quartzite, grit, phyllite, argillite, conglomerate, limestone, schist, gneiss and marble
AGE UNKNOWN
Granitic gneiss, amphibolite, schist
GOG GROUP
CARIBOO GROUP
MIETTE GP.
KAZA GP.
Geological contact
Fault
Thrust fault
Anticlinorium
Synclinorium
ISOGRADS
Chlorite and lower
Biotite
Garnet
Kyanite – staurolite
Sillimanite

Figure 1

The accompanying map is intended to be diagrammatic and is particularly sketchy in the region between Mount Robson and McBride. The map by Mountjoy is much more precise in this area.

GEOLOGY

From the geological standpoint, the route traverses from west to east the Quesnel Trough, Omenica Geanticline and Rocky Mountains. Visible to the west of the Quesnel Trough is the Pinchi Geanticline.

Pinchi Geanticline (not visited).

The Pinchi Geanticline, situated in the Interior Plateau, comprises the clastics, volcanics, cherts and limestones of the Permo-Pennsylvanian Cache Creek Group and associated ultrabasic rocks. During the early Mesozoic, the Geanticline appears to have been at least partially emergent because local Upper Triassic and Lower Jurassic conglomerates lie unconformably on and contain debris from the Cache Creek Group. The Omenica Geanticline on the other hand did not develop until the Jurassic, so that the Triassic and Jurassic rocks of the Quesnel Trough were presumably deposited in continuity with the Spray River and part of the Fernie Groups of the Rocky Mountain miogeosyncline, the nearest outcrops of which are only some 75 miles to the northeast.

Quesnel Trough (miles 1-12).

Also in the Interior Plateau, the Quesnel Trough is a tectonic rather than a sedimentary trough and is bounded to the southwest and northeast by the Pinchi and Omenica Geanticlines, respectively (Campbell and Tipper, 1970). The bulk of the Quesnel Trough is made up of volcanic-lithic clastic rocks, intermediate in composition, and of unknown but probably great thickness belonging to the Upper Triassic - Middle Jurassic Takla Group (Table 1). The underlying black argillaceous rocks of the Upper Triassic "sub-Takla" unit, which constitute the remainder of the succession, rest with slight angular discordance on rocks ranging in age from Precambrian to Late Paleozoic along the margins of the Trough. Although metamorphism in the Trough is usually non-existent and deformation slight, rocks along the northeast margin locally became involved in the Jurassic orogeny of the Omenica Geanticline (Fig. 1).

Omenica Geanticline (miles 12-170).

Partly in the Interior Plateau but mainly in the Cariboo Mountains, the Omenica Geanticline is underlain here by the Precambrian Kaza Group, the Precambrian and Cambrian Cariboo Group, and the Devonian (?) - Mississippian Slide Mountain Group (Table 1; Fig. 1). The Geanticline presumably emerged following the major episode or orogeny that affected much of the Columbia Mountains and adjacent terrains in Middle to Late Jurassic time; erosion of, for example, the Takla Group and its equivalents as well as older rocks from the geanticline provided clastics for the Tyaughton Trough and Rocky Mountain foredeep to the southwest and northeast, respectively. The northeastern boundary of the Omenica Geanticline in Late

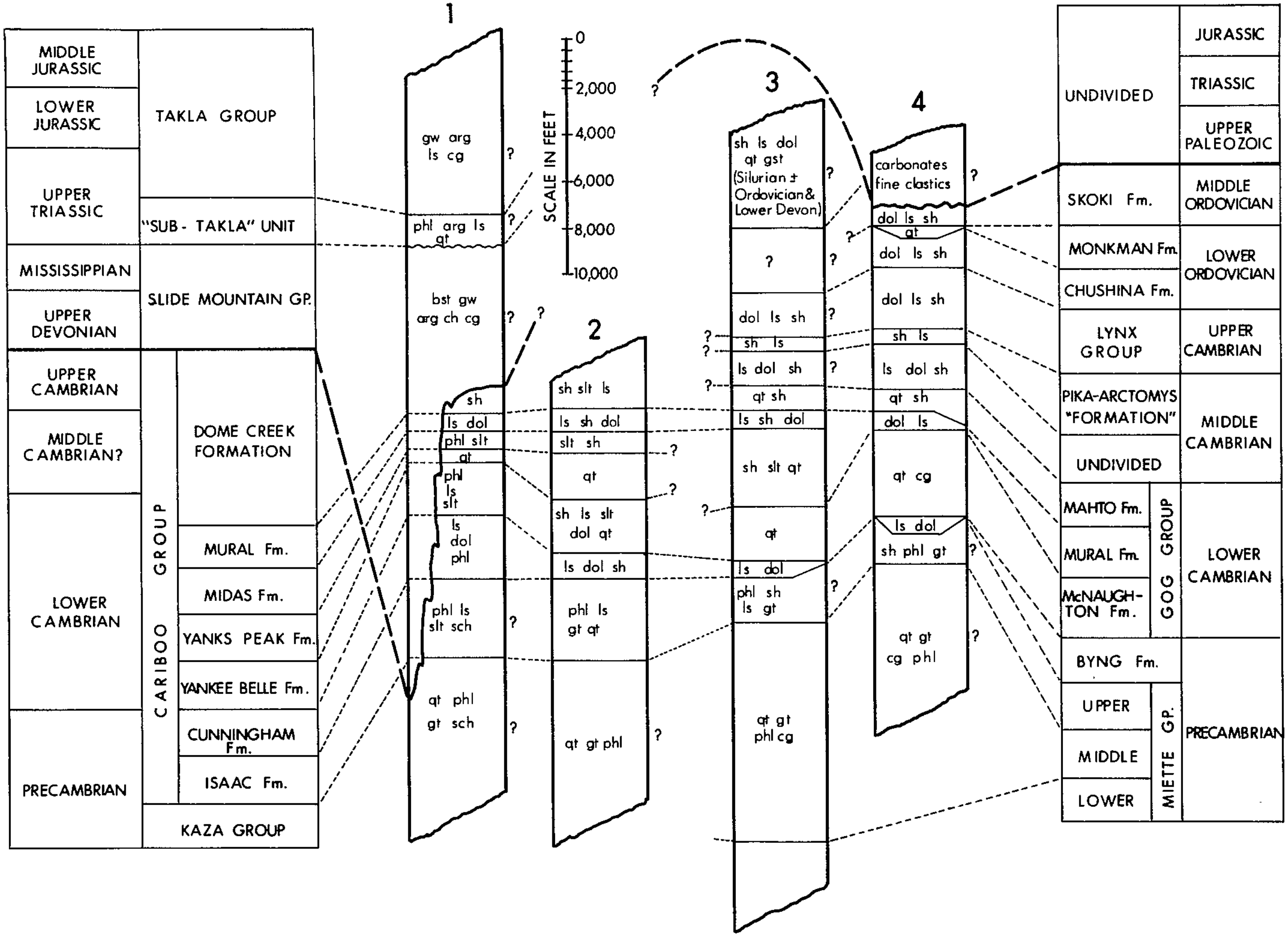

Table 1. Stratigraphic successions in Cariboo and Rocky Mountains near McBride, B.C.

arg - argillite, bst-basalt, cg- conglomerate, ch-chert, dol- dolomite, gst- greenstone, gt-grit, gw- greywacke, ls- limestone, phl- phyllite, qt - quartzite, sch - schist, sh-shale, slt-siltstone

Jurassic time may have coincided approximately with the present-day Rocky Mountain Trench. In a sense, with the creation of the Rocky Mountains in Cretaceous and early Tertiary time, the Geanticline continued to broaden until in the Eocene its northeast margin coincided approximately with the present-day edge of the Interior Plains.

In the unmetamorphosed state, the Precambrian Kaza Group (see e.g. Campbell, 1970) in the Interior Plateau and Cariboo Mountains would have been made up of over 10,000 feet of feldspathic sandstone, grit, siltstone and shale (Table 1). It probably originated in a continental shelf-slope-rise environment along the western margin of the craton. Although this margin appears to have been relatively stable, the presence of the intermediate volcanics of the Irene Formation in the correlative Windermere succession of the southern Selkirk Mountains suggests a measure of instability. To the north the Kaza Group is equivalent, at least in part, to the Misinchinka schists and to the "grit unit" of the Yukon; it is also equivalent to the Middle Miette Group of the Rockies. It has experienced considerable deformation and metamorphism; in the north the arenaceous rocks are quartzitic and the argillaceous rocks phyllitic or slaty, and in the south the Group is comprised of schists and gneisses for the most part. Where in the sillimanite grade it constitutes a major part of the Shuswap Metamorphic Complex, the northern boundary of which may be arbitrarily defined as the sillimanite isograd. If the Malton Gneiss in the northern Monashee Mountains represents remobilized cratonic basement, rather than the ultrametamorphosed Purcell rocks, the Kaza Group must have been deposited unconformably on this basement and not on Purcell rocks whose disappearance in this region is a problem.

The Cariboo Group (see e.g. Campbell, 1970) in the Interior Plateau and Cariboo Mountains ranges in age from Late Precambrian to Late Cambrian (Table 1). The lower part is divisible into the Isaac and Cunningham Formations. The Isaac was originally argillaceous, and the Cunningham calcareous and dolomitic, but both have since been regionally metamorphosed to a greater or lesser extent. The Cambrian part of the Group, generally less highly metamorphosed, is divisible into the argillaceous-calcareous-arenaceous Yankee Belle, the arenaceous Yanks Peak, the argillaceous Midas, the calcareous and dolomitic Mural, and the argillaceous-calcareous Dome Creek Formations. Although the Precambrian units of the Group are very similar lithologically to the correlative upper Miette Group and Byng Formation of the Rocky Mountains, the remainder of the Cambrian succession differs markedly from the Gog Group and younger Cambrian strata to which they are equivalent. In the Cariboo Mountains the Lower Cambrian is much shalier and contains more carbonates (the only clean quartzites are in the Yanks Peak Formation), and the Middle and Upper Cambrian contains no thick carbonates. The facies change in the Middle and Upper Cambrian is comparable to the one that occurs in rocks of similar age within the southern Rocky Mountains (see e.g. Cook, 1970). The only unit in the Cambrian part of the Cariboo Group that continues unchanged into the Rocky Mountains is the Mural Formation. This is not surprising for carbonates of Mural age appear to have been deposited as a continuous sheet generally about two hundred miles wide and less than 1000 feet thick, all the way from Mexico to the Yukon; in the southern Columbia Mountains this unit is the Badshot and part of the Donald Formation, which are overlain by the Lardeau Group and underlain by the Hamill

Group, at least partial equivalents of the Dome Creek Formation and of the pre-Mural Cariboo Group, respectively.

The Slide Mountain Group (see e.g. Sutherland Brown, 1963) in the Omenica Geanticline is divisible into the Upper Devonian (?) Black Stuart Formation (dominantly fine clastics), Lower Mississippian Guyet Formation (largely conglomeratic), and Mississippian and (?) younger Antler Formation (dominantly basalts, commonly pillowed and brecciated, with minor cherts, argillites and greywackes). The Group, whose rocks are deformed and in the zeolite metamorphic facies, clearly has oceanic affinities - it may be allochthonous or rest unconformably on rocks of the Kaza and Cariboo Groups. If allochthonous, it must have been emplaced during a Late Paleozoic tectonic event.

The structure of the northern Cariboo Mountains and adjacent Rockies is dominated by a series of large anticlinoria and synclinoria (Fig. 1). Generally these plunge northwest, so the Cariboo Group crops out mainly in the northwest and the Kaza Group in the southeast. There is a close relationship between stratigraphic level on the one hand and metamorphic grade and structural style on the other. In the northwest the essentially unmetamorphosed Cunningham Limestone and younger strata are concentrically folded, although complete folds are rare owing to the presence of numerous longitudinal and transverse faults. Immediately to the southeast, although the structure of the highest beds in the incompetent Isaac Formation is very similar to that of the Cunningham, most of the Formation contains numerous, closely spaced, small-scale, upright folds superimposed on anticlinoria and synclinoria, and is highly cleaved with metamorphic chlorite and muscovite replacing the original clay minerals. At the top of the underlying Kaza Group adjacent to the Trench, these small folds are replaced by larger, better defined, upright folds with axial-plane cleavage, whose axial surfaces are symmetrically fanned about an anticlinorial axis. Farther southeast the anticlinorium is replaced downwards by a broad smooth anticline, while opposite Tête Jaune (the name usually given to the locality where the Fraser River enters the Trench), Kaza rocks range from being in the biotite to the kyanite metamorphic grades and are isoclinally folded. The axial surfaces of these folds, which are approximately parallel to both bedding and metamorphic foliation, are arched over an antiform such as to be parallel to bedding and foliation in the overlying broad, smooth anticline, and to be normal to the axial surfaces of the still higher upright folds in upper Kaza strata; they also pass through a fan axis between the anticlinorium and the Trench.

Rocky Mountains.

The structural and stratigraphic differences between the Cariboo Mountains and the Main Ranges of the Rocky Mountains at this latitude do not appear to occur precisely on the line of the Trench. Instead they seem to be gradational over a distance of a few tens of miles. Thus the Trench, although locally the site of longitudinal faults, with considerable

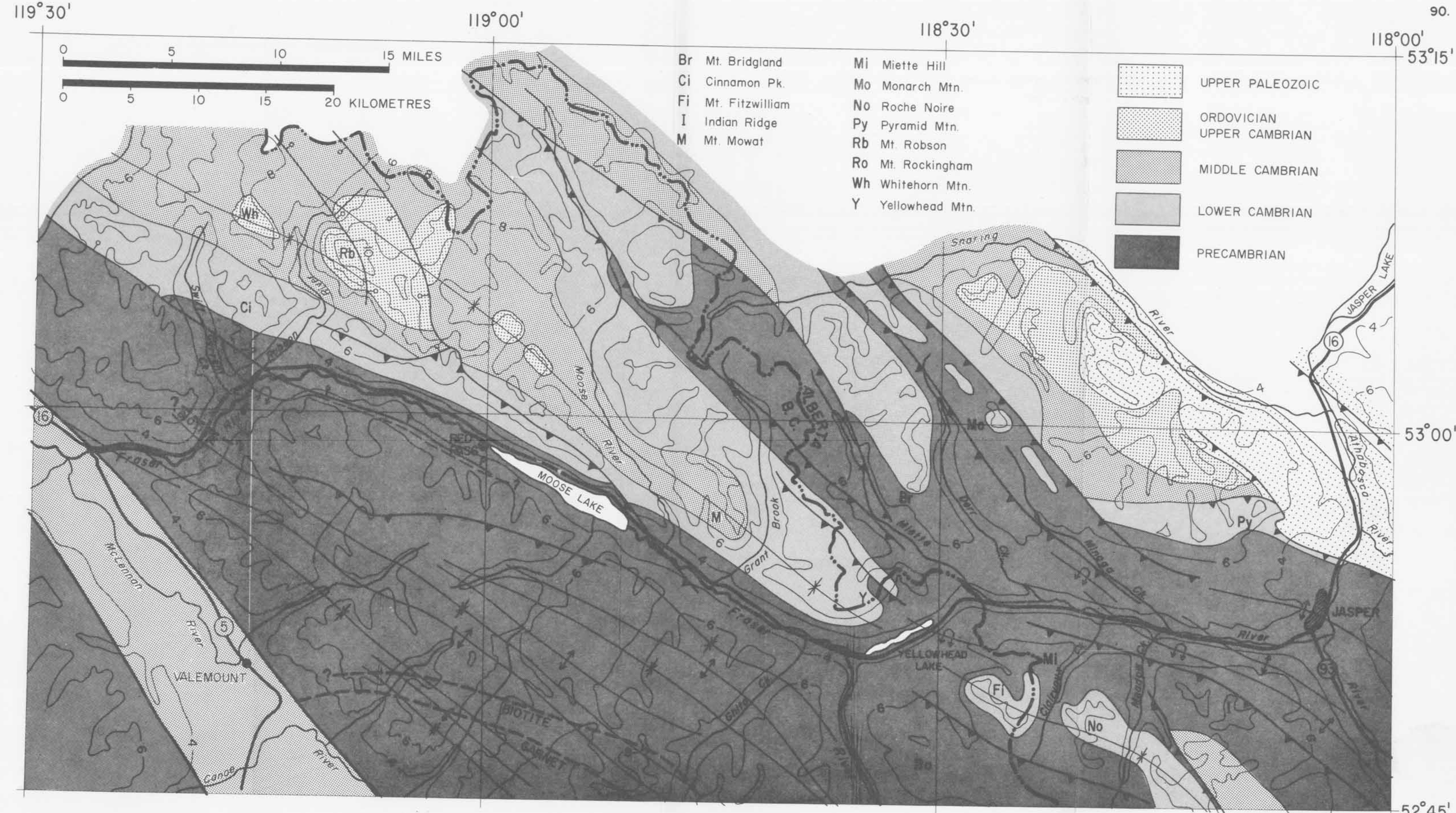
119°30'
119°00'
118°30'
118°00'
53°15'
53°00'
52°45'
0 5 10 15 MILES
0 5 10 15 20 KILOMETRES
Br Mt. Bridgland
Ci Cinnamon Pk.
Fi Mt. Fitzwilliam
I Indian Ridge
M Mt. Mowat
Mi Miette Hill
Mo Monarch Mtn.
No Roche Noire
Py Pyramid Mtn.
Rb Mt. Robson
Ro Mt. Rockingham
Wh Whitehorn Mtn.
Y Yellowhead Mtn.
UPPER PALEOZOIC
ORDOVICIAN
UPPER CAMBRIAN
MIDDLE CAMBRIAN
LOWER CAMBRIAN
PRECAMBRIAN
MOOSE LAKE
YELLOWHEAD LAKE
VALEMOUNT
JASPER
JASPER LAKE
ALBERTA
B.C.
BIOTITE
GARNET
Moose River
Grant Brook
Fraser River
Snaring River
Athabasca River
Miette
Canoe River
McLennan River
16
5
93

Figure 2

displacements, is primarily a geographic rather than a geologic boundary. Nevertheless, for the sake of convenience, the Rocky and Cariboo Mountains will be considered as geologically distinct. The route coincides approximately with a culmination affecting the Main Ranges only. For this reason, although Lower Paleozoic rocks are visible from the highway, outcrops at road level are all of Precambrian rocks (Fig. 2). The culmination is associated with a sigmoidal configuration to the structural grain of the Main Ranges, from northwest-southeast in the south and north, to westnorthwest-eastsoutheast within the culmination itself.

Within the Rocky Mountains between latitudes 50^0 and 54^0, Precambrian rocks are all assigned to the Miette Group, named by Walcott (1913) after the Miette River and equivalent to the Windermere rocks of southeast British Columbia. The Miette Group is divisible at Lake Louise into the Corral Creek (Sandstone, siltstone, slate, conglomerate), lower Hector (green and purple slate, breccia, limestone) and upper Hector (grey slate, siltstone, sandstone) Formations (Walcott, 1910), and at Jasper into the Meadow Creek (sandstone, siltstone, slate, conglomerate), Old Fort Point (green and purple slate, siltstone, limestone, breccia), lower Wynd (sandstone, siltstone, slate and conglomerate) and upper Wynd (slate, siltstone, sandstone, and conglomerate) Formations (Charlesworth et al., 1967). The Old Fort Point and lower Hector Formations are lithologically almost identical, so presumably the Wynd Formation is equivalent to the upper Hector, and the Meadow Creek to the Corral Creek. Between Tête Jaune and Moose Lake, the Miette Group is divisible into six units (Pinsent, in preparation). A is apparently equivalent to the Meadow Creek Formation, B to the Old Fort Point Formation, C-E to the lower Wynd Formation, and F to the upper Wynd Formation. Overlying the Miette Group are the carbonates of the lenticular Byng Formation which is correlative with the Cunningham. They in turn are succeeded by the Lower Cambrian Gog Group, divisible into the McNaughton, Mural and Mahto Formations, and by a series of carbonates and shales ranging in age from Middle Cambrian to Middle Ordovician (Table 1).

In contrast with most other stratigraphic levels in the Rocky Mountains, the Miette Group has experienced considerable penetrative deformation, commonly at all scales down to that of a hand specimen, leading to the development of cleavage, buckle folds of all sizes, and kink-bands. Thrusts and normal faults, more widely spaced than these features, also cut rocks belonging to the Miette Group. The rocks of Miette Group have been regionally metamorphosed and lie in the quartz-albite-chlorite-muscovite sub-facies of the greenschist metamorphic facies. However, in the extreme west, metamorphic biotite occurs, and a short distance southeast of the highway, garnet, kyanite and staurolite are known.

The Paleozoic rocks of the Rocky Mountains have been considerably shortened through movement along an array of interleaved thrust faults.

The underlying Precambrian cratonic basement on the other hand did not share in this thrusting and is obviously separated from its Paleozoic cover by a zone of décollement. In the Main Ranges this zone is usually thought of as being at the top of the basement, with the overlying 5-10,000 foot thick Miette Group being in structural continuity with the Paleozoics. However, the thrusts that have been responsible for most of the shortening in Paleozoic strata are much less conspicuous in the underlying Miette Group, whose considerably greater shortening has occurred mainly by folding and intralayer deformation. Hence throughout all but the extreme southwest margin of the Main Ranges, Miette and Paleozoic strata are not structurally continuous, the Paleozoics having moved farther northeast relative to the Columbia Mountains. Clearly there has to be a décollement zone towards the top of the Miette Group within which the rocks have experienced a strain approximating to simple shear parallel to bedding. Presumably this zone took much of the displacement along thrust faults in the overlying Paleozoics. This conclusion is supported by the occurrence at the top of the Miette Group of a gently southwest-dipping cleavage and recumbent drag folds. Another major décollement zone at the top of the basement occurs, and other zones exist within the Miette Group, as evidenced for example by the southwest-dipping slaty cleavage and axial surfaces of folds in the Old Fort Point Formation, and by the fact that this formation is more tightly folded than the lower Wynd. Thus the décollement zone between the basement and its Paleozoic cover should be thought of as occurring not at the base of but rather throughout the Miette Group. The deformation experienced by the Miette Group as a whole should, therefore, not be envisaged as simple shear parallel to bedding distributed uniformly between basement and Paleozoic cover. First, all but the highest Miette rocks have undergone considerable horizontal shortening. Secondly, the simple shear was concentrated in the more argillaceous units; thus the relatively arenaceous lower Wynd Formation has hardly any shear as indicated by the vertical slaty cleavage and axial surfaces of folds, whereas the argillaceous Old Fort Point Formation with its southwest-dipping surfaces and slaty cleavage has a great deal.

