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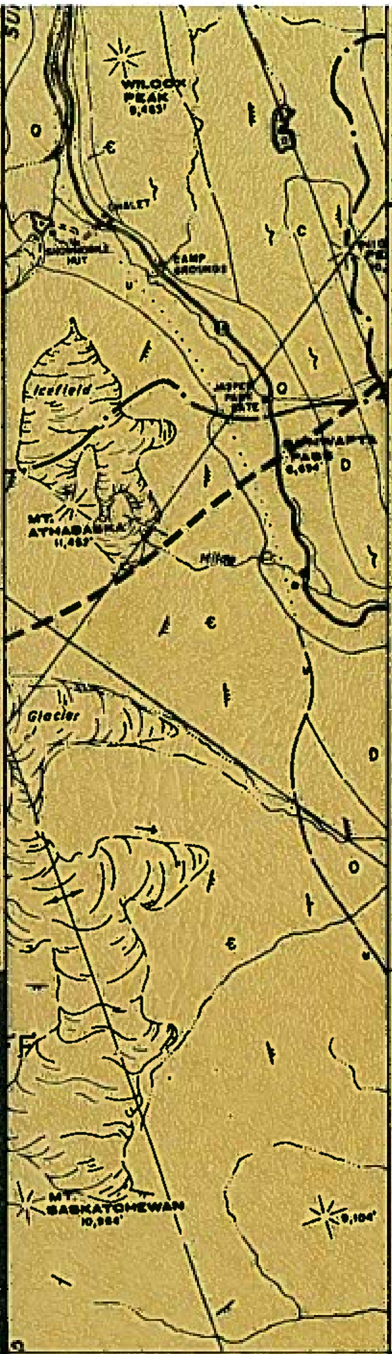
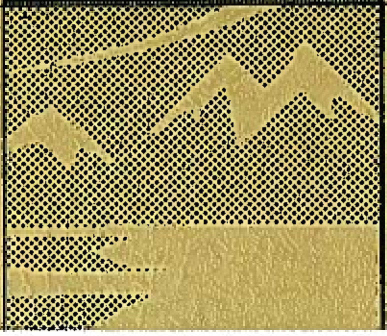


5 th annual
field trip
guide book

SUNWAPTA PASS AREA

AUGUST·



Edmonton Geological Society

Guide Book

Sunwapta Pass Area

5th Annual Field Trip

August, 1963

EDMONTON GEOLOGICAL SOCIETY

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CONTENTS

ILLUSTRATIONS

PREFACE

Welcome to the fifth annual field trip of the Edmonton Geological Society.

This field excursion is centered around the Sunwapta Pass area of the Banff - Jasper Highway. We have all often travelled this route which ranks among the great "highroads" of the world, with its spectacular scenery, replete with first class rock exposures of sediments ranging in age from Precambrian to Recent. In your guide book we are providing several papers which we believe will add to your knowledge, and stimulate your interest, in this area so easily accessible to all of us.

At this point we would like to make a public apology to Dr. A.C. Spreng for the material we have, of necessity, omitted from the paper, "Mississippian Cyclic Sedimentation, Sunwapta Pass Area, Alberta, Canada", due to space limitations.

We hope that you will enjoy the trip, and that this guide book will be useful not only to you, but to other who were unable to attend.

Alan A. McDermott, Chairman
Field Trip Committee

UPPER CAMBRIAN-LOWER ORDOVICIAN ROCK NOMENCLATURE IN THE SOUTHERN ROCKY MOUNTAINS

Robert G. Greggs

Department of Geological Sciences, Queen's University
Kingston, Ontario

The present Upper Cambrian and Lower Ordovician stratigraphic nomenclature for the southern Rockies was established by C.D. Walcott in a series of papers published between 1908 and 1928. In 1908, the Bosworth, Paget, and Sherbrooke Formations were erected on Mount Bosworth; in 1920, the Arctomys, Sullivan, Lyell, Mons, and Sarbach were described from the Glacier Lake valley; in 1923, the 1920 paper was considerably amplified; and, finally in 1928 all the Upper Cambrian and Lower Ordovician formations of the previous publications were described and another formation, the Sabine, was introduced into the Glacier Lake sequence.

Thus by 1928, the Upper Cambrian and Lower Ordovician strata had been subdivided into nine formations, none of which was well defined by modern standards. Attempts to apply these nine formation names during the last thirty-five years has resulted in considerably confusion. Application of this nomenclature was difficult for several reasons, of which the most important were: 1) the rock units were not defined or located with sufficient precision for easy recognition by other geologists; 2) inconsistency in application of the names by Walcott and others. A complete, continuous section of Upper Cambrian and Lower Ordovician was at that time unknown and an erroneous composite was built up due to unrecognised facies changes.

Despite the early establishment of the Bosworth-Sherbrooke succession of Upper Cambrian formation names, they were little used, and the Arctomys to Sarbach nomenclature of the Glacier Lake area proved more popular, possibly because application of the latter was thought to be easier than those of Mt. Bosworth. Based upon Walcott's well-known Glacier Lake nomenclature, Figure 1 outlines as accurately as possible the Upper Cambrian and Lower Ordovician rock units within the Arctomys-Sarbach nomenclature. To equate precisely the rock units of Figure 1 to Walcott's nomenclature is not possible; what Walcott intended to include in his formations is not altogether clear, and popular usage has changed the meaning of at least two of his formations, namely, the Arctomys, and the Mons.

Subsequent papers are planned to define a revised, formal nomenclature for the Upper Cambrian and Lower Ordovician rock units of the southern Rockies. Paleontological evidence will also be provided to document the ages of the various formations as they occur in the type sections, and to show the succession of Upper Cambrian faunal zones in the Canadian Rockies.

In summary, it must be emphasized that the accompanying figure is intended solely as a guide to the Upper Cambrian-Lower Ordovician rock units to be encountered on the field trip. The names applied to the rock units are casual, informal, and are added merely to facilitate reference to the rock units. The application of the stage names to the rock units, however, is reasonably correct and precise.

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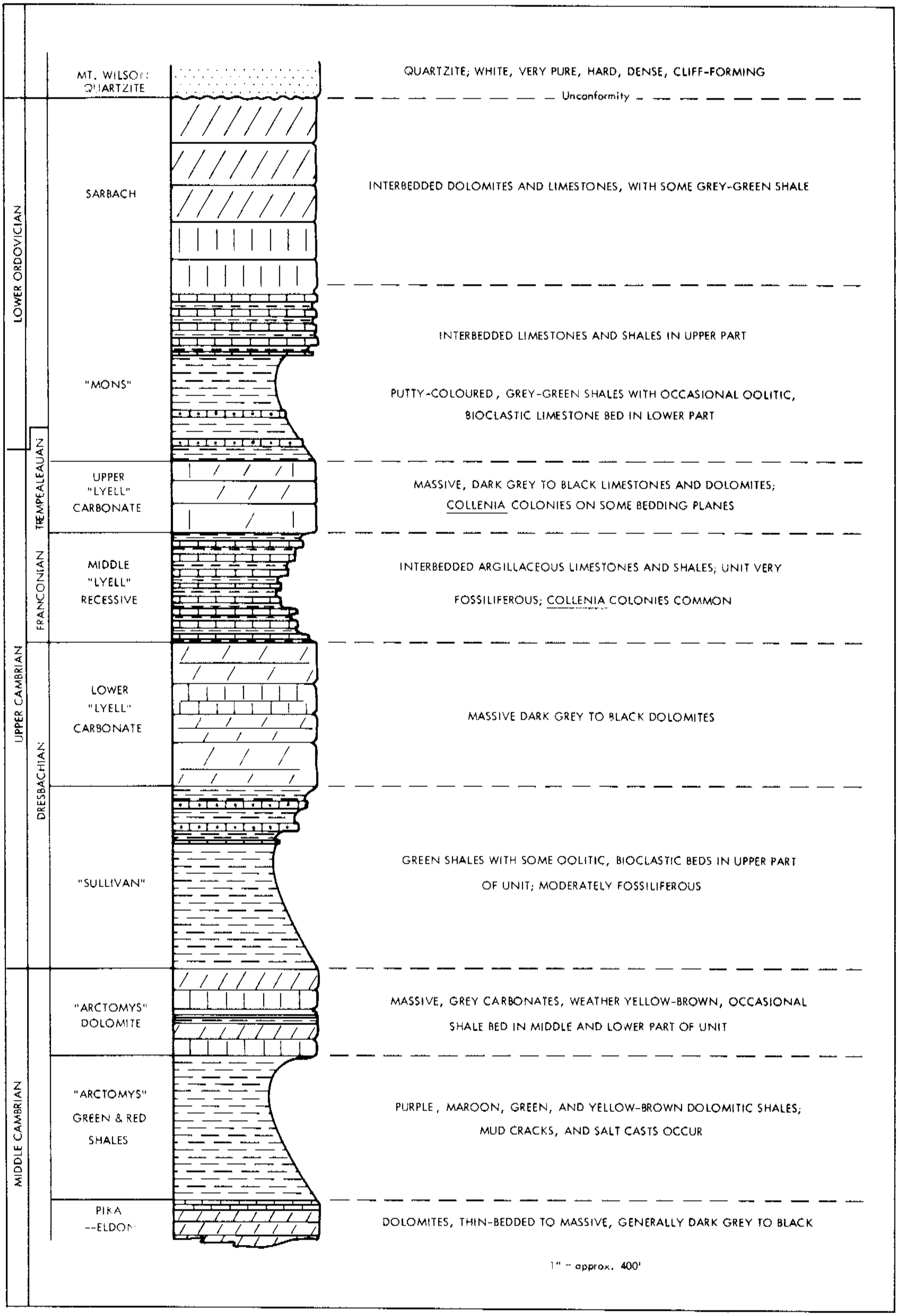


FIGURE I **UPPER CAMBRIAN - LOWER ORDOVICIAN ROCK UNITS MT. MURCHISON AREA, ALBERTA**

ORDOVICIAN STRATIGRAPHY, SUNWAPTA PASS AREA

E.E. Pelzer

The California Standard Co., Edmonton

INTRODUCTION

It must be emphasized from the outset that this contribution is an exercise in armchair geology. The author has no personal familiarity with the area under discussion, although a number of years have been spent considering similar stratigraphy in more northerly parts of the western Cordillera. The exercise is, therefore, limited to a consideration of the rather sparse literature of the area under discussion, a brief comparison with the literature of more northerly areas, and an attempt to define some of the outstanding problems of the Ordovician stratigraphy in the Sunwapta Pass area.

LITERATURE SUMMARY ON SUNWAPTA PASS AREA

Walcott (1923) designated type sections for the Sarbach and Mons of Ordovician age on the south side of Glacier Lake six miles southwest of Saskatchewan Crossing. His type section for the two formations is shown in Figure 1. From the Sarbach, Walcott collected a sparse fauna which Ulrich assigned to the Beekmantown. From the Mons came a somewhat larger collection that Harker, Hutchinson and McLaren (1954) state to be part of the Bellefontia fauna. This fauna was assigned by Walcott to the "Ozarkian System" of Ulrich.

Walcott's Sarbach-Mons boundary was drawn primarily on faunal rather than lithological grounds. This is not in accord with modern stratigraphic practice, and accepted usage at the present time (see North and Henderson, 1954) appears to restrict the Sarbach to the thick-bedded limestones and dolomites, placing all of the thin-bedded limestones and interbedded shales within the Mons. It is in this sense that the two terms are used in this paper. North and Henderson (1954) also state that the separation of the Sarbach and Mons is not everywhere possible, and they propose the elevation of the Goodsir Formation, a southern equivalent, to group status to embrace the combined Sarbach and Mons Formations.

The Chushina Formation of Walcott (1923) in the Mount Robson area, as described by Mountjoy (1962) consists of thin-bedded argillaceous limestone and calcareous shale with thin beds of intraformational limestone conglomerate. The formation carries the *Bellefontia* fauna and is clearly correlative with the Mons and with the lower *Bellefontia*-bearing portion of the Nigel Peak section of Harker, Hutchinson and McLaren (1954), which is illustrated in Figure 1.

The Sarbach Formation appears to be absent in the Jasper area due to pre-Devonian erosion, but is probably represented further west by Walcott's (1923) restricted Robson Formation of the Mount Robson area.

In summary, Devonian strata in the Glacier Lake area rest unconformably on "Goodsir Group", which may be divided into upper massive carbonates of the Sarbach and lower thin-bedded carbonates, shales and intraformational conglomerates of the Mons. The Mons rests, apparently conformably, on Lyell dolomites of Late Cambrian age. The lower part of the Mons may, therefore, contain the Cambrian-Ordovician boundary. In the Jasper area to the north, the Sarbach is missing due to pre-Devonian truncation, and the Devonian rests on Mon equivalent, here known as the Chushina Formation. Sarbach equivalents are represented farther west in the Robson Formation.

A partial faunal list of the "Goodsir Group" is as follows:

Sarbach and Robson Formations

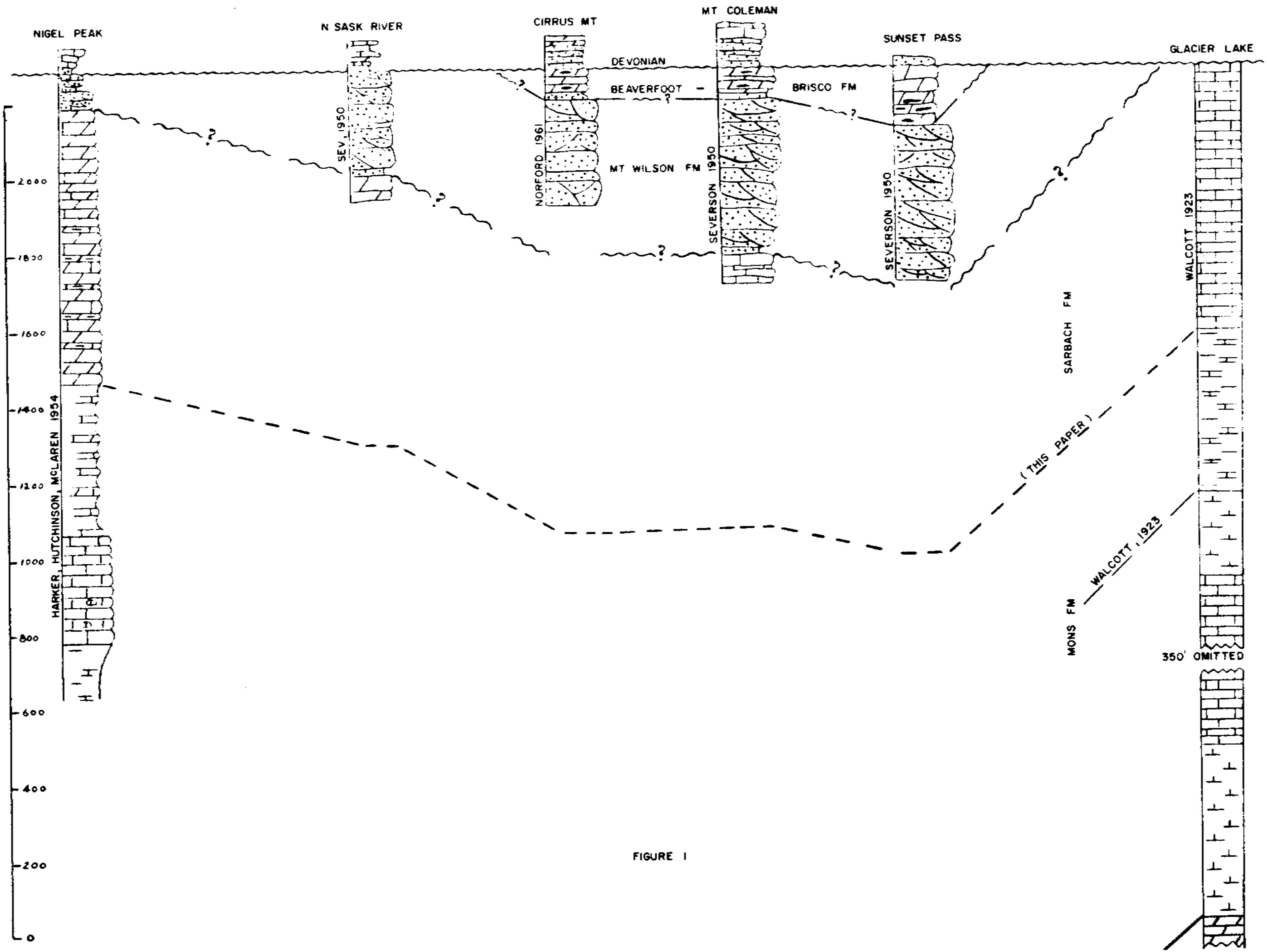
Illaenus sp.

Lecanospira sp.

Lophospira sp.

Orthid brachiopods

Palliseria robusta Wilson



NIGEL PEAK
N SASK RIVER
CIRRUS MT
MT COLEMAN
SUNSET PASS
GLACIER LAKE
DEVONIAN
BEAVERFOOT - BRISCO FM
MT WILSON FM
SARBACH FM
MONS FM
HARKER, HUTCHINSON, McLAREN 1954
SEV, 1950
NORFORD 1961
SEVERSON 1950
SEVERSON 1950
WALCOTT 1923
(THIS PAPER)
WALCOTT, 1923
350' OMITTED
2000
1800
1600
1400
1200
1000
800
600
400
200
0

FIGURE I

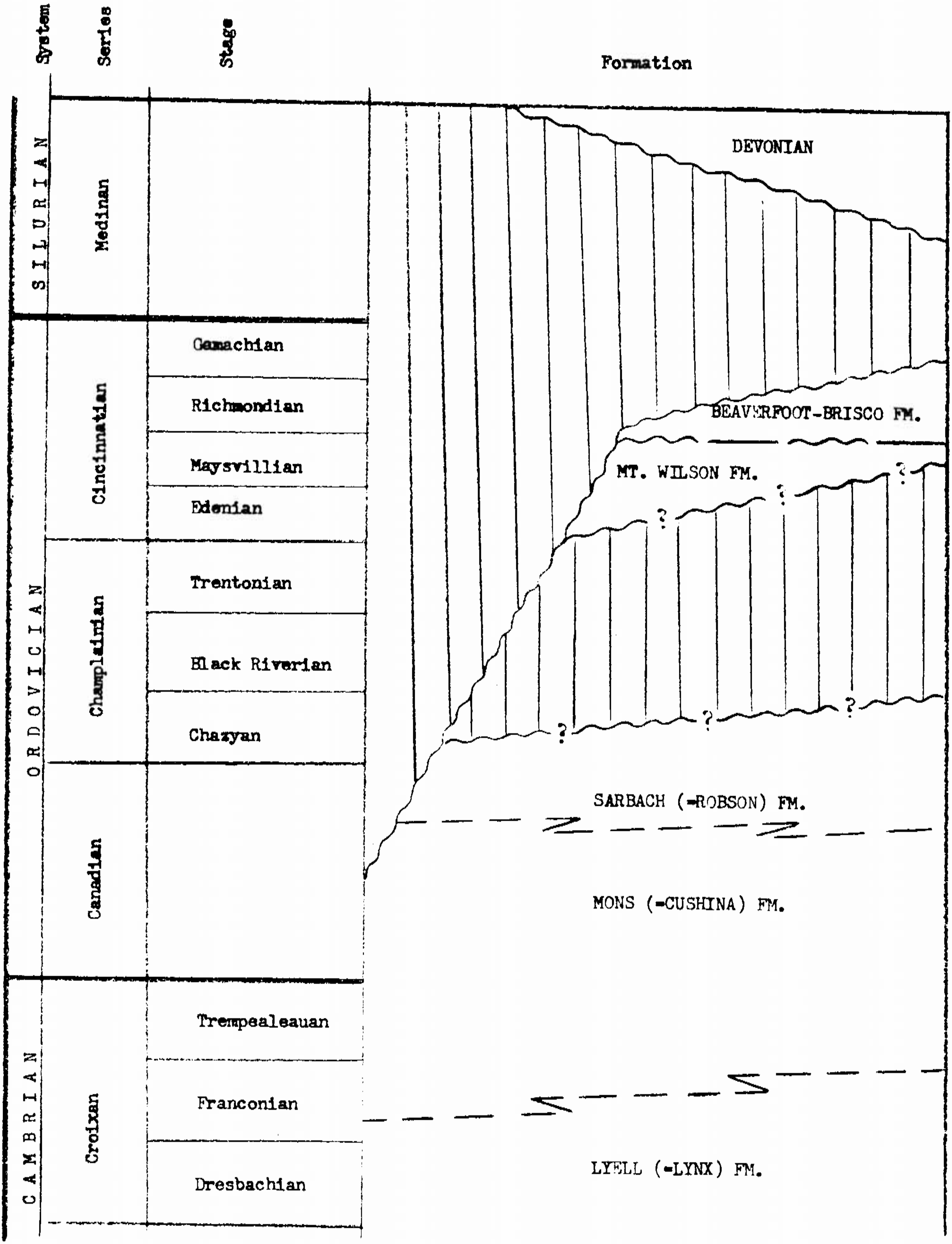

System
Series
Stage
Formation
SILURIAN
Medinan
ORDOVICIAN
Cincinnatian
Gamachian
Richmondian
Maysvillian
Edenian
Champlainian
Trentonian
Black Riverian
Chazyan
Canadian
CAMBRIAN
Croixan
Trempealeauan
Franconian
Dresbachian
DEVONIAN
BEAVERFOOT-BRISCO FM.
MT. WILSON FM.
SARBACH (=ROBSON) FM.
MONS (=CUSHINA) FM.
LYELL (=LYNX) FM.

Figure 2

Mons and Chushina Formations

Bellefontia nonius (Walcott)

Eorthis sp

Hormotoma lamus Walcott

Huenella sp.

Hystricurus sp.

Kainella sp.

Keytella sp.

Leiostegium sp.

Lingulella sp.

Orthoceras sp.

Syntrophina convexa (Kindle)

Syntrophia isis Walcott

Symphysurina sp.

The Sarbach fauna has been referred to the Beekmantown and therefore the Goodsir is Early Ordovician or older. It should be noted, however, that the fauna of the Sarbach is sparse, rather indeterminate, and so far as can be determined comes largely from the lower beds. While some reservation as to the upper limit of the Sarbach must therefore be maintained, it is worth noting that the southerly shale equivalents, the McKay Group, do not go higher than late Chazyan (Evans, 1933) i.e. early Middle Ordovician.

From Sunwapta Pass to Mount Wilson the Sarbach is overlain not by Devonian but by the Mount Wilson Formation. This cross-bedded, light coloured, fine- to coarse-grained quartzite was named by Walcott (1923), who equated it to the Ghost River Formation. Severson (1950) showed that at the north end of Mount Wilson and on Mount Coleman the Mount Wilson Formation was overlain by *Halysites*-bearing beds, which he believed to be Silurian in age. Norford (1961) found that these beds were also present on Mount Cirrus, where they contain a fauna of Late Ordovician age, common to the Beaverfoot-Brisco Formation. The published sections of Severson and of Norford appear on Figure 1.

The Mount Wilson Formation reaches a maximum thickness of just over 400 feet on Mount Coleman. Severson states that the quartzite rests conformably on the underlying Sarbach dolomite; the contact is apparently sharp. Severson describes the upper contact as disconformable, being overlain by a thin phosphate-bearing sand at the base of the *Halysites* beds. Norford found this contact concealed on Mount Cirrus, but did find pebble zones in the same thin sandstone unit.

No fossils have been reported from the Mount Wilson. Severson correlated it on lithology with the Wonah Formation, and dating of the *Halysites* beds as Ordovician gives support to this suggestion. The Wonah is underlain by Middle Ordovician and overlain by Upper Ordovician strata.

The Beaverfoot-Brisco Formation attains a thickness of about 160 feet on Mount Wilson and disappears abruptly south of this locality. North of Mount Wilson the unit thins until it is truncated just north of Mount Cirrus. The dolomites are light grey, finely crystalline to aphanitic, cherty and contain silicified fossils. Part of Norford's (1961) faunal list is as follows:

Favistella alveolata stellaris (Wilson)

Bighornia sp. cf. *B. parva* Duncan

Catenipora cf. *C. pulchellus* (Wilson)

C. robustus (Wilson)

Dinorthis sp. cf. *D. columbia* Wilson

D. rockymontana Wilson

Streptelasma prolongatum Wilson

Petroria rugosa Wilson

Thaerodonta sp. aff. *T. saxea* (Sardeson)

To review, between Saskatchewan Crossing and Sunwapta Pass the Devonian strata rest not on Sarbach as to the north and south, but on undated Mount Wilson, or on Beaverfoot-Brisco of Upper Ordovician age. Whether the preservation of these younger beds is due to erosional relief on the unconformity or to pre-unconformity downwarping is not entirely clear, but because the Devonian section is thicker by some 200 feet on Mount Coleman than on Nigel Peak (see Seversen, 1950), the latter is suggested as the more likely explanation. The literature carries a suggestion of disconformity between Beaverfoot-Brisco and Mount Wilson, but there is no recorded suggestion of disconformity between Mount Wilson and Sarbach despite the very abrupt lithological change.

