EDMONTON GEOLOGICAL SOCIETY

Third Annual Field Trip
Guide Book

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JASPER

August 1961

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PREFACE

All of the papers in this volume contain significant data and interpretation. That by Charlesworth, Evans and Stauffer is not directly applicable to petroleum geology, but participants in the field trip should be able to draw analogies between petroliferous rocks elsewhere and depositional characteristics, structures and other features of the Precambrian.

Mountjoy has spent several field seasons in the Jasper area, the results of which are only partly in print. The present paper gives Mountjoy's over-all view of the geology, and discusses some important aspects in detail. Readers will find it an ideal starting point for study of Athabasca Valley. The paper contains two significant new contributions. The first is the composite geological maps, in the pocket of the Guidebook, which will be of great use to structural geologists. The second is the analysis of the Lower Palaeozoic rocks. Geologists acquainted with this part of the section in Bow Valley will find comparison interesting, particularly with the pre-Devonian erosional pattern.

The Guidebook contains several papers on the Upper Palaeozic. These were written independently, and differences of opinion might be expected. While there are some, there is a surprising amount of agreement. For example, every paper which discusses the Greenock formation places its upper and middle members in the Rocky Mountain group. The interpretational differences are not important, and are due more to limitations imposed by time in re-writing parts of papers than to any other factor. McGugan and Rapson made significant faunal discoveries in the Jasper area this summer, and are now able to identify the Rocky Mountain beds at Mount Greenock and elsewhere as Permian. Before these results were available, Nelson and Rudy, on the basis of detailed work to the south, thought that the Rocky Mountain at Greenock might be Tunnel Mountain, and your editor in the paper "Detailed Carboniferous Correlations between Mount Greenock and Box Canyon, Southern Canadian Rockies," was of the same opinion. It was not practical to change these expressed opinions, which were anyway only tentative, because of the time element.

The identification of Permian beds at Mount Greenock remains dependent on stratigraphic correlations rather than faunal evidence, but as the reader will see, this evidence is strong. McGugan and Rapson are responsible for clearing up a great deal of the confusion which once existed in the terminology and interpretation of the uppermost Palaeozoic of the Banff area. In their present paper they do another thorough job.

Nelson and Rudy demonstrate from both lithologic and detailed faunal evidence that Tunnel Mountain-Rundle relationships are highly diachronic north and south from Banff.

Your editor supplies an unoriginal, but it thought useful, demonstration that Southern Alberta rock units can be carried from Nordegg vicinity to Mount Greenock. Mountjoy provides an up-to-date description of the Rundle at the latter locality, and it is interesting to note that the alternative contact for Mountjoy's formations C and D is close to the top of the Turner Valley determined by correlation from the south.

Although the data presented in this Guidebook solve many problems of Carboniferous stratigraphy they also raise another. McGugan and Rapson identified a fauna of Morrowan aspect from the uppermost Carboniferous of the Jasper area. Strata of comparable age at Banff lie in or near the Tunnel Mountain formation. This means that approximately 4,000 feet of beds at Banff correspond to 2,000 feet at Jasper. Detailed correlations between outcrop sections from Jasper to Banff, using the methods employed in constructing the Box Canyon-Mount Greenock cross section in this volume, suggest only minor thickening of Carboniferous chronostratigraphic units below the Livingstone in the Banff basinal area. The most important changes appear to be diachronic ones. The uppermost Carboniferous of the Greenock area should be at youngest Osagean by this criterion. Nelson and Rudy herein discuss some evidence of faunal condensation within the Mount Head formation north of Banff area, and Nelson (personal communication) on the basis of faunal studies, suspected that there might be an unconformity within that formation at Mount Greenock. Since the presence of a major unconformity within the Carboniferous of Jasper area is suggested in two different ways, the possibility should be kept in mind by future workers in the area. If the unconformity exists it should be possible to identify it by palaeontology, if not by detailed lithologic studies.

Meanwhile, have a pleasant and informative field trip.

James M. Drummond.

INTRODUCTORY REMARKS FOR THE THIRD EDMONTON GEOLOGICAL SOCIETY FIELD TRIP

by

Theo. A. Link

Link Downing Cooke and Co. Ltd., Calgary.