Figure 1: Geological map and structural cross-sections of the Cariboo Mountains and adjacent parts of the Interior Plateau and Rocky Mountains.

Figure 2: Geological map of the region between Tête Jaune and Jasper (modified after Price and Mountjoy, 1970).

Table 1: Stratigraphic successions in the Cariboo and Rocky Mountains near McBride, B.C. 1 - Wells-Barkerville area (modified after Young, 1969); 2 - Dome Creek - Goat River area (modified after Young, 1969); 3 - Torpy River - Morkill River area (modified after Young, 1969); 4 - Mt. Sir Alexander area (modified after Young, 1969 and Slind and Perkins, 1966).

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GEOLOGY OF THE MAIN RANGES BETWEEN TETE JAUNE CACHE AND JASPER

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INTRODUCTION

This paper briefly summarizes the geology of the field trip route from the Rocky Mountain Trench at Tete Jaune Cache, B.C. to Jasper, Alberta. This region is entirely within the Main Ranges of the Canadian Rocky Mountains, which are about 40 miles in width at this latitude. This cross section of the Main Ranges differs from the Pine Pass and Kickinghorse segments because of changes in the stratigraphic succession and because this region is part of a structural culmination and exposes older strata of Windermere age. The Main Ranges equivalent of the Pine Pass section is only 20 miles wide and is underlain primarily by the Precambrian Misinchinka 'schists', which are a northern extension of the Miette Group on the basis of mapping by Slind and Perkins (1966). Also, the structural style is different and the Front Ranges and Foothills are also narrower.

For purposes of discussion and description, the route traversed is divided into the following structural and geographic parts:

Rocky Mountain Trench
Tete Jaune Cache to Mount Robson (western Main Ranges)
Mount Robson
Mount Robson to Yellowhead Pass (boundary between eastern and western Main Ranges)
Yellowhead to Jasper (eastern Main Ranges)

The first part of the trip crosses an unnamed structural unit forming the Selwyn Range and mostly comprising middle Miette strata, which are complexly folded and faulted. The middle part of the trip, southeast of Mount Robson, follows the Moose Lake thrust which forms the boundary between the prominent Paleozoic Mount Robson syncline to the northeast and the Precambrian Miette strata of the Selwyn Range. The final part of the trip crosses the Mount Robson syncline and Moose Pass thrust sheet, and three other major thrust sheets; Monarch, Snaring and Pyramid (Figure 1).

Exposures are poor along much of the route except between Tete Jaune Cache and Swiftcurrent Creek and between Lucerne and Jasper. Heavy forest cover, much of it typical rain forest, covers most of the lower mountain slopes so that few of the structural features can be seen from the highway and only the more resistant stratigraphic units are visible. The following stops are recommended:

1. about 10 miles west of Mount Robson to view north end of Selwyn Range

2. Mount Robson viewpoint

3. between Grant Brook and Ghita Creek to observe Mount Fitzwilliam and adjacent mountains

4. Yellowhead Lake to observe Yellowhead Mountain

5. Miette outcrops at provincial boundary

6. lower Miette outcrops west of Geikie

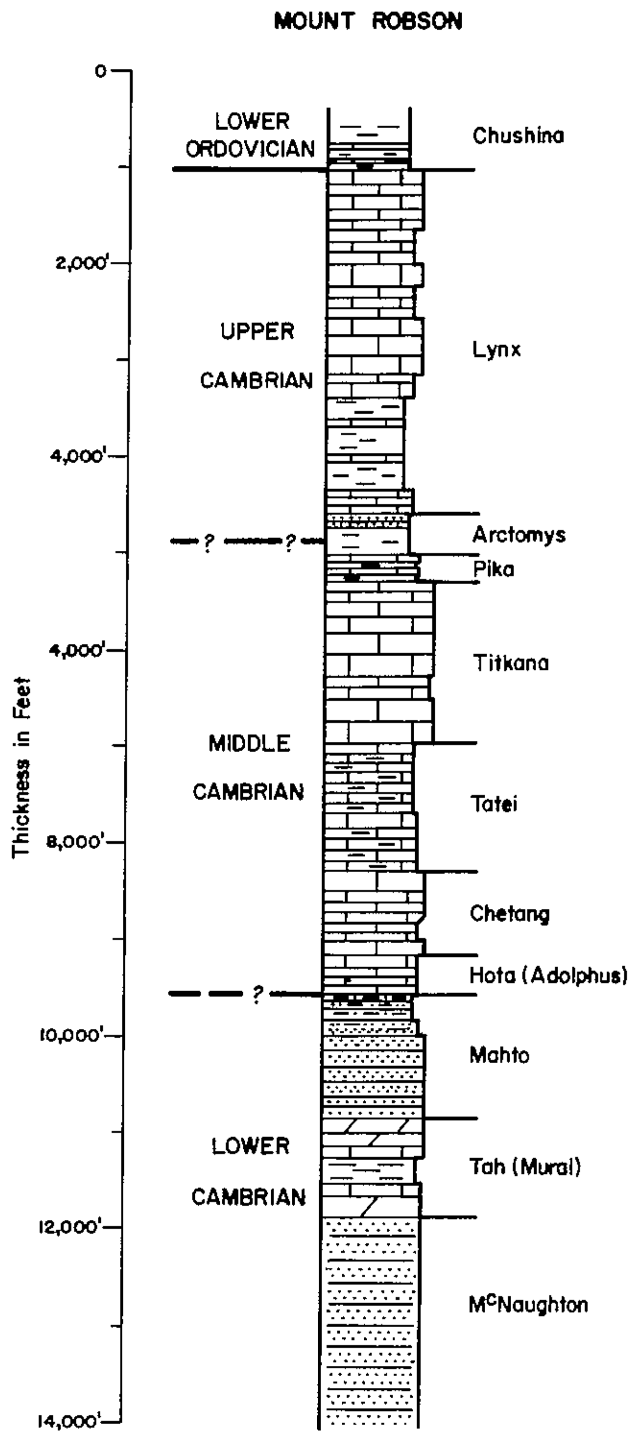
This summary is based upon observations obtained while employed by the Geological Survey of Canada during the summers of 1962 for the region northeast of the Fraser River (Mountjoy, 1962, 1964), 1964 for the Selwyn Range (see Campbell, 1968), 1965 and 1966 for the region south of the Fraser and Miette Rivers on Operation Bow-Athabasca (Price and Mountjoy, 1966; Price, 1967), and 1967 for the west half of the Robson area (Mountjoy, in press). The writer is grateful to the Geological Survey of Canada for the opportunity to work in these regions and to publish this summary. Grateful thanks are due to R.B. Campbell and R.A. Price for many hours of stimulating discussions from which have developed some of the interpretations presented here. R.H. Pinsent kindly provided information about his M.Sc. thesis of the area bordering the Fraser River, between Tete Jaune Cache and Mount Robson.

The geology of this region has been compiled on the accompanying generalized geological map (Figure 1). It is largely based on the studies of the writer, the persons mentioned above, as well as unpublished data from R.B. Campbell. Important information on regional geological relationships is available in the report by Slind and Perkins (1966) and for several areas between Yellowhead Lake and Jasper by Charlesworth et al. (1967) and his students.

REGIONAL GEOLOGY

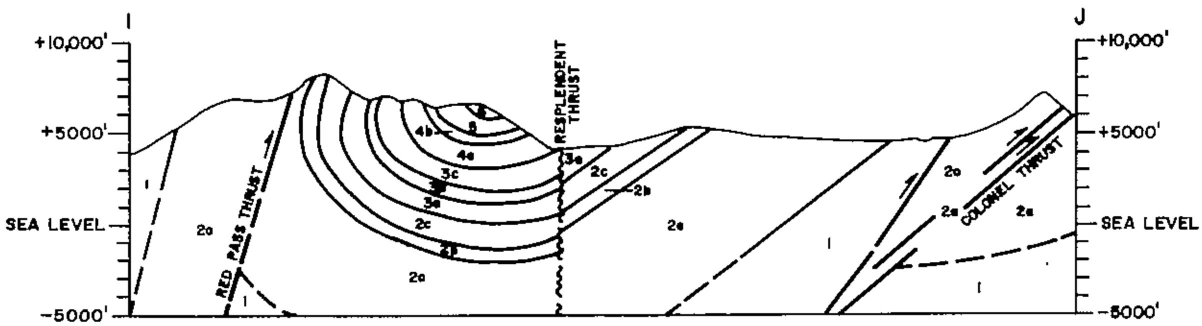
Rocky Mountain Trench

In the vicinity of Tete Jaune Cache, the Rocky Mountain Trench is a flat valley two to four miles wide filled with Recent and Pleistocene alluvium and glacial deposits. On the southwest side of the Trench, Kaza Group staurolite-kyanite-quartz-mica schists outcrop, whereas less metamorphosed probably middle Miette Group feldspathic quartzite and phyllites (stratigraphically equivalent to the Kaza Group) outcrop on the northeast side. In the floor of the Trench on the west side, marble and micaceous marble outcrop. The age of this marble is unknown. It was presumed to possibly be Middle Cambrian by Campbell (1968) but it could be Windermere in age and either a Cunningham equivalent or equivalent to the unnamed carbonate units at the top of Miette Group, which outcrop near Yellowhead Pass. Whatever their age, the presence of these carbonates indicates the presence of one or more important faults at this locality because these rocks are juxtaposed against older Middle Miette strata. The type of fault and relative displacement is unknown. Along strike to the southeast, the Purcell and Dogtooth thrusts



COLUMNAR SECTION FOR MOUNT ROBSON

Figure 2



1-Upper Miette
2a-McNaughton
2b-Mural
2c-Mahto
3a-Hota-Adolphus
3b-Chetang
3c-Tatei
4b-Titkana
4a-Pika
5-Arctomys-Waterfowl
6-Lynx

CROSS SECTION OF MOUNT ROBSON SYNCLINE ABOVE RED PASS B.C.

Figure 3

extend as far north as 52°30'. This important fault system may extend even farther northwest. The offset of gneiss schist, amphibolite and gneissic granite (Shuswap metamorphic complex), together with assuming a middle Cambrian age of the marbles in the floor of the Trench, suggests the presence of two normal faults (Price and Mountjoy, 1970) on either side of the Trench. Present evidence is inconclusive other than some sort of fault or faults are present. The recent work by Young (1970) on the stratigraphy and sedimentation of the Gog and Cariboo Groups, in the McBride area to the northwest, indicates abrupt facies and isopach changes occur across the Trench indicating juxtaposition of previously widely separated areas. This adds support to the likely presence of one or more major thrust faults beneath the Trench, possibly complicated by later normal faults.

Tete Jaune Cache - Mount Robson

This portion of the route has not been studied in detail. Strata on both sides of the Fraser Valley belong to the Miette Group and, except for two areas, appear to be middle Miette greenish colored, gritty, feldspathic quartzites with interbeds of dark grey phyllite. Mapping on the north end of the Selwyn Range by the writer indicates the presence of two thrust faults which cause repetitions within the middle Miette succession. In the western thrust sheet, just above Swiftwater, the folds are more open and plunge northwest. The eastern Moose Lake Thrust occurs on the northeast side of the range just above the Fraser River. In this thrust sheet, the folds are recumbent and plunge southeast (R. Pinsent, personal communication, June 1970). In the core of an anticline near Mount Robson ranch, R. Pinsent interprets the coarse grits and greenish siltstones to be equivalent to the Meadow Creek and Old Fort Point Formations (middle Miette Group, Table 2) near Jasper.

Much of the route follows the west limb of an anticline with folding becoming more intense southwestward. Immediately next to the Trench, particularly on the south side of the Fraser River and the junction of routes 5 and 16, a series of tight, isoclinal highly sheared folds occurs. This area may be separated from the broad fold in middle Miette strata to the east by a fault. These and strata along strike to the northwest are more phyllitic, having been metamorphosed to chlorite grade, and may represent the upper Miette Group. Northeast of Valemount 12 miles to the southeast, metamorphism increases to the garnet grade and to staurolite-kyanite grade 40 miles southeast of Tete Jaune Cache near Hugh Allan Creek.

Mount Robson

Mount Robson provides a superb view of the Upper and Middle Cambrian succession (Figure 2) in the west limb of the Mount Robson syncline (Figure 3). Exposed on Mount Robson are more than 9,500 feet of section from Kinney Lake at the base (3,230 feet elevation) to the top (12,972 feet). The most readily recognized unit is the orange brown weathering recessive band about half way down the mountainside (between 7,500 and 8,500 feet elevation), which is the Waterfowl and Arctomys Formations of latest Middle Cambrian age. Above this occurs the Lynx Formation. From binocular and helicopter observations, the Ordovician Chushina Formation does not appear to cap the top. The Pika Formation

TABLE 1. STRATIGRAPHIC TABLE

(Younger units present only beneath Pyramid or Snaring thrust sheets).

Age / unit	Formation	Lithology	Feet
Lower Ordovician			
	Cushina Formation (Survey Peak)	light putty grey shales and micritic limestones	400 to 700
Upper Cambrian			
	Lynx Formation	carbonates, silty, thin-bedded, argillaceous, intraformational conglomerate	2,400 to 3,000
Middle Cambrian			
	Waterfowl Formation	silty dolomites, siltstones, limestones	200 to 700
	Arctomys Formation	shale, silty, red and green, siltstone brown	400 to 600
	Pika Formation	limestone, argillaceous, shale thin bedded	400 to 700
	Titkana Formation (Eldon)	limestone massive	800 to 1,200
unnamed shale unit east of Monarch thrust (	Tatei Formation	limestone, calcareous shale, thin bedded	1,000 to 1,700
	Chetang Formation	limestone, light grey, bedded	400 to 700
Lower Cambrian			
	Hota-Adolphus	thin bedded carbonates, yellow, green, red	900
	Mahto Formation	thin bedded, dark brown siltstones and sandstones	500 to 1,100
	Mural Formation	light grey limestone, dark grey calcareous shale	400 to 800
Lower Cambrian and earlier			
	McNaughton Formation sandstones, at base	quartz fine to coarse conglomeratic and hematitic	6,000 to 8,000
Hadrynian (Windermere)	Byng Formation	grey dolomite, brown weathering	0 to 1,000
informal mappable units in Jasper, Mount Robson and McBride areas (	Upper Miette	dark shales with thin silt laminae and interbeds	2,500 to 4,000
	Middle Miette	sandstone, phyllite, pebble conglomerate	2,500 to 10,000
	Lower Miette	black to dark grey shales, limestones and sandstones	1,000 to 4,000

occurs below the Arctomys Formation, a thin bedded slightly recessive limestone unit about 700 feet thick; the succession continues with the Titkana Formation (Eldon equivalent) of resistant, massive carbonates about 1,200 feet thick, and the Tatei Formation of more recessive and brown weathering carbonates about 1,700 feet thick. The top of the prominent recessive band, to which trees extend, is the top of the Tatei Formation. Hidden from view or covered by trees are the Chetang and Hota-Adolphus Formations (Figure 2). The lower mountains to the left and right expose outcrops of Lower Cambrian or older McNaughton Formation. This formation and the Mahto weather to a characteristic dark grey or black color because of lichen. Where lichens are absent, the weathering color is white or light grey. Continuing to the left about 3,000 feet of recessive, dark weathering strata of the Upper Miette can be seen. Faulted against these strata are resistant middle Miette strata along Moose Lake thrust. The McNaughton Formation is also thinned in comparison to the Gog Group northwest or east of Mount Robson (see Figure 1) and hence the Red Pass thrust probably continues across this ridge and merges with the Moose Lake thrust in the valley of Swiftcurrent Creek to the northwest.

The four mile walk to Kinney Lake is highly recommended to observe the geology and scenery along the way and the present floral and fauna. Outcrops of the McNaughton Formation occur along the trail. At the bridge across Robson River, just below Kinney Lake, is an outcrop of the Mural carbonate which forms a distinctive unit in the upper part of the Gog Group (Table 1). This formation contains the lowest Early Cambrian Olenellus and Archaeocyathid fauna in the region. The olenellids are not the earliest forms and hence some portion of the upper part of the McNaughton Formation is Cambrian and, consequently, this formation is classified as being Lower Cambrian and earlier. Generally, the base of the Cambrian is placed at the bottom of the McNaughton Formation.

For those who enjoy hiking and spectacular views, the 18 mile hike (or ride) into the Berg Lake chalet and its primative but comfortable lodgings is highly recommended. The view of Tumbling and Berg glaciers, extending from the summit of Mount Robson into Berg Lake, are unforgettable.

For summaries of the Cambrian stratigraphy in this area, see the reports by Walcott (1928), Burling(1955), Mountjoy (1962, 1964), and Slind and Perkins (1966).

The Mount Robson syncline (Figure 3) extends northwestwards and gradually comes closer to the Trench, and forms the mountain range directly northeast of McBride. Southeastward, it ends in the Trident Range southwest of Jasper.

Upper Fraser River Valley (Mount Robson to Yellowhead)

The highway between Mount Robson and Yellowhead Pass follows along the tectonic strike. The Moost Lake thrust forms the boundary between the

Selwyn Range, to the southwest, and the Mount Robson syncline, to the northeast. The Moose Lake thrust occurs in the canyon in the Fraser River, immediately southeast of the Mount Robson viewpoint. To the northwest up Swiftcurrent Creek, this thrust places middle Miette strata against McNaughton Formation. To the southeast, the Moose Lake thrust appears to follow the southwest side of the valley and continues between Mount Fitzwilliam and Vista Peak across the Tonquin Valley and south to Fortress Lake.

About one mile southeast of the Mount Robson viewpoint are a series of excellent outcrops, which expose the dark grey argillites of the upper Miette which dip 40 to 60 degrees northeast and presumably are in normal position beneath Gog strata, which outcrop higher on the mountain side.

About five miles further along near Red Pass, one can observe the Red Pass thrust (Figure 3) within the McNaughton Formation and which, on Mount Kain, places McNaughton Formation over Titkana Formation. Most of the strata exposed here belong to the lower part of the McNaughton Formation, which weathers to a characteristic deep red color in all of the regions between here and Jasper. The red color is a hematite stain, presumably derived from weathering of magnetite black sands in the quartz sands.

Exposures of southwest dipping middle Miette strata occur on the other side of Moose Lake. Hence, the stratigraphic throw of the Moose Lake thrust is at least 5,000 feet. In the mountains to the southwest, these strata are deformed into a series of upright folds.

The glaciation of this region is interesting. Several low divides occur across the Selwyn Range; elevations of 5,930 feet opposite Moose Lake, 5,400 feet at the head of Ghita Creek and 4,675 feet between Ptarmigan Creek and the Fraser River. Glaciers, centered near the Cariboo Mountains, flowed eastward across the Selwyn Range and down the Miette and Athabasca valleys and deposited Shushwap type metamorphic glacial erratics near Hinton. The head of the Fraser River probably flowed into the Miette River drainage but appears to have been blocked by a moraine east of Yellowhead Lake.

The right lateral transcurrent Resplendent fault, along Moose River, is unusual and offsets the Robson syncline by about two miles. The southwest side of the fault is the downthrown side.

In the mountains between Moose River and Grant Brook, Middle Cambrian strata as high as the Titkana Formation are visible above tree line. At the Fraser River crossing, there is an excellent view of Mount Fitzwilliam on which outcrops the base of the McNaughton Formation and the upper part of the Miette Group. There, quartz sandstones of the McNaughton abruptly overlie about 1,000 feet of conspicuous, light colored, massive dolomites which correlate with the Byng Formation of Slind and Perkins (1966). To the southeast, these carbonates grade into sandstones, siltstones and mudstones in the upper Miette; they are not truncated by the basal McNaughton sediments. Beneath the Byng Formation, at least 2,000 feet of recessive upper Miette mudstones are present, followed by about 3,000 feet of middle Miette grits, which are exposed on the road east of Yellowhead Lake. The same dolomite occurs beneath the McNaughton Formation on Yellowhead Mountain, but there it is only 500 feet thick. The Byng dolomite thins southwest and interfingers with sands in the upper Miette and disappears just below tree line.

Yellowhead Pass to Jasper

Between Yellowhead and Jasper, the road follows the south side of the Miette River. All the strata exposed belong to the Miette Group. To the north, quartzites of the Gog Group form the summits of Mount Bridgland, Monarch Mountain and the Victoria Cross Ranges which end in Pyramid Mountain at Jasper. To the south, but not visible from the road, Gog strata also form the summits of Roche Noire, the Trident Range and Mount Edith Cavell. The Gog strata outline broad open folds or gently dipping thrust sheets which contrast with the complex folded nature of the underlying Miette strata exposed along the Miette River valley. This change in structural style is primarily due to two factors, the relative incompetence of the Miette Group, as compared to the Gog Group, and the presence of three major thrust faults in this region (Figure 1). Mapping on a regional scale indicates that these thrusts continue southeast across the Miette valley and southeast of the area form prominent thrust sheets east of the Banff-Jasper Highway (Mountjoy, 1961; Price and Mountjoy, 1970). Some of these major faults have not been recognized by Charlesworth et al (1967), probably because of the lack of suitable marker horizons in the middle Miette and because these detailed investigations have not been related to the regional structure.