SILURO-ORDOVICIAN OF THE NORTHERN CORDILLERA

Although the Sarbach is missing in the Main Ranges of the Jasper area, Harker, Hutchinson and McLaren (op. cit.) indicate that the unit probably reappears at Cecilia Lake, 110 miles northwest of Jasper. About the latitude of Peace River, the Beaverfoot-Brisco and Mount Wilson equivalents seem also to reappear, for Gallant (1962) describes a silty dolomite bearing silicified corals of Silurian age, with a basal sandy zone containing fossils of Late Ordovician age.

On the Alaska Highway, at Trout River, Laudon and Chronic (1949) record 1200 feet of "Silurian" dolomites resting disconformably on 450 feet of non-fossiliferous quartz sandstone. The authors date the fauna as Niagaran, but their list includes *Pentamerus* sp., which would also suggest the inclusion of Lower Silurian.

Norford (1962) states that the Sandpile Group of the McDame area carries only Clinton fossils, although the basal part is virtually barren. Gabrielse (1954), however, includes Upper Ordovician within the Sandpile, and states that the unit overlies Middle and Lower Ordovician Kechika Group with marked structural discordance.

In the McConnell Range of the Northwest Territories, Williams (1923) proposed the Mount Kindle Formation for 560 feet of magnesian limestone and dolomite containing a fauna identified by him as Niagaran. Borden (1956) reports from the Mount Kindle of the type area the following fossils:

Catenipora agglomeratiformis (Whitfield)

C. quebecensis (Lambe)

C. rubra Sinclair and Bolton

Manipora sp.

Paleophyllum halysitoides (Wilson)

P. calicina (Nicholson)

P. parvum Stearn

These are stated to indicate Late Ordovician age.

There is in the foregoing passages a considerable body of evidence to suggest that over much of northwestern Canada, the Upper Ordovician, Lower and Middle Silurian constitute a single rock unit or sequence.

At the base of this rock unit in many areas is a sand or sandy phase which contrasts strongly with the underlying carbonates. Underlying the sandy phase, sometimes with angular discordance, are rocks ranging in age from Early to Middle Ordovician, but with the Middle Ordovician in general incompletely represented or not represented at all, at least faunally.

The suggestion is made that the rock sequence indicates a period of shoaling and partial emergence in Middle Ordovician time, followed by Mount Kindle, Sandpile or Beaverfoot-Brisco transgression in Late Ordovician time. Such a break in the depositional record would correspond closely to the Taconic orogeny of the Appalachian region, although certainly of shorter duration and lesser intensity.

This break, if it does exist, would place the Mons and Sarbach in the Sauk Sequence of Sloss , Krumbein and Dapples (1949) and the Mount Wilson and Beaverfoot-Brisco in their Tippecanoe Sequence.

CONCLUSION AND STATEMENT OF PROBLEMS

A summary in diagrammatic form of the possible relationship of the Ordovician strata of the subject area to the standard North American stratigraphic references is shown in Figure 2. It must be emphasized that this diagram is highly interpretive, based on meagre literature and is by no means to be taken as authoritative.

A review such as this cannot hope, nor should it attempt, to solve any problems. This can come only from very careful examination of the rock units concerned. What we may hope to do is to define the outstanding problems of the area, and these appear to be framed in the following questions:

1. Where does the Cambrian-Ordovician boundary lie?
2. Is the Middle Ordovician represented?
3. If the Middle Ordovician is not represented, is its absence explained by a marked hiatus at the base of the Mount Wilson?
4. Is there a disconformity at the base of the Beaverfoot-Brisco, or do the basal sandy beds represent an intraformational break of minor consequence?
5. Is the local preservation of Mount Wilson and Beaverfoot-Brisco due to relief on the sub-Devonian unconformity or to downwarping in pre-unconformity time?
6. Does the presence of Mount Wilson have any bearing on the location of subsequent Devonian reef development?

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THE DEVONIAN OF SUNWAPTA PASS AREA, ALBERTA[1]

H.R. Belyea and D.J. McLaren

Geological Survey of Canada

INTRODUCTION

A series of outcrops in the northern corner of Banff National Park, in and immediately below Sunwapta Pass, expose a carbonate reef and bank and an adjacent off-reef terrigenous clastic succession. Furthermore, these exposures illustrate the way in which the Sassenach Formation is related to the underlying formations.

Devonian sections in the Sunwapta Pass area have been studied by Severson (1950). DeWit and McLaren (1950) described a section at the southern end of Cirrus Mountain, incorrectly cited as Mount Coleman, and further sections have been studied by the authors either jointly or separately. In addition, an "off-reef" section was measured in 1958 by Dr. E.W. Best and Mr. A.E.H. Pedder of Triad Oil Company Limited, who have kindly given details to the writers. Various references were made to outcrops in this area in the 1955 Guide Book of the Alberta Society of Petroleum Geologists Field Conference, Jasper National Park. Belyea (1960) commented briefly on the reef and its relationships to adjacent rocks in "The Story of the Mountains in Banff National Park". No study has yet shown the spatial relations of the outcrop, or attempted a synthesis of the Devonian of the area.

The Devonian sequence is similar to that of the Front Ranges of the Rocky Mountains described by deWit and McLaren (1950), McLaren (1956), and other writers. It also resembles the sequence found in the subsurface of central and south-central Alberta. The two sequences are compared in adjacent columns in Figure 1. Equivalents

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[1] Published by permission of the Director of the Geological Survey of Canada

of the thick Beaverhill Lake Formation (722 feet in the type section) of central Alberta, if present in the Sunwapta Area, are very thin.

Fossils collected from within 70 feet of the base of the Cairn Formation on Cirrus Mountain, include species of Atrypa, Allanaria, and Athyris. This is similar to a fauna collected from the lower part of the Flume Formation in the Front Ranges and suggests correlation with part of the Beaverhill Lake, probably the upper beds.

Aside from the reduced Beaverhill Lake Formation, the Sunwapta and the subsurface sequences are comparable, and the columns of Figure 1 may be considered as correlative. Hence, the exposed sections to be seen at Sunwapta Pass are probably the most accessible of those that can be compared to the oil and gas-bearing reefs of central Alberta.

OUTCROP LOCALITIES

The exposures are readily accessible from the Banff-Jasper Highway. The northernmost outcrop (A) in Figure 2 is at Sunwapta Pass, a short distance east of the Icefields Chalet. Here a section extending from the Exshaw Formation down to beds within the Mount Hawk is well exposed. A short distance to the east, a similar section (measured by Best and Pedder) exposes beds as low as the top of the Flume Formation.

Another section (B) outcrops poorly on Parker Ridge, a spur east of Mount Athabasca that separates Sunwapta Pass and the Banff-Jasper Highway from the Saskatchewan Glacier. A National Parks Branch nature trail leads up to it. The Fairholme Group here is also dominantly clastic in facies. The carbonate reef section (C) is easily reached from the gravel flat on the Saskatchewan River at the beginning of the last rise (known locally as the "Big Hill") to Sunwapta Pass. The most southerly outcrop (G) shown in Figure 3 rises from the road-side on the lower slope of Cirrus Mountain. The road between the "Big Hill" and Cirrus Mountain cuts through several outcrops. At (D) there is a road-cut through the coral beds (Grotto Member) at the southeastern end of the gravel

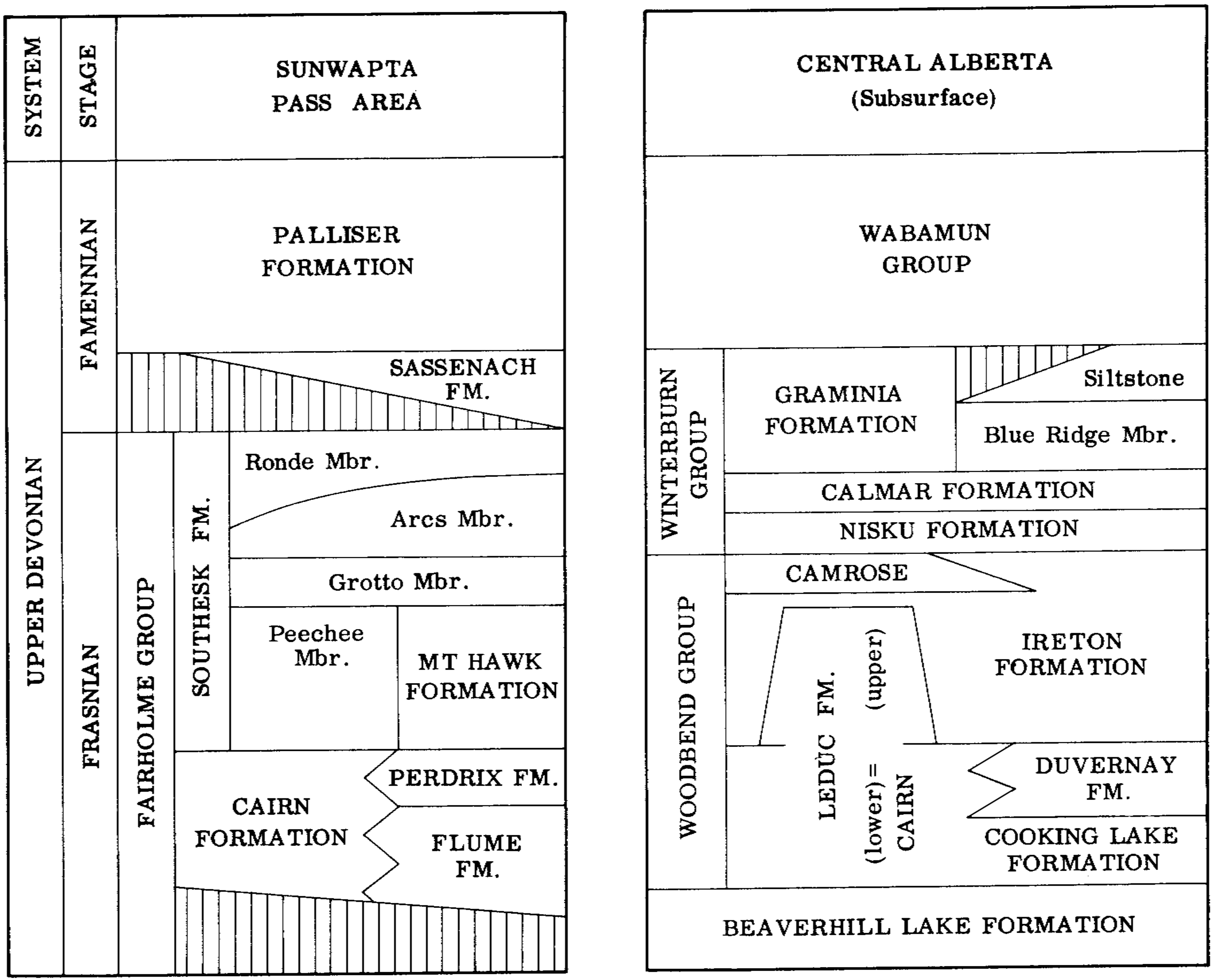
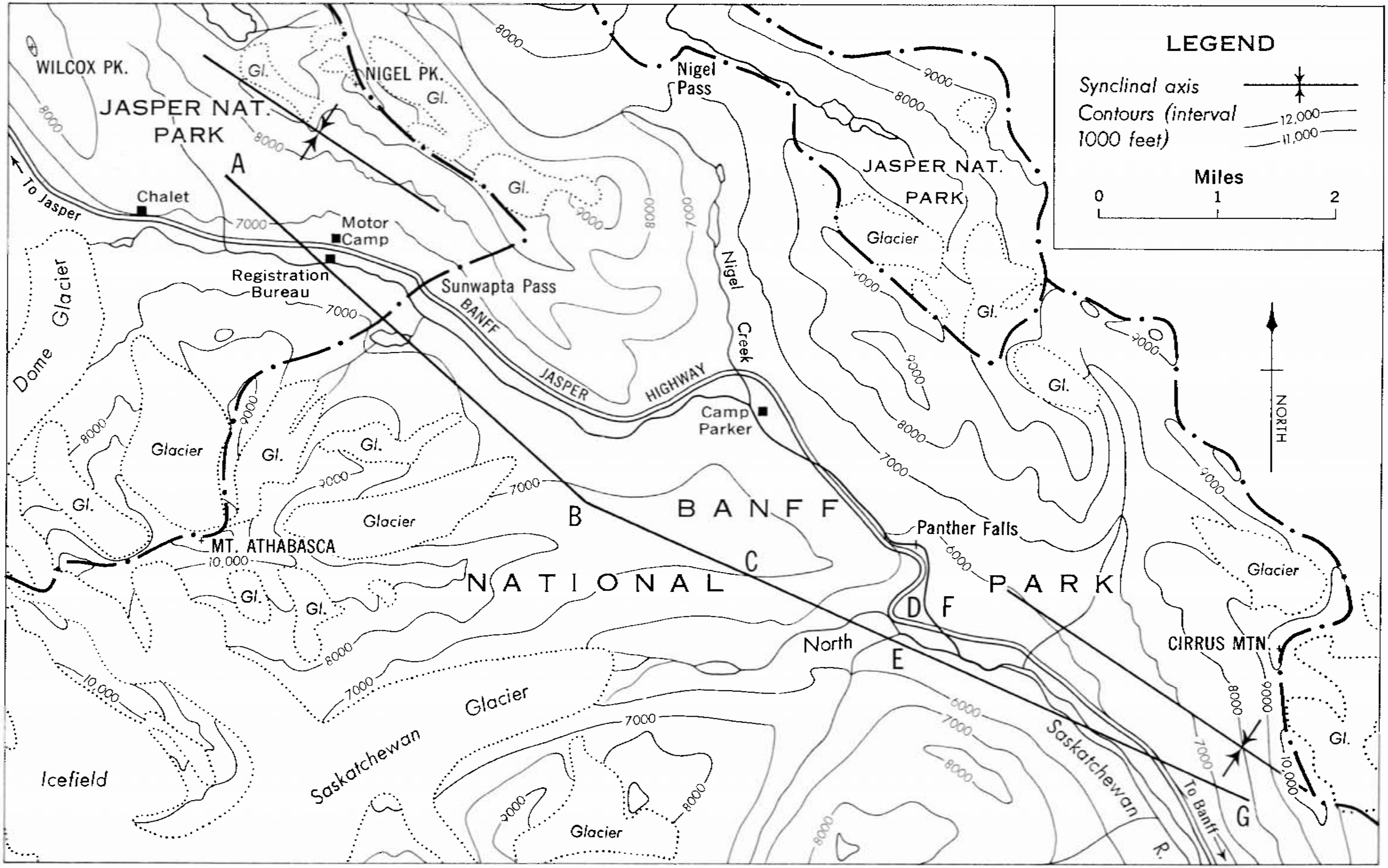


FIGURE 1. TABLE OF FORMATIONS



LEGEND
Synclinal axis
Contours (interval 1000 feet)
12,000
11,000
Miles
0
1
2
NORTH
WILCOX PK.
NIGEL PK.
JASPER NAT. PARK
Nigel Pass
JASPER NAT. PARK
Chalet
To Jasper
Motor Camp
Registration Bureau
Sunwapta Pass
BANFF JASPER HIGHWAY
Nigel Creek
Camp Parker
Panther Falls
Dome Glacier
Glacier
MT. ATHABASCA
BANFF NATIONAL PARK
North
Saskatchewan Glacier
Icefield
Saskatchewan R.
To Banff
CIRRUS MTN.
A
B
C
D
E
F
G

FIGURE 2

flats. A few feet below an outcrop (E) on the old road, the North Saskatchewan River drops out of sight into a narrow crevice in porous reef carbonate. This coarse, crystalline, vuggy dolomite resembles physically and has the same stratigraphic position as the dolomites of the Leduc, Redwater, and other oil fields of central Alberta. Continuing south, the road crosses a bridge in the Palliser Formation high above Nigel Creek (F), then drops to the foot of Cirrus Mountain, where the whole Devonian section rises above it. All of these outcrops dip to the east on the west limb of a syncline that passes through Nigel Peak and Cirrus Mountain (Figures 2,4,5).

BEDS BELOW THE FAIRHOLME GROUP

The base of the Fairholme Group is not exposed within the Pass nor on Parker Ridge (B). At "Big Hill" the Fairholme appears to rest directly on the Mount Wilson Quartzite, although there may be a sandy basal Devonian unit present. On Cirrus Mountain, 44 feet of quartzite underlie the cherty dolomite member of the Cairn Formation, and may be of Devonian age. They are underlain by 60 feet of the Beaverfoot-Brisco Formation and the Mount Wilson Quartzite below (Norford, 1961).

FAIRHOLME GROUP

Figure 3 summarizes the thicknesses and facies changes within the various formations and members of the Fairholme Group between Sunwapta Pass and Cirrus Mountain. The following comments are designed primarily to point out the more interesting aspects of the changes that take place along the line of section. On Nigel Peak (Section A) dark brown dolomites of the Flume Formation are overlain by dark grey mudstones and argillaceous limestones of the Perdrix and Lower Mount Hawk Formations. The upper part of the Fairholme is of carbonate facies and referred to the Southesk Formation. It consists of coral-bearing dolomite of the Grotto Member, about 150 feet in thickness, overlain by about 65 feet of light grey dolomite assigned to the Arcs Member. The overlying Ronde Member is some 140 feet thick and is composed of variably quartzose, silty, grey dolomite grading down into argillaceous and dolomitic siltstones at the base.

The section on Parker Ridge (B) is poorly exposed but seems to be similar to that at locality (A). The lower part of the slope on the west side above the North Saskatchewan River below the Saskatchewan Glacier is grass-covered and believed to be off-reef clastics. At the top, a cliff of brown coral beds (Grotto) is richly fossiliferous. This is overlain by grey dolomite of the Arcs Member, and by the silty and sandy dolomites of the Ronde Member. Between Parker Ridge (B) and "Big Hill" the change between the terrigenous clastic succession in the lower part of the Fairholme Group and an entirely carbonate succession takes place but is not exposed. The Mount Hawk and Perdrix Formations are replaced by the lower Southesk (Peechee Member) and the Cairn Formation; the Flume becoming eventually, the lower member of the Cairn.

On the "Big Hill", overlying the Mount Wilson Quartzite, the Cairn consists of thick-bedded to massive, dark brown to black, finely to coarsely crystalline dolomite, with abundant stromatoporoids in some beds. The matrix almost always has a tightly interlocking texture; most porosity results from leaching of stromatoporoid centers. In parts of the section there is a rhythmical succession of Amphipora-rich beds, barren beds, and beds rich in stromatoporoids. Some of the latter are replaced by chert. Higher in the sequence, the unit becomes thick to massive and varies from stromatoporoid-rich to beds containing only scattered specimens. Few were seen in position of growth. Other fossils include poorly preserved tabulate corals and traces of brachiopods. Two lenticular mounds of white dolomite occur at the boundary between the Cairn and Southesk Formations (Figure 6). Dark brownish grey shales are draped over the smaller mound.

The Peechee Member of the Southesk Formation consists, at the northwest end of the hillside, of light grey, massive, coarsely crystalline dolomite (Figure 6, near skyline), that weathers almost white. At the southern end of the exposure the dolomite is massive to thick-bedded, coarsely crystalline, with small vugs accentuating the bedded appearance.

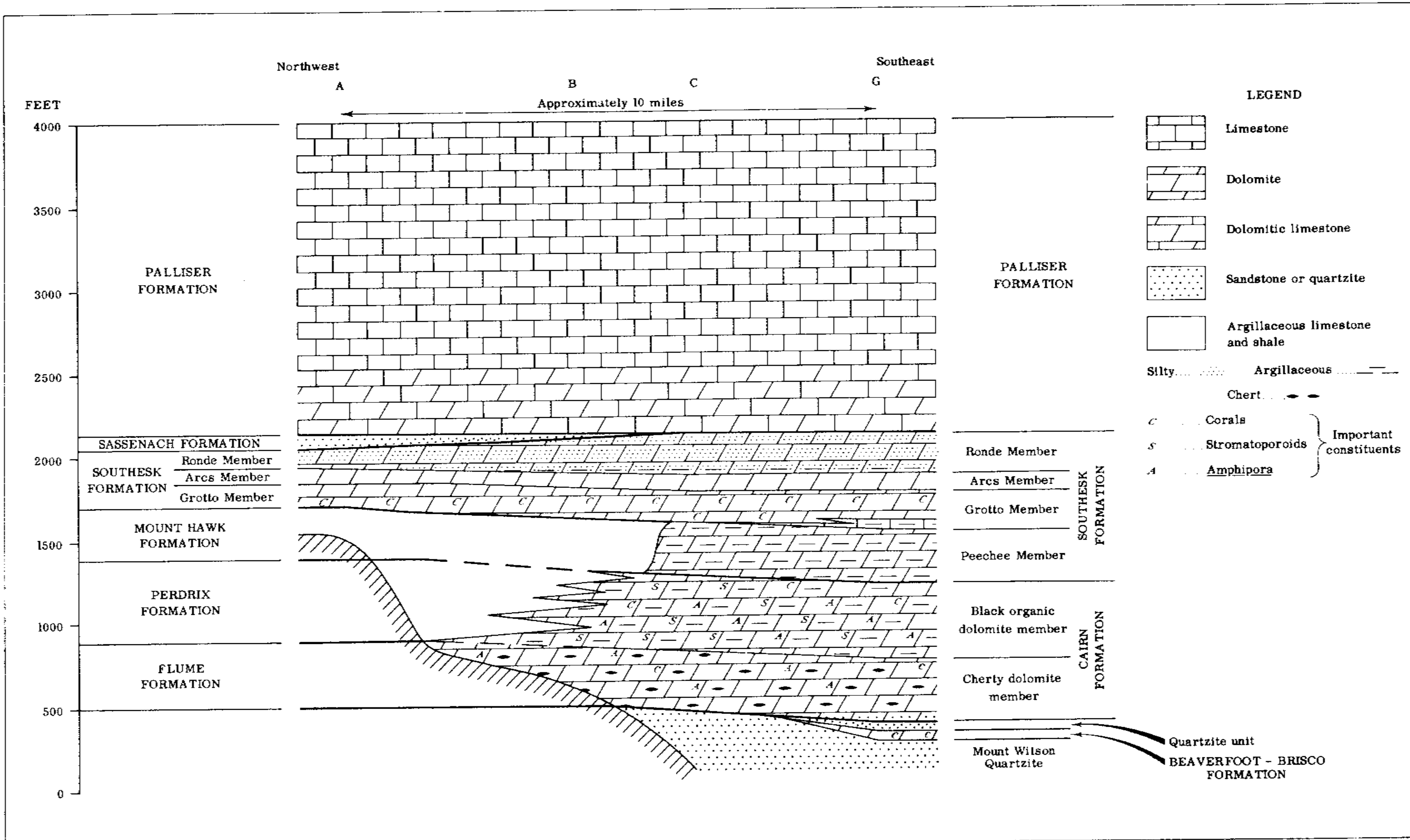


FIGURE 3. RELATIONSHIPS BETWEEN "REEF" AND "OFF-REEF" SECTIONS SUNWAPTA PASS AREA. FOR LOCATION OF SECTIONS A - B - C - G SEE FIGURE 2.

Figure 4 - Looking northwest from side of Cirrus Mountain showing Devonian section on the "Big Hill" on west limb of syncline that runs through Nigel Peak (on skyline to right).

Figure 5 - Devonian section on Cirrus Mountain, looking southeast. Palliser Formation forms cliff at left.

The latter structures suggest that the beds were originally coarse carbonate clastics, possibly calcarenites, whereas the massive exposures on the skyline may have been true reef with an organic lattice. The beds immediately overlying the massive carbonate present a more bedded appearance.

The Grotto Member (coral beds) is similar in development from locality (A) to (G), as are the light grey, coarsely crystalline, vuggy dolomites of the Arcs Member. The Ronde has thickened to some 240 feet at "Big Hill", and is characteristically grey and yellowish weathering, laminated, silty dolomite interbedded with purer dolomite (Figure 7). Breccias are not uncommon (Figure 8).

The Grotto Member is exposed at locality (D), and the Peechee at (E), where it has the same light colour, coarse crystallinity and vuggy porosity as on "Big Hill".

On Cirrus Mountain, a full carbonate Fairholme is developed. The Cairn Formation consists of about 840 feet of dark coloured to black dolomites with abundant organic remains, and a cherty member at the base. The Peechee Member of the Southesk, however, differs from its development at "Big Hill". It consists of some 310 feet of dark grey and black variably argillaceous fetid, dolomites, with medium to thick bedding developed. Some horizons are strongly cherty, and there is a high argillaceous content throughout.

Between the typical lithology of the Grotto Member, nearly 200 feet in thickness, and the Peechee Member, there are about 60 feet of grey argillaceous limestones with interbedded calcareous mudstones. They are here included in the Grotto Member. The Arcs and Ronde Members are very similar to their development at "Big Hill". Traces of Amphipora and corals occur within the Ronde at several horizons.