It is with great pleasure that I accept the honour of contributing an "Introductory Paper" to the 1961 Edmonton Geological Society Guidebook. Since I have already had the pleasure of addressing your Society a few years ago, (during its earlier days), when I met some of my old cronies from the University of Alberta as well as some of my former associates of Imperial Oil Ltd., I feel quite at home in joining you in this third geological field trip.

A Society which launched its first technical meeting with a paper by none other than Dr. Kelly Skeels was almost bound to become a successful venture, and aided by such a stalwart pillar of society as Ray (Bromo) Sluzar, its social achievements were bound to be second to none, with or without the piano and the beer. (Rumours have it that Ray is not allowed out late in the evenings any more).

Field trips such as this one are, in my opinion, useful and essential experiences for geologists engaged in the search for hydrocarbons, since these trips afford those who are dealing with the problems of subsurface stratigraphy in the office or laboratory an opportunity to see and actually walk on the formations which they wish to understand. Observation and study of a good core of a formation does not take the place of viewing an excellent exposure of it along the creek or river bank, or on a mountain face. As an example, the Cadomin Conglomerate is an abstract thing to a person who has never viewed an outcrop of that formation. Likewise, the indoor study of core upon core of the Leduc or D-3 reef cannot take the place of observing it on the mountain face.

The preparations which are needed, and the efforts put forth by those who undertake the staging of field trips can be appreciated only by those of us who have gone through the mill on similar projects, and because of this I wish to thank and congratulate your Committee on the arrangements for this field trip.

In view of the present unfortunate slowing up of exploratory field work, I believe that joint field trips with the Alberta Society of Petroleum Geologists in areas between Edmonton and Calgary should be encouraged, while in areas south of Calgary the Alberta Society of Petroleum Geologists should invite the Edmonton Geological Society to attend their show, and in areas north of Edmonton the Edmonton Geological Society should reciprocate. By arranging such a setup each Society could stage a field trip every other year, with joint ventures, let us say every five years, in the over-lapping zone between Edmonton and Calgary.

I sincerely hope that the weather will contribute toward a successful field trip in this beautiful Jasper area, and that from a financial angle it will exceed the previous one in profit to the Society. A glance at the program indicates that some interesting and instructive papers are presented in this Guidebook, while the excursion itself should be both pertinent and fascinating. I am sure all will return from this delightful area mentally and physically refreshed, and more informed regarding the geology of this and related areas.

PRECAMBRIAN GEOLOGY IN THE JASPER-GEIKIE AREA

by

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University of Alberta, Edmonton

ABSTRACT

In ascending order Precambrian rocks near Jasper, Alberta, are divisible into Old Fort Point, Miette and Jasper formations. Respectively, these are argillites and siltstones with some limestones and limestone-breccias; argillites, sandstones and pebble-conglomerates; and sandstones and conglomerates with some argillites and algaloid carbonates near the top. The Miette has deltaic or fluviatile characteristics, and the other two formations are probably of shallow-water marine origin. The materials for all three formations were apparently derived from a metamorphic and igneous terrain lying to the northeast. The strata, which now belong to the greenschist metamorphic facies, lie within the Pyramid thrust sheet and have been folded into a series of anticlinoria and synclinoria.

INTRODUCTION

The Precambrian rocks described in this paper belong to the Main Ranges which, together with the Eastern Ranges and Foothills, comprise the Canadian Rocky Mountains at the latitude of Jasper, Alberta. Although the relief of the country around Jasper is nearly 6000 feet, that of the 50-square mile map-area is only about 2000 feet. In places geological relationships are obscured by superficial deposits and dense tree cover. Aerial photographs, enlarged to a scale of 4 inches to the mile, were used in the field, while maps belonging to the National Topographic 1:50,000 Series, enlarged to 4 inches to the mile, served as base maps.