Just before and at the entrance to Jasper National Park, a series of typical middle Miette resistant grit units separated by recessive argillites, siltstones and mudstones outcrops. Immediately to the east, upper Miette dark grey to pale green silty argillites are exposed. They are separated from the middle Miette to the west by the Moose Pass thrust. This thrust repeats middle Miette strata on the ridges above the Miette valley and extends as far as Fortress Lake repeating Gog strata west of Mount Edith Cavell. From this point eastward to Geikie, the road gradually intersects lower stratigraphic levels of the lower part of the upper Miette and then middle Miette strata (lower Wynd, and Old Fort Point Formations, Table 2) about one half mile east of Clairvaux Creek. These middle Miette strata are exposed in the complex faulted Meadow Creek anticlinorium. The underlying Meadow Creek Formation is exposed about one mile south of the highway in the core of an anticline in Meadow Creek. The Monarch thrust follows Minaga Creek and probably repeats middle Miette strata on the east side of the Meadow Creek anticlinorium and crosses the highway somewhere east of Geikie.

TABLE 2. PRECAMBRIAN STRATIGRAPHY

Charlesworth *et al.*, 1967	Mountjoy this report Campbell, Mountjoy and Young (in press)
Upper Jasper Formation 1300	McNaughton Formation (base)
Lower Jasper Formation 250 Upper Wynd Formation 2200	Byng Formation (carbonates) Upper Miette 2500 to 5,000
Lower Wynd Formation 2400 Old Fort Point FM 1200 Meadow Creek FM 130+ (base not observed)	Middle Miette 4,000 to 9,000
	Lower Miette 3,000 +

This thrust continues southeast, duplicating middle Miette strata and then faulting these strata on Gog strata at Portal Creek. It continues along the Athabasca Valley and becomes the Simpson Pass thrust (Mountjoy and Price, 1970).

From Geikie to Jasper, the road cuts across highly folded middle Miette strata. These fold axes are generally upright, or slightly inclined to the southwest.

The Old Fort Point Formation is exposed in the core of the Muhigan anticlinorium, three miles east of Geikie. This formation does not outcrop again until the Jasper anticlinorium is crossed in the town of Jasper. The eastern part of the Jasper anticlinorium is bounded by the Snaring thrust which follows the west shoulder of Tekerra Mountain and crosses the Maligne Range near Shovel Pass and to the southeast merges with the Pyramid thrust.

STRUCTURAL SUMMARY

The thrust sheets of the Main Ranges are similar in most respects to those of the Front Ranges, except the thrust sheets are somewhat wider. The complexity is less in the Gog part of the stratigraphic succession and greater for portions of the Precambrian Miette Group. The Main Range thrusts dip less steeply than those of the Front Ranges, except for the western Main Ranges, which are steep dipping and in places have vertical dips. These thrusts exhibit an en echelon pattern and, where the stratigraphic separation across an individual thrust decreases and ends, the separation across adjacent or nearby thrusts proportionately increases. The aggregate displacement across a group of thrusts appears to remain relatively constant along strike. In essence, these faults represent slip or shear surfaces, which are interleaved, interlocked and discontinuous but allow the sedimentary pile or wedge to move or flow over the flank of the craton (Price and Mountjoy, 1970).

The eastern Main Ranges consist of thick relatively flat or shallow dipping thrust sheets, with broad, open folds. Cross cutting, steep dipping gravity faults are restricted to the western part of this region in the vicinity of the Robson syncline. These structures reflect development in the thick competent sequence of miogeosynclinal carbonates and quartz sandstones.

The western Main Ranges occur in thick, less competent, shaly and metamorphic facies, which are more homogeneous. Cleavage and complex fold patterns are widespread and laterally extensive large thrusts are rare. The structure tends to exert little control on topography, in contrast to the eastern Main Ranges and Front Ranges.

The area traversed represents a structural culmination, marked by the area of extensive exposure of the Miette Group, in the regional structural salient between Crowsnest Pass and Pine Pass. There is a change in structural grain from NW bending structures, south and north of the culmination, to WNW within the culmination (see Figure 2-1, Price and Mountjoy, 1970). There is no corresponding deflection of structural grain in the Front Ranges or Foothills.

About 60 miles southeast of Tete-Jaune Cache, on the west side of this culmination, paragneiss, schist, amphibolite, and gneissic granite (of Shuswap type metamorphic complex) emerge from beneath a cover of Windermere (Miette) metasedimentary rocks along the Purcell thrust fault and overlie Cambrian strata (Price and Mountjoy, 1970; Campbell, 1968). This metamorphic complex, according to Price and Mountjoy (1970, p.13), represents a tongue of hot mobile rock, which rose diapirically along the Purcell thrust from a deeply buried infrastructure into cooler, sedimentary rocks of the suprastructure. These structures provide a fundamental key to relating the structures of the eastern Crystalline Belt with those of the Rocky Mountains.

From the northern Selwyn Range in the outer metamorphic halo surrounding the above metamorphic complex, coarse biotite porphyroblasts grew with random orientation across both the schistosity and the other foliations in the phyllite. Hence, a significant part of the metamorphic recrystallization outlasted the penetrative deformation. Biotites from these rocks yielded a K-Ar date (Geol. Surv. Can.) of 111 m.y. This probably places an upper limit on the time of metamorphic recrystallization and the proceeding deformation, and confirms the earlier suggestions by several geologists that the structures gradually evolved from west to east.

When the above data is related to the record of the Upper Jurassic and younger clastic wedge and the volumes of sediment eroded from the Main Ranges, these strongly suggest that structures in the Main Ranges probably began to develop as early as Late Jurassic as an active zone of thrust (Price and Mountjoy, 1970, p.23). There is little need to involve source areas farther to the west, such as the Cariboo and Selkirk Mountains, as a provenance for the Mesozoic clastic wedge.

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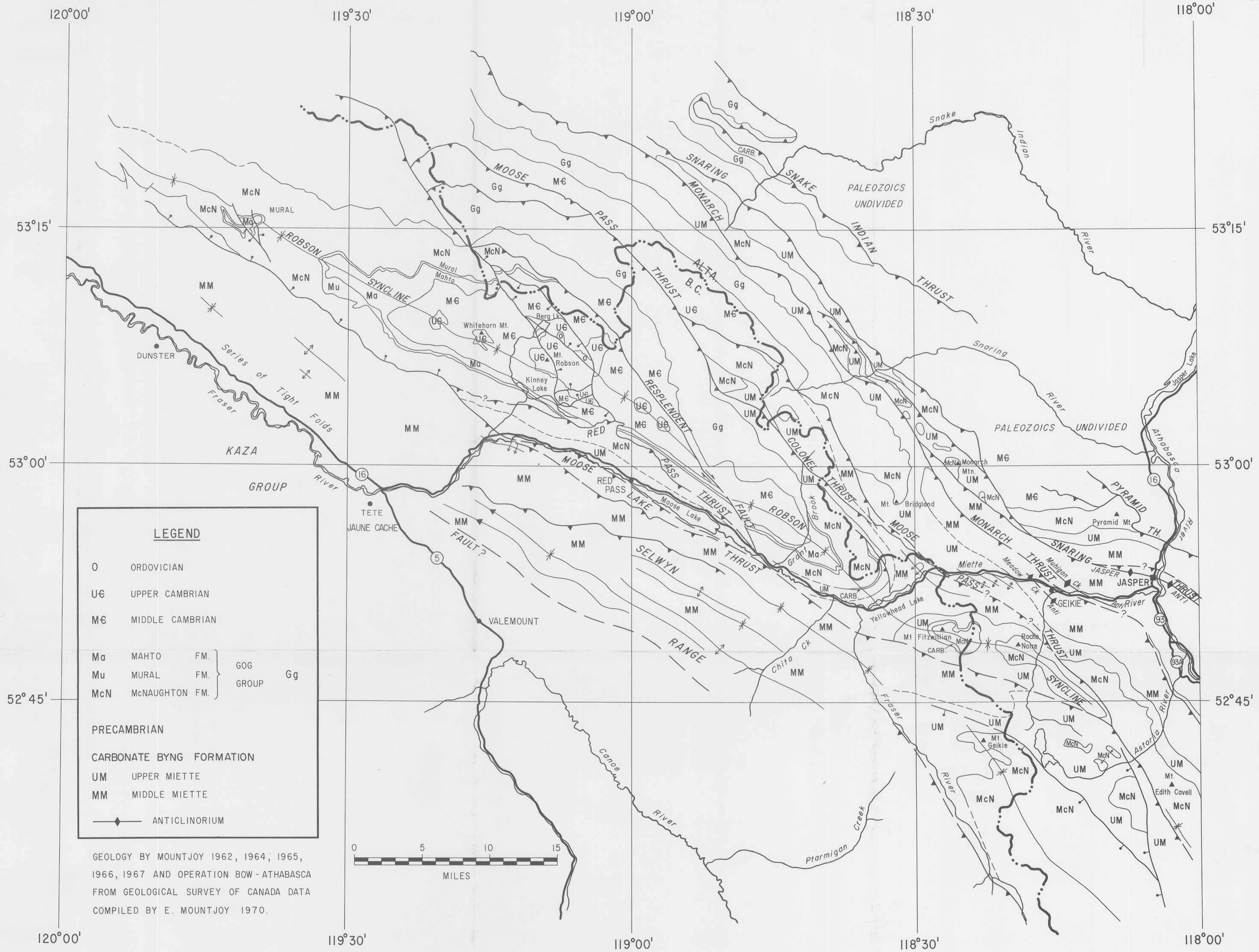

FIGURE I GEOLOGY OF MAIN RANGES BETWEEN TETE JAUNE CACHE TO JASPER

ERIC W. MOUNTJOY 1970

ROAD LOGS - 1970 E.G.S. FIELD CONFERENCE

PEACE RIVER - PINE PASS - YELLOWHEAD

ROAD LOG I (day 1)	Fort St. John - Hudson Hope - Bennett Dam. - route follows valley of Peace River.
ROAD LOG II (day 1)	Hudson Hope - Chetwynd.
ROAD LOG III (day 2)	Chetwynd - Pine Pass - Windy Point. - route follows valley of Pine River to Pine Pass, and valley of Misinchinka River to Windy Point in the Rocky Mountain Trench.
ROAD LOG IV (day 2)	Windy Point - Prince George. - route parallels drainage system of Crooked River.
ROAD LOG V (day 3)	Prince George - Jasper. - Yellowhead Route follows valley of Fraser River to Yellowhead Pass, continues in valley of Miette River to Jasper.

Mileages given have been calibrated to within approximately one percent of statute miles.

The editors gratefully acknowledge the contributions of Drs. D.F. Stott and G.C. Taylor, Geological Survey of Canada, Calgary, Alberta, for Road Logs I-III, and Dr. H.A.K. Charlesworth, University of Alberta, Edmonton, Alberta, for Road Log V. Photographs have been provided through the courtesy of Shell Canada Limited.

ROAD LOG I

FORT ST. JOHN TO W.A.C. BENNETT DAM

0.0 Junction of Alaska Highway and south turnoff into Fort St. John. Cairn commemorating historic journey by Sir Alexander Mackenzie who wintered near this site during the winter of 1792-1793 before continuing to the Pacific coast by way of Peace River. Fort St. John is a supply centre for northern exploration for oil and gas.

1.3 Junction of Alaska Highway and north turnoff into Fort St. John.

2.6 Cliffs of Upper Cretaceous Dunvegan sandstone appear along ridges to northeast.

4.4 Exposures of Dunvegan sandstone.

6.6 Charlie Lake settlement. Core storage facilities and offices of British Columbia Department of Mines and Petroleum Resources.

Dunvegan sandstone occurs on east side of Charlie Lake.

7.95 Junction of Alaska Highway and Highway 29, access road from Fort St. John into Hudson Hope.

Bedrock of Dunvegan sandstone is covered by thin veneer of glacial drift.

12.0 Interbedded sandstones and mudstones of Dunvegan Formation are exposed in road cut on north side of road.

13.76 Deep Creek bridge.

Shaftesbury shales occur in the valleys and Dunvegan sandstone caps the hills.

14.7 Approximate contact of Shaftesbury and Dunvegan Formation in road cut to north. Dunvegan strata are exposed in road cuts for next quarter mile.

15.7 View of mountain ranges to west.

16.8 Another view of mountain ranges and of Peace River valley with its glacial terraces.

Dunvegan sandstone occurs at top of hill.

18.7 Viewpoint just below level of glacial terrace.

Shaftesbury shales are exposed for half mile. Shaftesbury Formation is overlain by glacial lake silts. A large channel structure cuts downward into the silts.

20.1 Shaftesbury shales exposed on south side of river. Neogastroplites specimens are fairly common along this part of the river.

20.45 Shaftesbury Formation in road cut.

20.75 Cache Creek bridge.

Shaftesbury shales are well exposed in west bank.

Road ascends glacial terrace and higher terrace rises to north. Shaftesbury shales show in gullies on south side of Peace River.

$24.6^{\pm}$ Layered and crossbedded glacial gravels. Large exposures of Shaftesbury shales on Peace River to south.

26.3 Glacial silts in road cuts to top of uppermost terrace.

Road continues along upper terrace. Cross-sections of dunes appear in road cuts on either side.

28.4 Road descends from terraces to valley bottom.

Glacial silts and minor outcrops of Shaftesbury Formation appear in road cuts on north side.

30.0 Attachie school.

30.95 Halfway River bridge.

Shaftesbury shales outcrop along east bank.

31.65 Shaftesbury shales.

32.35 Gravel pit to north.

32.9 End of pavement July 24, 1970.

33.75 Glacial silts.

37.3 Glacial silts.

38.9 Gravel pit.

39.4 Crossbedded glacial gravels.

Plate 1: Crossbedded glacial gravels.
Mile 39.4.

Plate 2: Gates sandstone exposed on
south side of Peace River.
Mile 48.9.

41.5 Log cabin and corral on south side of highway. Good spring water to west of buildings.

45.0 Top of terraces. Road cut in glacial gravels. Shaftesbury Formation exposed toward valley floor.

45.2 Farrell Creek. Large cut bank of Shaftesbury shales on east bank. Shales exposed in road cuts to top of terrace.

46.7 Large exposures of Shaftesbury Formation along river.

48.1 Basal beds of Shaftesbury Formation in gully to north and Gates sandstone at river level. Gastroplites specimens have been obtained from the gully.

48.6 Gates sandstone occurs along river.

48.7 Beginning of pavement (July, 1970).

49.2 Thin-bedded Gates sandstone on south side.

50.0 Lower Shaftesbury shales in north bank.

52.1 Lynx Creek.

52.3 Glacial gravels to top of terrace.

55.95 Hudson Hope.

Junction of Highway 29 to Chetwynd (south) and road into W.A.C. Bennett dam.

57.75 View of Peace River bridge, valley to west, and anticline in Gates sandstone along river.

58.1 Top of terrace. View to west of Mount Gething and Butler Ridge to north, formed by folds in Lower Cretaceous Minnes and Bullhead strata.

63.8 Anticline to northwest. Cadomin conglomerate forms massive ridges at crest.

66.6 Trapper Cabin picnic area.

67.45 Right-of-way used for hauling earth-fill from moraine deposit to dam. Storage area for surplus equipment including conveyor system to north.

68.0 Gething sandstone exposed in small fold.

68.9 Office buildings. Viewpoint for reservoir--Williston Lake.

69.1 Turnoff to public lookout. The power house lies to the north of the lookout.

Type section of Gething Formation extends downstream along canyon. Uppermost beds of Cadomin Formation are exposed at toe of dam.

69.9 Schrum Generating Station.

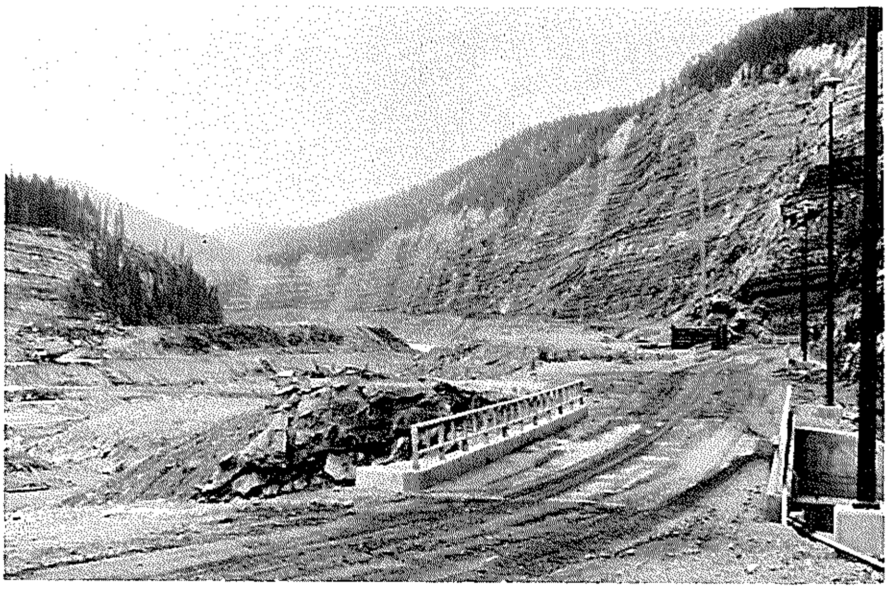

Plate 3: Gething Formation viewed from toe of Bennett Dam looking downstream toward Gething Creek.

ROAD LOG II

HUDSON HOPE TO CHETWYND

0.0 Junction Highway 29 and turnoff to Bennett dam.

1.0 Western limits of Hudson Hope.

2.45 Alwin Holland Memorial Park entrance.

Excellent exposures of Gates sandstone upstream and Moosebar shales downstream.

Road is on glacial terrace with higher terrace to north.

3.2 Gates Formation exposed along west flank of anticline in river to south.

4.7 Peace River bridge.

Gates sandstone exposed in road cuts and in cliffs along river both upstream and downstream.

5.3 Gates sandstone on either side of road.

6.6 View to west of Portage Mountain.

8.0 View to east of Peace River valley.

10.9 Mile Post 30

12.6 Glacial gravels

13.3 South dipping Hasler shales in road cuts for 1½ mile.

15.6 Hasler shales.

16.3 Upper Cameron Lakes on west side of road.

Easternmost exposures of Goodrich Formation in road cuts for .25 mile. The Goodrich Formation is not mappable on surface east of this point.

17.0 Lower beds of Cruiser Formation in road cut to east.

18.4 Lower Cameron Lakes to west.

Ridges to east and west are capped by Dunvegan sandstone.

19.9 West end of Moberly Lake.

Ridges to north and south of lake are capped by Dunvegan sandstone.

Cruiser shales in road cuts on either side.

20.4 Cruiser shales in road cuts to south for half mile.

21.1 Mile post 20.

21.4 Intermittent outcrops of Cruiser shales for 3 miles.

28.9 Moberly River bridge at outlet of Moberly Lake.

31.2 Mile post 10.

34.65 Dunvegan mudstone and argillaceous sandstone for quarter mile.

37.2± Glacial silts in road cut to west.

38.6 Dunvegan Formation outcrops in long road cut toward bottom of hill.

View to west of Foothills and to south, of glacial valley.

40.2 Town limits of Chetwynd.

41.5 Junction of Highway 29 and John Hart Highway (Highway 97).

Chetwynd Hotel is northwest of intersection.

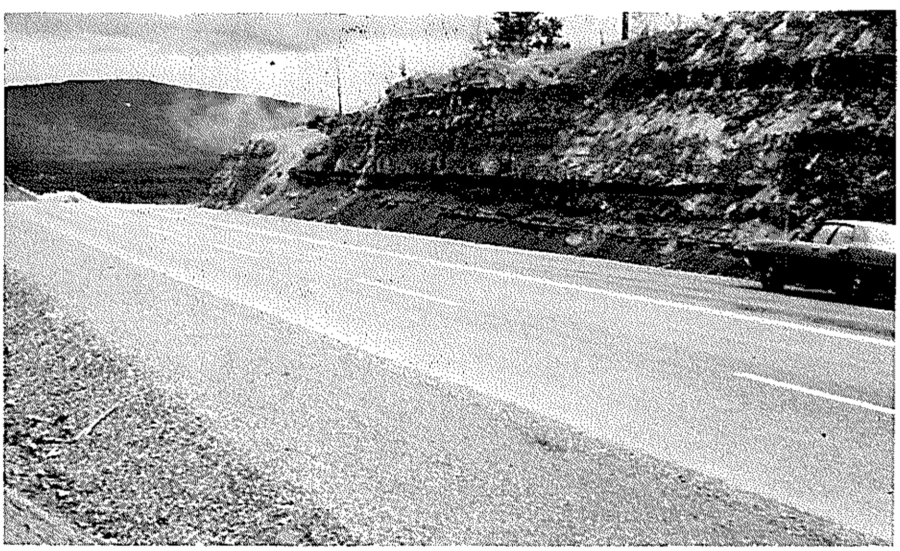

Plate 4: Dunvegan Formation near Chetwynd. Mile 38.6.

ROAD LOG III

CHETWYND TO WINDY POINT

0.0 Junction of John Hart Highway (Highway 97) and Highway 29.

0.4 View to south of Upper Cretaceous Kaskapau sandstone on Tuscoola Mountain and Elephant Ridge.

0.5 British Columbia Forestry station.

2.6 Dunvegan sandstone on hills to north and south, underlain by Cruiser shale.

3.1 Lake silts of Pleistocene Lake Peace.

3.4 Cruiser shales in road cut to north.

4.45 Wildmare Creek.

Anticlinal axis.

5.65 Quarry in Dunvegan sandstone.

6.15 Bissett Creek.

Outcrops of Dunvegan crossbedded sandstone in road cuts to north for next .75 mile. Gentle folds are visible in the Dunvegan Formation which caps the ridges.