SASSENACH FORMATION

The problem of the equivalents of the Alexo Formation in the Sunwapta Pass area has already been summarized by McLaren (in Henness, 1963). Earlier reports have included both the Ronde Member of the Southesk and, where present, the

Sassenach Formation in the "Alexo" in this area. The disconformity present within the Alexo in the Jasper Region (McLaren and Mountjoy, 1962), is also present in the Sunwapta area. On Nigel Peak (A), 55 feet of the Sassenach Formation are present, and consist of quartzose, sandy dolomite and grey to light grey dolomitic sandstone, well bedded and weathering to pale yellowish-grey. The beds become softer towards the base, grading down into a partly covered interval containing scattered blocks of thin-bedded, sandy dolomite with strong wavy laminae and argillaceous partings. A few fragments of silicified brachiopods resembling Cyrtiopsis were found about 20 feet above the base. The upper and lower contacts of the formation are sharp; the basal beds of the overlying Palliser Formation consisting of granular, brownish grey dolomitic limestone; and the underlying Ronde Member of the Southesk being composed of massive to thick-bedded, vuggy, silty dolomite. The Sassenach Formation is present also on Parker Ridge (B) but has disappeared on "Big Hill" (C). Here, the Palliser rests directly on the Ronde Member of the Southesk with a very sharp break and evidence of small scale erosion of the underlying beds. Nor is the formation present on Cirrus Mountain. This is a situation analogous to that described by McLaren and Mountjoy (1962, p. 13), between Mount Haultain and Mount Sassenach in the Colin thrust sheet some 20 miles north of Jasper.

PALLISER FORMATION

The Palliser Formation was measured on Nigel Peak by Best and Pedder, who report a total thickness of 1880 feet, consisting mainly of limestones with some dolomitic limestones, all assigned to the Morro Member. It is overlain by a thick Exshaw, and it rests on the Sassenach Formation. Southeastwards, the Palliser is not conveniently measured on "Big Hill", and is inaccessible from Cirrus Mountain, where it rests with sharp disconformity on the Ronde Member of the Southesk Formation (Figure 9).

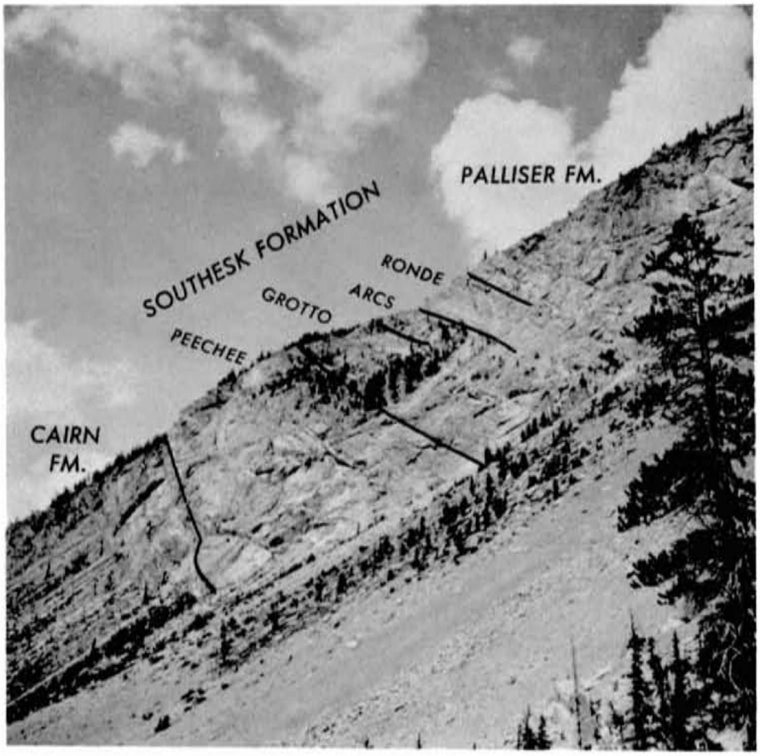


Figure 6 - Devonian section on the "Big Hill".

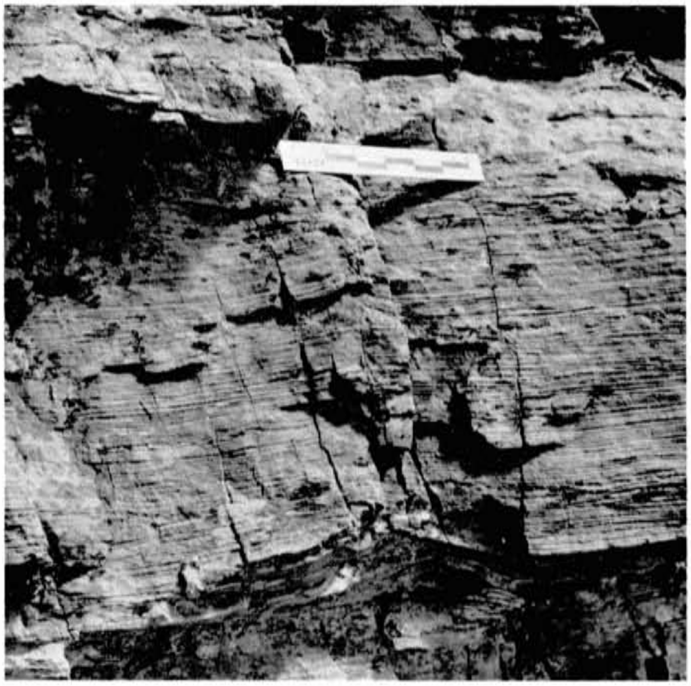


Figure 7 - Laminated silty dolomite in the Ronde Member of the Southesk Formation on "Big Hill".

Figure 8 - Dolomite breccia in the Ronde Member of the Southesk Formation on "Big Hill".

Figure 9 - Contact between the Palliser Formation and Ronde Member of the Southesk Formation on Cirrus Mountain.

CONDITIONS OF DEPOSITION

The Cairn, with its massive stromatoporoid-rich beds but with few other organisms, must have formed under restricted conditions. Wave action seems to have been heavy enough to move the stromatoporoids but not to aerate and oxidize the organic material completely. Alternatively, deposition may have been rapid enough to cover underlying sediments before decomposition could occur, thus preserving bituminous material. The stromatoporoid-rich rock seems to form beds and biostromes, rather than bioherms.

In the vicinity of "Big Hill", the overlying Peechee Member of the Southesk suggests one side of an atoll. The massive dolomites on the northern margin of the carbonate mass may have been a true wave-resistant reef composed of an organic lattice, now completely destroyed by dolomitization. The beds to the south are massive with some bedded structure. They may be back-reef beaches or bars composed of reef-derived clastics. A few miles away on Cirrus Mountain the dark dolomites may represent the fetid deposits of a sheltered lagoon. Although now dolomite, they conceivably were originally fine-grained muds containing much organic material.

Dark shales and coral beds of the Grotto suggest a return to more abundant widespread organic life, and probably rapid burial. Ripple marks and fragmentation of corals point to water depths within the zone of wave action.

The Arcs are light coloured and barren and suggests a return to the shallower aerated water conditions of the Peechee. This was followed by the thin-bedded, laminated, silty Ronde Member. Breccias in the Ronde may represent evaporites. (Compare the evaporites and silty dolomites of the central Alberta Blue Ridge Member of the Graminia Formation). The presence of silt suggests the denudation of a source of quartz silt and, in fact, represents a regression of the sea and the close of the Frasnian Stage.

The transgression marking the first sediments deposited in the Famennian Stage initiated sedimentation in basinal areas lying between the carbonate banks in advance of any sedimentation over the banks themselves. In the Sunwapta area the thin Sassenach Formation developed on Nigel Peak represents the close of a cycle of terrigenous clastic deposition more fully developed to the north e.g. around Medicine Lake. This phase was possibly followed by another period of non-deposition or erosion and then the spread of uniform conditions over the whole region initiated the formation of Bahamas type limestones of the Palliser Formation (Beales, 1956).

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MISSISSIPPIAN CYCLIC SEDIMENTATION

SUNWAPTA PASS AREA, ALBERTA, CANADA[1]

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INTRODUCTION

The author's attention was first focused on the problem of cyclic sedimentation in the Banff Formation when he served as a member of a field party, working in the Wapiti Lake area British Columbia under the direction of L.R. Laudon.

The area chosen for preliminary study lies about 220 miles southeast of Wapiti Lake and about 90 miles north of Banff. The purpose of the study was to examine lithologic variations within the formation, trace the Banff-Dessa Dawn contact to the type area of the Banff, and to make a study of the cycles and to ascertain their value as a tool for correlation. Sections were measured on the mountains just east of the Banff-Jasper highway in the vicinity of the Banff-Jasper Park boundary at Sunwapta Pass and at Mt. Coleman, about 12 miles southeast in Banff Park.

Thick Cambrian clastics, Ordovician quartzites, Silurian dolomites, Devonian carbonates and shales, and Mississippian carbonates and shales make up the general stratigraphic section in the area as has been tabulated by Severson (1950, Table 1, p. 1827).

The Exshaw Formation of Late Devonian age underlies the Banff Formation in this area. Although it has a variable thickness, it occurs persistently along the Rocky Mountain front from Crowsnest Pass in the south (de Witt and McLaren, 1950, Figure 1) to Wapiti Lake (Laudon et al., 1949, p. 1519).

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[1] Originally published in the Bulletin of the American Association of Petroleum Geologists, Vol. 37, No. 4, April 1953, pp. 665-689, 9 Figs., and here reprinted in part by permission of the author, A.C. Spreng, and the A.A.P.G.

According to Severson (1950, p. 1846), the thickness of the black shale member which makes up the lower part of the Exshaw, varies from 120 to 150 feet in this area. A much thinner and more variable, buff-brown, silty, limestone member, 3-20 feet thick, overlies the shale.

Although there is little evidence of unconformity between the Banff Formation and the underlying Exshaw, these two formations are believed to be disconformable as shown by variations in the thickness of the upper silty limestone member of the Exshaw. At the type locality 115 miles southeast of Mount Coleman, the Exshaw consists of fissile, black, silty shale followed by 30 feet of yellow-weathering, black, argillaceous limestone. This limestone member varies from 2 to 10 feet as measured in several places on "Mount Coleman"[1]. At Sunwapta Pass, 12 miles north, the limestone is only about 3 feet thick. At Maligne Canyon, just north of Medicine Lake, the Exshaw limestone and shale are missing, but pebbles lithologically similar to the Exshaw shale were found in the basal shales of the Banff. The limestone member is not present at Wapiti Lake and in some sections in that locality, the shale is absent. On the basis of these observations, it seems that the basal shales of the Banff were deposited over an Exshaw erosion surface.

The term "Banff" is used in this paper in the sense used by Warren (1927, p. 21-27; 1937), and modified by Laudon et al. (1949, p. 1536-40). Accordingly, the Banff Formation includes a series of black, calcareous shales, argillaceous limestones, and crinoidal limestones between the Upper Devonian Exshaw shale (Warren, 1937) below, and the Mississippian Dessa Dawn limestone (Laudon et al., 1949, p. 1536) above. In this paper the Banff is not divided into members because it is believed that consideration of the formation as an entity is more applicable to a study of its cyclic elements. The author was fully aware, however, that subdivision of the Banff is possible.

The basal part of all three sections is composed largely of soft, easily weathered, rhythmic, thin-bedded, black, calcareous shale and argillaceous limestone. The Banff

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[1] Editor's note: It is suspected that Spreng measured the Mississippian sections on Cirrus Mountain instead of Mount Coleman. See also a notation of this error in Belyea and McLaren (p. 14 of this Guide Book).

gradually becomes more calcareous upward until limestone predominates. A cliff-forming limestone development is succeeded in the Mount Coleman-Sunwapta area by a series of thin-bedded, argillaceous limestones and thick, black calcareous shales. This parallels the three divisions noted by Clark (1949, p. 627) near Exshaw, Alberta, to the southeast.

At Wapiti Lake and at Medicine Lake, to the north, the return to the argillaceous phase is not as strongly developed as it is in the southern sections. Above the first massive cliff of limestone, only a few, thin-bedded, argillaceous limestones, and a few thin shale beds occur, these are considered to represent the return to argillaceous conditions found in the Mount Coleman-Sunwapta sections.

The Banff is overlain by the Rundle Formation composed predominantly of limestone and dolomite. In the Wapiti Lake area, Laudon et al. (1949, p. 1536) proposed the name Dessa Dawn for the lower, scarp-forming, limestone part of the Rundle. The fauna of both the Banff and Dessa Dawn Formations consists of lower Mississippian forms while the Rundle contains middle Mississippian faunas.

If the name Dessa Dawn is applied in the area under consideration, the contact between the Dessa Dawn and the Banff Formations should be drawn at the base of the first massive, thick limestone. Facies changes within either of the two aforementioned formations may cause the position of the boundary to shift vertically in various sections. This is shown by a study of the cycles of sedimentation and the faunas.

The Banff Formation is considerably thicker in the Sunwapta-Mount Coleman area than it is in the areas to the north and south. At "Mount Coleman" and Sunwapta Pass, the Banff is 1,600 and 1,755 feet thick respectively. To the north and west at Medicine Lake, the Banff is 643 feet thick and 700 feet thick at Wapiti Lake (Laudon et al., 1949, p. 1512). The thickness at Lake Minnewanka, 90 miles south of "Mount Coleman", is about 1,175 feet as reported by Shimer (1926, p. 19).

This noticeable variation in thickness can be explained by considering the lower part of the Dessa Dawn Formation as a limestone facies that begins at about the same number of feet above the base of the Banff at Medicine Lake and at Wapiti Lake, but, about 900 feet higher in the thicker Sunwapta Pass-Mount Coleman sections, and some 400 feet higher in the Lake Minnewanka section.

FAUNA OF BANFF FORMATION

The fauna of the greater part of the Banff Formation shows pronounced Kinderhookian aspects. Most of the species collected in the study area have been described from the Kinderhookian beds of the Mississippi Valley and many have also been reported from the Lodgepole limestone of western United States.

The most significant change in the entire fauna is the development of new faunal elements transitional between the Kinderhookian forms of the lower and middle beds and forms typical of Osagean strata in the Mississippi Valley. This change is concurrent with the development of the predominantly calcareous beds near the top of each section.

Changes in the fauna of the Banff are closely related to lithologic changes. In the shaly beds, Ambocoelia, Chonetes, Platyceras, and a few pelecypods are found. Corals were found in the thicker limestone beds of the megacycles exclusively. The most abundant and varied fauna occurs in the alternating limestone and shale beds within the major cycles. In these beds, brachiopods, crinoids, and bryozoans are especially abundant, with species of Spirifer dominating the fauna.

Recurrence of faunas in the Banff Formation is shown only on a broad scale. There is no evidence of a cyclic sequence of faunas corresponding with the smaller, lithologic cycles. There is, however, a general faunal repetition coinciding with broad lithologic fluctuations.

The brachiopoid - crinoid fauna reappears throughout the section wherever there is a recurrence of the minor, limestone-shale cycles. This varied and abundant fauna changes gradationally from the lower part of the section to the top. The change is most apparent in the spiriferoid brachiopods.[1]

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[1] At this point in the original paper, the author included a comprehensive account of the faunas collected from the Sunwapta Pass and 'Mount Coleman" sections. Due to space limitations in the "Guide Book", this faunal list has been omitted.

In conclusion, when the faunal sequence of the area of discussion is compared to that of the Wapiti Lake section we find that the Dessa Dawn at Wapiti Lake has a fauna most closely comparable with the fauna of the middle, calcareous part of the Banff Formation at Sunwapta Pass-Mount Coleman. This suggests that the Dessa Dawn-Banff contact transgresses time-lines and that the base of the Dessa Dawn at "Mount Coleman" and Sunwapta Pass is much younger than at the sections to the northwest.

SEDIMENTARY CYCLES IN BANFF FORMATION

The term cycle, as used by the author, is the sedimentary evidence of an environment of sedimentation which changes from an original condition only to return to that same condition. It is a general term in the sense that there are no strict requirements for the pattern of the occurrence or to the duration of the pattern. The comparable parts must be equal in expression only; not necessarily in thickness. Thus, the only requirement is that there be a recognizable pattern of recurrence. A change in sedimentary layers from say a shale to limestone, which repeats itself, is therefore, considered a cycle. Cyclic patterns of various lengths may be superimposed upon or contained within other cycles of larger scope.

The author observed six different types of cycles in the Banff Formation in the study area (Figure 1). The types are presented more or less in order of stratigraphic occurrence.

Cycle Type A

The first recognizable pattern begins near the base of the sections studied. It consists of repetitions of very thick, grey, calcareous, clay shales separated by much thinner, fine-grained, even-bedded, generally non-fossiliferous limestone units. The contact with the limestone units is distinct.

The most significant characteristic of this pattern is the relative thickness of the limestone and shale units. The limestones are 1 to 10 inches thick, and the shales vary from 30 to 40 feet in thickness.

The limestones and the more calcareous shales are laminated. The laminations range from 0.5 mm to 4.0 mm, with an average thickness of 1.5 mm. This is within the order of thickness reported for annual layers (varves) deposited in lakes (Bradley, 1929; Antevs, 1925, 1926) and in marine basins (Rubey, 1931; Stamp, 1925).

Cycle Type B

Another cycle type consists of 2- to 10-inch limestone beds separated by several, thin argillaceous limestone layers.

The total thickness of the thin-bedded unit approximates the thickness of the individual limestone beds. The thick limestones are sharply separated from the bounding thin-bedded layers on both sides. The thick limestone unit has a uniformly fine-grained texture, commonly contains shale partings, and in places is laminated. The thin beds have an undulatory bedding and vary in thickness from 1/4 to 1 inch.

Cycle Type C

This cycle type consists of a very uniformly bedded generally non-fossiliferous limestone alternating with beds of shale or with soft, shaly siltstone whose thickness is similar to that of the limestone unit. The shales are calcareous and grey or light brown, some exhibit laminations which have an average thickness of 1.0 to 1.2 mm. The limestones vary from 2 to 10 inches in thickness, depending on the locality of the section, but at any one locality, they have a constant thickness. They are much less variable in thickness than the limestones of the type B cycle.

This type of cycle commonly extends through a considerable thickness of section, and in the field, imparts to the section a striking cyclic pattern.

Cycle Type D

This fourth type can first be recognized above the main development of cycle type C. It consists of argillaceous limestone beds alternating with softer, grey, shaly beds.

This thickness of the calcareous part may vary from 6 inches to several feet and may be considerably thicker or thinner than the adjacent shale units. Bedding is somewhat