The work was performed while C.R.E. and M.R.S. were respective holders of Imperial Oil and California Standard fellowships, for which thanks are expressed. Field work was generously supported by the Research Council of Alberta, without whose financial assistance the study would not have been possible, and by the National Research Council and the Shell Oil Company of Canada, to each of whom we extend our grateful thanks. We also wish to acknowledge the helpful criticism and advice of various members of the Geology Department, University of Alberta. The Director of National Parks kindly gave permission to carry out field work in Jasper National Park.

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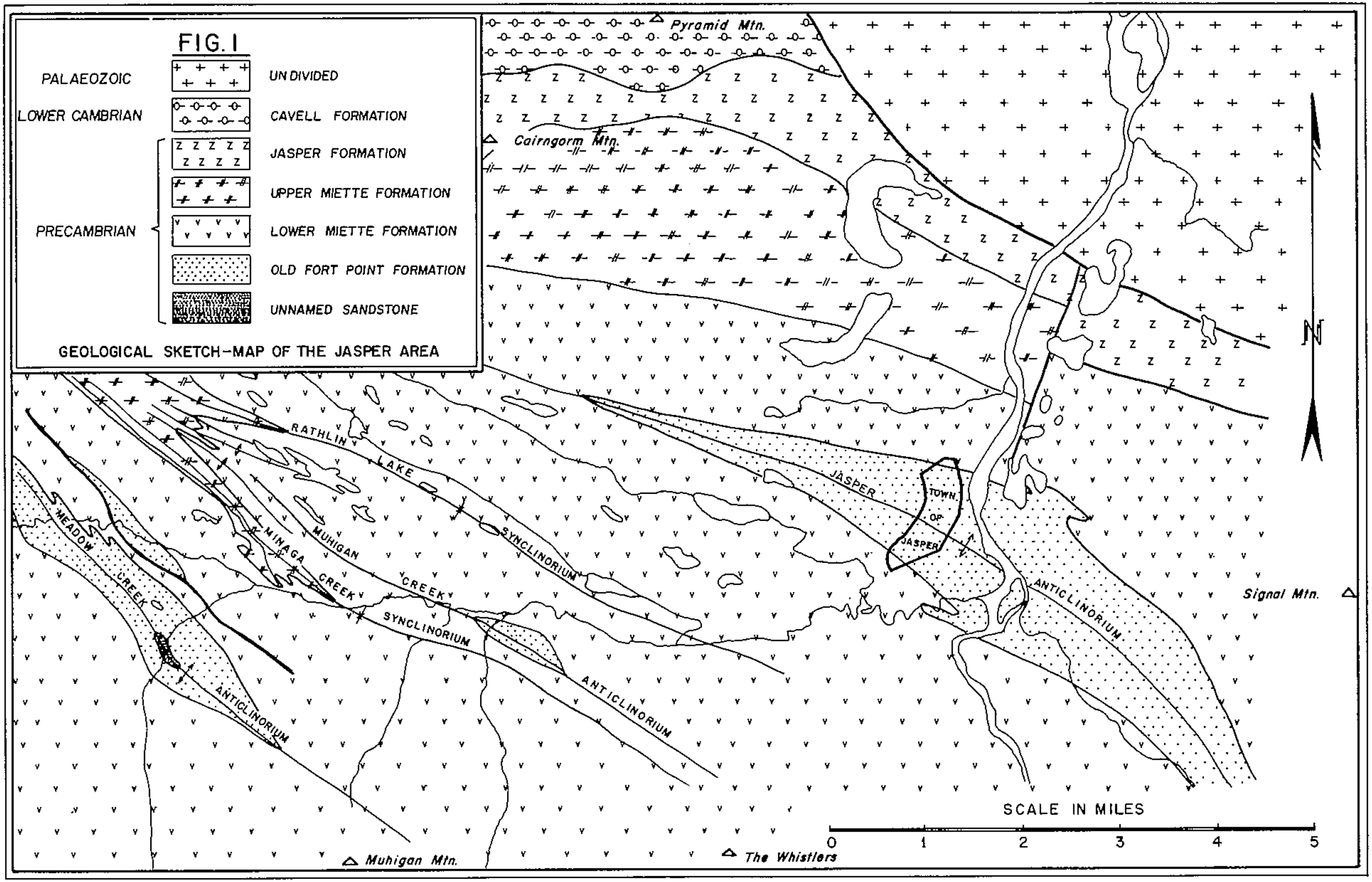