9.3 Cruiser shales and interbedded argillaceous sandstone in road cuts to north for ¼ mile.

10.85 Cruiser shales in road cut to north.

11.7 Fault along east flank of Commotion anticline. Goodrich sandstone in hanging wall forms conical hill to northwest. Cruiser shales in foot-wall to east are overlain by Dunvegan sandstone.

13.2 Commotion Creek.

Commotion anticline with beds of the Commotion Formation exposed along creek. Site of British Columbia Government Pine River No. 1 well drilled in 1942.

Type section of Boulder Creek Member of Commotion Formation. Prominent cliffs extending north of road for 1 mile are formed by basal unit of fine to medium-grained, clean sandstone and by overlying unit of massive conglomerate.

14.7 To north, Hasler shales occur on lower slopes and Goodrich sandstones occur at top of ridge.

16.0 Type section of Goodrich Formation is visible to north in gully tributary to Bowlder Creek.

16.2 Hasler shales occur in road cuts along north side of road for .75 mile..

18.0 Hasler shales and siltstones occur in road cut on north side for 1 mile. The contact between the lower unit of massive silty mudstone and argillaceous siltstone and the overlying unit of rubbly, concretionary mudstone is well exposed.

20.5 Hasler shales in road cut along north side of road. Ridges to north and south are capped by Goodrich Formation.

22.5 Bedded glacial gravels in road and railroad cuts.

23.7 Glacial silts and gravels, to north.

25.3 Glacial silts in cut bank, to north.

View to west of Mount Bickford comprised by a faulted anticline in Lower Cretaceous Minnes Group.

25.8 Glacial silts, sands, and gravels for .75 mile.

26.9 Willow Flats settlement and West Coast Transmission Pumping Station.

Dokie Ridge section of Fort St. John Group is about 6 miles to the north. Goodrich sandstones form flat-topped ridge to east. Valley of Fred Nelson Creek lies in Hasler shales. Sharp, double-humped ridge to north is underlain by Commotion Formation and Crassier Creek flows through Moosebar shales.

28.8 Crassier Creek bridge.

29.25 East-dipping sandstone of Gething Formation on flank of small anticline in road cut to north.

29.6 West-dipping Gething sandstones with coal, for .25 mile.

30.1 Willow Creek anticline on south side of Pine River.

Several wells, including Hunt Sands Sun Falls c-18-G, have been drilled along this structure.

Commotion sandstone on ridge to west of valley.

Upper unit

Lower unit

Plate 5: Hasler Formation showing contact between lower massive siltstone unit and upper rubbly, concretionary mudstone unit. Mile 18.0.

Rubbly weathering, concretionary mudstone and siltstone.

Massive, silty mudstone and argillaceous siltstone.

Plate 6: Hasler Formation showing detail of contact between upper and lower units. Mile 18.1.

30.2 View to southeast of Falls Mountain, capped by Commotion Formation. Also good view to southwest of Pyramis Peak capped by Minnes Group.

30.65 Folds in Gething Formation for next .5 mile.

31.75 Pleistocene silts in cut bank to north.

32.1 Moosebar Formation, massive to blocky weathering mudstone and siltstone.

32.6 Fisher Creek bridge.

Outcrop visible some distance upstream is Moosebar shale occurring along axis of Fisher Creek syncline.

33.5 Gething Formation exposed in road cuts for next mile. Trenches and adit at west of exposure reveal several seams of coal, 10 to 20 feet thick.

34.2 Cadomin Formation exposed on power line, north of highway, on east flank of Bickford anticline.

35.9 Contact between Monteith and Beattie Peaks Formations on west flank of Bickford anticline.

37.8 Anticline with Monteith quartzose sandstone at road level.

Hunt-Sands-Sun, Boulder b-74-D well site is south of the highway.

38.55 Big Boulder Creek Bridge. Beattie Peaks Formation exposed south of road.

39.3 Martin Creek.

Series of minor folds in Minnes strata may be seen on ridge south of Pine River.

40.25 Lillico (Little Boulder) Creek bridge. Excellent view to southeast of Pyramis Peak.

40.9 Le Moray Lodge.

To south, Jurassic Fernie shales and Jurassic-Cretaceous Monteith sandstone appear in hanging wall of thrust plate. Triassic beds appear along lower slopes of Mount Le Moray to the southwest and are overlain by Jurassic Fernie shales. The upper part of Mount Le Moray is formed by Monteith sandstone which is also exposed along powerline west of lodge.

Plate 7: Monteith Formation; massive, cross-bedded sandstones. Mile 41.4.

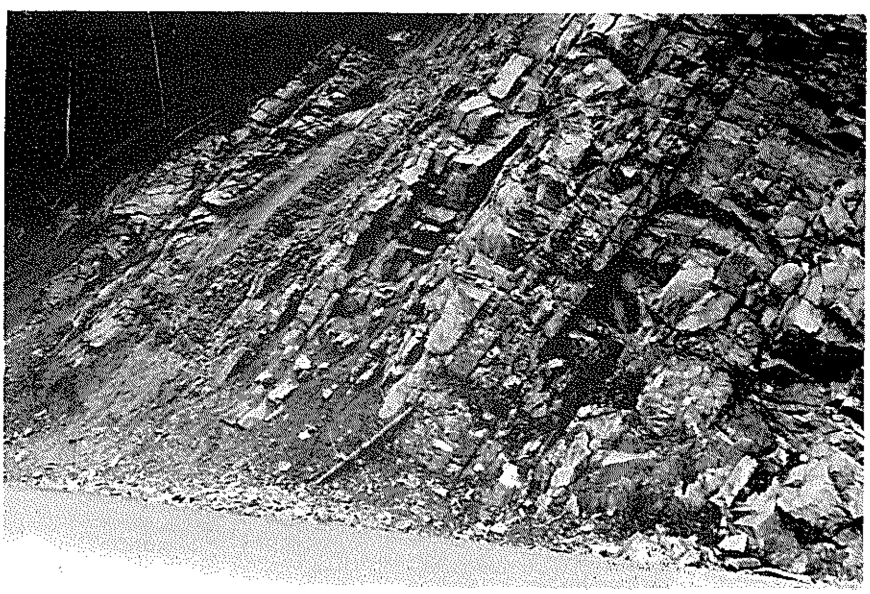

Plate 8: Triassic Grey Beds with clean, cross-bedded, porous sandstones (rubbly weathering). Mile 44.5.

41.2 West dipping Monteith beds are exposed for .25 mile. Massive sandstones show crossbedding and channel structures.

Synclinal axis (possibly fault of small displacement) occurs in covered interval at west end of exposure.

41.6 Overturned beds of Monteith Formation with base to west.

41.9 Fernie Passage beds, vertical to overturned eastward.

43.15 Cairnes Creek bridge.

43.5 Abandoned well site, Triad, Bush Mountain b-23-A(1).

View to west of Solitude Mountain with Mississippian strata along crest. Imbricate thrust zone at base involves Mississippian, Permian, and Triassic rocks.

44.25 Anticline in Triassic Grey Beds, with fault to west.

44.35 "Charlie Lake" evaporites of Triassic Grey Beds.

44.5 Triassic Grey beds in road cut to north with clean cross-bedded sandstones in western portion of cut.

Abandoned well site, Triad-British Petroleum, Bush Mountain a-15-A.

45.0 Triassic Pardonet beds are exposed east of Silver Sands Creek and Jurassic Nordegg beds occur to west.

45.1 Silver Sands Creek.

45.85 Subway beneath Pacific Great Eastern Railway.

Picnic site to south.

Pardonet beds on east side of subway abutment.

45.95 Pine River bridge.

Triassic Pardonet beds along railway cut to north are overlain by Jurassic Nordegg beds. Triassic Pardonet beds are in fault contact with Jurassic beds to west.

46.1 Triassic "Charlie Lake" solution breccias in road cut and exposures to south.

46.35 Triassic Toad-Grayling shales in road cut to south.

46.95 Beds of Mississippian lower Prophet Formation exposed in road cuts to south.

47.3 Upper Prophet beds in road cut to south.

47.6 Permian Mount Green and Fantasque chert in exposures to south.

48.0 Triassic Toad Formation in road cuts to south for next mile.

48.7 Folding in cliff south of road (Solitude Mountain).

49.1 Permian Fantasque Formation is exposed above road on slope but not at road level. Mount Green Beds unconformably overlie Mississippian Prophet cherty limestones. Toad Formation at road level.

49.3 Prophet Formation is exposed south of road.

49.95 Link Creek.

51.3 Besa River shales in road cuts for next mile. Prophet Formation exposed on ridge to north.

52.1 Pleistocene gravels in pit to north.

53.2 Besa River in road cuts and along river bank for next .5 mile.

54.0 View to north of Mt. Garbitt (elev. 5830) capped by Upper Cambrian and Lower Ordovician nodular limestones which have been thrust over Besa River shales.

54.25 Mount Hawk equivalent. Devonian argillaceous limestones.

View west of conical hill capped by Misinchinka Group which has been thrust over Cambro-Ordovician limestones.

54.6 Power line crosses road.

Miette rocks are thrust on Devonian Mount Hawk equivalents. Above road to south, Miette sandstone forms abutment of transmission tower.

55.1 Miette quartzite and argillite in road cut to southeast. Good view of Mt. Garbitt and conical hill.

55.3 Chloritic schists of Miette Group along road. Lower Cambrian Gog sediments overlie Miette Group on mountains to northwest.

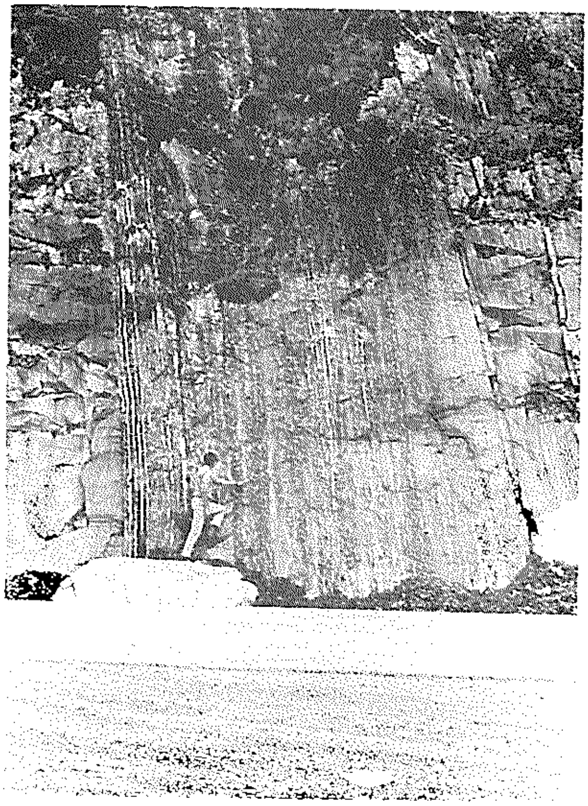

Plate 9: Prophet Formation; cherty limestones.
Mile 49.3.

Plate 10: Azouzetta Lake; Ordovician and Cambrian carbonates on west flank of Murray Range.
Mile 68.7.

55.5 Chloritic schists and phyllites of Miette Group.

55.9 Miette argillites and phyllites for .5 mile on southeast side.

57.3 Gog sediments occur above highway.

57.9 Dolomitic sandstone of middle part of Gog.

58.1 Varicoloured dolomites of Gog, equivalent to Mural Formation.

Axis of syncline of Murray Range.

58.5 Gog quartzite.

59.2 Middle Cambrian Titkana dolomite (?).

59.4 Arctomys Formation on cliff to southeast.

59.5 Titkana dolomite at road level.

59.9 Arctomys Formation at road level in trees.

60.3 Upper Cambrian Lynx strata to east.

60.55 Nodular limestone, probably about 500 feet above base of Lynx, for .5 mile.

60.75 View of Murray Range, straight ahead.

61.0 Railroad tunnel.

View south of Upper Cambrian and Lower Ordovician limestones which form cliffs on hillside.

62.15 Cliffs of Cambrian Lynx limestone to southeast.

64.25 Westcoast Transmission Pumping Station.

Rock slide for approximately 2 miles.

65.8 Microwave repeater station.

Ordovician Chushina Formation forms dip slopes to east. Upper Cambrian Lynx carbonates occur in Pine Valley to west.

67.55 Pine Valley Service Station.

67.7 Monkman quartzite in cliffs to west.

Misinchinka schist in hanging wall of Back Ranges Fault.

68.7 Azouzetta Lake, viewpoint.

View along syncline to northwest and southeast. Ordovician carbonates form dip slopes on east side of Lake and Cambrian beds appear along peaks and ridge to east.

Monkman quartzite is exposed in cliffs below viewpoint.

69.0 Intermittent outcrops of Misinchinka schist, chloritic and carbonaceous phyllite for one mile.

Major fault between lookout and these exposures.

70.7 Azu Village.

71.05 Summit of Pine Pass. View of Misinchinka valley to south.

71.9 Chloritic talc schist of Misinchinka Group.

72.1 Impure micaceous quartzite in chloritic phyllite.

72.6 Intermittent outcrops for 1.5 mile of phyllite and quartzite.

74.05 Underpass.

74.15 Intermittent to continuous outcrop of quartz-chlorite-epidote phyllite.

75.0 Bijou Creek picnic site.

Phyllite in cliffs.

75.1 Crossing Bijou Creek.

75.3 Intermittent outcrops for one mile of green phyllite with interbedded, very coarse-grained quartzite and metamorphosed sandstone.

76.2 Large blocks of rutilate quartz.

76.4 Quartz-chlorite-biotite phyllite of Misinchinka Group.

76.8 Hungry Moose Creek.

77.2 Sheared, schistose conglomerate.

77.4	View to south of Old Friend Mtn. composed of uppermost Misinchinka Group (slate, greywacke, quartzite, conglomerate) capped by lower Cambrian quartzite.
77.5	Intermittent to continuous outcrop for 2 miles of chlorite-muscovite phyllite and quartzite.
78.1	Rolston Creek.
80.4	Railway crossing.
80.8	Crossbedded sandstone and biotite phyllite overlain by chloritic phyllite with thin interbeds of quartzite (cleavage 330/85 SW, bedding 285/54 SW).
80.8	Power Line.
	Quartzites and interbedded quartz muscovite phyllite.
81.1	Carbonaceous, chloritic phyllite.
81.35	Outcrop of chloritic phyllite with prominent bedding and near vertical cleavage.
81.4	Intermittent outcrops of limestone, talc phyllite, quartz-muscovite-biotite phyllite, and quartzite.
82.0	Honeymoon Creek.
	Maintenance Camp.
83.4	Intermittent outcrops for one mile of green chlorite-muscovite schists and phyllitic limestones, meta-conglomerate, coarsely-grained quartzite, and quartz-muscovite schist.
84.65	Caswell Creek.
84.85	Chloritic schists.
85.45	Intermittent outcrops for 2.5 miles of conglomeratic quartzite, chlorite phyllite, and quartz-muscovite-chlorite schist.
89.1	Trapper Creek.
89.95	Kennedy Siding Road to south.
95.35	Power Line.
95.7	View to west across Rocky Mountain Trench.
95.85	Railway crossing.
96.2	Junction of Highway 97 and highway to Mackenzie and Findlay Forks.
96.6	Parsnip River bridge.
97.45	Windy Point Lodge.

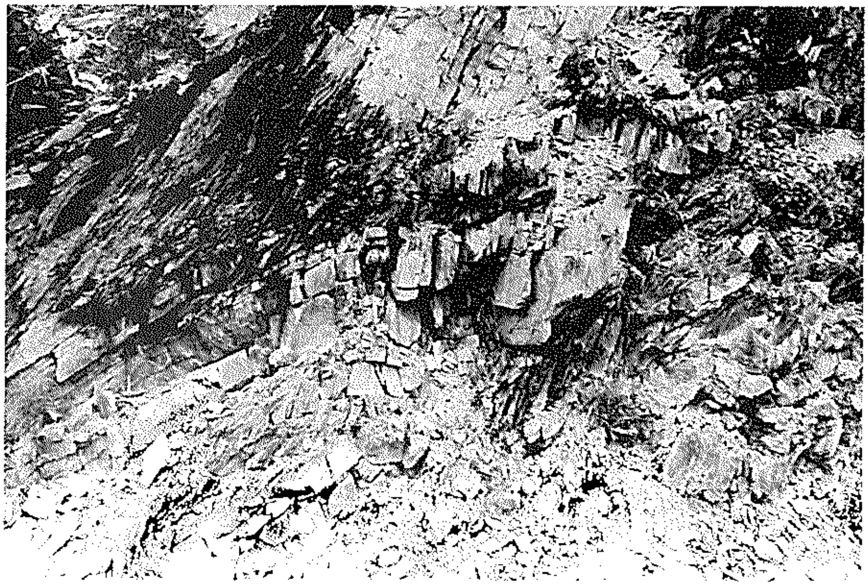

Plate 11: Misinchinka Group; chloritic phyllite and quartzitic sandstone showing relation of bedding to cleavage. Mile 80.8.

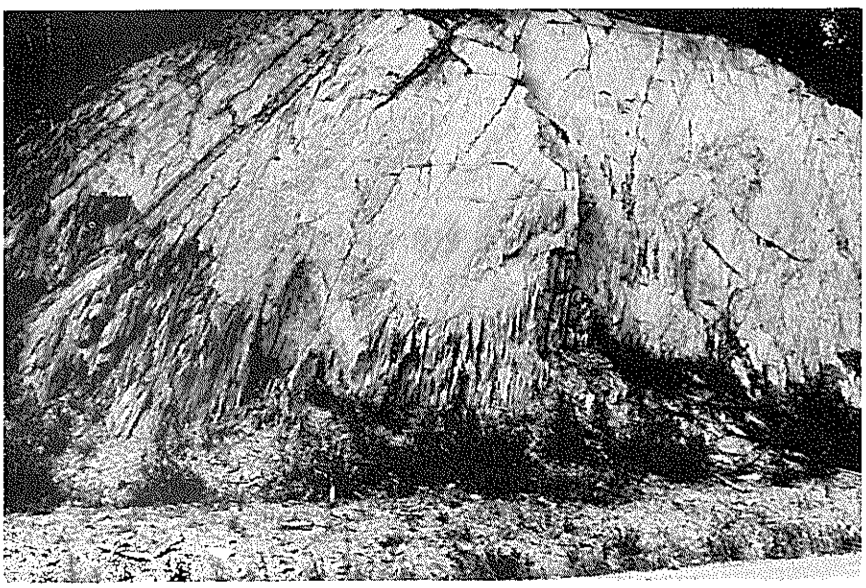

Plate 12: Misinchinka Group; chloritic phyllite and quartzite showing bedding (285/54' SW) and prominent cleavage (330/80' SW). Mile 81.35.

ROAD LOG IV

WINDY POINT TO PRINCE GEORGE

0.00 Windy Point Lodge.

.70 B.C. Forest Service access roads.

2.05 Glacial gravels on left.

2.55 Road to Trout Lake.

3.35 View to right of Tudyah Lake.

3.45 Glacial silts and clays.

4.45 Road to Melville Lodge.

6.65 Westcoast Transmission Compressor Station. Continuous outcrops of glacial sands, silts and gravels for about one half mile.

9.5 Ft. MacLeod.

9.95 "Ft. Ghastly"; cardboard and plastic replica bears and moose browsing in the bushes.

10.35 MacLeod Lake. At this point the route crosses the dominant structural feature of the area, the MacLeod Lake fault, which separates the rock sequence of the Interior Plateau from that of the Rocky Mountains. Highway 97 parallels the fault trace for approximately forty-five miles.

11.25 View of MacLeod Lake and hills on west of lake which are composed of basaltic pillow lavas of the Devonian-Mississippian Slide Mountain Group. Diabase and diorite dykes and sills cut the Group and may be correlative with the Mississippian (?) Mount Murray Intrusions.

17.05 Whiskers Creek Campground.

17.15 Whiskers Creek.

23.2 Crooked River Cabins. Route has passed the south end of MacLeod Lake and now runs sub-parallel to the Crooked River.

26.25 42 Mile Creek.

26.30 Tributary road to east which leads to small rubbly outcrops (in about 1 mile) of dark, fossiliferous, argillaceous dolomitic limestone likely Silurian-Ordovician in age.

26.8 Exposure of glacial gravels on left.

27.1 View west across MacLeod Lake fault into mouth of Weedon Creek which cuts through the plateau-like hills composed of regularly bedded Slide Mountain Group.

27.4 Crooked River on right.

30.1 Lomas Creek.

32.0 Exposure of crossbedded gravels in gravel pit.

33.8 Kerry Lake.

41.05 Redrocky Creek.

44.3 Passing west across approximate trace of MacLeod Lake Fault.

45.75 Bridge over Angusmac Creek.

47.75 Glacial sands discontinuously exposed for approximately seven miles.

Route passes onto a Pleistocene sand plain having a decorative, uniform stand of toothpick pine.

51.0 Turn off to Bear Creek townsite.

52.0 Bear Lake Picnic Ground.

52.1 Bear Lake service station.

52.6 Bear Lake campground.

53.4 Glacial gravels.

53.92 Railroad crossing (P.G.E.).

54.05 Horizontally bedded gravels in gravel pit.

58.1 Low hills to right are underlain primarily by Miocene lava flows of the Endako Group which is generally less than 200 feet thick.

66.15	Railroad Crossing.
67.3	Entering Summit Lake.
67.8	Arctic Divide (divide between Arctic and Pacific watersheds).
68.7	Railroad crossing.
71.3	Crossing power lines.
77.05	Crossing power lines.
80.65	Railroad crossing.
82.60	Bridge over Salmon River.
85.5	Low hills to west are underlain by Cambrian Cariboo Group.
97.8	Bridge over Fraser River, northwest section of Prince George.