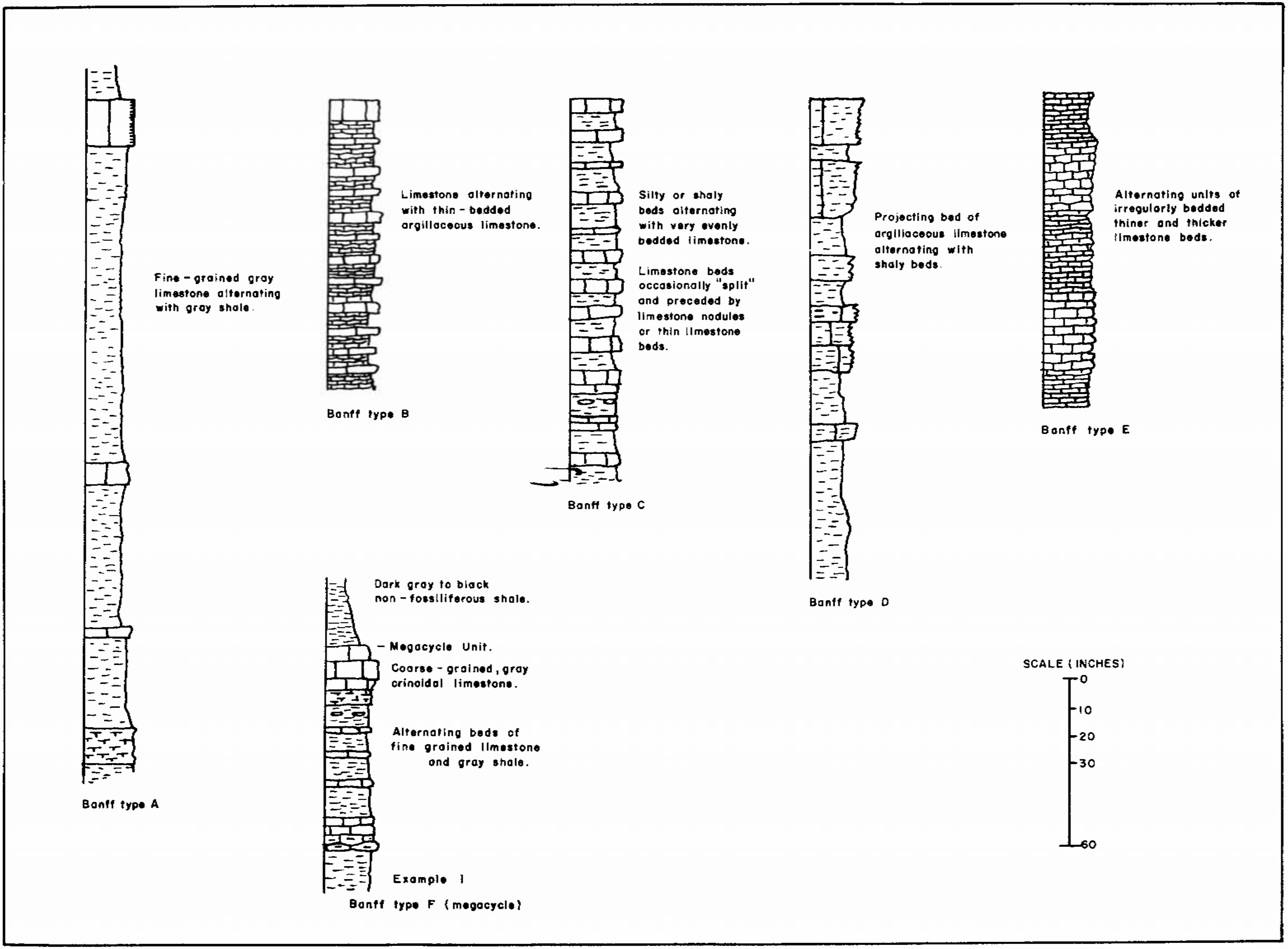

FIG 1 - CYCLE TYPES

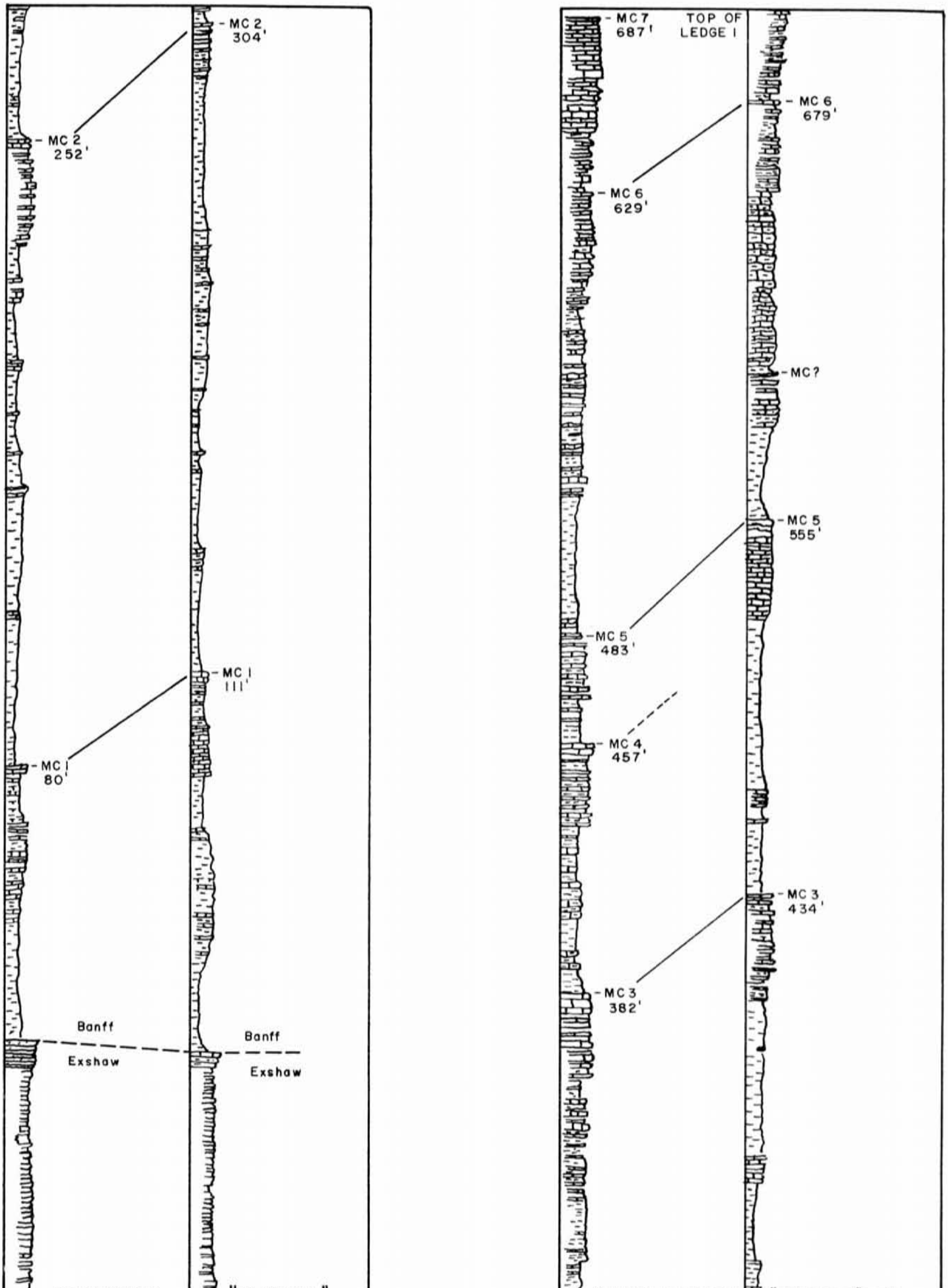

FIG 2A – CORRELATION CHART

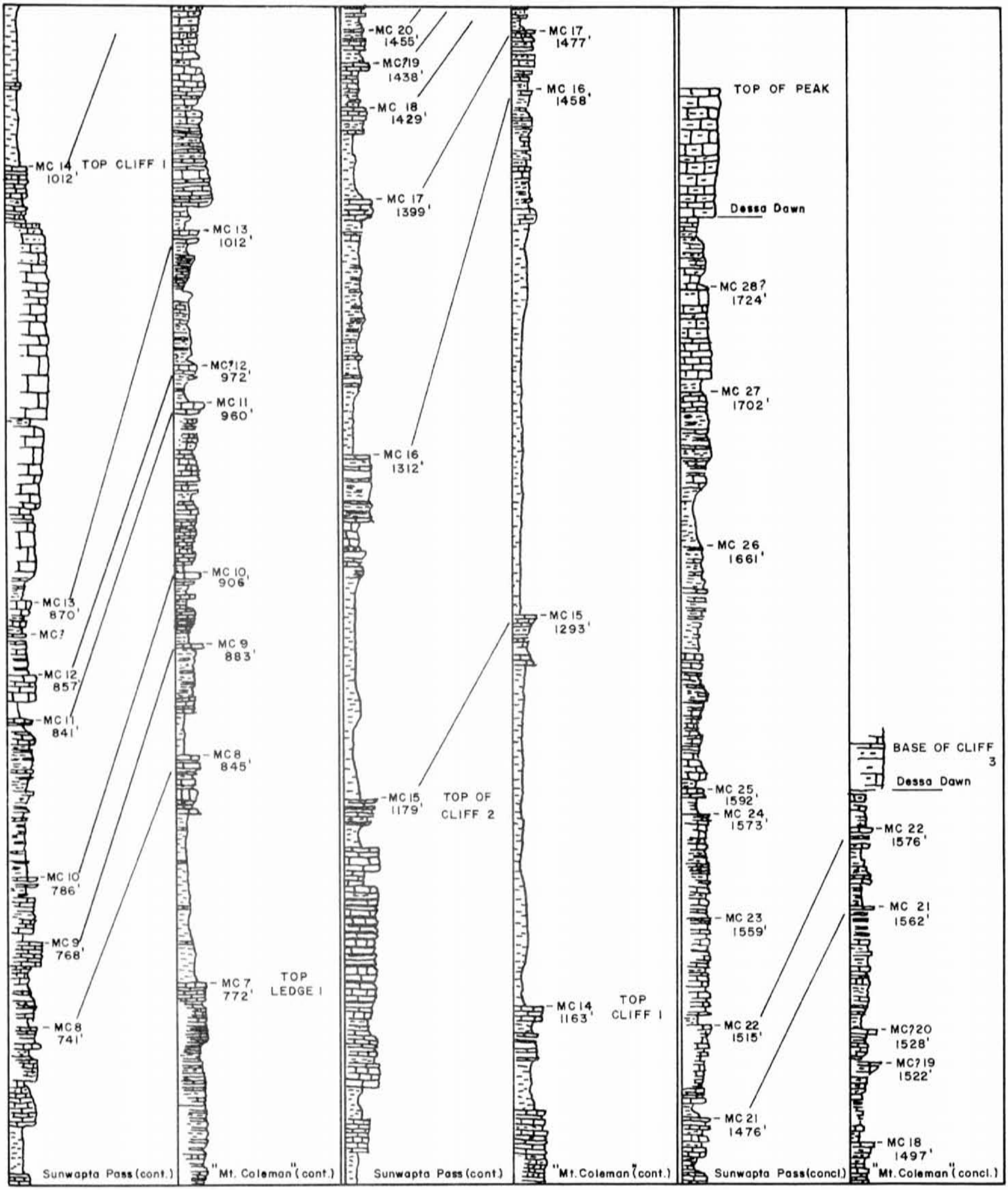

FIG 2B - CORRELATION CHART (Concluded)

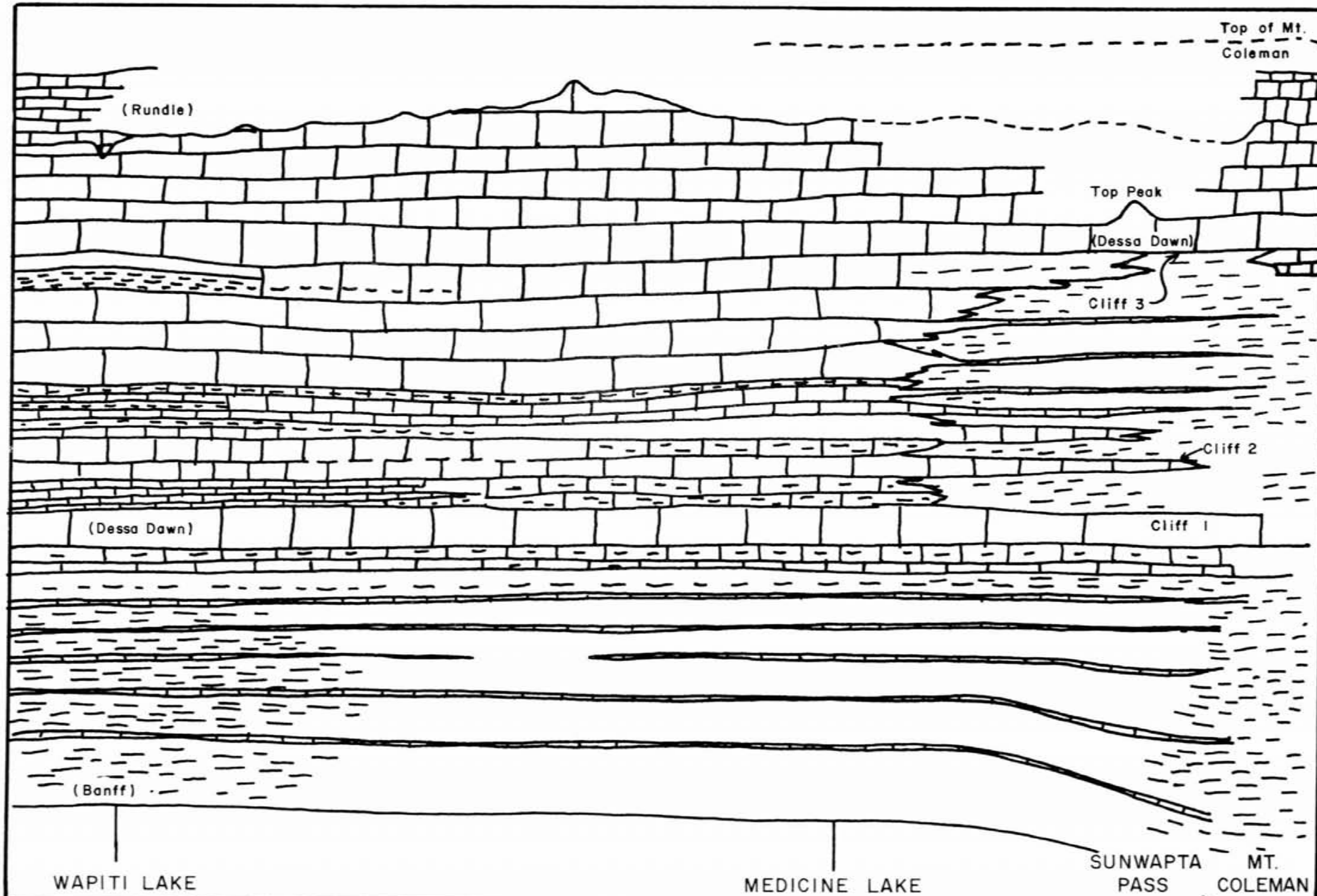

FIG. 3 – Diagramic cross section showing intertonguing of Banff and Dessa Dawn facies. Thickness of Dessa Dawn at Medicine Lake is estimated. Distance between Medicine Lake and Wapiti Lake not drawn to scale. Vertical scale greatly exaggerated.

irregular, and due to the similar weathering colour of the two lithologies, the contact between the shale and limestone is often difficult to locate. Ambocoelia, small Chonetes, and Platyceras occur in the calcareous units.

Cycle Type E

This consists essentially of alternations between two types of limestone, both are composed of thin layers and are irregularly bedded.

The alternating units both have an average thickness of 2 feet, and are unlike principally in the number and thickness of the individual layers which compose them.

One of these units consists of numerous very thin (1/8 to 1 inch), irregularly bedded, fine- or coarse-grained limestone layers separated by thin shale partings. Bryozoan and crinoidal remains are common. The other unit is lithologically similar to the first, but the layers are thicker. In places, the thicker bedded unit is replaced in the sequence by a uniform bed of argillaceous limestone about one foot in thickness.

The contact between the two units is readily recognized where weathering has emphasized the bedding plane between them.

Cycle Type F - "megacycle"

Recurring throughout the section are cycles of a more complex nature. These cycles attain their maximum point of development where thick-bedded limestones are followed rather abruptly by a thick shale sequence. Preceding the limestones and succeeding the shales are a series of cycles of any of the types previously described. Since these large cycles embrace many smaller cycles, the term "megacycle"[1] is used to indicate their more inclusive nature.

The megacycles show a considerable variation in thickness, the range of those considered in this study varies from 5 to 150 feet. The thicker megacycles are the result of an unusually thick shale sequence in the unit.

Within the alternating beds of the megacycles, there is usually a rapid displacement of one type of cycle with another. Occasionally one cycle type may

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[1] This term should not be confused with "megacyclothem" (Moore, 1936). In this paper it is used in the same sense as by Laudon and Chronic (1949, p. 210).

dominate a megacycle, but the minor cycle sequence within adjacent megacycles is generally unlike.

The thick-bedded limestone member represents from one tenth to one fourth of the total thickness of a megacycle. The topographic relief expressed by a megacycle is proportional to the thickness of these limestones.

Vertical variation in the thick, megacyclic limestones are similarly developed in the Sunwapta Pass and "Mount Coleman" sections. In the basal beds of each section the megacycle limestones are weakly developed. They are typically best developed in the middle of each section. In the upper part of the sections the thick-bedded, megacyclic limestone is missing in some places and the sequence goes directly from the alternating beds to the thick shale unit.

Where both members are well developed, the shale member follows the limestone member abruptly, with the shales varying between 6 and 300 inches in thickness.

CORRELATION BASED ON STUDY OF SEDIMENTARY CYCLES

The study of the cycles of the Banff Formation was made by the author primarily to ascertain their value as a tool in correlation. It was hoped that they might provide more precise, detailed points of correlation than those afforded by his study of the fauna.

Cycle types, number of beds, thickness of units, and the character and sequence of the megacycles were studied for properties that would continue from section to section.

A study of the cycle types gave no indication that there was a corresponding sequence between the sections. Even when grouped within the limits of fossil horizons, lithologic zones, or the megacycles, no relationship seems to appear.

The use of the larger, more complex, megacycle, however, appeared to offer the best possibility of success. A preliminary check of the number of megacycles represented in the "Mount Coleman" and Sunwapta Pass sections showed obvious discrepancy. It was considered that one or all of three variables could cause such a discrepancy. These variables are:

1) variation in the relief of the pre-Banff surface;

2) the fact that the Banff-Dessa Dawn contact is drawn on the basis of a lithologic change that can be shown to transgress time-lines;

3) local variations in the conditions of deposition causing a cycle to be present in one area, and absent in an adjacent area. With regard to this last point, it should be stated that the author assumed that the cycles were developed in response to pulsating forces which affected areas of a regional magnitude.

It becomes apparent that if successful correlation by means of cycles was to be undertaken, they should be first studied between marker planes that can be traced from one section to another.

Two conspicuous scarp-forming limestone units are present in the Banff sections at both Sunwapta Pass and "Mount Coleman", which appeared to fit the requirements for a marker horizon. The lower scarp-forming unit terminates at about 687 feet above the base of the Sunwapta Pass section (Figure 2a) and 772 feet above the base at "Mount Coleman" (Figure 2b). The upper limestone beds are 1,012 and 1,163 feet above the base in the respective localities. That the upper and lower marker units of each segment are correlative is suggested by (1) lithologic similarity and similar topographic expression as ledge-formers; (2) similar position with respect to the sequence of lithologic units above and below; and (3) similar faunal content.

Detailed examination of the megacycles occuring between the two marker units indicated that six megacycles were strongly developed in each of the sections. Another more weakly developed megacycle in the "Mount Coleman" section was included as it appears to correspond to megacycle (MC) 12 in the Sunwapta Pass sections, thus making a total of seven megacycles that could be correlated.

Correlation of this segment of the Sunwapta Pass - Mount Coleman sections with the Medicine Lake section just south of Jasper, was possible with only minor reservations. It is considered highly significant that the author was able to match so closely such small stratigraphic units over a distance of some 50 miles.

CORRELATION OF LOWER PART OF BANFF

At "Mount Coleman", 23 feet of shale intervene between the base of the section and the first limestone bed. The succeeding series of limestones and argillaceous limestones develops into a good megacycle at foot 111. This was designated as megacycle 1 (Figure 2a, MC 1). In the Sunwapta Pass section the first limestone bed is 35 feet above the base. A megacyclic series of argillaceous limestones and limestones is developed above this limestone at foot 80, similar in expression to that at "Mount Coleman". Succeeding this megacycle in each section is a thick series of shales interupted by limestone beds.

The megacyclic succession between megacycle 1 up to and including the first ledge-former were counted and six megacycles could be successfully correlated. These were numbered from one to six and are so designated on the correlation chart.

There are two anomalies in the "Mount Coleman" section. The thick limestone unit of megacycle 2 is divided by a shale member which is similar to the typical "thick shale" megacycle. Since there is a return to massive limestones, without the occurrence of the alternating beds, this suggests the shale does not represent another megacycle.

The second irregularity is that megacycle 4 is not developed at "Mount Coleman". The interval at which this megacycle should occur is occupied by a shale sequence that appears to be a continuation of the post-limestone shales of megacycle 3 (Figure 2a). These anomalies are explained by the more argillaceous character of the sediments in this section, where abrupt lateral lithologic changes have been observed. An example of such a change is cited, where a 10 foot thick shale bed was observed to give way to thin crinoidal limestone beds within a distance of 150 feet along strike.

The numbering system was then carried up the section through the previously correlated megacycles between ledge 1 and cliff 1, making a total of fourteen megacycles correlated between the sections.

CORRELATION OF UPPER PART OF BANFF

Eight megacycles of the Banff lithology can be counted and correlated above cliff 1 in both the Sunwapta Pass and "Mount Coleman" sections, making a total of twenty-two correlated megacycles.

Above the shale of megacycle 22 at "Mount Coleman" is a massive, cherty, cliff-forming limestone believed to mark the base of the Dessa Dawn Formation. At Sunwapta Pass six thin megacycles are developed stratigraphically above megacycle 22. The massive, cherty, cliff-forming crinoidal limestones directly above megacycle 28 is here believed to mark the base of the Dessa Dawn Formation.

BANFF - DESSA DAWN CONTACT

The Banff - Dessa Dawn contact has been placed by the author more or less arbitrarily at the base of the terminating cliff (cliff 3, Fig. 2b) in the Sunwapta Pass-Mount Coleman area. This conforms with the definition of the Dessa Dawn Formation in the type area at Wapiti Lake. At Wapiti Lake the Dessa Dawn Formation is designated as a series of massive, cliff-forming limestones that continue interupted to the unconformity which marks the contact with the overlying Rundle Formation. As the Dessa Dawn is a lithologic unit, its boundaries are not defined by time-lines, therefore, Cliffs 1 and 2 in the Sunwapta Pass - Mount Coleman area are by definition, tongues of the Dessa Dawn within the Banff Formation (Figure 3).

GENERAL CONDITIONS OF DEPOSITION

The area in which the Banff Formation was deposited was a depositional site throughout most of the Palaeozoic Era. At the end of the Upper Devonian, the sea withdrew from the area for a period of time sufficient to allow the development of an erosion surface on the Palliser limestone and the Exshaw shale, and permit the evolution of the new faunal elements of the Banff Formation.

Sedimentation, once initiated, was continuous during Banff time, at least within the study area.

That the Banff sea was connected with the Mississippian seas on the south is shown by the similarity of the Banff fauna with that of the Lodgepole Formation of Montana, and the Kinderhookian fauna of the Mississippi Valley.

The absence of significant amounts of coarse, detrital material in the section indicates that the area of deposition was (1) too far from the shore to receive appreciable amounts of detritus, (2) bordered by a landmass of very low relief, or (3) both.

Studies of other sections measured in this general area, and the well logs available to the author at that time, led him to the conclusion that the sections of the study area were located within the zone of thickest accumulation of Banff sediments.

The abundance of corals in the thick limestones, the scattered occurrence of cross-bedding, the abundance of fossils in some of the limestones and calcareous shales all indicate deposition in shallow water. The prevalence of currents is suggested by the persistence of isolated brachiopod valves, water-worn shell debris, and dissociated crinoid remains.

The deposition of the limestone-shale facies of the Mississippian, herein described by the author as the Banff, occurred on a "mildly unstable" shelf as termed by (Dapples, Krumbein, and Sloss, 1948, p. 1934-36). In this case the sea bottom is periodically active, with the resultant movement being downward. Considered on a regional basis the "Mount Coleman" area was more unstable than the areas on the north or south.

The carbonates of the Dessa Dawn and the Rundle which follow stratigraphically above the Banff appear to indicate deposition in the shelf edge area. The change from unstable shelf to shelf edge environment is transitional; and did not begin everywhere at the same time as has been shown in connection with the study of the cycles.

In closing the author states he believes that tectonics were perhaps fundamental in developing the cyclic nature of the beds, but also suggests that other factors, notably climatic changes, should be given careful consideration.

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SOME COMMENTS ON THE CARBONIFEROUS OF THE ROCKY MOUNTAIN FRONT RANGES BETWEEN BANFF AND JASPER

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INTRODUCTION

The purpose of this paper is to outline the salient stratigraphic features of the Carboniferous strata in the Sunwapta and Jasper areas in the hope that it will serve as a useful review of the Carboniferous stratigraphy that will be seen on this field trip as well as complementing the preceeding paper on Mississippian Cyclic Sedimentation.

GENERAL STATEMENT

The growth of the classification of the post-Devonian Palaeozoic strata in western Canada has been hampered by the lack of precise definition of the limits of the component formations and the somewhat meagre nature of the faunal zones. Further ambiguity has arisen among the geologists working with these strata, particularly in the case of oral presentation, where certain workers have at times implied different interpretations to those presented. For a complete review of the history and development of nomenclature the reader is referred to Moore (1958).

The Permo-Carboniferous of the Alberta Front Ranges is composed of three major lithologic units. These are, in ascending order: the Banff Formation, a predominantly shaly facies; the Rundle Formation, a limy facies; and the Rocky Mountain Formation, an arenaceous and limy facies. A suggested correlation of these units between Banff and Wapiti Lake is shown in Figure 1.

SUNWAPTA PASS AREA

In the Sunwapta Pass area, Carboniferous strata are well exposed at two localities only. One is at Nigel Peak, just north of the Jasper and Banff National Parks boundary and the second is on the south end of Cirrus Mountain.

Although it appears that a number of geologists have examined these sections, there is very little published on the results of their observations.

The general lithologic and faunal characters of the Carboniferous strata present in the Sunwapta Pass area seems to be similar to that of the Banff area.

The Exshaw Formation is considerably thicker than in the type section, being between 120 and 150 feet in thickness (fide Severson, 1950).

The Banff Formation appears to be somewhat more argillaceous than in the Banff area, and is between 1600 and 1700 feet in thickness. This thickness is, therefore, comparable to or slightly thicker than the type section but considerably thicker than that of the Mount Greenock.

The Rundle Formation is about 1100 feet thick, the most complete section being preserved on Cirrus Mountain. This is considerably thinner than the type section at Mount Rundle, somewhat thicker than the Mount Greenock section, and similar in thickness to that encountered on Morro Peak, on the east side of the Athabasca River about 5 miles south of Mount Greenock.

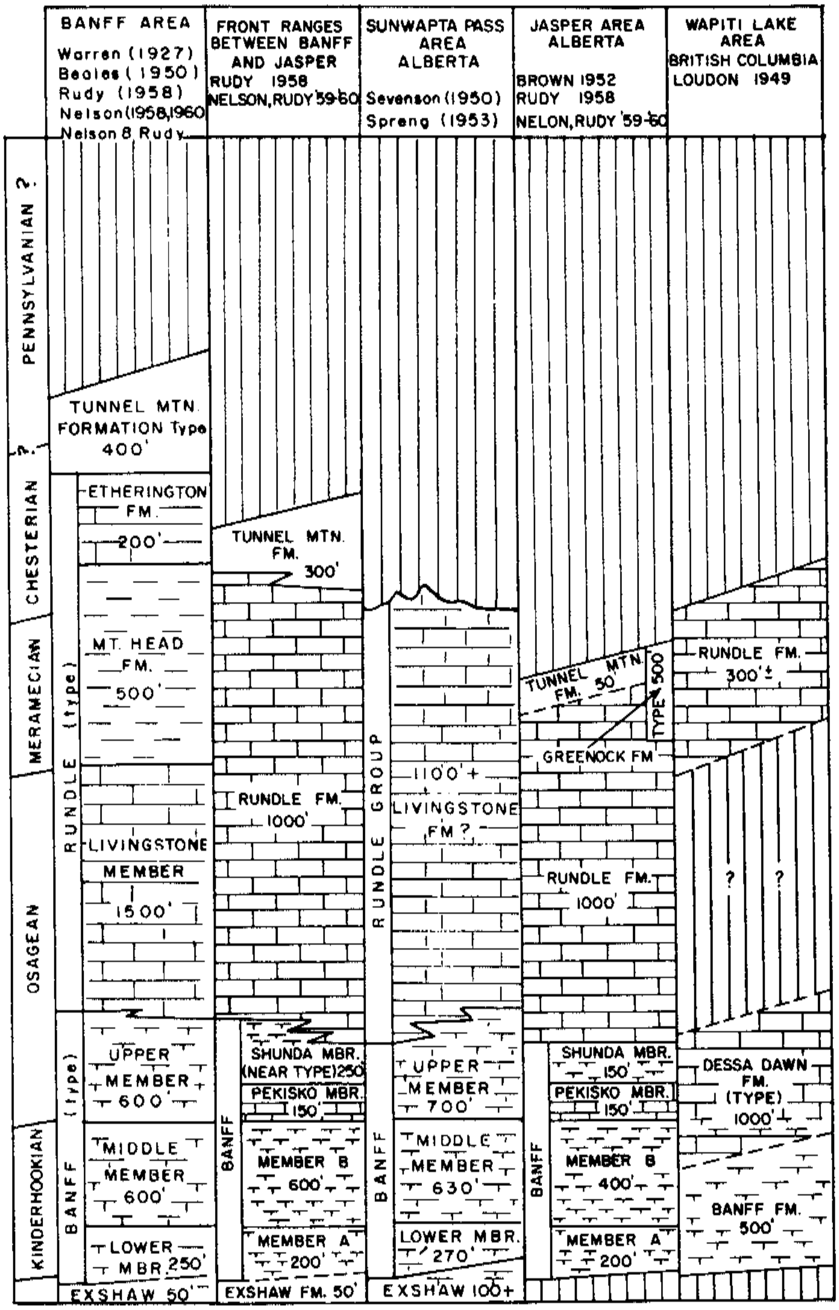
Since the carbonates of the Rundle Formation form the peaks of both Nigel and Cirrus it is assumed that the Carboniferous is incompletely represented.

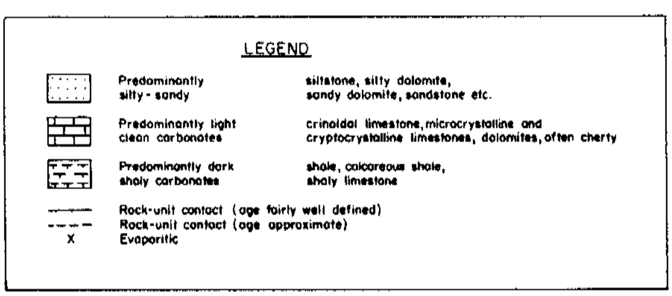
BANFF FORMATION

A twofold division of the Banff is recognized in Jasper Park. The lower member is of variable thickness in this area, being approximately 100 to 250 feet. It consists largely of dark grey to black shales, alternating with thin-bedded argillaceous limestones and limestones. The lower 30 feet suggests the "Exshaw shales" of the Banff area, being moderately soft, dark grey to black fissile shale. Since Brown (1952) was unable to find the "typical"

CORRELATION OF MISSISSIPPIAN FORMATIONS
SELECTED SECTIONS

* MODIFIED AFTER S.J. NELSON 1961





fauna of the Exshaw Formation, he refrained from using the name.

The upper member consists of between 400 and 500 feet of relatively unfossiliferous fine-grained argillaceous limestones, grading upwards into alternating crystalline limestones, argillaceous limestones , dolomites, and lesser calcareous shale bands and lenses. This unit on the whole is quite fossiliferous. Brown draws attention to the presence in the uppermost beds of hard, finely-banded siltstones, which he uses as marker beds.

The Banff-Rundle contact is transitional showing no distinct break in sedimentation. Relying on the definitions of these formations in the type area, the contact is drawn below the basal massive limestone unit.

Brown, in his work in the Mount Greenock area has established two faunal assemblages. The lower he calls the *Spirifer* cf. *cascadensis* faunule, ranging entirely within the limits of the Banff Formation. The upper is the *Spirifer albertensis* faunule, ranging from the upper Banff into the lower Rundle. These faunules have strong Kinderhook affinities.

RUNDLE FORMATION

In the Mount Greenock area the basal beds of the Rundle Formation are relatively grey massive limestones, dolomitic limestones, and crinoidal limestones. Texturally they are medium to coarsely crystalline. There are also dark grey to black, bedded chert nodules, scattered throughout the unit. The lower massive beds pass upwards rather abruptly into a thin zone of argillaceous limestones and argillites, that are dark brown to grey weathering. Above this the formation consists predominantly of grey limestones and dolomitic limestones that weather grey to buff-brown. They are commonly dense to finely crystalline, in contrast to the type area. Bedded chert nodules are common, but on the whole the over-all silica content is markedly reduced.

Commonly associated with the cherts are zones of fine-grained limestones with small calcite segregations or speckles. In the Athabasca Valley the Rundle Formation varies from 900 to 1150 feet in thickness.

The Banff-Rundle contact is transitional. The Rundle-Rocky Mountain contact, according to Allan et al. shows no evidence of erosional unconformity. Brown felt that the Rundle-Greenock contact was transitional, and placed the contact where the massive, crystalline dolomite gives way upward to the sharply bedded, argillaceous and silty limestones with rusty weathering chert bands and nodules.

In the upper Rundle, Brown has designated what he calls the *Composita esplanadensis* faunule. This faunule contains a predominance of Kinderhook forms although numerous forms correlate with the Osage.

ROCKY MOUNTAIN FORMATION (GREENOCK FORMATION)

On a basis of lithology and stratigraphic position, Allen et al. (1932) correlated the strata overlying the Rundle with the Rocky Mountain Formation of the type area at Banff. They did not make a detailed study of the formation and no fossils were collected. Brown proposed the Greenock Formation for the strata lying between the top of the Rundle and the "base" of the Spray River Formation of Triassic age. The type locality is on the southwest spur of Mount Greenock, immediately north of Snaring Point, Jasper National Park, Alberta. Brown divides the formation into lower, middle and upper members. The formation varies locally from 450 to 500 feet thick being 526 feet thick at the type locality.

Lower Member

The Lower Member is variable, consisting predominantly of dark blue-grey lithographic, siliceous dolomites, that bear conspicuous nodules and bands of dark grey, rusty weathering chert. These chert nodules are commonly pseudomorphs or internal moulds of brachiopods. Thickness at type section is 305 feet.

A less common type of lithology of the lower member is moderately crystalline to coarsely crystalline crinoidal limestone, apparently well dolomitized.

Middle Member

The Middle Member is white to dark grey, finely crystalline chert, that weathers pink. Lenses of sandstone are common throughout. Thickness at type section is 138 feet.

Upper Member

The Upper Member consists of light-grey, fine-grained, quartzitic sandstone, commonly containing lenses of light grey, pink weathering chert. This member varies in thickness from 40 to 90 feet, having a thickness of 42 feet at the type section.

The Greenock-Spray River contact is drawn by Brown at the abrupt change from the quartzitic sandstone facies of the Greenock to dark grey argillaceous, calcareous siltstone facies of the Spray River. Brown feels that two points illustrate the advisability of the new name - Greenock Formation. Firstly the strata are divisible into three distinct members that cannot be recognized in the type area. Secondly, the age of the Rocky Mountain Formation although still in doubt, is thought to be Pennsylvanian and/or Permian. The only fossils obtained from the Greenock Formation indicate that at least the lower member is Mississippian in age.

Brown established a small faunal assemblage from the lower member of the Greenock Formation which he calls the Spirifer n. sp. A faunule; this he tentatively refers to the Visean of the European Carboniferous. Further, he states that the forms that constitute this faunule have affinities with the Meramecian faunas of the Mississippi Valley.

The correlation of the Banff type section with the Mount Greenock type section has been demonstrated by a number of workers. Two of the more recently published papers showing the correlation of the Mount Greenock section, with sections to the south, are those of Drummond (1961) and Nelson and Rudy (1961).

The correlations suggested by the above mentioned authors involve detailed consideration of the finer subdivisions (members) of the three gross units Banff, Rundle and Rocky Mountain/Greenock Formations, and therefore, lies beyond the scope of this paper.

GENERAL STATEMENT ON REGIONAL CARBONIFEROUS STRATIGRAPHY

The marked westerly and southerly thickening of the Carboniferous strata suggests that a series of sags developed in the depositional basin following roughly the strike of the known outcrop pattern. The marked thinning of the formations, in particular the Rundle Formation, to the north in the Jasper Park area, and to the east in the Front Ranges, would suggest either erosion or non-deposition of the upper part of the Rundle. The idea has been put forward that in the Banff area the Rocky Mountain Formation represents a shore-line deposit formed during the retreat of the Carboniferous sea. If this is true, then the field observations lend themselves to the possible interpretation that the Rocky Mountain facies represents a regressive overlap that developed towards the south, with the uplift movement being initiated at an earlier period in the north and east. This interpretation is substantiated by Nelson and Rudy's (1961) work on Carboniferous sections in eastern Front Ranges and by the writer's observations along the Brazeau River near the mouth of Job Creek.

In general, the facies of the Carboniferous from south to north, follow quite closely those of the type area. The rocks were apparently all laid down under relatively shallow water, and predominantly aerobeic conditions.

Early Banff time is characterized by the deposition of fine silt and mud. This gives way to more "normal" marine conditions and the deposition of considerable organic limestone.

In late Banff time, the strata are of a mixed character with both carbonates and fine clastics being deposited.

By Rundle time, more normal marine conditions again prevailed, and organic limestones, and carbonate rocks in general, are representative of the typical Rundle facies.

Towards the close of the Rundle, in at least the north and northeast, uplift of the adjacent land mass had begun, and considerable quantities of fine sand and silt was being supplied at several points along the northeastern margin of the basin.

The Rocky Mountain Formation, at least in the more northerly sections, appears to be characterized by the predominance of dolomites whereas towards the south (in the direction of the withdrawal of the sea) sandstones become increasingly important.

With the coming of Rocky Mountain time, the regression of the sea was well established and the Carboniferous was drawing to a close.

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PERMIAN STRATIGRAPHY AND NOMENCLATURE, WESTERN ALBERTA AND ADJACENT REGIONS

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ABSTRACT

The Permian Ishbel Group in western Alberta attains a composite thickness of 2000 feet and consists of six formations. From the bottom upwards these are:- Belcourt, Johnston Canyon, Telford, Ross Creek, Ranger Canyon, and Mowitch Formations. The Belcourt Formation ("Lower Unit" of Forbes and McGugan, 1959) consists of dolomites with chert nodules containing Schwagerina emaciata, Schwagerina sp., Pseudofusulinella sp., and bryozoa. It is mainly of Wolfcampian age and occurs only between Jasper and Wapiti Lake. The Johnston Canyon Formation ("Lower Ishbel" of McGugan and Rapson, 1961) consists of black phosphatic dolomitic siltstones and silty dolomites with black spicular cherts and rare silicified limestone lenses which contain Schwagerina rapsoni. It is mainly of early Leonardian age, and occurs from the U.S. border to Banff. The Telford Formation ("Middle Ishbel" of McGugan and Rapson, 1962) consists of sandy limestones with the "Russian" brachiopod fauna including Spirifer osborni Harker, Choristites cf. søderberghi Dunbar, Spiriferella cf. saranae (de Verneuil), and is of Leonardian to Guadalupian age. It occurs in some westerly sections only. The Ross Creek Formation ("Middle Ishbel" upper part of McGugan, 1963) consists of a lensed complex of carbonate, siltstone and phosphate rock containing Spirifer osborni, Crurithyris sp., Chonetina sp., bryozoa and ?Pleramplexus sp., of probable late Guadalupian age. It occurs in the Elk Valley and Fernie areas only. The Ranger Canyon Formation ("Upper Ishbel" of McGugan and Rapson, 1961) consists of chert with subordinate sandstone and siltstone, and with an associated phosphatic conglomerate at its base. The chert contains Dictyoclostus sp., Spiriferella sp., Waagenoconcha sp., and Echinoconchus sp., of probable Late Permian age, while the conglomerate contains Helicoprion, Orbiculoidea, Lingula, Conularia, bones and teeth. The Ranger Canyon Formation is extremely widespread from the U.S.A. to the Yukon and Northwest Territories

above an extensive unconformity, which erodes beds of earlier Permian and Carboniferous age. It is considered to represent Zechstein conditions in North America. The Mowitch Formation ("Unit 2" of McGugan and Rapson, 1961b) consists of calcareous sandstone with subordinate chert, and contains Neospirifer cf. striato-paradoxus (Toula), Lingula, fish teeth and bone fragments. The Mowitch Formation is of late Permian age, and occurs only in the Jasper area and northwards. Regionally, the Ishbel Group may be correlated with the Phosphoria Formation of the northwest U.S.A. Rocks of apparently similar age are found in the subsurface of the Peace River area where they are called the Belloy Formation. It is recommended that the name Rocky Mountain Group should be discarded, and that the late Carboniferous clastics known as the Kananaskis and Tunnel Mountain Formations should be included under the new group name Spray Lakes Group.

INTRODUCTION

This paper, based on both recently completed and previous fieldwork, presents new data on the Permian succession north of Jasper, which expands the writers' correlation (1961 b, Fig. 6) between Jasper and Wapiti Lake, British Columbia. Since detailed information is now on hand from 130 sections between the U.S. border and Wapiti Lake, without any significant gaps, some important general aspects of Permian stratigraphy can be reviewed and discussed. Background information regarding previous work may be found in the papers listed in the bibliography. The writers are greatly indebted to the Research Council of Alberta for supporting field work in the Smoky River area during July 1963.

STRATIGRAPHY BETWEEN JASPER AND WAPITI LAKE

The stratigraphic succession is illustrated by Table 1, which is a composite section. Three distinct Permian formations are represented in this area; from the base of the succession upwards these are, the Belcourt Formation ("Lower Unit" of Forbes and McGugan, 1959) of Early Permian (Wolfcampian) and possibly Middle Permian

Table 1. Composite Section, Jasper to Wapiti Lake

ISHBEL GROUP	MOWITCH FORMATION 30 - 250 feet ?UPPER PERMIAN	Mainly brown weathering sandstone with subsidiary chert *Neospirifer* sp.
	RANGER CANYON FORMATION 20 to 150 feet UPPER PERMIAN	Mainly chert with subsidiary sandstone and siltstone *Dictyoclostus*, *Waagenoconcha*, *Echinoconchus*, *Spiriferella*, ?*Marginifera*
	ooooooooooooooooooooooo	Phosphatic Conglomerate Regional Unconformity
	BELCOURT FORMATION 25 to 160 feet LOWER AND ?MIDDLE PERMIAN	Buff-weathering dolomites with chert nodules *Schwagerina emaciata*, *Schwagerina* spp. *Pseudofusulinella* sp.
	ooooo ooooo	Conglomerate Unconformity
	CARBONIFEROUS Pennsylvanian and Mississippian	Various carbonates

(Leonardian) age, the Ranger Canyon Formation ("Upper Ishbel" of McGugan and Rapson, 1961a) and the Mowitch Formation ("Rock Unit 2" of McGugan and Rapson, 1961b) both of probably Late Permian age. The Ranger Canyon Formation is everywhere underlain by a great regional unconformity. The Ishbel Formation (McGugan and Rapson, 1961a) is here raised to group status to include the above formations and three other Permian formations for which new names are proposed; it is recommended that the name "Rocky Mountain Group" be discarded, and that the late Carboniferous clastics of the Tunnel Mountain and Kananaskis Formations should be included under the new name Spray Lakes Group. This new nomenclature is illustrated by Table 2.

Permian; Ishbel Group.

Belcourt Formation.

Forbes and McGugan, (1959) described up to 145 feet of siltstones, sandstones, conglomerates, cherts and arenaceous dolomites which occur at the top of the Paleozoic section between the Narraway River and Wapiti Lake, British Columbia. Cherta and coarse clastics high in the succession (the "Upper Unit" of Forbes and McGugan) are apparent correlatives of the Mowitch, Ranger Canyon, and possibly Telford Formations, while the underlying buff-weathering dolomites with chert nodules (the "Lower Unit" of Forbes and McGugan) are here named the Belcourt Formation. In this formation, chert nodules contain an abundant fauna of the Wolfcampian fusulinid Schwagerina emaciata (Beede). The entire Pennsylvanian System is evidently missing in this area, since the Belcourt Formation overlies limestones of Mississippian age. The basal bed of the Belcourt Formation is a thin chert breccio-conglomerate, and other physical evidence of unconformity includes apparent topography on the Mississippian surface. It appears that the upper part of the Belcourt Formation may be of similar age to the Johnston Canyon Formation ("Lower Ishbel" of McGugan and Rapson, 1961a); at Winnifred Pass, and at Llama Mountain, north of the Smoky River, the Belcourt Formation is well developed and contains, in addition to Schwagerina emaciata, other schwagerinids which indicate a slightly higher level, possibly as high as early Leonardian. The lower part, however, is demonstrably older than any other fossiliferous Permian in the Canadian Rockies,

	ORIGINAL NAME: AUTHOR: TYPE AREA/SECTION		PROPOSED NEW NAME: TYPE SECTION: AGE
ROCKY MOUNTAIN GROUP (UPPER PART)	UNIT 2: McGugan and Rapson, 1961b Jasper Area, Section 60	ISHBEL GROUP	MOWITCH FORMATION Deer Creek Headwaters, Jasper, Section 60 ?UPPER PERMIAN
ROCKY MOUNTAIN GROUP (UPPER PART)	UPPER ISHBEL FORMATION: McGugan and Rapson 1961a Banff Area, Section 4	ISHBEL GROUP	RANGER CANYON FORMATION Mt Ishbel, Sawback Range, Banff, Section 4 ?UPPER PERMIAN
ROCKY MOUNTAIN GROUP (UPPER PART)		ISHBEL GROUP	Conglomerate — UNCONFORMITY
ROCKY MOUNTAIN GROUP (UPPER PART)	MIDDLE ISHBEL FORMATION, Upper Part McGugan, 1963, Elk Valley, B.C. Section 66	ISHBEL GROUP	ROSS CREEK FORMATION Telford Creek, Elk Valley, B.C. Section 66 MIDDLE PERMIAN - Guadalupian
ROCKY MOUNTAIN GROUP (UPPER PART)	MIDDLE ISHBEL FORMATION, Lower Part McGugan and Rapson, 1962, Elk Valley, B.C., Section 66	ISHBEL GROUP	TELFORD FORMATION Telford Creek, Elk Valley B.C. Section 66 MIDDLE PERMIAN - Guadalupian and Leonardian
ROCKY MOUNTAIN GROUP (UPPER PART)	LOWER ISHBEL FORMATION McGugan and Rapson, 1961 Banff Area, Section 4	ISHBEL GROUP	JOHNSTON CANYON FORMATION Mt. Ishbel, Sawback Range, Banff, Section 4 Middle and ?Lower Permian Leonardian and ? Wolfcampian
ROCKY MOUNTAIN GROUP (UPPER PART)	"LOWER UNIT" Forbes and McGugan, 1959 Wapiti Lake Area, Sections 1-5	ISHBEL GROUP	BELCOURT FORMATION Wapiti Lake B.C., Section 4 of Forbes and McGugan, 40-197 ft. LOWER AND ?MIDDLE PERMIAN Wolfcampian and ?Leonardian
LOWER PART	KANANASKIS FORMATION (Middle Pennsylvanian)	SPRAY LAKES GROUP	KANANASKIS FORMATION (Middle Pennsylvanian)
LOWER PART	TUNNEL MOUNTAIN FORMATION (Lower Pennsylvanian)	SPRAY LAKES GROUP	TUNNEL MOUNTAIN FORMATION (Lower Pennsylvanian)

being Wolfcampian in age.

The Belcourt Formation occurs as outliers on the Carboniferous erosion surface beneath the widespread sub-Ranger Canyon unconformity. The lower contact of the formation is also marked by an unconformity, which at Winnifred Pass shows several feet of relief in a short distnace. Horizons recognised beneath this unconformity range from probable Early Pennsylvanian down to the Mt. Head Formation of Mississippian (Meramec) age, and the unconformity is frequently also marked by chert and carbonate breccio-conglomerates.

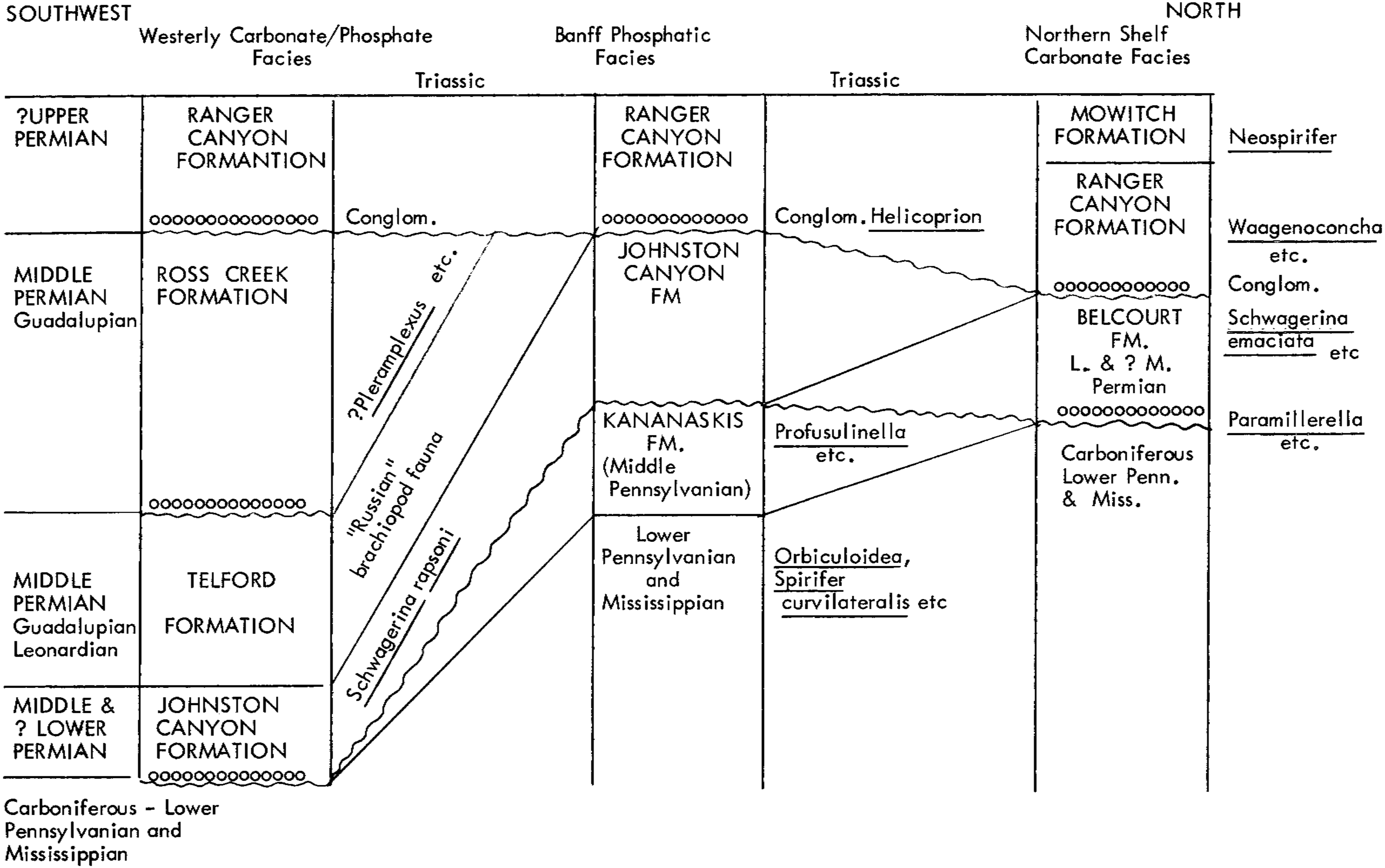
The formation is named after Belcourt Creek, where Section 4 (40-197 ft) of Forbes and McGugan is the designated type section. Section 1 (36-114 ft) and 5 (30-88 ft) are supplementary type sections.

RANGER CANYON FORMATION

This formation consists of a complex deposit of phosphatic chert and siltstone with smaller amounts of sandstone and silicified carbonate. It is considered to result from semi-evaporitic conditions and may represent Zechstein development in North America. The formation is everywhere underlain by a distinctive phosphatic chert conglomerate usually less than one foot thick, which rests on beds of greatly varying age beneath a widespread unconformity (see Table 3). North of Banff, at Jasper and at various localities west of the Alaska Highway the conglomerate overlies various Carboniferous horizons from Middle Pennsylvanian to Mississippian. In the Smoky River and Wapiti Lake areas the underlying carbonates range in age from Lower or Middle Permian to Mississippian. South of Banff, the unconformity "climbs the section" finally eroding late Middle Permian west of the Elk Valley.

The components of the phosphatic chert conglomerate are very variable, both in composition and size, and may be matched with source rocks of widely varying age; derived microfossils are common; in the Jasper area the conglomerate contains probable Lower Pennsylvanian staffellid foraminifera. At Deer Creek headwaters (McGugan and Rapson, 1961b) Schwagerina occurs in chert pebbles, and at Winnifred Pass, Belcourt Formation

Table 3. Gross stratigraphic relationships, Permian of Western Alberta



schwagerinids occur with occasional productid brachiopods in the conglomerate. Indigenous fossils also occur; at Sundance Canyon, Banff, two specimens of the distinctive Middle Permian vertebrate Helicoprion Karpinsky have been found, and at many localities the conglomerate contains fossils of less stratigraphic importance including Lingula, Conularia, Orbiculoidea, fish and reptile bones and teeth. Yields of phosphate up to 29 per cent have been obtained from selected matrix in the conglomerate. Both the upper and lower contacts of the conglomerate are sharp, indicating that it is a depositional entity, and was well lithified before the Ranger Canyon Formation was deposited. The conglomerate is believed to be essentially a lag gravel, which was winnowed and reworked during a long period on the erosion surface. At Winnifred Pass and in sections near the Smoky River and on Llama Mountain north of the Smoky, relief up to at least 5 feet has been observed on the top of the underlying beds in a short distance.

Permian fossils occur low in the Ranger Canyon Formation in a westerly section at Winnifred Pass including Waagenoconcha, Dictyoclostus, Echinoconchus, Spiriferella, ?Marginifera, and other brachiopods and pelecypods.

The placement of the Ranger Canyon Formation as high as Upper Permian is based on four factors: 1. The occurrence of probable Pleramplexus of Guadalupian age in the Ross Creek Formation (Middle Ishbel, Upper Part, of McGugan, 1963) which lies below the unconformity at Telford Creek, Elk Valley, B.C.

2. The stratigraphic position of the Ranger Canyon Formation above an erosional condensate of great duration overlying a regional unconformity which erodes the Ross Creek Formation.

3. The distinctive brachiopod fauna of the Ranger Canyon.

4. The distinctive lithology of the Ranger Canyon Formation, with its complex diagenetic history, which is interpreted as indicating semi-evaporitic conditions of deposition comparable to the Zechstein of Europe (Upper Permian), the Ochoan evaporites of the U.S.A., and late Permian evaporitic deposits elsewhere.

The Ranger Canyon Formation has quite remarkable extent, especially considering its relatively modest thickness; in fact it rivals the renowned Exshaw shale in this respect. It is found in all but the most easterly sections (where it is eroded) from the U.S. border to the Northwest Territories, a distance of some 800 miles. Either the Rex or the Tosi Chert of the Phosphoria Formation in Montana is correlative with the Ranger Canyon, and homotaxial equivalents occur in the Yukon and northwards almost to the Arctic Ocean in the Richardson Mountains, giving a probable total extent of some 1800 miles.

The Ranger Canyon Formation is called after Ranger Canyon, an approved new geographic name for the canyon which cuts through the Sawback Range in the vicinity of Massive, near Banff, Alberta. The type section is that described as Upper Ishbel Formation by McGugan and Rapson, 1961a.