ROAD LOG V

PRINCE GEORGE TO JASPER

0.0 Junction between Highway 16 and road to airport, approximately 3 miles E of Prince George. Ridge to E is underlain by Takla rocks. That to SE exposes Precambrian metamorphics intruded by Cretaceous granitic rocks. Gap between ridges exposes sub-Takla unit intruded by latest Triassic or earliest Jurassic granitic rocks (Fig. 1).[1] Although nearby Takla does not appear to contain debris from this intrusion, similar intrusions to S were unroofed during Early Jurassic and contributed material to sediments of this age.

0.0 - 8.0 Interval with no road outcrops underlain by sub-Takla unit. Tabor Lake to SE between 6.0 and 7.0.

8.0 - 11.0 Interval with scattered road outcrops underlain by Takla Group which will be examined at 9.7. Low hills to W visible from this stop are underlain by ultrabasic rocks of Pinchi Geanticline.

8.45 Junction between Highway 16 and road to Giscome.

10.0 Rocky Mountains are visible to E. Rocky Mountain Trench at this latitude merges with Interior Plateau. Hills in foreground are underlain by Slide Mountain Group of Omenica Geanticline.

11.0 - 12.0 Interval with no road outcrops underlain by sub-Takla unit.

12.0 - 39.0 Interval with scattered, commonly glaciated, road outcrops underlain by Antler Formation of Slide Mountain Group. Basalts will be examined at 28.8. Argillites are characteristically darker than basalts, although they occasionally are rusty-weathering.

18.9 Bridge over Willow River.

24.8 Outcrop of Antler Formation: dark green, brecciated, and slickensided crystal tuff with narrow shear zones.

25.2 Bridge over Vama Vama Creek.

1 Cross sections and figures used as reference in Road Log V are from the paper by Campbell and Charlesworth.

32.55	Bridge over Bowron River. Few miles to SE is Upper Cretaceous or Lower Tertiary non-marine sedimentary basin with deposits of coal and amber.
34.15	Outcrop of Antler Formation argillites.
36.25	Service station; last gas until McBride (90 miles).
36.85	Example of roche moutonnée.
38.7	Outcrop of rusty weathering, slickensided and quartz-vined argillite.
39.0 - 42.0	Interval, with good road outcrops of cleaved and kinked phyllite and grit, underlain by Kaza Group, which is possibly unconformable beneath Slide Mountain Group.
42.0 - 47.0	Interval, with several glaciated road outcrops, underlain by Mural Formation (e.g. 42.4), separated from Kaza Group to W by longitudinal fault. Across Fraser River from 44.5, structure of westernmost Rocky Mountains is that of synclinorium continuous with Mount Robson syncline to SE. In core of synclinorium are Silurian shale, limestone, dolomite, and quartzite; quartzite visible towards SE end of flat-topped ridge. At NW extremity of ridge is plutonic intrusion containing ultrabasic rocks and syenite associated with large magnetic anomaly and metamorphic aureole.
43.65	Bridge over Kenneth Creek.
47.0 - 48.7	Interval with few road outcrops underlain by Cunningham (?) Formation.
48.7 - 52.0	Interval with several road outcrops underlain by quartzite and siltstone of Yanks Peak and possibly Midas Formation. to S, Sugarbowl Mtn. at NW extremity of Cariboo Mountains exposes gently dipping Yankee Belle strata which, together with Cunningham Formation is separated from Yanks Peak and Midas Formations by NW striking fault.
52.0 - 55.0	Interval, with several road outcrops, underlain by Mural Formation. At 53.1 it contains fragments of archeocyathids and trilobites.
53.95	Bridge over Hungary Creek.

Plate 13: Mural Formation, slickensided and quartz-veined cyclical carbonates. Mile 42.4.

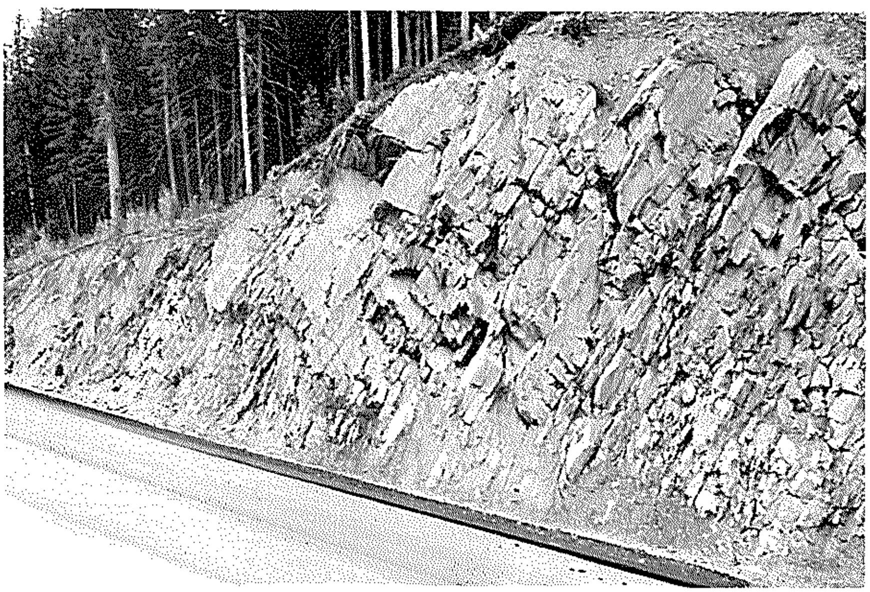

Plate 14: Kaza Group, cleaved phyllite. Mile 103.6.

55.0 - 72.0	Interval with several road outcrops underlain by Yankee Belle and Yanks Peak Formations. At 58.4 are some orange-weathering dolomites near top of Yankee Belle Formation and at 61.25 Yanks Peak Formation may be examined. From this point Silurian quartzites in core of Mount Robson synclinorium are visible on NE slopes of Trench.
60.5	Bridge over Driscoll Creek. From this point to McBride, silts and sands several hundred feet thick and deposited in an ice-dammed lake are exposed (e.g. 68.35).
72.35	Bridge over Slim Creek. Mountains visible to SW for next few miles contain gently dipping but complexly faulted complete Cambrian section of Cariboo type that is now only 20 miles from nearest typical Rocky Mountain Cambrian section.
72.4 - 79.4	Covered.
77.7	Bridge over Dome Creek. Structure across this part of route is illustrated in Figure 1A.
79.4 - 90.4	Interval with several road outcrops underlain by Yankee Belle and Yanks Peak Formations. Across Trench to SE, Mt. Rider with Gog and Mural strata in Mount Robson synclinorium comes into view at 83.2 (see 121.0). Ridge immediately NE of highway at 85.8 is of Mural Formation.
86.4	Bridge over Ptarmigan Creek. To SW tallest peak contains vertical Cunningham strata bounded to NE by gently SW-dipping panel containing Yankee Belle to Dome Creek Formations.
90.4 - 103.5	Covered. To SE, mountain with smooth rounded slopes coming into view at 90.4 is underlain by Isaac Formation. At 97.9 stop may be made to observe Zig-Zag Ridge to SW with Cunningham and Yankee Belle strata; mountain NW of ridge and on other side of Snowshoe Creek exposes Yankee Belle and Cunningham strata in peak, faulted against panel of Mural to Yankee Belle Formations structurally continuous with that on Zig-Zag Ridge.
92.45	Catfish Creek.
97.55	Bridge across Snowshoe Creek.

103.5 - 110.5	Interval, with several road outcrops, underlain by Kaza Group which will be examined at 103.55.
103.9	Bridge across Goat River.
110.6 - 121.6	Covered.
110.9	Bridge over West Twin Creek. Peak coming into view to SE across Trench has Gog underlain by Miette in SW limb of Mount Robson synclinorium. Structure across this part of route is illustrated in Figure 1B.
119.3	Bridge over Clyde Creek.
121.0	Bridge over McIntosh Creek. Across Trench, farthest peak to NW is Mt. Rider (see 79.4 - 90.4). Peak and upper part of SW shoulder expose Gog strata in core and overturned NE limb of syncline. Another overturned syncline with Gog and Mural strata occurs SW of steep fault that intersects skyline in prominent col. Peak SE of Mt. Rider exposes overturned NE limb of synclinorium with Gog and Mural strata. Succeeding peak to SE is that mentioned in 110.9. Ridge SE of this exposes Miette strata in SW limb of Mount Robson synclinorium.
121.5 - 143.5	Route lies in Trench which is here apparently underlain by folded Gog strata (Rocky Mountain facies) down-faulted on both sides against Precambrian rocks. Gog becomes visible to NE at 127.4. To S, Premier Range in Cariboo Mountains becomes visible at 127.4.
126.75	Railway crossing (uncontrolled). Hills to SW underlain by isoclinally folded Isaac (smooth topography) and Kaza (rugged topography) rocks.
127.15	Bridge across Doré River.
129.7	McBride Railway Station.
131.15	Bridge over Fraser River.
137.2	Bridge over Holmes (Beaver) River. Valley of Raush River is visible to SW. Structure across this part of route is illustrated in Figure 1C.
142.3	Bridge over King (Nevin) Creek.
143.0 - 162.0	Covered.

146.6 Bridge over Baker (Halliday) Creek. To SE is Malton Range at NW extremity of Monashee Mountains, with possible remobilized cratonic basement.

150.5 Turn off to Dunster.

157.55 Bridge over Horse (Harvey) Creek.

157.65 Big Foot campground.

161.0 Service Station.

162.2 Bridge over Small Creek.

162.5 - 171.5 Although covered, this part of Trench is apparently underlain by Middle Cambrian carbonates (Rocky Mountain facies ?) downfaulted on both sides against Precambrian. These rocks may be structurally continuous with Lower Cambrian around McBride. Prominent SW-dipping layering to S is metamorphic foliation and not bedding. Structure across this part of route is illustrated in Figure 1D.

171.5 Route now leaves Trench to enter Main Ranges of Rocky Mountains. From here to Jasper route underlain entirely by strata belonging to Miette Group (Figure 2).

172.0 Tete Jaune Cache Lodge.

172.1 Junction between highways 5 and 16.

172.1 - 172.5 Interval, with almost continuous roadside outcrop, underlain by metasedimentary succession that originally consisted of sandstone with interbeds of pebble-conglomerate, siltstone and shale. These rocks, which Pinsent (in preparation) correlates with Meadow Creek Formation of Jasper area, now have well developed foliation parallel to axial surfaces of very small-scale tight folds that here and for the next few miles are usually upright and plunge gently NW. Metamorphic biotite occurs in these and other Miette rocks as far E as about 177.0. A stop will be made to examine these rocks at 172.4 where graded bedding is prominent.

172.5 - 173.0 Interval, with numerous road outcrops, of metasedimentary sequence that originally consisted of shale, siltstone and minor sandstone. The rocks which are now tightly folded, highly foliated and separated from the sequence to SW by a fault, are thought to be equivalent to lower Wynd strata near Jasper.

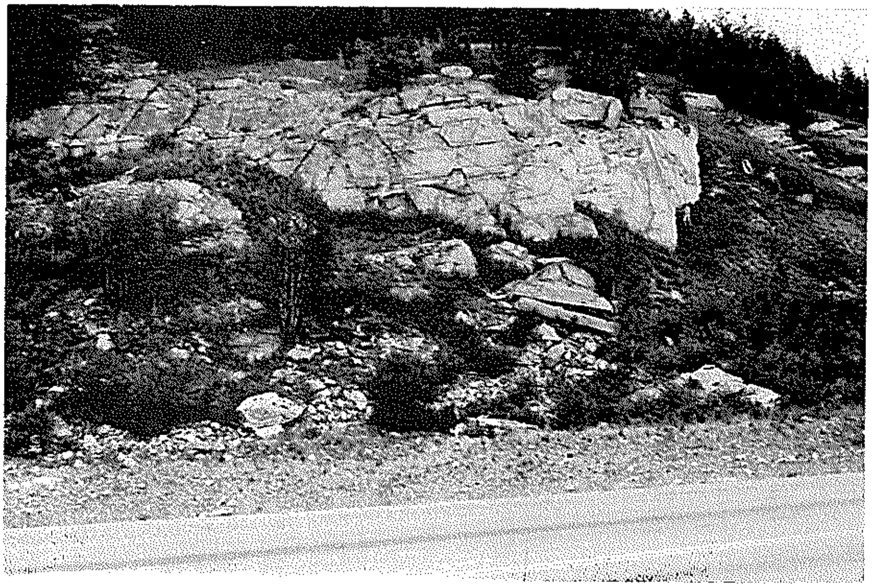

Plate 15: Meadow Creek Formation (middle Miette Group). Mile 172.4.

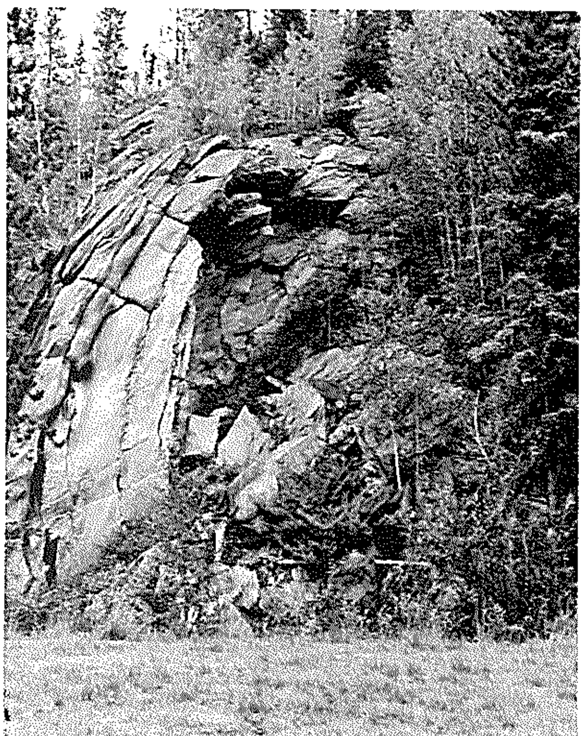

Plate 16: Fold in Lower Wynd Fm. Mile 221.8, Continental Divide.

172.6	New bridge over Fraser River.
173.0 - 173.5	Interval, with very few road outcrops, underlain by metasedimentary sequence, perhaps correlative with base of Wynd Formation, that originally consisted of sandstone with minor shale and siltstone interbeds. These beds occur in core of anticlinal structure and are overlain by sequence exposed to E and W.
173.5 - 173.9	Interval, with no road outcrops, underlain by same sequence, as that underlying 172.5 - 173.0 in core of synclinal structure.
173.9 - 180.6	Interval, largely covered, underlain by same sequence as that underlying 173.0 - 173.5. Scale of folding is somewhat larger, however. At 175.3 good exposures along railway cuts display NW plunge. At 177.4 Mt. Robson with nearly horizontal Middle to Upper Cambrian strata in core of Mt. Robson syncline comes into view to NE; to W of Mt. Robson is Cinnamon Pk with steep NE-dipping Gog. Axial surface of major synclinorium crossed at about 177.6, this surface coincides approximately with biotite metamorphic isograd.
175.3	Rear Guard Falls.
180.6	Bridge over Swiftcurrent Creek.
180.6 - 181.9	Interval with no road outcrops underlain by rocks thought to be equivalent to Meadow Creek and Old Fort Point Formations in core of large anticline overturned to NE.
181.9	Bridge over Robson River.
181.9 - 183.1	Interval, covered, underlain by rocks thought to be equivalent to lower Wynd Formation. These strata lie in NE limb of major anticline and are cut by NE-dipping normal fault.
183.1	Road junction, from which geology of surrounding area may be viewed.
183.1 - 192.6	Interval with numerous road outcrops underlain by steeply NE-dipping argillaceous rocks belonging to highest unit of Miette Group, presumably equivalent to upper Wynd Formation. These may be examined at 184.5. From 183.1 to 204.0 route parallels structural trend, with folded Miette rocks underlying Selwyn Range to SW and NE-dipping Gog in Rainbow Range to NE.

193.5 - 202.0 Moose Lake to SW.

203.9 Bridge over Moose River. To NE, Gog outcrops in timber and prominent Middle-Upper Cambrian cliffs are in SW limb of Mount Robson syncline, and on skyline dip slopes of Upper Cambrian are in NE limb of syncline. To E is Mt. Mowat with Upper Cambrian in core of syncline.

204.0 - 218.7 Covered, but probably largely underlain by upper Miette strata.

206.8 Bridge over Grant Brook.

214.0 Last crossing of Fraser River with remnants of railway bridge to SW.

214.8 To SE, Mt. Fitzwilliam in core of Mt. Robson syncline exposes dark-coloured Gog arenaceous rocks at summit, underlain successively by light Byng and dark Miette (largely covered by Byng talus). To N is Yellowhead Mtn. in NE limb of syncline with Gog Group apparently separated by structural discordance from underlying Byng.

215.7 - 218.6 Lucerne and Yellowhead Lakes to N. From E end of Yellowhead Lake, Byng carbonates on Yellowhead Mtn. appear lenticular. They and overlying Gog are cut by fault at E end of outcrop and are structurally much simpler than underlying Miette strata exposed down to lake level. From here to 242.0 route crosses four anticlinoria, in cores of which are Old Fort Point strata, and three synclinoria exposing beds belonging to Wynd Formation. Yellowhead anticlinorium crosses E end of Yellowhead Lake where road outcrops of Old Fort Point slates occur.

218.7 - 223.0 Interval with numerous road outcrops underlain by lower Wynd Formation, usually overturned to SW but near continental divide affected by some folds whose axial surfaces dip about 45^{o} SW. Lower Wynd Formation, some 2500 feet thick near Jasper, consists of arenaceous and argillaceous units, largely sandstone-conglomerate and slate-siltstone, respectively. Sandstones and conglomerates are feldspathic, slightly calcareous, poorly sorted, poorly bedded, lenticular, and display graded bedding and local cross-bedding; they may represent distributary deposits or be fluxoturbidites. Slates and siltstones also display graded bedding and may represent inter-distributary deposits or be turbidites. At 222.1 argillaceous rocks near contact between lower and upper Wynd Formation display graded bedding, ripples, micro-crossbedding, abundant pyrite at base of many graded beds, and slaty cleavage.

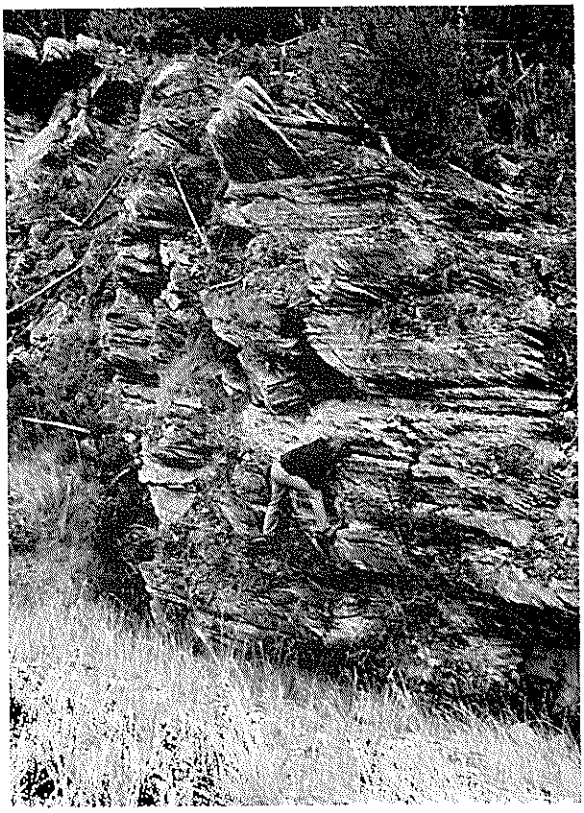

Plate 17: Wynd Formation - near contact between upper and lower Wynd. Cross-bedded and cleaved argillaceous siltstones and sandstones. Mile 222.1.

Plate 18: Old Fort Point Fm. Fold in variegated slates and siltstones. Mile 228.0.

217.6	Bridge over Rockingham Creek.
221.8	Continental divide, beyond which route follows Miette River to Jasper.
223.0 - 226.0	Interval with few road outcrops underlain by recessive upper Wynd Formation in core of Dominion Prairie synclinorium.
226.0 - 228.0	Interval with numerous road outcrops underlain by lower Wynd Formation.
227.7	Bridge over Clairvaux Creek.
228.0 - 229.8	Interval with good road outcrops largely underlain by Old Fort Point Formation in core of Meadow Creek anticlinorium. Formation is divisible here into (1) 90 ft. of blue slate, (2) 390 ft. of green slate, (3) 230 ft. of purple slate and siltstone, (4) 35 ft. of thinly interbedded limestone (purple towards base and grey towards top) and calcareous slate (purple towards base and green towards top), (5) 3-15 ft. of dark blue slate, (6) 2-9 ft. of breccia with angular fragments of blue limestone in matrix of calcareous sandstone, and (7) 275 ft. of green slate. At 228.9 units 3-7 are well displayed in anticline-syncline pair associated with axial-plane cleavage and SW-dipping normal fault.
229.8 - 233.0	Interval with good outcrops underlain by lower Wynd Formation in core of Minaga Creek synclinorium. At 232.0 division into arenaceous and argillaceous units, graded beeding, shale fragments (curved in places) in arenaceous rocks, green colour imparted by chlorite (also present in veins), abundance of feldspar in arenaceous rocks, and curved slaty cleavage in graded argillaceous rocks are all well displayed.
230.6	Bridge over Meadow Creek.
233.0 - 233.5	Interval, with good outcrops to S along abandoned railway grade and in quarry underlain by Old Fort Point Formation in core of Muhigan Creek anticlinorium.
233.5 - 238.0	Interval with several road outcrops underlain by lower Wynd Formation in core of Rathlin Lake synclinorium.
237.6	Junction between Highways 16 and 93. Route continues on 16.
238.0 - 239.5	Interval with no road outcrops underlain by Old Fort Point Formation in core of Jasper anticlinorium.