MOWITCH FORMATION

In the Jasper area, and at other northerly localities, the Ranger Canyon Formation is separated from the overlying Triassic by a sandstone unit up to 250 feet in thickness, named the Mowitch Formation. The sandstone is brown weathering, and ranges from fine- to coarse-grained, and thin- to thick-bedded; it is frequently calcareous with glauconite and phosphate grains. Silicified carbonate patches occur in the sandstone at several localities near Jasper and northwards, and bedded lenticular chert is common. Phosphatic fish remains occur, particularly in pebble beds and coarse sandstones, and considerable numbers of cylindrical borings normal to the bedding are seen. The upper and lower contacts of the formation appear structurally conformable, but in some sections it is difficult to separate from the underlying Ranger Canyon Formation due to an increase in chert in the Mowitch Formation and an increase in sandstone in the Ranger Canyon Formation. The topmost bed of the Mowitch Formation is usually a distinctive coarse sandstone with black phosphatic nodules.

Permian brachiopods of the genus *Neospirifer* (possibly *N. striato-paradoxus* (Toula) occur with *Lingula* and other shell and fish fragments in calcareous sandstone east of the headwaters of the south fork of Sulphur River. A homotaxial sandstone unit on Mt Merrill in the Yukon is also reported to contain Permian fossils (see Sutherland, 1958; McLearn and

Kindle, 1950; Kindle, 1944), including "Productus uralicus Tschernyschew, Marginifera cf. fisueneis Chao and Spirifer sp." The Mowitch Formation is called after Mowitch Creek, a tributary of Rock Creek, Jasper, Alberta. The type section is Section 60 of McGugan and Rapson 1961b, 0-100 feet, originally designated "Rock Unit 2".

REGIONAL STRATIGRAPHY

Surface

Between the Belcourt Formation and the Ranger Canyon Formation, and represented in the Jasper and Wapiti Lake areas by the unconformity, three formations originally designated Lower and Middle Ishbel are recognised. These are, from the bottom upwards, the Johnston Canyon Formation ("Lower Ishbel" of McGugan and Rapson, 1961), the Telford Formation ("Middle Ishbel" of McGugan and Rapson, 1962), and the Ross Creek Formation ("Middle Ishbel", upper part, 30 to 500 feet, of McGugan, 1963).

The Johnston Canyon Formation is called after Johnston Canyon near Banff, Alberta; the type section is Section 4 of McGugan and Rapson (1961a). This formation is not recognised north of the Clearwater River; it merges, either by stratigraphic condensation or erosion, or both, into the phosphatic conglomerate at the base of the Ranger Canyon Formation. Southwards, the formation may be correlated with part of the Phosphoria Formation, possibly the Meade Peak phosphatic shale.

The Telford Formation is named after Telford Creek, a westerly tributary of the Elk River north of Natal, B.C. The type section is Section 66 of McGugan and Rapson (1962), 0-700 feet. The Telford Formation may be recognised at several other localities in the Canadian Rockies, always in westerly sections; between Banff and Jasper, sections near the headwaters of the Panther, Red Deer, and Clearwater Rivers display developments of carbonates homotaxial with the Telford Formation, but unfortunately without diagnostic fossils. In sections north and south of Pine Pass the formation measures up to 500 feet in thickness (Dr Gordon Williams, personal communication, 1962) and contains brachiopods of Middle Permian age including *Choristites søderberghi* and *Dictyoclostus* cf. *neoinflatus*. *Waagenoconcha* occurs in black shaly carbonate close to the Hart Highway. North of the Peace River, Hovdebo, 1962, reports a carbonate similar to the Telford Formation, which also contains the "Russian" Permian fauna including "*Spiriferella keilhavii* (von Buch), *Brachythyridina sokolovi* (Tschernyschew), *Muirwoodia transversa* Cooper and *Waagenoconcha* sp." In the Yukon, the Takandit Formation is probably correlative with the Telford Formation.

The Ross Creek Formation paraconformably overlies the Telford Formation at its type locality, which is also the type section of the Ross Creek Formation (Section 66 of McGugan 1963, 30 to 500 feet). The formation is named after Ross Creek, a westerly tributary of the Elk River, north of Natal, B.C. The Ross Creek Formation consists of a thin to thick bedded, rhythmically deposited, lensed complex of shaly and phosphatic siltstone, silty carbonate, bedded and nodular chert, and phosphate rock in both nodular and oolitic form. The lower 150 feet of the formation are somewhat recessive and the bottom 60 feet is poorly exposed, due to a higher percentage of shaly beds.

Brachiopod coquinas, composed mainly of *Crurithyris* sp. occur at regular intervals, frequently associated with intraformational conglomerates. The formation also contains other brachiopods including *Spirifer* cf. *osborni* Harker, *Chonetina* sp., the small solitary coral ?*Pleramplexus* sp., and numerous undetermined bryozoa. Stromatolites occur near the top of the formation. On the basis of ?*Pleramplexus* sp., and the underlying brachiopod fauna in the Telford Formation, it appears probable that the Ross Creek Formation is late Middle Permian (Guadalupian) in age. The Ross Creek Formation is overlain paraconformably by the usual phosphatic chert conglomerate, which contains *Lingula* and bone fragments. The conglomerate is in turn overlain by the Ranger Canyon chert.

The Ross Creek Formation may be recognised at several localities in the Fernie area, where the sections have suffered structural inversion and are poorly exposed.

Gross stratigraphic relationships of the Permian are shown by Table 3.

Subsurface; The Peace River

Halbertsma, 1959, classified as Permian beds previously known as Permo-Pennsylvanian; this sequence, which is reported to contain Permian invertebrates and spores, was named the Belloy Formation by Halbertsma. The type section is the interval 4087 to 4246 in the well Imperial Belloy No. 12-14 in Lsd. 12-14-78-1W.6M., where these beds were completely cored. According to Halbertsma, the type Belloy consists of three members, an upper carbonate member, a middle sand member, and a lower carbonate member. Both the upper and lower limits of the formation are said to be marked by a regional unconformity. Patches, nodules and beds of chert are common throughout the formation. In the type section at 4088 feet the brachiopods Neospirifer cf. cameratus Morton and Juresania cf. ovalis Dunbar and Condra have been identified by Crickmay (in Halbertsma, 1959). Crickmay (1960) considers this fauna to be Early to Middle Pennsylvanian in age. In his 1960 paper, Crickmay also lists Anisopyge sp. ind. from Pacific Fort St. John No. 23, at 6288 feet, and Meddlicottia sp., and Paralegoceras sp. from Imperial Sikanni Chief No. 1 at 3325 feet. These fossils are considered by Crickmay to be "without doubt Permian" and "clearly Middle Permian". On the other hand, Jansonius (personal communication, 1962) considers all the subsurface Belloy Formation to be Permian in age, and probably Leonardian to Guadalupian, on the basis of the fossil microflora:- Alisporites ovatus, Striatites limpidus, Hamipollenites bifurcatus, Protosacculina wodehousei, Vittatina minima, V. saccifer, V. simplex, V. striata, and Spheripollenites scissus.

With further stratigraphic work it is considered probable that the Belloy Formation can be reliably correlated with the outcrop formations of the Ishbel Group to the west.

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THE CROWFOOT DIKE

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LOCATION AND EXTENT

The Crowfoot Dike forms a conspicuous outcrop along the Lake Louise - Jasper highway, 19.8 miles north of the junction with the Trans-Canada Highway. About 100 feet outcrops in the road cut, but neither contact is exposed. The dike can be traced up the hill to the northeast for 4200 feet or 1100 feet above the road cut, beyond which it is covered with talus (See Fig. 1). It does not cut the massive quartzite cliff on the skyline, but it outcrops again below this quartzite on the northeast side of the hill in the valley of Helen Creek. Where both contacts are exposed the dike is consistently about 190 feet wide. It strikes N43°E and dips 85°NW. The near-vertical joints in the road outcrop conform to the attitude of the dike.

To date no other dikes have been reported near the highway between Lake Louise and Jasper, but diorite dikes and sills occur on Cross River, 16 miles north-east of Radium Hot Springs (Hedley, 1954).

STRATIGRAPHY

The following is a brief summary of the stratigraphy in the vicinity of the dike (see Fig. 1).

The Hector Formation is more than 1300 feet thick and the base is not exposed. The lower 300 feet contain some beds of conglomerate up to 120 feet thick. The next higher 500 feet or so consist of grey, thin-bedded, varved siliceous and sericitic shale. The upper 500 feet is less siliceous and sericitic, and consists of grey to grey-green and some maroon colored shale.

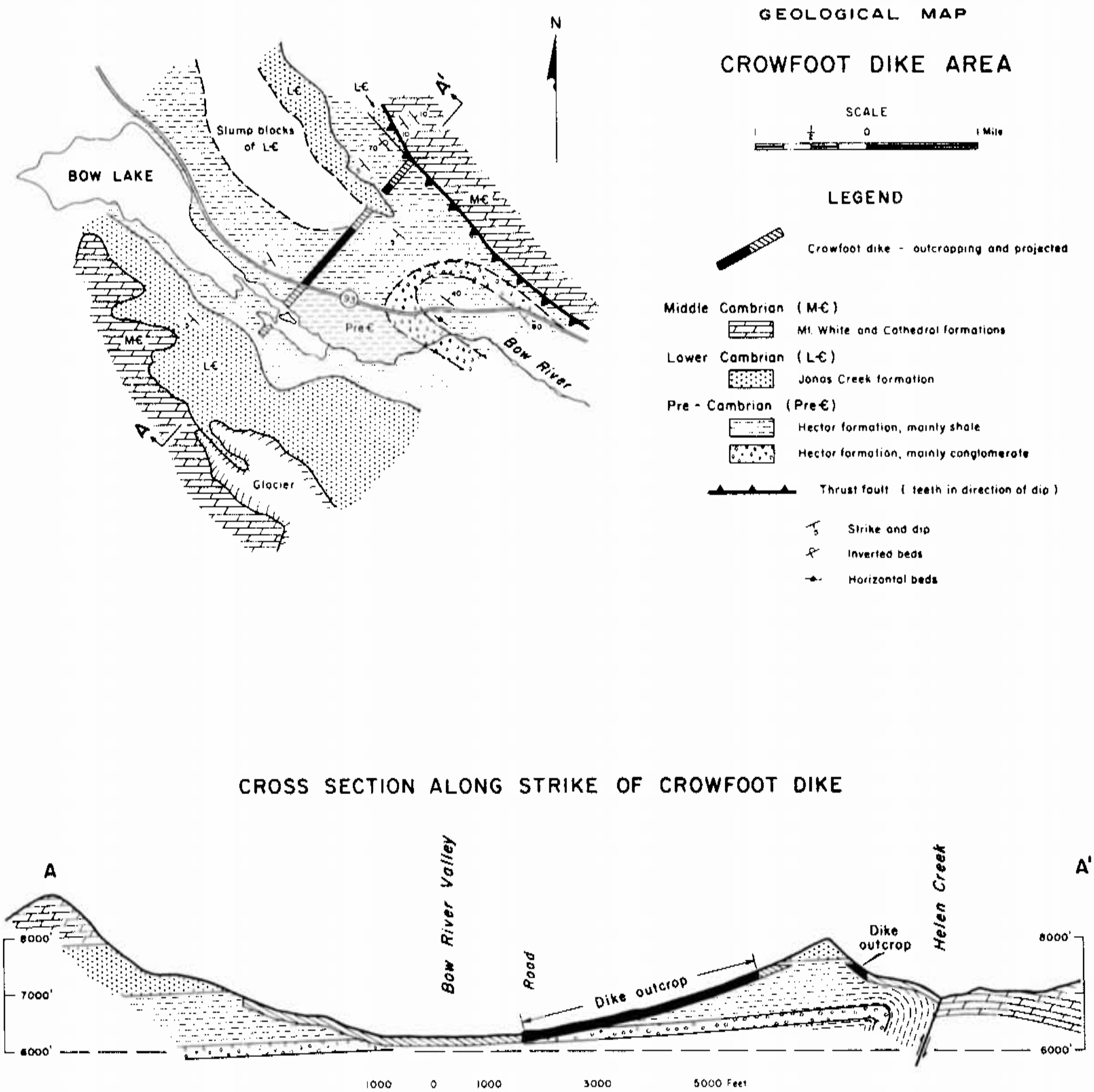
GEOLOGICAL MAP
CROWFOOT DIKE AREA
SCALE
1 Mile
LEGEND
Crowfoot dike - outcropping and projected
Middle Cambrian (M€)
Mt. White and Cathedral formations
Lower Cambrian (L€)
Jonas Creek formation
Pre - Cambrian (Pre€)
Hector formation, mainly shale
Hector formation, mainly conglomerate
Thrust fault (teeth in direction of dip)
Strike and dip
Inverted beds
Horizontal beds
N
BOW LAKE
Slump blocks of L€
L€
M€
Pre€
A
A'
Bow River
Glacier
CROSS SECTION ALONG STRIKE OF CROWFOOT DIKE
A
A'
Bow River Valley
Road
Dike outcrop
Dike outcrop
Helen Creek
8000'
7000'
6000'
1000
0
1000
3000
5000 Feet

Figure 1

The contact of the Hector and Jonas Creek Formations was not seen, but there is a very abrupt change over a foot or so from the Hector shales to the massive conglomerates and quartzites of the Jonas Creek Formation.

Only the lower 1000 feet of the Jonas Creek Formation was examined. The lower 500 feet consist entirely of massive coarse quartzites and quartzose conglomerates. the quartzite is light grey with maroon mottling and weathers rusty buff. It forms the cliff on the crest of the ridge northeast of the road outcrop. The massive quartzite grades up into thinner bedded quartzite with dark grey-green argillaceous partings and laminae. "Scolithus" is abundant in these beds.

STRUCTURE

The dike is located in the eastern sector of the main ranges subprovince (North and Henderson, 1954, p. 29). Structures in this part of the Rockies are typically broad open folds. On the west, the subprovince is cut by a normal fault downthrown 3000 feet on the west. This fault, if projected northwestward, would be about 8 miles southwest of the dike. Possibly the Main Ranges, when compared with the Front Ranges, could be regarded as a positive, more rigid block cut by normal faults and high-angled sheared zones. Probably there was considerable transcurrent movement along the shear zones.

The Ice River and Cross River intrusives (Hedley, 1954, p. 117) are in the western subprovince of the Main Ranges 30 and 70 miles south-southeast of the dike. Located structurally further east, the Crowfoot Dike is in the eastern subprovince of the Main Ranges, near the crest of the Bow River anticline. In the vicinity of the dike this broad anticline plunges northwest at 300 feet per mile and broadens in the same direction. On the east the Bow River syncline plunges and broadens southward and, in line with the dike, this syncline is crossed by a minor arch. Between the anticline and syncline there is a high-angle sheared zone and possibly the two structures acted as separate rigid blocks, with some transcurrent movement between them. Possibly the dike was intruded where the sheared zone crossed the minor arching referred to above.

COMPOSITION OF THE DIKE

The following is a description of the dike rock by A.O. Stanley and S.B. Fulton: "A medium grained hypidiomorphic granular rock composed of small euhedral to subhedral augite grains within a felted mass of large crystals of anhedral-subhedral plagioclase. Mafic material altering to chlorite and other secondary minerals. Feldspars altering to carbonate and also acicular crystals of 'epidote'(?) and actinolite."
The rock consists of about 65 per cent plagioclase, 20 per cent augite, 10 per cent chlorite, 3 per cent calcite and actinolite and 2 per cent pyrite and magnetite and is classified as a metadiabase (Fig. 3).

The dike near the walls grades to a "chilled" phase and consist of grey-green feldspar laths (30%), embedded in a glassy matrix (50%); chlorite blebs (15%), quartz "eyes" and calcite (5%) make up the balance.

METAMORPHISM OF WALL ROCK

For about 20 feet on each side of the dike the Hector is locally metamorphosed to a slabby-weathering light grey-green rock. This rock consists mainly of feldspar grains which become coarser toward the dike and quartz eyes. The bedding and laminae of the normal Hector Formation continue without change into the metamorphosed phase, suggesting that the dike was intruded after the Hector was folded.

UPPER CONTACT OF THE DIKE

This contact can be seen in the valley of Helen Creek. The dike can be traced to within a few feet of the base of the Jonas Creek Formation where it becomes finer grained and loses its characteristic vertical jointing. It grades out in a few feet to

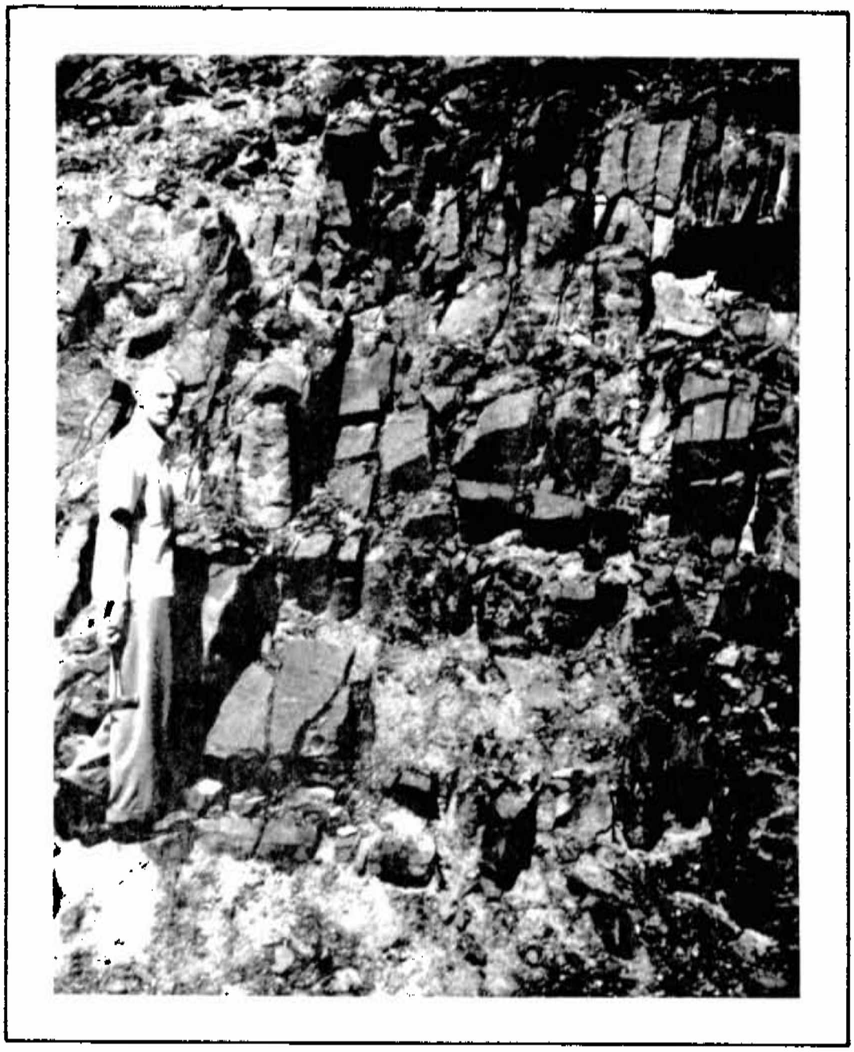

Figure 2 - Outcrop of the Crowfoot dike at mile 19.8 on the Lake Louise -Jasper highway. The steeply dipping joints are comformable with the attitude of the dike.

Figure 3 - Thin sections of meta - diabase from the Crowfoot dike (x 25). Euhedral to subhedral grains of augite (A) in a felted mass of large twinned crystals of plagioclase. Augite partly altered to chlorite (C).

metamorphosed Hector Formation, similar to that already described. The outcrop on top of the dike is not complete, but there are enough to show that the dike grades out into the Hector Formation and is not eroded by an unconformity at the base of the Jonas Creek Formation.

MINERALIZATION

On the southeast side of the dike, veins up to 8 inches wide are common. These veins consist of calcite, partly replaced by quartz. There are wisps of chloritized rock with pyrite cubes and a few specks of chalcopyrite near the walls of the veins. Near the north side of the road cut there is a vein 6 inches wide consisting of cream colored magnesite, calcite and quartz. Cutting across the dike in the road outcrop there is a vein 2 inches wide consisting of coarse calcite spar (60%), asbestos (30%), and quartz (10%).

The Jonas Creek Formation overlying the dike in Helen Creek valley is mineralized with many small veins of calcite and quartz.

ACKNOWLEDGMENTS

The writer is indebted to Dr. R.E. Folinsbee and Dr. H.A.K. Charlesworth of the University of Alberta for information on the geology of the area and to Mr. A.O. Stanley and Mr. S.B. Fulton for descriptions of thin sections of the dike rock.

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APPENDIX I

PRECAMBRIAN ROCKS AT JASPER

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The Precambrian rocks that outcrop in the vicinity of Jasper are to be examined on the last day of the field conference. The purpose of this note is to help those attending the conference to follow more easily the structure and stratigraphy of these rocks. Further details concerning structure, stratigraphy and metamorphism are to be found in Charlesworth et al. (1961), Charlesworth and Evans (1962), and Evans et al. (1963). A complete account of the Precambrian geology of the Jasper area is in preparation.

Some 10,000 feet of Precambrian and Lower Cambrian strata, predominantly clastics, outcrop near Jasper. Mountjoy (1962, p. 3) has divided this succession into two groups (Fig. 1). The lower of the two units, the Miette Group, is a recessive unit, consisting dominantly of interbedded coarse and fine clastics, whereas the Gog Group is made up primarily of cliff-forming sandstones and quartzites. The succession may be divided further into five formations. Since the nomenclature of the formations is still undecided, they are here referred to as A, B, C, D and E. The names previously assigned to them by Charlesworth et al. (1961) are also included in Figure 1. Formation E contains olenellids and archaeocyathids and is undoubtedly Lower Cambrian. In the absence of any marked stratigraphic break in the remainder of the succession, the boundary between the Cambrian and the Precambrian has provisionally been placed at the base of Formation E.

Structurally, the Precambrian beds lie in the Pyramid thrust-sheet and have been strongly folded into a series of anticlinoria and synclinoria (Fig. 2), with overturned dips being common. Folding in the competent Gog Group is on a much larger scale than that in the incompetent Miette Group. Thrust-, normal and wrench-faults cut the folds. Axial-plane slaty cleavage characterizes the argillaceous strata, and fracture-cleavage is common in the arenaceous strata of the Miette Group. Jointing, commonly associated with quartz-calcite-chlorite veining, is widespread in the arenaceous strata of the Miette Group.