238.9 Viewpoint. To N, beyond Jasper town, are Pyramid (on right) and Cairngorm (on left) Mtns. in NE limb of Jasper anticlinorium and in hanging wall of Pyramid thrust. Thrust is almost horizontal where it crosses E shoulder of Pyramid Mtn. but dips at about 45^{o} SW where it crosses route at 242.0. Miette-Gog contact descends from skyline on SW shoulder of Cairngorm Mtn. to road level at 241.5. Orange-weathering rocks at contact in gully between two mountains may belong to Byng Formation. To E are Paleozoics of Colin Range in footwall of Pyramid thrust. To SE, just across Athabasca River, is Old Fort Point, and on skyline beyond is Mt. Tekarra exposing Miette-Gog contact. To SW are Mt. Kerkeslin with synclinal Lower-Middle Cambrian, and Mt. Edith Cavell with gently SW-dipping Gog underlain by Byng and Miette strata.

239.5 - 241.5 Interval with no road outcrops underlain by Wynd Formation in NE limb of Jasper anticlinorium.

241.5 Junction between Highway 16 and road to Maligne Lake.

241.6 Faulted Miette-Gog contact exposed in railway cut to NW.

241.6 - 242.0 Interval with good road outcrops underlain by sandstones and pebble-conglomerates of basal Gog Group in NE limb of Jasper anticlinorium. To SE at road level across river is cliff of gently SW-dipping Byng carbonates underlain by Miette shales.

242.0 Surface trace of Pyramid thrust immediately E of which is road outcrop of Devonian carbonate and shale.

Road Log V should be augmented with maps from the papers authored by Campbell and Charlesworth, and by Mountjoy.

Sheets 1 and 2, Geological Map: Pine Valley (following pages) have been reproduced, with permission, from B.C. Department of Mines and Petroleum Resources, Bulletin No. 52: Geology of the Pine Valley, by J.E. Hughes. These map sheets are intended to augment Road Logs I - III.

41.5 Log cabin and corral on south side of highway. Good spring water to west of buildings.

45.0 Top of terraces. Road cut in glacial gravels. Shaftesbury Formation exposed toward valley floor.

45.2 Farrell Creek. Large cut bank of Shaftesbury shales on east bank. Shales exposed in road cuts to top of terrace.

46.7 Large exposures of Shaftesbury Formation along river.

48.1 Basal beds of Shaftesbury Formation in gully to north and Gates sandstone at river level. Gastroplites specimens have been obtained from the gully.

48.6 Gates sandstone occurs along river.

48.7 Beginning of pavement (July, 1970).

49.2 Thin-bedded Gates sandstone on south side.

50.0 Lower Shaftesbury shales in north bank.

52.1 Lynx Creek.

52.3 Glacial gravels to top of terrace.

55.95 Hudson Hope.

Junction of Highway 29 to Chetwynd (south) and road into W.A.C. Bennett dam.

57.75 View of Peace River bridge, valley to west, and anticline in Gates sandstone along river.

58.1 Top of terrace. View to west of Mount Gething and Butler Ridge to north, formed by folds in Lower Cretaceous Minnes and Bullhead strata.

63.8 Anticline to northwest. Cadomin conglomerate forms massive ridges at crest.

66.6 Trapper Cabin picnic area.

67.45 Right-of-way used for hauling earth-fill from moraine deposit to dam. Storage area for surplus equipment including conveyor system to north.

68.0 Gething sandstone exposed in small fold.

68.9 Office buildings. Viewpoint for reservoir--Williston Lake.

69.1 Turnoff to public lookout. The power house lies to the north of the lookout.

Type section of Gething Formation extends downstream along canyon. Uppermost beds of Cadomin Formation are exposed at toe of dam.

69.9 Schrum Generating Station.

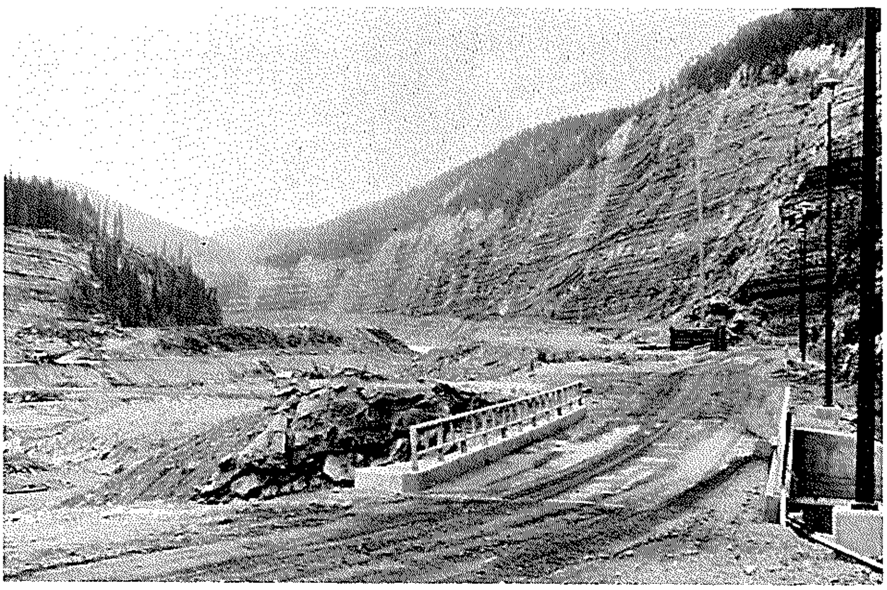

Plate 3: Gething Formation viewed from toe of Bennett Dam looking downstream toward Gething Creek.

ROAD LOG II

HUDSON HOPE TO CHETWYND

0.0 Junction Highway 29 and turnoff to Bennett dam.

1.0 Western limits of Hudson Hope.

2.45 Alwin Holland Memorial Park entrance.

Excellent exposures of Gates sandstone upstream and Moosebar shales downstream.

Road is on glacial terrace with higher terrace to north.

3.2 Gates Formation exposed along west flank of anticline in river to south.

4.7 Peace River bridge.

Gates sandstone exposed in road cuts and in cliffs along river both upstream and downstream.

5.3 Gates sandstone on either side of road.

6.6 View to west of Portage Mountain.

8.0 View to east of Peace River valley.

10.9 Mile Post 30

12.6 Glacial gravels

13.3 South dipping Hasler shales in road cuts for 1½ mile.

15.6 Hasler shales.

16.3 Upper Cameron Lakes on west side of road.

Easternmost exposures of Goodrich Formation in road cuts for .25 mile. The Goodrich Formation is not mappable on surface east of this point.

17.0 Lower beds of Cruiser Formation in road cut to east.

18.4 Lower Cameron Lakes to west.

Ridges to east and west are capped by Dunvegan sandstone.

19.9	West end of Moberly Lake.
	Ridges to north and south of lake are capped by Dunvegan sandstone.
	Cruiser shales in road cuts on either side.
20.4	Cruiser shales in road cuts to south for half mile.
21.1	Mile post 20.
21.4	Intermittent outcrops of Cruiser shales for 3 miles.
28.9	Moberly River bridge at outlet of Moberly Lake.
31.2	Mile post 10.
34.65	Dunvegan mudstone and argillaceous sandstone for quarter mile.
37.2±	Glacial silts in road cut to west.
38.6	Dunvegan Formation outcrops in long road cut toward bottom of hill.
	View to west of Foothills and to south, of glacial valley.
40.2	Town limits of Chetwynd.
41.5	Junction of Highway 29 and John Hart Highway (Highway 97).
	Chetwynd Hotel is northwest of intersection.

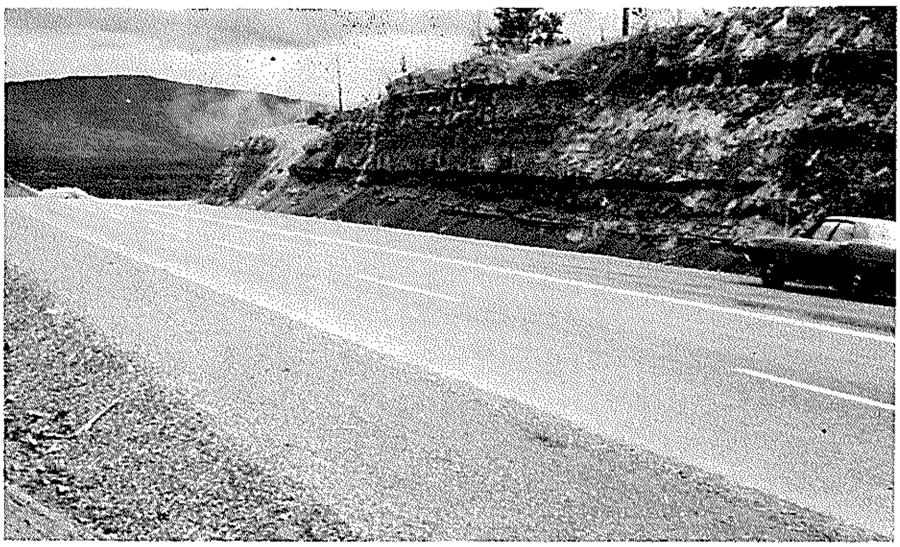

Plate 4: Dunvegan Formation near Chetwynd. Mile 38.6.

ROAD LOG III

CHETWYND TO WINDY POINT

0.0	Junction of John Hart Highway (Highway 97) and Highway 29.
0.4	View to south of Upper Cretaceous Kaskapau sandstone on Tuscoola Mountain and Elephant Ridge.
0.5	British Columbia Forestry station.
2.6	Dunvegan sandstone on hills to north and south, underlain by Cruiser shale.
3.1	Lake silts of Pleistocene Lake Peace.
3.4	Cruiser shales in road cut to north.
4.45	Wildmare Creek.
	Anticlinal axis.
5.65	Quarry in Dunvegan sandstone.
6.15	Bissett Creek.
	Outcrops of Dunvegan crossbedded sandstone in road cuts to north for next .75 mile. Gentle folds are visible in the Dunvegan Formation which caps the ridges.
9.3	Cruiser shales and interbedded argillaceous sandstone in road cuts to north for ¼ mile.
10.85	Cruiser shales in road cut to north.
11.7	Fault along east flank of Commotion anticline. Goodrich sandstone in hanging wall forms conical hill to northwest. Cruiser shales in foot-wall to east are overlain by Dunvegan sandstone.
13.2	Commotion Creek.
	Commotion anticline with beds of the Commotion Formation exposed along creek. Site of British Columbia Government Pine River No. 1 well drilled in 1942.
	Type section of Boulder Creek Member of Commotion Formation. Prominent cliffs extending north of road for 1 mile are formed by basal unit of fine to medium-grained, clean sandstone and by overlying unit of massive conglomerate.

14.7 To north, Hasler shales occur on lower slopes and Goodrich sandstones occur at top of ridge.

16.0 Type section of Goodrich Formation is visible to north in gully tributary to Bowlder Creek.

16.2 Hasler shales occur in road cuts along north side of road for .75 mile.

18.0 Hasler shales and siltstones occur in road cut on north side for 1 mile. The contact between the lower unit of massive silty mudstone and argillaceous siltstone and the overlying unit of rubbly, concretionary mudstone is well exposed.

20.5 Hasler shales in road cut along north side of road. Ridges to north and south are capped by Goodrich Formation.

22.5 Bedded glacial gravels in road and railroad cuts.

23.7 Glacial silts and gravels, to north.

25.3 Glacial silts in cut bank, to north.

View to west of Mount Bickford comprised by a faulted anticline in Lower Cretaceous Minnes Group.

25.8 Glacial silts, sands, and gravels for .75 mile.

26.9 Willow Flats settlement and West Coast Transmission Pumping Station.

Dokie Ridge section of Fort St. John Group is about 6 miles to the north. Goodrich sandstones form flat-topped ridge to east. Valley of Fred Nelson Creek lies in Hasler shales. Sharp, double-humped ridge to north is underlain by Commotion Formation and Crassier Creek flows through Moosebar shales.

28.8 Crassier Creek bridge.

29.25 East-dipping sandstone of Gething Formation on flank of small anticline in road cut to north.

29.6 West-dipping Gething sandstones with coal, for .25 mile.

30.1 Willow Creek anticline on south side of Pine River.

Several wells, including Hunt Sands Sun Falls c-18-G, have been drilled along this structure.

Commotion sandstone on ridge to west of valley.

Upper unit

Lower unit

Plate 5: Hasler Formation showing contact between lower massive siltstone unit and upper rubbly, concretionary mudstone unit. Mile 18.0.

Rubbly weathering, concretionary mudstone and siltstone.

Massive, silty mudstone and argillaceous siltstone.

Plate 6: Hasler Formation showing detail of contact between upper and lower units. Mile 18.1.

30.2 View to southeast of Falls Mountain, capped by Commotion Formation. Also good view to southwest of Pyramis Peak capped by Minnes Group.

30.65 Folds in Gething Formation for next .5 mile.

31.75 Pleistocene silts in cut bank to north.

32.1 Moosebar Formation, massive to blocky weathering mudstone and siltstone.

32.6 Fisher Creek bridge.

Outcrop visible some distance upstream is Moosebar shale occurring along axis of Fisher Creek syncline.

33.5 Gething Formation exposed in road cuts for next mile. Trenches and adit at west of exposure reveal several seams of coal, 10 to 20 feet thick.

34.2 Cadomin Formation exposed on power line, north of highway, on east flank of Bickford anticline.

35.9 Contact between Monteith and Beattie Peaks Formations on west flank of Bickford anticline.

37.8 Anticline with Monteith quartzose sandstone at road level.

Hunt-Sands-Sun, Boulder b-74-D well site is south of the highway.

38.55 Big Boulder Creek Bridge. Beattie Peaks Formation exposed south of road.

39.3 Martin Creek.

Series of minor folds in Minnes strata may be seen on ridge south of Pine River.

40.25 Lillico (Little Boulder) Creek bridge. Excellent view to southeast of Pyramis Peak.

40.9 Le Moray Lodge.

To south, Jurassic Fernie shales and Jurassic-Cretaceous Monteith sandstone appear in hanging wall of thrust plate. Triassic beds appear along lower slopes of Mount Le Moray to the southwest and are overlain by Jurassic Fernie shales. The upper part of Mount Le Moray is formed by Monteith sandstone which is also exposed along powerline west of lodge.

Plate 7: Monteith Formation; massive, cross-bedded sandstones. Mile 41.4.

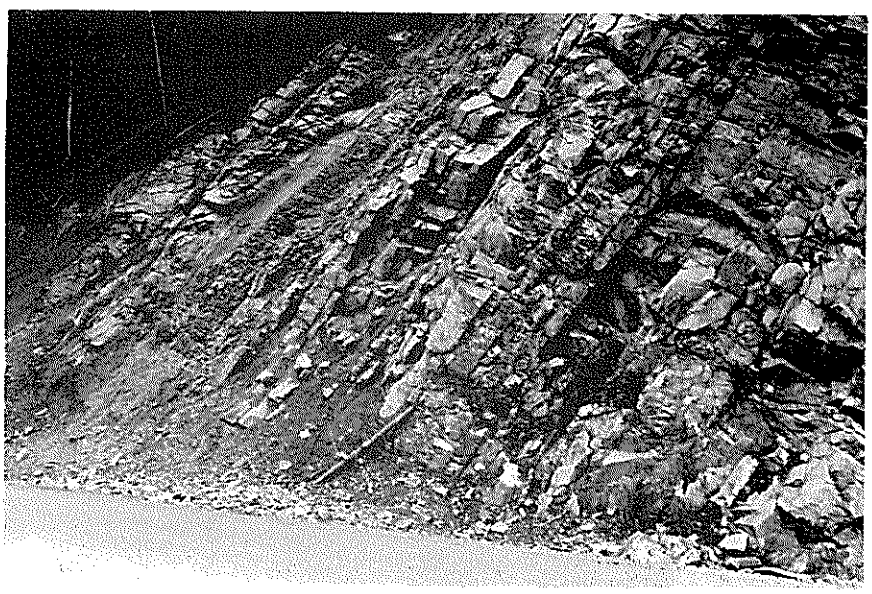

Plate 8: Triassic Grey Beds with clean, cross-bedded, porous sandstones (rubbly weathering). Mile 44.5.

41.2 West dipping Monteith beds are exposed for .25 mile. Massive sandstones show crossbedding and channel structures.

Synclinal axis (possibly fault of small displacement) occurs in covered interval at west end of exposure.

41.6 Overturned beds of Monteith Formation with base to west.

41.9 Fernie Passage beds, vertical to overturned eastward.

43.15 Cairnes Creek bridge.

43.5 Abandoned well site, Triad, Bush Mountain b-23-A(1).

View to west of Solitude Mountain with Mississippian strata along crest. Imbricate thrust zone at base involves Mississippian, Permian, and Triassic rocks.

44.25 Anticline in Triassic Grey Beds, with fault to west.

44.35 "Charlie Lake" evaporites of Triassic Grey Beds.

44.5 Triassic Grey beds in road cut to north with clean cross-bedded sandstones in western portion of cut.

Abandoned well site, Triad-British Petroleum, Bush Mountain a-15-A.

45.0 Triassic Pardonet beds are exposed east of Silver Sands Creek and Jurassic Nordegg beds occur to west.

45.1 Silver Sands Creek.

45.85 Subway beneath Pacific Great Eastern Railway.

Picnic site to south.

Pardonet beds on east side of subway abutment.

45.95 Pine River bridge.

Triassic Pardonet beds along railway cut to north are overlain by Jurassic Nordegg beds. Triassic Pardonet beds are in fault contact with Jurassic beds to west.

46.1 Triassic "Charlie Lake" solution breccias in road cut and exposures to south.

46.35 Triassic Toad-Grayling shales in road cut to south.

46.95 Beds of Mississippian lower Prophet Formation exposed in road cuts to south.

47.3 Upper Prophet beds in road cut to south.

47.6 Permian Mount Green and Fantasque chert in exposures to south.

48.0 Triassic Toad Formation in road cuts to south for next mile.

48.7 Folding in cliff south of road (Solitude Mountain).

49.1 Permian Fantasque Formation is exposed above road on slope but not at road level. Mount Green Beds unconformably overlie Mississippian Prophet cherty limestones. Toad Formation at road level.

49.3 Prophet Formation is exposed south of road.

49.95 Link Creek.

51.3 Besa River shales in road cuts for next mile. Prophet Formation exposed on ridge to north.

52.1 Pleistocene gravels in pit to north.

53.2 Besa River in road cuts and along river bank for next .5 mile.

54.0 View to north of Mt. Garbitt (elev. 5830) capped by Upper Cambrian and Lower Ordovician nodular limestones which have been thrust over Besa River shales.

54.25 Mount Hawk equivalent. Devonian argillaceous limestones.

View west of conical hill capped by Misinchinka Group which has been thrust over Cambro-Ordovician limestones.

54.6 Power line crosses road.

Miette rocks are thrust on Devonian Mount Hawk equivalents. Above road to south, Miette sandstone forms abutment of transmission tower.

55.1 Miette quartzite and argillite in road cut to southeast. Good view of Mt. Garbitt and conical hill.

55.3 Chloritic schists of Miette Group along road. Lower Cambrian Gog sediments overlie Miette Group on mountains to northwest.

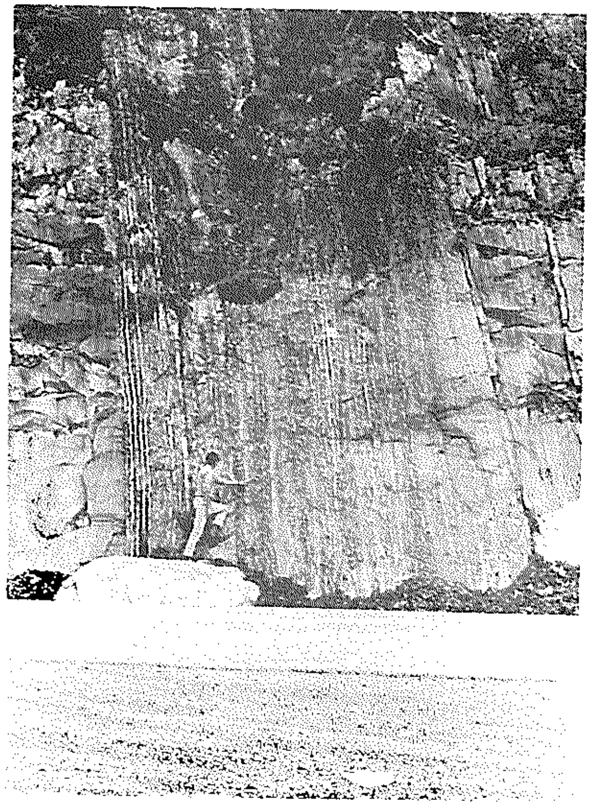

Plate 9: Prophet Formation; cherty limestones.
Mile 49.3.