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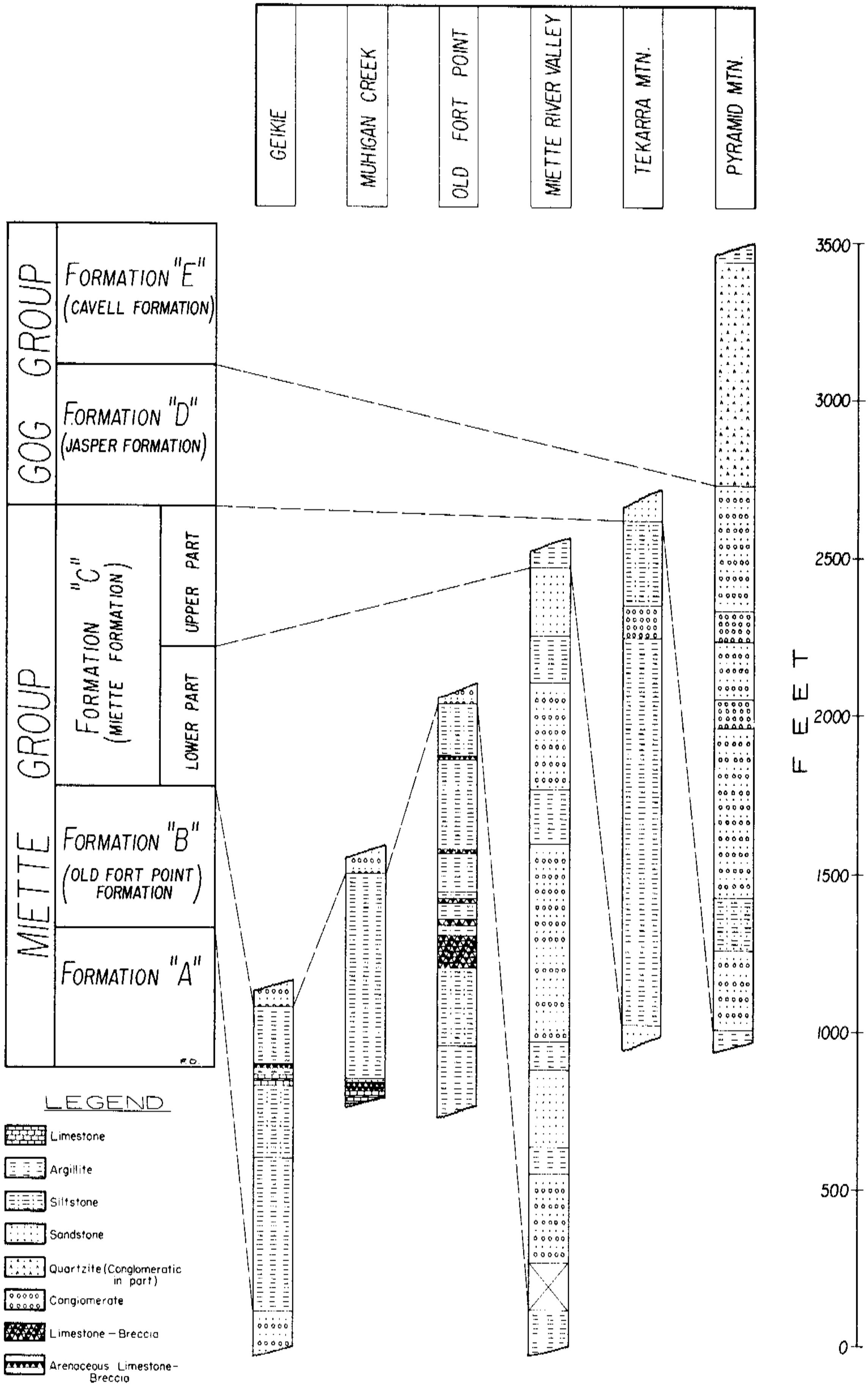
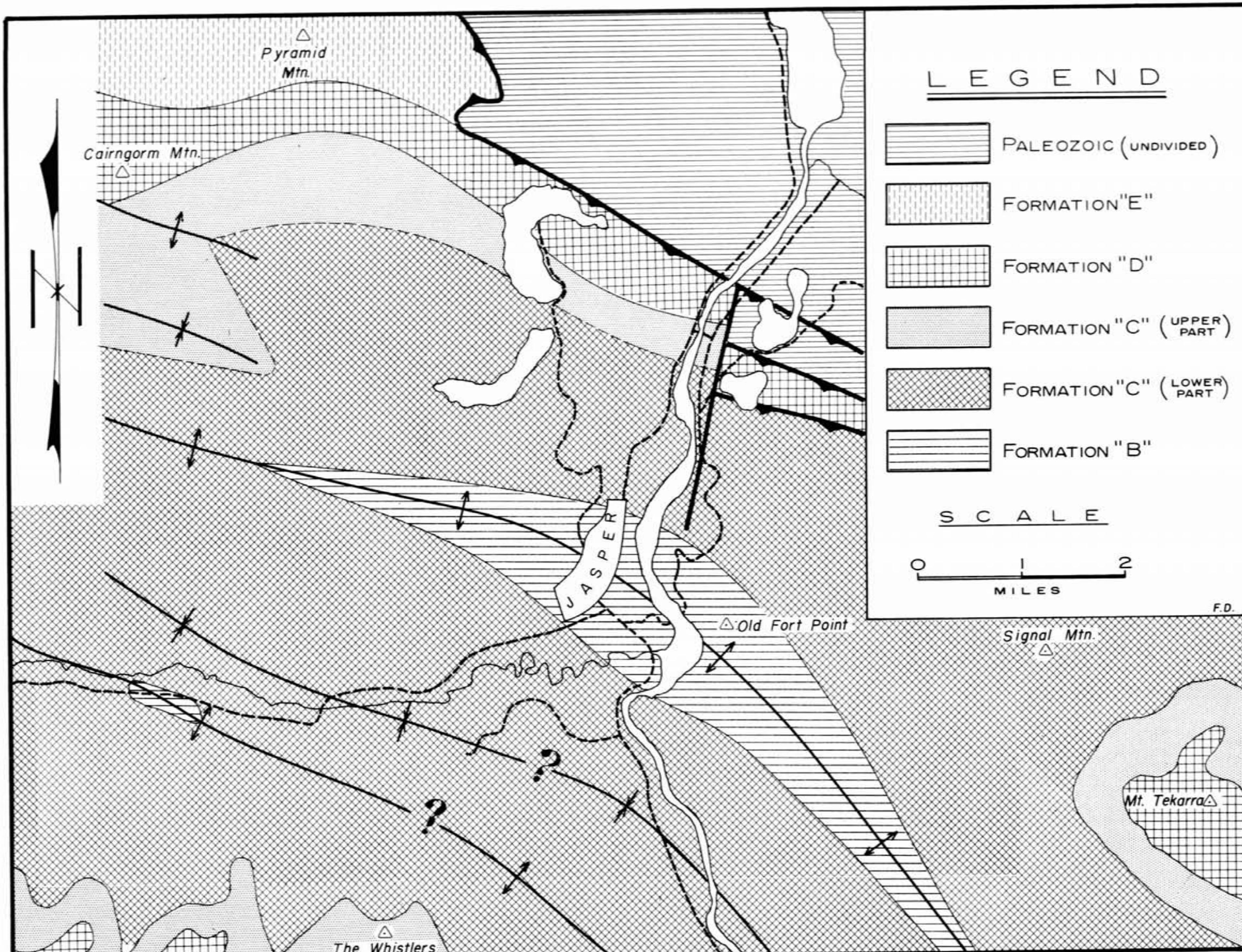


FIGURE I

PRECAMBRIAN AND LOWER CAMBRIAN STRATIGRAPHIC SECTIONS - JASPER AREA



Pyramid Mtn.
Cairngorm Mtn.
JASPER
Old Fort Point
Signal Mtn.
Mt. Tekarra
The Whistlers
?
?
LEGEND
PALEOZOIC (UNDIVIDED)
FORMATION "E"
FORMATION "D"
FORMATION "C" (UPPER PART)
FORMATION "C" (LOWER PART)
FORMATION "B"
SCALE
0 1 2
MILES
F.D.

FIGURE 2

APPENDIX II

ROAD LOG - HIGHWAY NO. 16

HINTON TO JASPER

For the convenience of participants in the E.G.S. Sunwapta Pass field trip who are driving from Edmonton, road logs for highway 16 from Hinton to Jasper from the A.S.P.G. 1955 Jasper Field Trip Guide Book and the E.G.S. 1961 Jasper Field Trip Guide Book are reproduced here with minor alterations.

Highway 16 from Hinton to Jasper displays an excellent cross-section of the Foothills, Front Ranges and Main Ranges sub-provinces. Rocks representing parts of the geologic section from Precambrian to Upper Cretaceous are exposed.

0.0 (49.1)	Canadian National Railway Station on north side of Highway 16, Hinton, Alberta.
0.8 (48.3)	Bridge crossing Happy Creek. Brazeau strata exposed along banks of creek.
2.5 (46.6)	Approximate position of axis of Prairie Creek anticline, commonly considered to be the easternmost foothills structure in this area.
3.9 (45.2)	Bridge crossing Maskuta (Prairie) Creek.
4.3 (44.8)	North - Road to Entrance.
6.9 - 7.2 (41.9 - 42.2)	North - Road-cut exposing Brazeau strata dipping steeply northeastward in common limb of Seabolt anticline on the west and Entrance syncline on the east.
8.5 - 8.6 (40.5 - 40.6)	Road cut exposing Brazeau sandstone.
9.6 (39.5)	Approximate position of axis of "Seabolt" syncline.
9.8 (39.3)	North - Outcrop of Brazeau formation dipping very gently eastward.
10.4 (38.7)	South - Cap Ridge formed by the gently east dipping resistant Solomon sandstone member at the base of the Brazeau formation which overlies the Wapiabi shales.
13.8 (35.3)	South - Small rounded outcrops of east dipping Rundle.
14.1 (35.0)	Approximate position of axis of Folding Mountain anticline. Rundle strata are exposed in the axial zone on the hillside south of the highway.

14.5 (34.6) North - Outcrops of Spray River siltstones overlying very light grey, locally very siliceous Rundle limestones.

14.6 (34.5) Out crop of Spray River siltstones dipping westward on west limb of Folding Mountain anticline.

15.3 (33.8) North - Road to Overlander Lodge. Good view of eastern part of Boule Range straight ahead. This is the front range of the Rocky Mountains in this area. The Boule Thrust is well exposed with light grey weathering Palliser limestones overlying black Fernie shales.

16.1 (33.0) South - View of eastern part of Roche à Perdrix. The Boule Thrust underlies the resistant Rundle strata which forms a broad syncline immediately east of the mountain proper. A subsidiary thrust, accompanied by complex local deformation is present between this syncline and the mountain. (See E.G.S. 1961 Jasper field trip guide, p.26, for an annotated photo of this mountain).

16.6 (32.5) Park gate. South - A view of the axis of disharmonically folded anticline involving Devonian strata in Roche à Perdrix.

18.0 (31.1) Bridge over Fiddle Creek. Looking northward along Fiddle Creek a section across Bedson Ridge may be seen with several complex folds.

18.2 (30.9) Fiddle Creek campground.

19.6 (29.5) South - Palliser limestone cliff on west flank of Ashlar Ridge extends nearly to the highway.

21.0 (28.1) South - Pocahontas Basin, North - Moosehorn Basin. Jurassic and Cretaceous sandstones and shales comprise the bulk of the strata in these synclinal basins.

21.8 (27.3) Pocahontas junction with road to south to Miette Hot Springs.

22.0 (27.1) Pocahontas Warden Headquarters.

22.1 (27.0) Roche à Bosche (6,966 feet) and Roche Ronde (7,014 feet) to the west comprise the south end of the Bosche Range.

22.2 (26.9) South - Slack pile of abandoned Jasper Colliery. Coal was mined from seams in the basal Luscar formation in the footwall of the Miette fault.

22.3 (26.8) North - Strike valley of Moosehorn Creek on north side of Athabasca. Deformed Cretaceous strata form the Moosehorn basin. Note the resistant ridges of Cadomin conglomerate.

23.1 (26.0) Approximate surface position of Miette fault.

23.9 (25.2) South - Roche Miette (7,599 feet) on the north end of the Miette Range. The massive cliff of Palliser limestone is underlain by Alexo, Mount Hawk and folded Perdrix shales. Maligne and Flume limestones represent the lowermost Devonian strata. These overlie Cambrian sediments of the Arctomys, Pika, Titkana formations and part of an unnamed shale unit, which is thrust over Mesozoics.

24.3 (24.8) Left - White sulfur spring deposit at side of pond.

24.4 - 24.5 (24.6 - 24.7) South - Outcrop of poorly fossiliferous Mount Hawk formation in near vertical east limb of an anticline.

24.8 (24.3) South - Perdrix black shale outcrops have a dip to the southwest. The small quarry and waste heap are relics of a small lime plant near the faulted contact of Perdrix and Alexo formations.

25.0 (24.1) South - Disaster Point Alpine Hut.

25.1 - 25.5 (23.6 - 24.0) South - Palliser, Alexo and Mount Hawk formations are exposed at the roadside. The beds are vertical or overturned on the west limb of a large anticline.

25.5 - 25.7 (23.4 - 23.6) South - Roadside outcrops consist of basal Rundle and upper Banff formations in overturned west limb of an anticline.

27.0 (22.1) Northwest - A structure profile of Roche à Bosche.

27.2 (21.9) Rocky River Bridge.

27.4 (21.7) North - Monument commemorating second site of Jasper House (1826 - 1884).

28.3 (20.8) South - Valley of Rocky River is underlain by Triassic and Jurassic strata. To the south, in the distance, the rounded crest of Makwa Ridge is formed of anticlinal Triassic and Mississippian strata.

31.3 (17.8) For the next three miles the road follows a wind drifted sand bar which lies between Jasper Lake and Talbot Lake.

31.5 (17.6) South - Roadside outcrop of Rocky Mountain strata together with Mount Head, Turner Valley and Shunda formations of the Rundle Group. Banff is exposed in the anticlinal axis on the forested slope directly south.

31.9 (17.2) South - Roadside outcrop of Triassic Spray River siltstone.

32.1 (17.0) North - Mount Greenock (6,881 feet) a part of the De Smet Range. Strata range from Spray River on the west slope downward stratigraphically through the Rocky Mountain, Rundle, Palliser, Alexo, Mount Hawk, Perdrix and possibly Flume. The Greenock Thrust at the base of the eastern slope superimposes basal Devonian onto Triassic.

32.6 (16.5) South - Edna Lake; North - Jasper Lake. These lakes together with Talbot Lake and Brule Lake were once part of an extensive lake which flooded the Athabasca Valley in late Pleistocene time. Portions of the Pleistocene lake terrace can be observed approximately 350 feet above the present water level.

32.7 (16.4) South - Cinquefoil Mountain (7,412 feet) - The Banff/Palliser contact is directly east of the small gulley with Banff on the peak above.

32.8 (16.3) South - Contact of the dark Rocky Mountain formation and light Rundle is visible on the north spur of Cinquefoil Mountain.

32.9 (16.2) South - Red weathering Triassic siltstones and shales and cherty beds of the Rocky Mountain are exposed on the west slopes of Cinquefoil Mountain at the northwest end of the Jacques Ranges.

34.5 (14.6) South - Near the road the Banff and Palliser form an anticline which is continuous with the one present in Grassy Ridge on the north side of the Athabasca where a gulley displays the Banff/Palliser contact.

34.6 (14.5) South - Roadside outcrop of Rocky Mountain formations.

34.7 (14.4) South - Roadside outcrop of Triassic Spray River formation.

35.1 (14.0) South - Approximate surface position of Colin Thrust. The Cambrian Lynx formation is thrust on Rundle and Whitehorse strata. North - The Colin Thrust can be traced across the river where it is in the east slope of Esplanade Mountain.

35.5 (13.6) South - Cold Sulphur Spring issues at the contact between the Flume and Maligne formations. The latter is overlain by black Perdrix shales.

Warren's (1932) abundantly fossiliferous type Eleutherokomma jasperensis zone is in the upper one foot of limestone directly over the black shales. The base of the Devonian is approximately 60 feet west of the retaining wall.

35.6 (13.5) South - Perdrix shales underlie a forested saddle to the east of Morro Peak.

35.7 (13.4) South - Mount Hawk limestones are exposed on the ridge above the east end of pond.

35.8 (13.3) South - Directly above the west end of the pond outcrops display the contact between dolomitic limestones of the Palliser and silty limestones of the Alexo formation.

35.9 (13.2) South - A road outcrop at the base of Morro Peak consists of massive dark grey lower Palliser limestone. Note the glacial polish and scour on rock spurs.

36.0 (13.1) Bridge across Athabasca River.

Athabasca Point on the east bank is formed of Banff limestones. The Rundle/Banff contact is exposed on the west promontory.

36.2 (12.9) Continuity along strike of light grey weathering Palliser and darker Alexo and Mount Hawk and partly covered Perdrix, Maligne and Flume formations, can be observed from Esplanade Mountain in the northwest to Morro Peak in the southeast.

36.3 (12.8) North - Gargoyle Mountain, on strike with Esplanade Mountain, shows folding on its western flank.

36.4 (12.7) Canadian National Railway crossing.

North - Esplanade Mountain with easternmost peak of Palliser underlain by Alexo, Mount Hawk, Perdrix and Flume formations. The next peak west is in upper Banff.

37.2 (11.9) Approximate surface trace of Chetamon thrust.

38.2 (10.9) Bridge across Snaring River.

Southeast - Good view of Roche Bonhomme structure. The Colin Range is associated with the Chetamon and Colin thrusts. These thrusts give rise to the Mount Hawk and Roche Bonhomme structural units. The Mount Hawk unit consists predominantly of Carboniferous, Devonian and Cambrian strata. In the Roche Bonhomme unit Ordovician strata are present between the Devonian and Cambrian. Triassic Sulphur Mountain formation is preserved in the syncline forming the peak of Roche Bonhomme.

39.0 (10.1) East - Mount Hawk. The peak is Palliser limestone with Banff and Rundle on the west slopes.

39.3 (9.8) View of the Palisades and Chetamon Mountain.

40.6 (8.5) West - Cliff at foot of the Palisades is composed of Lynx formation which is hard, light grey limestones and dolomites interbedded with intraformational conglomerates and yellow-weathering, silty limestone with rare sandstone. The cliff is continuous with the west peak of Chetamon Mountain where there is about 5,000 feet of faulted Upper Cambrian strata between the Arctomys and Lower Ordovician. The true thickness of these beds is in the order of 2,500 feet.

41.0 (8.1) East - Garonne Creek gorge in Devonian limestones on west slopes of Colin Range. Mount Colin is on the south side of gorge, and

Mount Hawk on the north. These mountains form a single structural unit, and are separated from the Roche Bonhomme structure by the Chetamon fault, which brings Ordovician to the surface at Beaver Lake.

41.4 (7.7) The road is here cut in Pleistocene lacustrine sands.

41.5 (7.6) Chetamon Mountain and The Palisades.

41.6 (7.5) Canadian National Railways underpass.

41.8 (7.3) Branch road to Jasper airport on east side of highway.

42.1 (7.0) East - The old lake terrace on Athabasca east bank is approximately 300 feet above present river level. View to right rear of Roche Bonhomme structure.

42.2 (6.9) West - Branch road to Palisades Motel and Lodge. This is the old Swift Ranch, near which Kindle (1929) obtained a Lower Ordovician Bellefontia fauna.

42.4 (6.7) Good view of Pyramid Mountain (9,076 feet) through gorge in The Palisades.

42.7 (6.4) West - The Palisades. The upper cliffs are Palliser formation; middle slope is shale facies of the Fairholme Group (Alexo, Mount Hawk, Perdrix and Flume formations); lower cliff consists of Ordovician and Cambrian strata. The east face of The Palisades is controlled by jointing while the western slopes conform to Palliser bedding planes. The Palisades, like Roche Bonhomme on the East side of the Athabasca Valley, are located in the foot wall of Pyramid fault and form the westernmost Front Range here.

43.1 (6.0) East - Gorge in northwest ridge of Roche Bonhomme is the eroded axial zone of a syncline exposing pre-Devonian, Devonian and Banff formations.

44.3 (4.8) West - Gently dipping Palliser strata exposed beside the railway represent the southern end of The Palisades.

44.9 (4.2) Southeast - Valley of Maligne River, an important tributary of the Athabasca, with Colin Range to northeast and Maligne Mountains to southwest. The Maligne gorge is in or at the top of Palliser limestone.

45.8 (3.3) West - Road Outcrop of deformed dark grey limestone and black shale in foot wall of Pyramid fault. The rocks are in a fault slice of Flume, Perdrix and Mount Hawk formations. Good exposures along the rail cut above the road demonstrate the fault relationships of these formations.

45.9 (3.2) Culvert of Pyramid Creek on approximate surface position of Pyramid fault, in which Jasper formation is thrust upon Upper Palaeozoics.

46.3 (2.8) West - Road and railroad outcrops of sandstones and conglomerates of Jasper formation, overlying Miette argillites.

46.5 (2.6) Branch road to Jasper Park Lodge on east side of highway.

47.0 (2.1) Southwest - Good view of Mount Edith Cavell (11,033 feet) a prominent pyramidal peak, composed of about 4,000 feet of Lower Cambrian and Proterozoic sediments. The Proterozoics are the treed slopes.

47.2 (1.9) Northeast - The Colin Range demonstrates outcrop expression of Devonian and Carboniferous strata. Triassic forms the peak of Roche Bonhomme.

47.5 (1.6) Southeast - Signal Mountain (7,397 feet) at the north end of Maligne Range is formed of Miette sandstones, conglomerates and argillites. The Maligne Range is structurally continuous with Pyramid Mountain on the north side of Athabasca Valley. Both are in the hanging wall of Pyramid fault, and constitute the easternmost Main Range.

47.7 (1.4) Branch road to Cottonwood Creek campground and cabins.

47.8 (1.3) Canadian National Railways underpass.

48.0 (1.1) North - Terrace of lacustrine sands, 150 feet above the road or approximately 400 feet above present river level.

48.3 (0.8) Signpost at eastern outskirts of Jasper Town.

49.1 (0.0) East - Canadian National Railway Station, Jasper.
West - Jasper Park Administration Building.

ROAD LOG - HIGHWAY NO. 93

JASPER TO LAKE LOUISE JUNCTION

The highway route between Jasper and Lake Louise junction follows mainly along regional strike upon the Castle Mountain thrust within the eastern sector of the Rocky Mountains Main Ranges subprovince. Two major, parallel, longitudinal structures can be traced in the mountains adjacent to the route throughout almost its entire length. The frontal structure is a syncline, Castle Mountain syncline, sometimes referred to locally as the Mount Coleman syncline, located mainly to the east of the route. The succeeding structure is the Bow River anticline west of the route. The main depression axis of the syncline is located in the vicinity of Nigel Peak at the summit of Sunwapta Pass, and that of the anticline in Mount Forbes, west of the North Saskatchewan River crossing. Because of the pitch of these folds, the successive road level outcrops along the route expose strata of Precambrian to late Mississippian in age. The geological map and composite columnar section (in pocket) may be used in conjunction with the road log for guidance.

0.0 (141.8)	The corner of Connaught and Pyramid, opposite the Jasper National Park Administration Building. Look east across the valley of the Athabasca River to Signal Mtn. (7,397 ft.); this mountain marks the end of the Maligne Range. The lower tree covered slopes are composed of Old Fort Point Formation argillites and siltstones, overlain by the resistant arenaceous beds of the lower part of the Miette Formation. Beyond Signal is Mt. Tekarra (8,818 ft.). The lower slopes of Mt. Tekarra are composed of the softer argillite series of the Upper Miette Formation. Tekarra is capped by the resistant cliff forming sandstones and conglomerates of the Jasper Formation. All the above mentioned formations are of Precambrian age.
0.4 (141.4)	Canadian National Railway level crossing at southwest outskirts of Jasper. The railway crosses the continental divide at Yellowhead Pass, eighteen miles directly west. This pass, which has an elevation of 3,711 feet, is one of the lowest passes across the Rockies on the continent.
0.5 (141.3)	Right (W) - Junction Yellowhead Highway, road follows abandoned Canadian Northern Railway grades from the point as far west as Geikie station.
0.7 (141.1)	Left (E) - Junction Lac Beauvert Road. Road crosses Athabasca River past Old Fort Point on to Lac Beauvert. Old Fort Point is site of trading post built by William Henry.
1.0 (140.8)	Left (E) - Tekarra Lodge.
1.1 (140.5)	Bridge crossing Miette River; headwaters at Yellowhead Pass, confluence with Athabasca River directly east.

1.3 (140.4) Left (E) - Mt. Tekarra (8,818 ft.) in the Maligne Mtns. This range lies in hanging wall of easternmost Rocky Mountain Main Ranges' fault (Pyramid Mtn. - Castle Mtn. fault).

1.6 (140.2) Right (W) - Kiefer's Alpine Village Bungalows.

2.1 (139.9) Right (W) - Junction with road to Whistlers Ski Lodge. Look back (N), good view of Pyramid Mtn. (9,076 ft.) in the hanging wall of the Pyramid Mtn. thrust. Hanging wall succession in ascending order:- Precambrian Upper Miette argillites, Jasper Formation conglomerates, sandstones, argillites and limestones capped by Lower Cambrian Cavell Formation quartzites and argillites.

2.6 (139.4) Left (E) - Jasper House Bungalows.

3.0 (138.9) Right (W) - The Whistlers (8,085 ft.), directly south is Marmot Mtn. (8,557 ft.). Both mountains are composed of Precambrian conglomerates, sandstones and argillites of the Lower Miette Formation, capped by Upper Miette argillites.

3.4 (138.5) Bridge crossing Whistlers Creek.

3.6 (138.1) Left (E) - Becker's Bungalows.

4.5 (137.9) Right (SW) - Good view of Mt. Edith Cavell (11,033 ft.) composed of Precambrian strata capped by Lower Cambrian beds dipping gently southwest in the west limb of an anticline. Suspected sequence in ascending order:- very thick Miette sandstone and argillite series, Jasper Formation not definitely recognized, capped by very thick Lower Cambrian Cavell Formation quartzites and argillites with possible other Lower Cambrian undivided. Note: Angel Glacier lies in saddle on northeast slope, due to rate of retreat, the ice tongue on the cliff side hangs like a suspended icefall.

6.0 (136.4) Bridge crossing Portal Creek.

8.0 (134.4) Bridge crossing Astoria River, Precambrian and/or Lower Cambrian outcrops in channel. River has cut down through great plug of glacial deposits clearly visable along the flanks of the valley.

8.1 (133.3) Right (W) - Junction road to Mt. Edith Cavell (9 miles) and trail to Amethyst Lakes and the Ramparts.

8.6 (132.8) Left (E) - Antler Mtn. in Maligne Range.

10.5 (130.9) Right (W) - Scattered outcrops of quartzites along road side referred to Lower Miette sandstone.

11.3 (130.1) Left (E) - Shovel Pass on north slopes of Curator Mtn. Trail leads over pass to Medicine Lake.

12.3 (129.1) Left (E) - Mt. Hardisty westerly dipping Precambrian and Lower Strata in east limb of syncline suggested sequence in ascending order:- Miette Formation overlain by Jasper Formation with Cavell Formation forming the upper slopes to the summit.

12.8 (128.6) Left (E) - "Meeting of the Waters" campground, confluence of Athabasca and Whirlpool Rivers - Athabasca River headwaters fed by melt-water from the Columbia Icefield, river debouches into Lake Athabasca 500 miles downstream; Whirlpool River headwaters near the continental divide and flows northeastward through the valley between Whirlpool Mtn. and Mt. Edith Cavell.

14.3 (127.1) Bridge crossing Whirlpool River. Whirlpool River trail on north bank leads some 30 miles westward to Athabasca Pass on the continental divide. David Thompson discovered the "Pass" in 1811, thus making the Athabasca River an important link in the trade route between British Columbia and the interior trading posts.