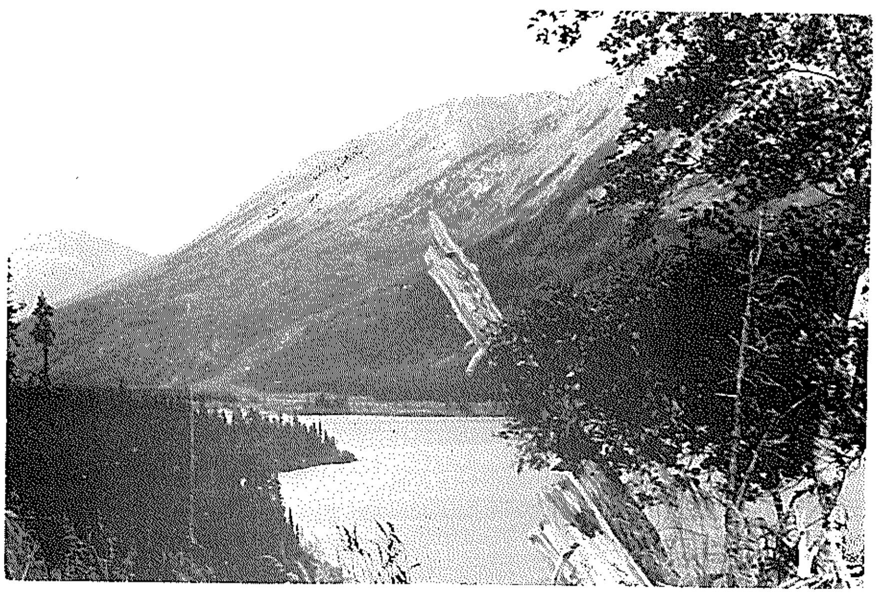

Plate 10: Azouzetta Lake; Ordovician and Cambrian carbonates on west flank of Murray Range.
Mile 68.7.

55.5 Chloritic schists and phyllites of Miette Group.

55.9 Miette argillites and phyllites for .5 mile on southeast side.

57.3 Gog sediments occur above highway.

57.9 Dolomitic sandstone of middle part of Gog.

58.1 Varicoloured dolomites of Gog, equivalent to Mural Formation.

Axis of syncline of Murray Range.

58.5 Gog quartzite.

59.2 Middle Cambrian Titkana dolomite (?).

59.4 Arctomys Formation on cliff to southeast.

59.5 Titkana dolomite at road level.

59.9 Arctomys Formation at road level in trees.

60.3 Upper Cambrian Lynx strata to east.

60.55 Nodular limestone, probably about 500 feet above base of Lynx, for .5 mile.

60.75 View of Murray Range, straight ahead.

61.0 Railroad tunnel.

View south of Upper Cambrian and Lower Ordovician limestones which form cliffs on hillside.

62.15 Cliffs of Cambrian Lynx limestone to southeast.

64.25 Westcoast Transmission Pumping Station.

Rock slide for approximately 2 miles.

65.8 Microwave repeater station.

Ordovician Chushina Formation forms dip slopes to east. Upper Cambrian Lynx carbonates occur in Pine Valley to west.

67.55 Pine Valley Service Station.

67.7 Monkman quartzite in cliffs to west.

Misinchinka schist in hanging wall of Back Ranges Fault.

68.7 Azouzetta Lake, viewpoint.

View along syncline to northwest and southeast. Ordovician carbonates form dip slopes on east side of Lake and Cambrian beds appear along peaks and ridge to east.

Monkman quartzite is exposed in cliffs below viewpoint.

69.0 Intermittent outcrops of Misinchinka schist, chloritic and carbonaceous phyllite for one mile.

Major fault between lookout and these exposures.

70.7 Azu Village.

71.05 Summit of Pine Pass. View of Misinchinka valley to south.

71.9 Chloritic talc schist of Misinchinka Group.

72.1 Impure micaceous quartzite in chloritic phyllite.

72.6 Intermittent outcrops for 1.5 mile of phyllite and quartzite.

74.05 Underpass.

74.15 Intermittent to continuous outcrop of quartz-chlorite-epidote phyllite.

75.0 Bijou Creek picnic site.

Phyllite in cliffs.

75.1 Crossing Bijou Creek.

75.3 Intermittent outcrops for one mile of green phyllite with interbedded, very coarse-grained quartzite and metamorphosed sandstone.

76.2 Large blocks of rutilate quartz.

76.4 Quartz-chlorite-biotite phyllite of Misinchinka Group.

76.8 Hungry Moose Creek.

77.2 Sheared, schistose conglomerate.

77.4 View to south of Old Friend Mtn. composed of uppermost Misinchinka Group (slate, greywacke, quartzite, conglomerate) capped by lower Cambrian quartzite.

77.5 Intermittent to continuous outcrop for 2 miles of chlorite-muscovite phyllite and quartzite.

78.1 Rolston Creek.

80.4 Railway crossing.

80.8 Crossbedded sandstone and biotite phyllite overlain by chloritic phyllite with thin interbeds of quartzite (cleavage 330/85 SW, bedding 285/54 SW).

80.8 Power Line.

Quartzites and interbedded quartz muscovite phyllite.

81.1 Carbonaceous, chloritic phyllite.

81.35 Outcrop of chloritic phyllite with prominent bedding and near vertical cleavage.

81.4 Intermittent outcrops of limestone, talc phyllite, quartz-muscovite-biotite phyllite, and quartzite.

82.0 Honeymoon Creek.

Maintenance Camp.

83.4 Intermittent outcrops for one mile of green chlorite-muscovite schists and phyllitic limestones, meta-conglomerate, coarsely-grained quartzite, and quartz-muscovite schist.

84.65 Caswell Creek.

84.85 Chloritic schists.

85.45 Intermittent outcrops for 2.5 miles of conglomeratic quartzite, chlorite phyllite, and quartz-muscovite-chlorite schist.

89.1 Trapper Creek.

89.95 Kennedy Siding Road to south.

95.35 Power Line.

95.7 View to west across Rocky Mountain Trench.

95.85 Railway crossing.

96.2 Junction of Highway 97 and highway to Mackenzie and Findlay Forks.

96.6 Parsnip River bridge.

97.45 Windy Point Lodge.

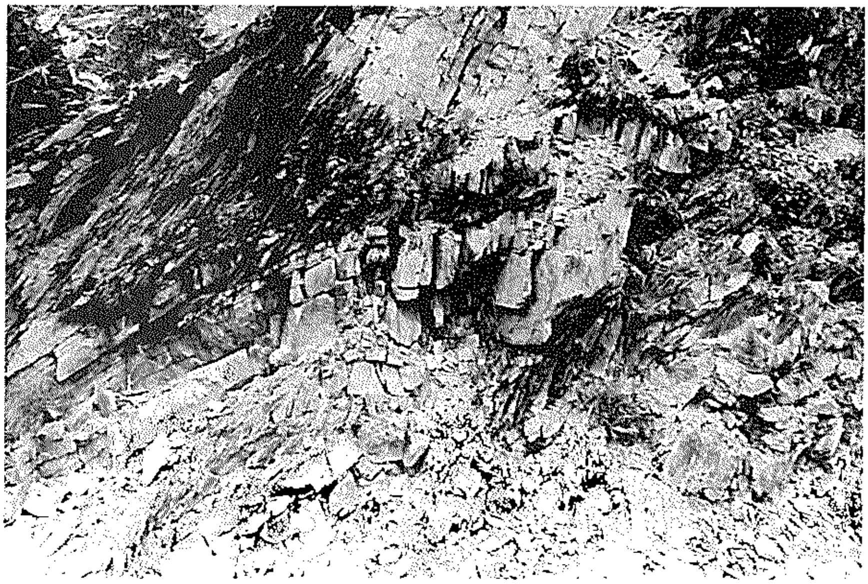

Plate 11: Misinchinka Group; chloritic phyllite and quartzitic sandstone showing relation of bedding to cleavage. Mile 80.8.

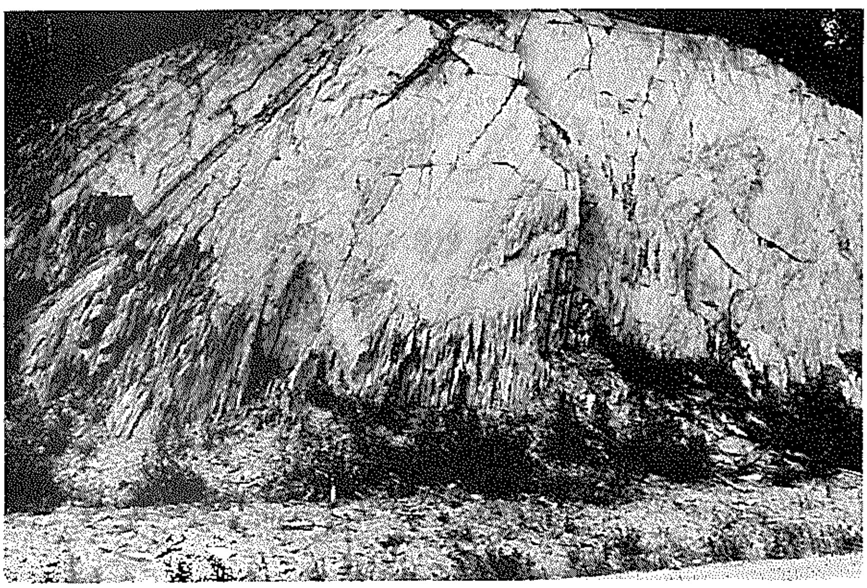

Plate 12: Misinchinka Group; chloritic phyllite and quartzite showing bedding (285/54' SW) and prominent cleavage (330/80' SW). Mile 81.35.

ROAD LOG IV

WINDY POINT TO PRINCE GEORGE

0.00	Windy Point Lodge.
.70	B.C. Forest Service access roads.
2.05	Glacial gravels on left.
2.55	Road to Trout Lake.
3.35	View to right of Tudyah Lake.
3.45	Glacial silts and clays.
4.45	Road to Melville Lodge.
6.65	Westcoast Transmission Compressor Station. Continuous outcrops of glacial sands, silts and gravels for about one half mile.
9.5	Ft. MacLeod.
9.95	"Ft. Ghastly"; cardboard and plastic replica bears and moose browsing in the bushes.
10.35	MacLeod Lake. At this point the route crosses the dominant structural feature of the area, the MacLeod Lake fault, which separates the rock sequence of the Interior Plateau from that of the Rocky Mountains. Highway 97 parallels the fault trace for approximately forty-five miles.
11.25	View of MacLeod Lake and hills on west of lake which are composed of basaltic pillow lavas of the Devonian-Mississippian Slide Mountain Group. Diabase and diorite dykes and sills cut the Group and may be correlative with the Mississippian (?) Mount Murray Intrusions.
17.05	Whiskers Creek Campground.
17.15	Whiskers Creek.
23.2	Crooked River Cabins. Route has passed the south end of MacLeod Lake and now runs sub-parallel to the Crooked River.

26.25 42 Mile Creek.

26.30 Tributary road to east which leads to small rubbly outcrops (in about 1 mile) of dark, fossiliferous, argillaceous dolomitic limestone likely Silurian-Ordovician in age.

26.8 Exposure of glacial gravels on left.

27.1 View west across MacLeod Lake fault into mouth of Weedon Creek which cuts through the plateau-like hills composed of regularly bedded Slide Mountain Group.

27.4 Crooked River on right.

30.1 Lomas Creek.

32.0 Exposure of crossbedded gravels in gravel pit.

33.8 Kerry Lake.

41.05 Redrocky Creek.

44.3 Passing west across approximate trace of MacLeod Lake Fault.

45.75 Bridge over Angusmac Creek.

47.75 Glacial sands discontinuously exposed for approximately seven miles.

Route passes onto a Pleistocene sand plain having a decorative, uniform stand of toothpick pine.

51.0 Turn off to Bear Creek townsite.

52.0 Bear Lake Picnic Ground.

52.1 Bear Lake service station.

52.6 Bear Lake campground.

53.4 Glacial gravels.

53.92 Railroad crossing (P.G.E.).

54.05 Horizontally bedded gravels in gravel pit.

58.1 Low hills to right are underlain primarily by Miocene lava flows of the Endako Group which is generally less than 200 feet thick.

66.15 Railroad Crossing.

67.3 Entering Summit Lake.

67.8 Arctic Divide (divide between Arctic and Pacific watersheds).

68.7 Railroad crossing.

71.3 Crossing power lines.

77.05 Crossing power lines.

80.65 Railroad crossing.

82.60 Bridge over Salmon River.

85.5 Low hills to west are underlain by Cambrian Cariboo Group.

97.8 Bridge over Fraser River, northwest section of Prince George.

PRINCE GEORGE TO JASPER

0.0	Junction between Highway 16 and road to airport, approximately 3 miles E of Prince George. Ridge to E is underlain by Takla rocks. That to SE exposes Precambrian metamorphics intruded by Cretaceous granitic rocks. Gap between ridges exposes sub-Takla unit intruded by latest Triassic or earliest Jurassic granitic rocks (Fig. 1).[1] Although nearby Takla does not appear to contain debris from this intrusion, similar intrusions to S were unroofed during Early Jurassic and contributed material to sediments of this age.
0.0 - 8.0	Interval with no road outcrops underlain by sub-Takla unit. Tabor Lake to SE between 6.0 and 7.0.
8.0 - 11.0	Interval with scattered road outcrops underlain by Takla Group which will be examined at 9.7. Low hills to W visible from this stop are underlain by ultrabasic rocks of Pinchi Geanticline.
8.45	Junction between Highway 16 and road to Giscome.
10.0	Rocky Mountains are visible to E. Rocky Mountain Trench at this latitude merges with Interior Plateau. Hills in foreground are underlain by Slide Mountain Group of Omenica Geanticline.
11.0 - 12.0	Interval with no road outcrops underlain by sub-Takla unit.
12.0 - 39.0	Interval with scattered, commonly glaciated, road outcrops underlain by Antler Formation of Slide Mountain Group. Basalts will be examined at 28.8. Argillites are characteristically darker than basalts, although they occasionally are rusty-weathering.
18.9	Bridge over Willow River.
24.8	Outcrop of Antler Formation: dark green, brecciated, and slickensided crystal tuff with narrow shear zones.
25.2	Bridge over Vama Vama Creek.

1 Cross sections and figures used as reference in Road Log V are from the paper by Campbell and Charlesworth.

32.55 Bridge over Bowron River. Few miles to SE is Upper Cretaceous or Lower Tertiary non-marine sedimentary basin with deposits of coal and amber.

34.15 Outcrop of Antler Formation argillites.

36.25 Service station; last gas until McBride (90 miles).

36.85 Example of roche moutonnée.

38.7 Outcrop of rusty weathering, slickensided and quartz-vined argillite.

39.0 - 42.0 Interval, with good road outcrops of cleaved and kinked phyllite and grit, underlain by Kaza Group, which is possibly unconformable beneath Slide Mountain Group.

42.0 - 47.0 Interval, with several glaciated road outcrops, underlain by Mural Formation (e.g. 42.4), separated from Kaza Group to W by longitudinal fault. Across Fraser River from 44.5, structure of westernmost Rocky Mountains is that of synclinorium continuous with Mount Robson syncline to SE. In core of synclinorium are Silurian shale, limestone, dolomite, and quartzite; quartzite visible towards SE end of flat-topped ridge. At NW extremity of ridge is plutonic intrusion containing ultrabasic rocks and syenite associated with large magnetic anomaly and metamorphic aureole.

43.65 Bridge over Kenneth Creek.

47.0 - 48.7 Interval with few road outcrops underlain by Cunningham (?) Formation.

48.7 - 52.0 Interval with several road outcrops underlain by quartzite and siltstone of Yanks Peak and possibly Midas Formation. to S, Sugarbowl Mtn. at NW extremity of Cariboo Mountains exposes gently dipping Yankee Belle strata which, together with Cunningham Formation is separated from Yanks Peak and Midas Formations by NW striking fault.

52.0 - 55.0 Interval, with several road outcrops, underlain by Mural Formation. At 53.1 it contains fragments of archeocyathids and trilobites.

53.95 Bridge over Hungary Creek.

Plate 13: Mural Formation, slickensided and quartz-veined cyclical carbonates. Mile 42.4.

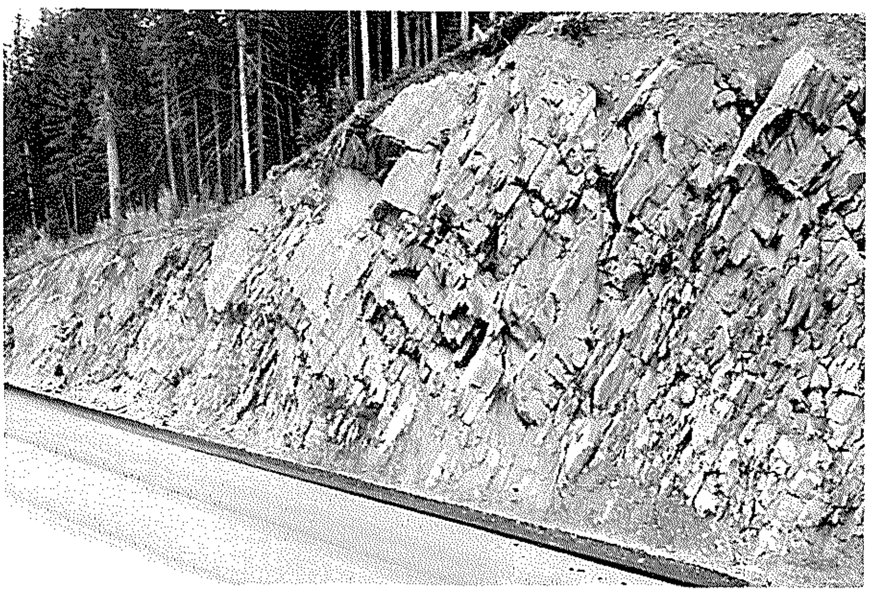

Plate 14: Kaza Group, cleaved phyllite. Mile 103.6.

55.0 - 72.0	Interval with several road outcrops underlain by Yankee Belle and Yanks Peak Formations. At 58.4 are some orange-weathering dolomites near top of Yankee Belle Formation and at 61.25 Yanks Peak Formation may be examined. From this point Silurian quartzites in core of Mount Robson synclinorium are visible on NE slopes of Trench.
60.5	Bridge over Driscoll Creek. From this point to McBride, silts and sands several hundred feet thick and deposited in an ice-dammed lake are exposed (e.g. 68.35).
72.35	Bridge over Slim Creek. Mountains visible to SW for next few miles contain gently dipping but complexly faulted complete Cambrian section of Cariboo type that is now only 20 miles from nearest typical Rocky Mountain Cambrian section.
72.4 - 79.4	Covered.
77.7	Bridge over Dome Creek. Structure across this part of route is illustrated in Figure 1A.
79.4 - 90.4	Interval with several road outcrops underlain by Yankee Belle and Yanks Peak Formations. Across Trench to SE, Mt. Rider with Gog and Mural strata in Mount Robson synclinorium comes into view at 83.2 (see 121.0). Ridge immediately NE of highway at 85.8 is of Mural Formation.
86.4	Bridge over Ptarmigan Creek. To SW tallest peak contains vertical Cunningham strata bounded to NE by gently SW-dipping panel containing Yankee Belle to Dome Creek Formations.
90.4 - 103.5	Covered. To SE, mountain with smooth rounded slopes coming into view at 90.4 is underlain by Isaac Formation. At 97.9 stop may be made to observe Zig-Zag Ridge to SW with Cunningham and Yankee Belle strata; mountain NW of ridge and on other side of Snowshoe Creek exposes Yankee Belle and Cunningham strata in peak, faulted against panel of Mural to Yankee Belle Formations structurally continuous with that on Zig-Zag Ridge.
92.45	Catfish Creek.
97.55	Bridge across Snowshoe Creek.

103.5 - 110.5 Interval, with several road outcrops, underlain by Kaza Group which will be examined at 103.55.

103.9 Bridge across Goat River.

110.6 - 121.6 Covered.

110.9 Bridge over West Twin Creek. Peak coming into view to SE across Trench has Gog underlain by Miette in SW limb of Mount Robson synclinorium. Structure across this part of route is illustrated in Figure 1B.

119.3 Bridge over Clyde Creek.

121.0 Bridge over McIntosh Creek. Across Trench, farthest peak to NW is Mt. Rider (see 79.4 - 90.4). Peak and upper part of SW shoulder expose Gog strata in core and overturned NE limb of syncline. Another overturned syncline with Gog and Mural strata occurs SW of steep fault that intersects skyline in prominent col. Peak SE of Mt. Rider exposes overturned NE limb of synclinorium with Gog and Mural strata. Succeeding peak to SE is that mentioned in 110.9. Ridge SE of this exposes Miette strata in SW limb of Mount Robson synclinorium.

121.5 - 143.5 Route lies in Trench which is here apparently underlain by folded Gog strata (Rocky Mountain facies) down-faulted on both sides against Precambrian rocks. Gog becomes visible to NE at 127.4. To S, Premier Range in Cariboo Mountains becomes visible at 127.4.

126.75 Railway crossing (uncontrolled). Hills to SW underlain by isoclinally folded Isaac (smooth topography) and Kaza (rugged topography) rocks.

127.15 Bridge across Doré River.

129.7 McBride Railway Station.

131.15 Bridge over Fraser River.

137.2 Bridge over Holmes (Beaver) River. Valley of Raush River is visible to SW. Structure across this part of route is illustrated in Figure 1C.

142.3 Bridge over King (Nevin) Creek.

143.0 - 162.0 Covered.

146.6 Bridge over Baker (Halliday) Creek. To SE is Malton Range at NW extremity of Monashee Mountains, with possible remobilized cratonic basement.

150.5 Turn off to Dunster.

157.55 Bridge over Horse (Harvey) Creek.

157.65 Big Foot campground.

161.0 Service Station.

162.2 Bridge over Small Creek.

162.5 - 171.5 Although covered, this part of Trench is apparently underlain by Middle Cambrian carbonates (Rocky Mountain facies ?) downfaulted on both sides against Precambrian. These rocks may be structurally continuous with Lower Cambrian around McBride. Prominent SW-dipping layering to S is metamorphic foliation and not bedding. Structure across this part of route is illustrated in Figure 1D.

171.5 Route now leaves Trench to enter Main Ranges of Rocky Mountains. From here to Jasper route underlain entirely by strata belonging to Miette Group (Figure 2).