16.9 (124.5) Right (W) - Leach Lake camping and picnic area.

19.1 (122.3) Right (W) - Junction with trail to Geraldine Lakes.

19.5 (121.9) Bridge at Athabaska Falls. The full volume of the Athabasca River plunges over highly jointed, cross-bedded quartzites that appear to dip northeast into the Castle Mountain-Mt. Coleman syncline. On the basis of lithology, it is suggested that the rocks exposed are Jasper Formation.

19.7 (121.7) Left (E) - Mt. Kerkeslin (9,790 ft.) in synclinal axis of Castle Mountain syncline. The syncline extends on strike in peaks from Mt. Kerkeslin south to latitude of Lake Louise. Suggested sequence in ascending order:- basal tree covered slopes Precambrian Miette Formation argillites, siltstones, sandstones and arenaceous argillites - Jasper Formation sandstones and quartzites - Lower Cambrian or older Gog group sandstones, with the uppermost cliff forming sequence Middle Cambrian Cathedral - Eldon undivided, composed of carbonates, silts and shales.

19.8 (121.6) Junction with new road.

20.2 (121.2) Left (E) - Athabasca District Warden Headquarters.

20.8 (120.6) Right (W) - Whirlpool Pk. on south side of Whirlpool River - northwest Mt. Edith Cavell.

22.7 (118.7) Right (W) - Mt. Fryatt (11,026 ft.) with cirques and hanging valleys. Mountain formed of Precambrian, Cambrian and the peak is reported to be carbonates of Ordovician age.

24.0 (117.4) Right (W) - Park viewpoint excellent-view of Mt. Fryatt, Mt. Belanger (10,200 ft.), Mt. Christie (10,180 ft.) and Brussels Pk. (10,370 ft.) just west (behind) Mt. Christie.

26.4 (115.0) Right (W) - Mt. Christie (10,180 ft.) composed of southwest dipping Precambrian and Lower Cambrian strata. Mountain named after Wm. J. Christie, Chief Factor, Hudson's Bay Company, who was in charge at Edmonton when Palliser's expedition wintered there in 1858-59.

29.8 (111.6) Left (E) - North termination of Endless Chain Ridge; ridge composed of steeply dipping Precambrian and Lower Cambrian clastics in the east limb of Castle Mountain (Mt. Coleman) syncline.

30.5 (110.9) Ranger Creek crossing (start of new construction).

31.0 (110.4) Left (E) - The south plunge of the Castle Mtn. syncline is clearly evident in Endless Chain Ridge.

31.5 (109.9) Right (W) - Viewpoint of valleys of Athabasca and Chaba Rivers. Mt. Quincy (10,400 ft.) is the prominent peak at river fork; Athabasca River flows on east side of Mt. Quincy, Chaba River and Fortress Lake lie on the west.

32.6 (107.8) Left (E) - Junction road to Honeymoon Lake campgrounds and trail to Osprey Lake.

34.9 (105.5) Right (W) - Junction road to Sunwapta Falls. Right at the falls the Sunwapta River changes course very sharply from northwest to southwest then plunges over falls into a deep canyon. It appears that the river has been forced out of a preglacial valley by glacial damming. Just below the foot bridge, the canyon takes an abrupt right angle bend, due to either a small fault or the joint system in the rock thus indicating the direction of river erosion is partly controlled by these features.

35.2 (105.2) Road-cut outcrop, limestone beds preserved in trough of syncline suggested age Middle Cambrian, Lower Cambrian quartzites are visable in the limbs of the syncline on opposite sides of valley.

35.9 (104.5) Left (E) - road-cut outcrop of Middle Cambrian limestone.

36.3 (104.1) Right (W.N.W.) - Good view of Dragon Pk. and Catacombs Mtn. (10,800 ft.).

38.7 (101.7) Bubbling Springs picnic area.

40.4 (100.0)	End of construction.
43.5 (96.9)	Right (W) - Scattered outcrops of Cambrian quartzite can be seen in the trees.
44.7 (95.7)	View straight ahead of unnamed mountain lying between Poboktan and Jonas Creeks, mountain beyond to south and west is Sunwapta Pk. (10,875 ft.). Sequence in ascending order:- Lower Cambrian quartzites, Mt. Whyte Formation at level of brown talus covered slopes, Middle Cambrian carbonates in upper cliff forming unit. Type section of Sunwapta Pk. Formation (Hughes, 1953) which is composed of 2,000 to 2,500 feet of Middle Cambrian limestones, dolomites and minor shales.
46.0 (94.4)	Bridge crossing Poboktan Creek (Stoney Indian for owl). Contact of Lower Cambrian (Jonas Formation) and Precambrian (Hector Formation), on east side of Endless Chain Ridge, crosses Poboktan Creek about four miles upstream from bridge (not visible from road).
46.8 (93.6)	View straight ahead (S) - Sunwapta Pk.
48.1 (92.3)	Left (E) - Landslide of blocks of pink and white Lower Cambrian quartzites from dip slope of Endless Chain Ridge. The slide swept down across highway and into Sunwapta River where it forms a series of small rapids. Quartzite used extensively as decorative building stone in Jasper, i.e. Information Booth.
49.2 (91.2)	Jonas Creek crossing.
53.5 (86.9)	View ahead (S) - north end of Tangle Ridge. Type section of Tangle Ridge Formation (Hughes, 1953), an Upper Cambrian carbonate sequence 1,900 feet thick, located on lower slopes of ridge between altitudes 6,900 and 8,760 feet. This formation is overlain by about 750 feet of Ordovician cherty limestones, which are in turn, overlain by about 10 feet of Mt. Wilson quartzite which forms the crest of the sharp ridge near summit of mountain. Note: normal fault, apparently not recognized, or at least not mentioned by Hughes.
53.8 (86.6)	Left (NE) - South end of Endless Chain Ridge formed of Precambrian and/or Lower Cambrian quartzites on east flank of Castle Mountain syncline.
54.4 - 58.0 (86.0-89.6)	Left (E) - Scattered roadside and near roadside outcrops, mostly on east side of road - quartzites and carbonates tentatively referred to as Lower and Middle Cambrian.

55.0 (85.4)	Left (E) - Beauty Creek and Stanley Falls just upstream from the road crossing. Stream has cut a deep narrow canyon through flat-lying Middle Cambrian carbonates. Axis of the regional syncline crosses the highway obliquely near the mouth of Beauty Creek, north of creek, highway is on east limb, south of creek, highway is on west limb of fold.
56.4 (84.0)	View ahead (S) - excellent view of north end and part of west side of Tangle Ridge. Normal fault on north end has Tangle Ridge Formation in fault contact with Sunwapta Pk. Formation of the west face. Right (W) - Middle Cambrian carbonates exposed on the north face of unnamed mountain in an overturned anticline; a fault has been inferred to separate this anticline from the syncline in ridges directly east.
57.9 (83.5)	Right (W) - Diadem Pk. (11,060 ft.) and Mt. Wooley (11,170 ft.). Left (E) - roadside outcrops, structurally contorted carbonates, suggested age Middle Cambrian (?).
59.3 (82.1)	Left (E) - Excellent view of west side Tangle Ridge, note fault about midway along west face.

Suggested Sequence

Hughes (1955)	E.G.S. (1963)
Devonian	Devonian
Mt. Wilson	Mt. Wilson
Ordovician B	Sarbach
Ordovician A	Mons
(Fault)	(Lyell?
Tangle Ridge	(Sullivan
Sunwapta Peak	(Arctomys
	Eldon

60.6 (80.8)	Right (W) - View of Stutfield Pk. (11,320 ft.) and Stutfield Glacier on upper slopes a northeast tongue of the Columbia Icefields. Note the many ice-falls; a superb double set of ice-falls occurs on the steep back wall of glacier. Left (E) - Roadside outcrop interesting structure; folded and faulted Cambrian carbonates.
61.2 - 61.6 (79.8-80.2)	Left (E) - Extensive road-cut outcrops, possible Upper Lyell carbonates overlain by Mons shales and argillites.
61.8 (79.6)	Tangle Creek crossing.

62.3 (79.1) Right (W) - Upper view point - north shoulder of Mt. Kitchener (11,500 ft.) named after Viscount Kitchener, Secretary of State for War (1914-1916). From top of talus slope good exposure of Middle Cambrian Eldon carbonates overlain by thin section of Pika carbonates.

Left (E) - New road-cut through Ordovician Sarbach.

62.6 (78.8) Left (E)-Road-cut through Sarbach.

65.0 (76.4) Right (W) - Broad alluvial plain of valley Sunwapta River debris is largely outwash from melt-waters of Dome and Athabaska glaciers, appears to be some landslide material also.

66.1 (75.3) Left (E) - Just off road excellent exposure of Middle Cambrian Arctomys red and green shales.

66.3 (75.1) Left (E) - Fault slice of Upper Cambrian Upper Lyell carbonates, particularly interesting limestone - dolomite relationships.

66.5 (74.9) Left (E) - Icefields Chalet, at south end of ground floor lunch counter Geodetic Bench Mark No. 713E has been set into cement wall of chalet.

Right (W) - looking across to the west is panoramic view of Columbia Icefields. From north to south you see: Stutfield Pk. (11,320 ft.), Mt. Kitchener (11,500 ft.), with Dome Glacier, the "Snow Dome" (11,340 ft.) to west behind the Snow Dome "The Twins" north peak (12,085 ft.), south peak (11,675 ft.) Athabasca Glacier descending from the northward face of Mt. Athabasca (11,452 ft.).

The Columbia ice-field, with its outlet glaciers covers an area of nearly 130 square miles, of which at least 50 square miles are more than 8,500 feet above sea level. From the great central ice reservoir, lying between Snow Dome, Mt. Castleguard and Mt. Columbia, and capping the continental divide for a distance of about 20 miles, three main valleys radiate outward. Through these valleys flow the Athabasca Glacier to the northeast, the Saskatchewan to the east, and the Columbia to the northwest. In addition, to the three main glaciers, small tongues of ice flow into surrounding valleys, and at a number of points ice tumbles over precipices to form reconstructed glaciers. Dome Glacier is an excellent example of one of these small ice tongues.

The melt-waters of the Columbia Icefields is the source of three great rivers: the Athabasca (765 miles) a subtributary of the Mackenzie River which empties into the Arctic Ocean; the Saskatchewan (1,205 miles) which crosses the prairies and flows into Lake Winnipeg, thence via the Nelson River to Hudson's Bay; and the Columbia (1,210 miles) which crosses into northwestern U.S.A., before debouching into the Pacific Ocean.

The Athabasca Glacier moves forward about 50 feet per year, but the margin retreats at a rate of 100 feet per year. One of the first published photographs of the glacier taken in 1908, showed that the terminus had receded about 400 to 500 feet from the terminal moraine. Later pictures (1908 to 1919) indicated a recession of 300 to 400 feet. From 1922 to 1948, the net recession was about 1,750 feet. For the past five years, the yearly recession has been about 102 feet. The glacial lake at the foot of the glacier has a diurnal rise and fall of around two feet, dependent upon the flow of the epiglacial streams.

Both Mt. Kitchener and Mt. Athabasca are formed of Cambrian strata. These mountains are structurally complex containing numerous faults and the stratigraphy is not well understood so no breakdown will be attempted. On the shoulder of Mt. Athabasca, just south of the road to the Snowmobile lookout, Upper Cambrian Upper Lyell carbonates with prominent Collenia colonies are clearly visible. The thick sequence of light brown arenaceous shales on Mt. Kitchener contains an abundance of Middle Cambrian cystoid remains.

Left (E) - just north of the Chalet is Wilcox Pk. (9,463 ft.) composed of Upper Cambrian and Ordovician strata.

67.0 (74.4) Left (E) - Nigel Pk. (10,535 ft.) with twin castellate peaks of Carboniferous Rundle Group carbonates. Sequence in ascending order:- Ordovician Sarbach in fault contact (?) with covered Devonian Fairholme, Devonian Palliser, Exshaw (very thick) Mississippian Banff and Rundle. The peak at south end of Nigel is the Sunwapta Pass section of Spreng. Nigel marks the approximate locus of central depression of northwest trending Castle Mtn. syncline.

67.8 (73.6) Left (E) - Headwaters tributary of North Saskatchewan River.

68.0 (73.4) Boundary Monument marking boundary between Jasper National Park and Banff National Park. Summit of Sunwapta Pass (6,675 ft.).

70.7 (70.7) Left (NE) - Viewpoint of south face of Nigel Pk. Note small fault in Banff Formation.

The southeast Cirrus Mtn. (10,685 ft.). Note fault on west face of Cirrus towards the north end bringing up Cambrian? Ordovician Sarbach, and Mt. Wilson with Devonian above. South end of Cirrus can be seen better from lower down "Big Hill".

73.6 (67.8) Left (E) - Excellent view of Cirrus Mtn. in error referred to as Mt. Coleman by Severson, Spreng and Woodward. Sequence at south end of Cirrus Devonian Palliser forming prominent cliff sequence towards base with carboniferous section above, Rundle carbonates from the peak.

Right (W) - Roadside outcrop of Devonian Palliser, there is almost continuous exposure along the right side of the road to the base of Big Hill. The Palliser is underlain by a Fairholme reef section.

74.3 (67.1) Left (E) - Nigel Creek and canyon.

75.0 (66.4) Right (N) - View of south face of shoulder of Mt. Athabasca, sequence in ascending order:- Ordovician Mt. Wilson quartzites, Beaverfoot-Brisco covered to very poorly exposed, overlain by a thin Devonian sandstone sequence, in turn overlain by Devonian Fairholme and Palliser.

Right (W.S.W.) - View of northward facing slopes of Mt. Saskatchewan (10,964 ft.) formed of very steeply dipping Fairholme beds.

Left (S.E.) - View of Cirrus Mtn., Mt. Coleman barely visible to the southeast behind Cirrus. The obvious discordance in dips between the Fairholme-Palliser sections of Athabasca and Cirrus with the Fairholme on Saskatchewan suggests that a fault is located in valley floor.

75.7 (65.7) Left (E) - Roadside outcrop of Fairholme exposing the Cairn/Southesk contact.

76.2 (65.2) Bridge crossing Nigel Creek. Upper Fairholme and Alexo Formations exposed in the creek channel.

77.2 (64.2) Left (E) - Road cut through Palliser Formation.

77.5 (63.9) Crossing Tumble Creek. Water cascades down cliff of Palliser limestone.

77.8 (63.6) Right (N.W.) - Near vertically dipping lower Fairholme dolomites, Beaverfoot-Brisco, Mt. Wilson and Sarbach. Eastward face Mt. Saskatchewan, on east limb of Bow River anticline.

78.6 (63.2) Crossing Cataract Creek excellent exposure of Palliser.

80.2 (61.6) Left (E) - Cirrus Mtn. campgrounds. Stratigraphic sequence on both sides of the road greatly foreshortened due to perspective.

81.5 (60.3) Crossing Coleman Creek river channel cut in Ordovician Mons.

82.2 (59.6) Left (E) - Mt. Coleman (10,262 ft.) named after Emeritus Professor A.P. Coleman, University of Toronto, Canadian geologist who explored the Rockies between North Saskatchewan and Athabasca Rivers. Sequence in ascending order: poorly exposed Ordovician Mons at base, Sarbach, prominent cliff forming Mt. Wilson, Beaverfoot-Brisco, Devonian Cairn-Southesk and Palliser at top. Beds all nearly flat-lying, mountain located in axis of Castle Mountain syncline, may be thin Exshaw basal Banff section resting on the Palliser.

At several points along this westward face of Mt. Coleman, light cream quartzite talus blocks from the Mt. Wilson reach near road level.

83.0 (58.8) Right (W) - roadside outcrop of Upper Cambrian Upper Lyell carbonates.

83.9 (57.9) Right (W) - Road-cut through Upper Lyell carbonates.

84.2 (57.6) Right (W) - Extensive road outcrops of Upper Lyell in contact with overlying Mons also Upper Lyell in fault contact with Upper Lyell.

84.9 (56.9) Right (W) - Mt. Amery (10,940 ft.) with flat-lying beds of Upper Cambrian Sullivan and Lyell Formations exposed in peak, located about in the crest of Bow River anticline.

85.0 (56.8) Right (N.W.) - confluence of east flowing Alexandra River and North Saskatchewan River, Mt. Saskatchewan and The Castelets on the north side, Alexandra River, Mt. Amery on south side.

85.2 (56.6) Left (E) - View of northwest face of Mt. Wilson (10,631 ft.) sequence in descending order:- thin Cairn underlain by Mt. Wilson, underlain by thick Sarbach section.

85.3 (56.5) Crossing Norman Creek.

85.9 (55.9) Left (E) - Road-cut exposure of Middle and Upper Lyell sequence faulted.

86.1 (55.7) Right (N.W.) - Excellent view of Mt. Saskatchewan, sequence in descending order:- Upper Lyell, Middle Lyell, Lower Lyell, Sullivan, Arctomys dolomite, Arctomys shales.

86.5 - 86.9 (54.9-55.3) Extensive roadside cut exposing Upper Cambrian Middle Lyell recessive weathering unit.

The following can be observed, fucoid markings, dolomitic mottling, sedimentary breccia, _Trilobite_ fragments.

87.4 (54.4) Crossing Rampart Creek.

87.5 (54.3) Left - Rampart Creek Campgrounds.

89.4 (52.4) Left (E) - Mount Wilson section greatly foreshortened due to perspective, in ascending order sequence is:- upper tree covered slopes Middle Cambrian Arctomys, lower cliff forming sequence Upper Cambrian Sullivan, followed by Lower Middle and Upper Lyell, Ordovician Mons and Sarbach, with upper massive cliff forming sequence Mount Wilson with thin Cairn on top.

90.4 (51.4) Left (E) - Outcrop of sheared Arctomys in ditch.

90.5 (51.3) Left (E) - Excellent view of massive cliff of Mount Wilson quartzite at top of mountain.

92.7 (49.1) Right (W) - Tributary valley of Arctomys Creek with Mount Hooge (10,550 feet) on north side and Mount Erasmus (10,700 ft.) on south side. Arctomys Creek fed by melt-waters from glaciers on southeast side of Mount Lyell (11,495 ft.) at the Continental Divide. Mount Lyell named after Sire Charles Lyell (1795-1875), noted British geologist.

93.8 (48.0) Right (W) - Surfey Peak (8,781 ft.) composed of Ordocician and Upper Cambrian strata.

94.5 (47.3) Left (E) - Saskatchewan River Bungalows (overnight stop). View south of Mt. Murchison (10,936 ft.) - sequence in descending order:- peak and upper slopes Ordovician Sarbach, underlain by Upper Cambrian cliff forming Upper Lyell recessive Middle Lyell and cliff forming Lower Lyell, followed by Sullivan which extends down into tree cover. Sequence of slightly more resistive beds about mid-way down tree cover are referred to the Middle Cambrian Arctomys dolomites, underlain by Arctomys shales, base of mountain carbonates of the Pika/Eldon. Mountain named after Sir Roderick Impey Murchison (1792-1871), Director General of the Geological Survey of Great Britain. View north Mt. Wilson (10,631 ft.) type locality of the Mt. Wilson Formation (Walcott, 1923), formation is 550 feet thick here, and is composed of thick to massive bedded quartzose sandstone. For sequence see notes for mile 89.4, (52.4).

94.9 (46.9) Right (W) - View of the valley of the northeast flowing House River and the east flowing Glacier River and Glacier Lake. North of Glacier Lake is Sullivan Peak (9,915 ft.), type section Middle Cambrian Arctomys and Upper Cambrian Sullivan formation. South is Mt. Outram (10,670 ft.), and the the west of Outram is Mt. Forbes (11,902 ft.). The main depression axis of the Bow River anticline is located at Mt. Forbes. Rundle limestones are reported to be present at the summit of Forbes, underlain by the (Devonian Pipestone and Messinecial Formation of Walcott), which rest on Ordovician Mons and Sarbach, Upper Cambrian Lyell forms the basal cliffs.

95.5 (46.3) Bridge crossing the North Saskatchewan River.

95.8 (46.0) Left (E) - Saskatchewan River District Warden Headquarters.

97.8 (44.0) Right (W) - Canyon of the north flowing Mistaya River

Left (E) - Mt. Murchison.

99.2 (42.6) Left (E) - Road-cut exposure of Middle Cambrian Eldon carbonate.

99.5 (42.3) Left (E) - Road-cut exposure of Middle Cambrian Eldon carbonates, exhibiting excellent dolomitic mottling, and good vug porosity. The pale grey to white and dark to medium grey dolomites impart a "zebra strip" appearance to the outcrop. This dolomitic mottling has been referred to as algal in origin by some geologists.

99.8 (42.0) Left (E)-Roadside outcrop of Eldon carbonates.

100.7 (41.1) Right (W) - Mt. Sarbach (10,260 ft.), type section Sarbach Formation, directly south Kaufmann Pks. (10,150 and 10,200 ft.) named after two Swiss guides, who accompanied Collie upon many 'first ascents' in this area.

101.9 (39.9) Crossing at Bison Creek, View of Mt. Murchison.

102.3 (39.5) Left (E) - Roadside exposure of Eldon.

104.1 (37.7) Left (E) - Road-cut through Eldon, with good dolomitic mottling.

105.7 (36.1) Bridge crossing Totem Creek.

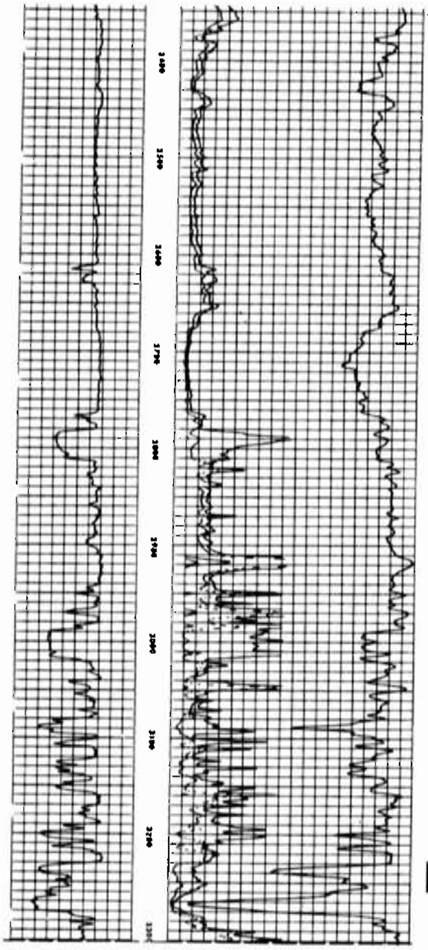
106.5 (35.3) Right (W) - Mt. Chephren (10,715 ft.), mountain originally 'Pyramid', but changed in 1918 to Chephren (name of second great pyramid of Egypt) to avoid duplication with Pyramid Mtn. directly north of Jasper.

107.4 (34.4) Right (W) - Viewpoint of Waterfowl Lakes. Mt. Chephren, Howse Pk. (10,800 ft.), Mt. Synge (9,700 ft.), Midway Pk. (9,570 ft.), Stairway Pk. (9,840 ft.) all these mountains are composed of Lower Cambrian and Middle Cambrian strata.

107.5 (34.3) Left (E) - Mt. Noyes (10,040 ft.) composed of Middle Cambrian strata.

110.7 (31.1) Right (W) Barbette Mtn. (10,080 ft.) at the head of Delta Creek, Mt. Patterson (10,490 ft.) to the north and Mistaya Mtn. (10,100 ft.) to the south. These mountains are composed of Middle Cambrian carbonates, underlain by Lower Cambrian strata.

111.8 (30.0)	Roadside outcrop of Lower Cambrian ferruginous quartzites tentatively referred to as St. Piran.
112.3 (29.5)	Left (E) - Mt. Weed (10,100 ft.), succession in descending order:- Lower Lyell, underlain by Sullivan, Arctomys dolomites and shales, with Pika and Eldow below in the tree covered slopes.
117.4 (24.4)	Left (E) - Observation Pk. (10,214 ft.), composed of Lower and Middle Cambrian strata.
	View to right (a) Peyto Glacier and Peyto Pk. (9,805 ft.).
118.9 (22.9)	Summit of Bow Pass (6,785 ft.) separates north flowing Mistaya River of the North Saskatchewan drainage basin, from south flowing tributaries of Bow River.
120.8 (21.0)	Right (W) - Bow Lake, lake level is 1,800 ft. above elevation of Banff townsite (4,538 ft.), to west, Mt. Thompson (10,119 ft.) and directly south Portal Pk. (9,552) Bow Glacier ice field extends from south shoulder of Portal Pk. on the north, to north shoulder of St. Nicholas Pk. (9,616 ft.). Above mountains formed of Lower and Middle Cambrian strata.
	Left (E) - Cirque Pk. (9,768 ft.) composed of Lower and Middle Cambrian strata.
121.8 (20.0)	Left (E) - Roadside exposure of dike described by J.Y. Smith, this Guide Book.
	Right (W) - Crowfoot glacier on the east face of unnamed mountain (9,975 ft.), directly behind Bow Pk. (9,194 ft.) both mountains formed of almost flat lying Cambrian and older rocks.
141.8 (0.0)	Junction of Highway 93 (Banff-Jasper) and Trans-Canada Highway.



NOTES