172.0 Tete Jaune Cache Lodge.

172.1 Junction between highways 5 and 16.

172.1 - 172.5 Interval, with almost continuous roadside outcrop, underlain by metasedimentary succession that originally consisted of sandstone with interbeds of pebble-conglomerate, siltstone and shale. These rocks, which Pinsent (in preparation) correlates with Meadow Creek Formation of Jasper area, now have well developed foliation parallel to axial surfaces of very small-scale tight folds that here and for the next few miles are usually upright and plunge gently NW. Metamorphic biotite occurs in these and other Miette rocks as far E as about 177.0. A stop will be made to examine these rocks at 172.4 where graded bedding is prominent.

172.5 - 173.0 Interval, with numerous road outcrops, of metasedimentary sequence that originally consisted of shale, siltstone and minor sandstone. The rocks which are now tightly folded, highly foliated and separated from the sequence to SW by a fault, are thought to be equivalent to lower Wynd strata near Jasper.

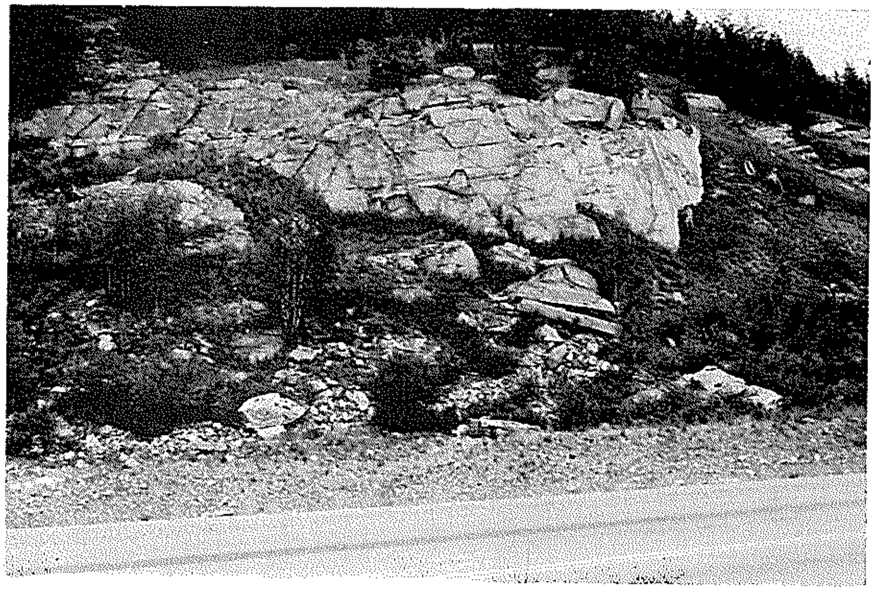

Plate 15: Meadow Creek Formation (middle Miette Group). Mile 172.4.

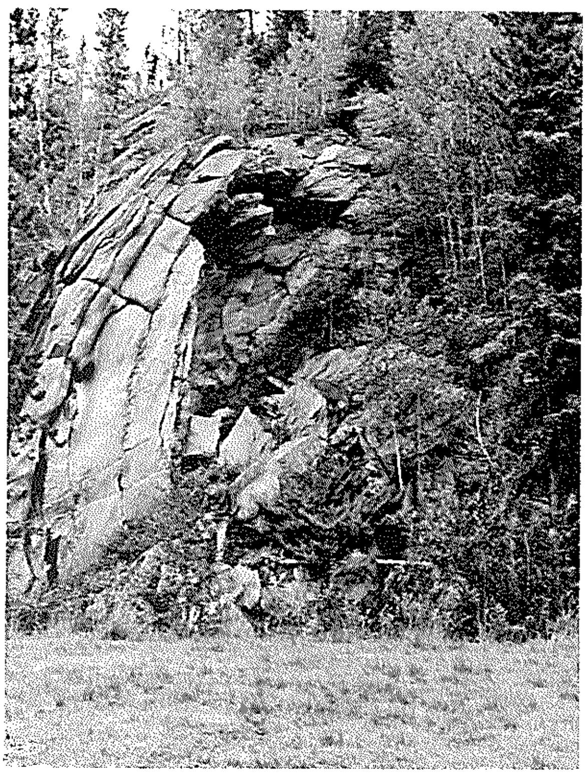

Plate 16: Fold in Lower Wynd Fm. Mile 221.8, Continental Divide.

172.6	New bridge over Fraser River.
173.0 - 173.5	Interval, with very few road outcrops, underlain by metasedimentary sequence, perhaps correlative with base of Wynd Formation, that originally consisted of sandstone with minor shale and siltstone interbeds. These beds occur in core of anticlinal structure and are overlain by sequence exposed to E and W.
173.5 - 173.9	Interval, with no road outcrops, underlain by same sequence, as that underlying 172.5 - 173.0 in core of synclinal structure.
173.9 - 180.6	Interval, largely covered, underlain by same sequence as that underlying 173.0 - 173.5. Scale of folding is somewhat larger, however. At 175.3 good exposures along railway cuts display NW plunge. At 177.4 Mt. Robson with nearly horizontal Middle to Upper Cambrian strata in core of Mt. Robson syncline comes into view to NE; to W of Mt. Robson is Cinnamon Pk with steep NE-dipping Gog. Axial surface of major synclinorium crossed at about 177.6, this surface coincides approximately with biotite metamorphic isograd.
175.3	Rear Guard Falls.
180.6	Bridge over Swiftcurrent Creek.
180.6 - 181.9	Interval with no road outcrops underlain by rocks thought to be equivalent to Meadow Creek and Old Fort Point Formations in core of large anticline overturned to NE.
181.9	Bridge over Robson River.
181.9 - 183.1	Interval, covered, underlain by rocks thought to be equivalent to lower Wynd Formation. These strata lie in NE limb of major anticline and are cut by NE-dipping normal fault.
183.1	Road junction, from which geology of surrounding area may be viewed.
183.1 - 192.6	Interval with numerous road outcrops underlain by steeply NE-dipping argillaceous rocks belonging to highest unit of Miette Group, presumably equivalent to upper Wynd Formation. These may be examined at 184.5. From 183.1 to 204.0 route parallels structural trend, with folded Miette rocks underlying Selwyn Range to SW and NE-dipping Gog in Rainbow Range to NE.

193.5 - 202.0 Moose Lake to SW.

203.9 Bridge over Moose River. To NE, Gog outcrops in timber and prominent Middle-Upper Cambrian cliffs are in SW limb of Mount Robson syncline, and on skyline dip slopes of Upper Cambrian are in NE limb of syncline. To E is Mt. Mowat with Upper Cambrian in core of syncline.

204.0 - 218.7 Covered, but probably largely underlain by upper Miette strata.

206.8 Bridge over Grant Brook.

214.0 Last crossing of Fraser River with remnants of railway bridge to SW.

214.8 To SE, Mt. Fitzwilliam in core of Mt. Robson syncline exposes dark-coloured Gog arenaceous rocks at summit, underlain successively by light Byng and dark Miette (largely covered by Byng talus). To N is Yellowhead Mtn. in NE limb of syncline with Gog Group apparently separated by structural discordance from underlying Byng.

215.7 - 218.6 Lucerne and Yellowhead Lakes to N. From E end of Yellowhead Lake, Byng carbonates on Yellowhead Mtn. appear lenticular. They and overlying Gog are cut by fault at E end of outcrop and are structurally much simpler than underlying Miette strata exposed down to lake level. From here to 242.0 route crosses four anticlinoria, in cores of which are Old Fort Point strata, and three synclinoria exposing beds belonging to Wynd Formation. Yellowhead anticlinorium crosses E end of Yellowhead Lake where road outcrops of Old Fort Point slates occur.

218.7 - 223.0 Interval with numerous road outcrops underlain by lower Wynd Formation, usually overturned to SW but near continental divide affected by some folds whose axial surfaces dip about 45^{o} SW. Lower Wynd Formation, some 2500 feet thick near Jasper, consists of arenaceous and argillaceous units, largely sandstone-conglomerate and slate-siltstone, respectively. Sandstones and conglomerates are feldspathic, slightly calcareous, poorly sorted, poorly bedded, lenticular, and display graded bedding and local cross-bedding; they may represent distributary deposits or be fluxoturbidites. Slates and siltstones also display graded bedding and may represent inter-distributary deposits or be turbidites. At 222.1 argillaceous rocks near contact between lower and upper Wynd Formation display graded bedding, ripples, micro-crossbedding, abundant pyrite at base of many graded beds, and slaty cleavage.

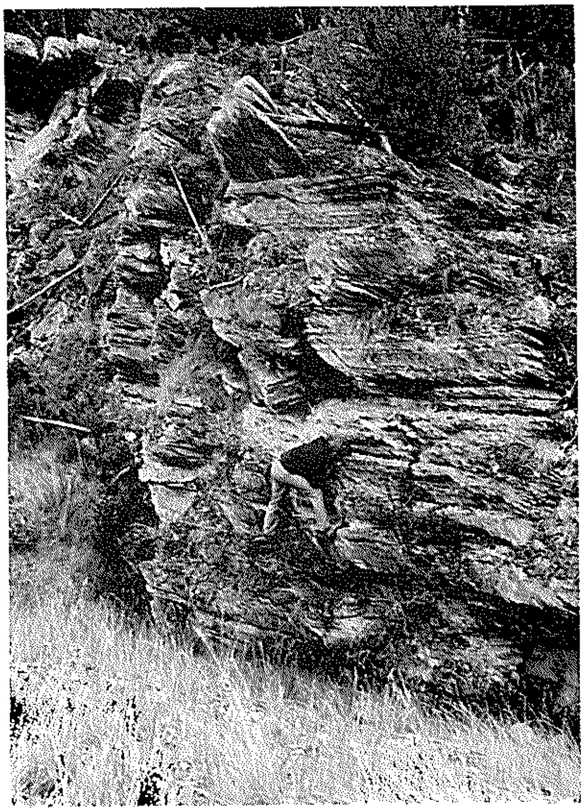

Plate 17: Wynd Formation - near contact between upper and lower Wynd. Cross-bedded and cleaved argillaceous siltstones and sandstones. Mile 222.1.

Plate 18: Old Fort Point Fm. Fold in variegated slates and siltstones. Mile 228.0.

217.6 Bridge over Rockingham Creek.

221.8 Continental divide, beyond which route follows Miette River to Jasper.

223.0 - 226.0 Interval with few road outcrops underlain by recessive upper Wynd Formation in core of Dominion Prairie synclinorium.

226.0 - 228.0 Interval with numerous road outcrops underlain by lower Wynd Formation.

227.7 Bridge over Clairvaux Creek.

228.0 - 229.8 Interval with good road outcrops largely underlain by Old Fort Point Formation in core of Meadow Creek anticlinorium. Formation is divisible here into (1) 90 ft. of blue slate, (2) 390 ft. of green slate, (3) 230 ft. of purple slate and siltstone, (4) 35 ft. of thinly interbedded limestone (purple towards base and grey towards top) and calcareous slate (purple towards base and green towards top), (5) 3-15 ft. of dark blue slate, (6) 2-9 ft. of breccia with angular fragments of blue limestone in matrix of calcareous sandstone, and (7) 275 ft. of green slate. At 228.9 units 3-7 are well displayed in anticline-syncline pair associated with axial-plane cleavage and SW-dipping normal fault.

229.8 - 233.0 Interval with good outcrops underlain by lower Wynd Formation in core of Minaga Creek synclinorium. At 232.0 division into arenaceous and argillaceous units, graded beeding, shale fragments (curved in places) in arenaceous rocks, green colour imparted by chlorite (also present in veins), abundance of feldspar in arenaceous rocks, and curved slaty cleavage in graded argillaceous rocks are all well displayed.

230.6 Bridge over Meadow Creek.

233.0 - 233.5 Interval, with good outcrops to S along abandoned railway grade and in quarry underlain by Old Fort Point Formation in core of Muhigan Creek anticlinorium.

233.5 - 238.0 Interval with several road outcrops underlain by lower Wynd Formation in core of Rathlin Lake synclinorium.

237.6 Junction between Highways 16 and 93. Route continues on 16.

238.0 - 239.5 Interval with no road outcrops underlain by Old Fort Point Formation in core of Jasper anticlinorium.

238.9 Viewpoint. To N, beyond Jasper town, are Pyramid (on right) and Cairngorm (on left) Mtns. in NE limb of Jasper anticlinorium and in hanging wall of Pyramid thrust. Thrust is almost horizontal where it crosses E shoulder of Pyramid Mtn. but dips at about 45° SW where it crosses route at 242.0. Miette-Gog contact descends from skyline on SW shoulder of Cairngorm Mtn. to road level at 241.5. Orange-weathering rocks at contact in gully between two mountains may belong to Byng Formation. To E are Paleozoics of Colin Range in footwall of Pyramid thrust. To SE, just across Athabasca River, is Old Fort Point, and on skyline beyond is Mt. Tekarra exposing Miette-Gog contact. To SW are Mt. Kerkeslin with synclinal Lower-Middle Cambrian, and Mt. Edith Cavell with gently SW-dipping Gog underlain by Byng and Miette strata.

239.5 - 241.5 Interval with no road outcrops underlain by Wynd Formation in NE limb of Jasper anticlinorium.

241.5 Junction between Highway 16 and road to Maligne Lake.

241.6 Faulted Miette-Gog contact exposed in railway cut to NW.

241.6 - 242.0 Interval with good road outcrops underlain by sandstones and pebble-conglomerates of basal Gog Group in NE limb of Jasper anticlinorium. To SE at road level across river is cliff of gently SW-dipping Byng carbonates underlain by Miette shales.

242.0 Surface trace of Pyramid thrust immediately E of which is road outcrop of Devonian carbonate and shale.

Road Log V should be augmented with maps from the papers authored by Campbell and Charlesworth, and by Mountjoy.

Sheets 1 and 2, Geological Map: Pine Valley (following pages) have been reproduced, with permission, from B.C. Department of Mines and Petroleum Resources, Bulletin No. 52: Geology of the Pine Valley, by J.E. Hughes. These map sheets are intended to augment Road Logs I - III.

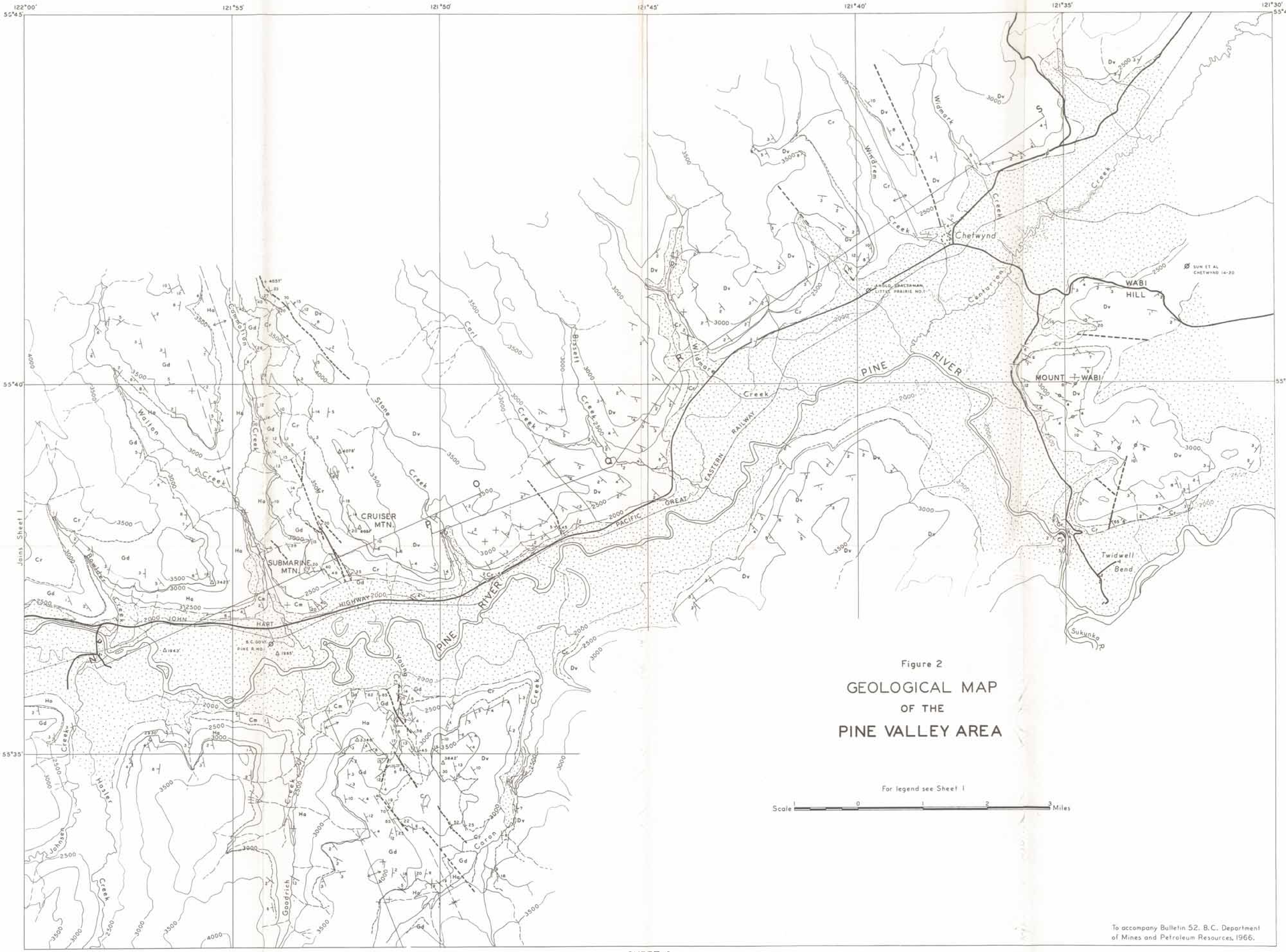

Figure 2
GEOLOGICAL MAP
OF THE
PINE VALLEY AREA

To accompany Bulletin 52, B.C. Department of Mines and Petroleum Resources, 1966.

SHEET 2

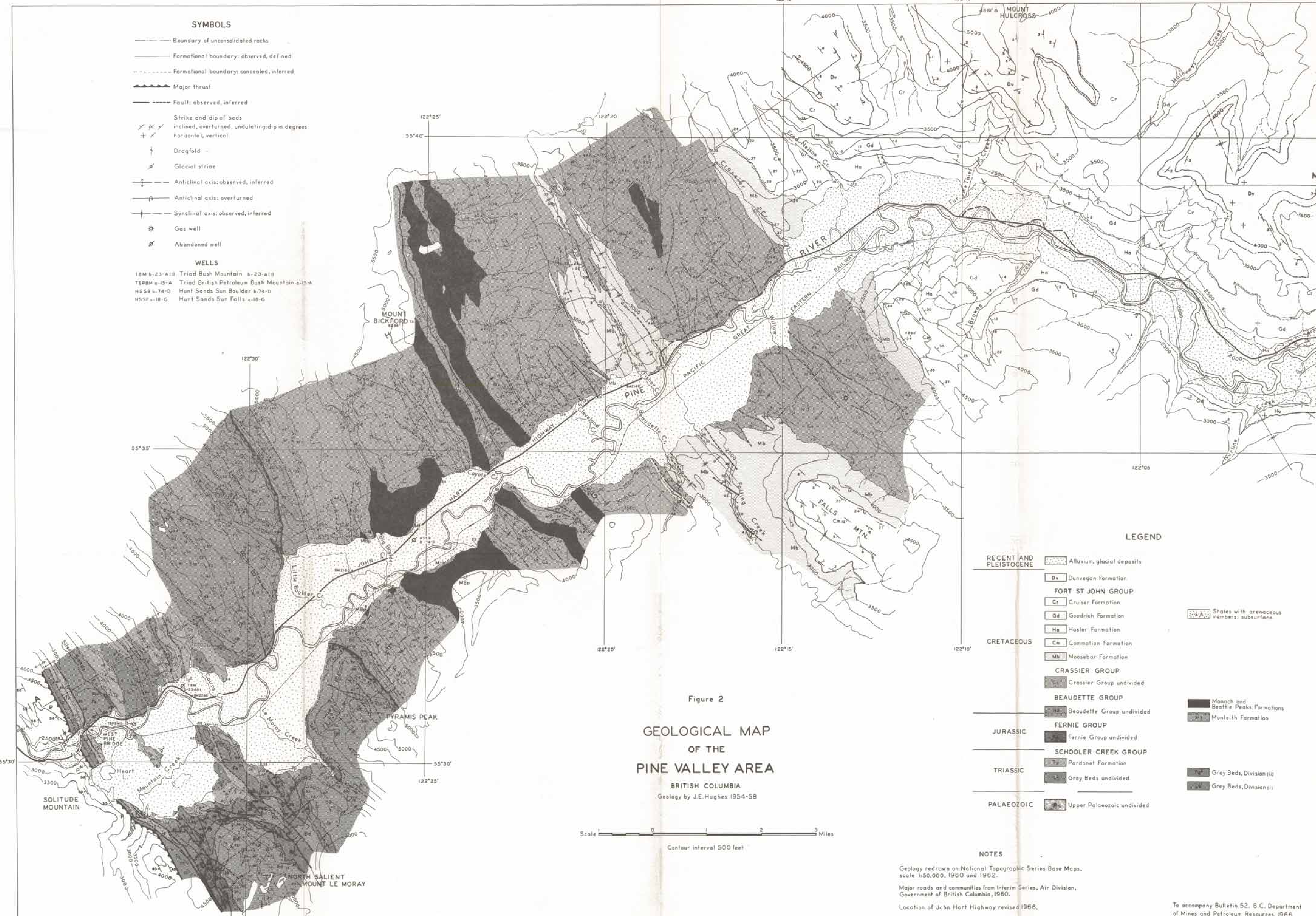

Figure 2

GEOLOGICAL MAP OF THE PINE VALLEY AREA

BRITISH COLUMBIA

Geology by J.E. Hughes 1954-58

SHEET I