FIG. I

GEOLOGICAL SKETCH-MAP OF THE JASPER AREA

HISTORY OF RESEARCH

The Precambrian of the Jasper region was first described by McEvoy (1901, p. 31D), who recognized three rock units of unstated stratigraphic relationship. The first was described as fine-grained conglomerates, the second as interbedded fine-grained conglomerates and slates, and the third as argillites with some calcareous sandstones. Subsequently, Walcott (1913, p. 340) used the term Miette formation for the "massive-bedded, grey sandstones with thick bands of grey and greenish siliceous shale," 2000 feet or more in thickness, which outcrop in the valley of the Miette River west of Jasper. Allan et al (1932, p. 47) described a series of buff-coloured quartzites, argillites, sedimentary breccias, slates and conglomerates from the neighbourhood of Jasper which they termed the Jasper series.

In ascending order, Charlesworth & Remington (1960, p. 12) divided the Precambrian rocks in the vicinity of Jasper into the Old Fort Point, Miette, and Jasper formations, which may correspond to McEvoy's 3rd, 2nd and 1st units, respectively. The uppermost Precambrian rocks were described as consisting of sandstones and pebble-conglomerates, with some carbonates near the contact with the quartzites of the Lower Cambrian Cavell formation. The name Jasper was retained for these strata so as to avoid adding to formational nomenclature, although the description used by Allan et al (1932, p. 47) suggests that rocks now referred to the Old Fort Point formation were included in what was called the Jasper series. The underlying interbedded sandstones, conglomerates and argillites were grouped under Walcott's term Miette. It was decided to retain Walcott's name since his lithologic description was consistent with present usage, although rocks belonging to both Miette and Old Fort Point formations outcrop in the valley of the Miette River west of Jasper. A new term, Old Fort Point, was used to describe greenish grey argillites, siltstones, intraformational breccias and limestones which underlie the Miette formation.

STRATIGRAPHY

Old Fort Point formation

Strata belonging to the Old Fort Point formation, 1000 to 1300 feet thick, outcrop in the cores of the Jasper, Muhigan Creek and Meadow Creek anticlinoria (see Figure 1 for locations and Plate I for detail).

The basal 300 to 400 feet are homogeneous, dark bluish grey, poorly laminated, well-cleaved argillites, composed chiefly of chlorite with some muscovite and quartz. Interbedded siltstones occur towards the top of the unit. The base of the Old Fort Point formation is exposed only in the Meadow Creek anticlinorium, where it is underlain by an unnamed series of sandstones, conglomerates and argillites.

In the Meadow Creek structure the basal blue-grey argillites are overlain by about 100 feet of green ones, then by 200 feet of purple silty argillites and siltstones which become increasingly calcareous towards the top. The siltstones are not exposed in the Muhigan Creek anticlinorium, are very much thinner in the southwestern limb of the Jasper anticlinorium, and are absent elsewhere in this structure.

The Meadow Creek purple siltstones grade up into about 60 feet of interbedded limestones and calcareous argillites. The argillites vary from purple at the base to green at the top, and the limestone from pinkish grey to grey. The upper 20 feet of this unit shows incipient brecciation in the southwestern limb of the Jasper anticlinorium. The limestones are absent elsewhere on this structure. Cryptocrystalline calcite, with minute crystals of siderite, makes up about 80 per cent of the limestone, the remainder consisting mainly of grains of albite less than 0.15 mm. in diameter, with chlorite, quartz, and muscovite.

In the northeastern limb of the Jasper anticlinorium the green argillites, purple siltstones and limestones are represented by about 400 feet of greenish grey, laminated argillite with interbedded thin siltstones and lenticular intraformational limestone-breccias. In the argillites, which contain numerous brown silty laminae, very fine-grained chlorite and muscovite parallel the cleavage while books of chlorite with interlayered muscovite 0.1 to 0.2 mm. in diameter cross-cut the cleavage and comprise 5 to 10 per cent of the rock. Other components are quartz and albite, with some minute crystals of siderite, while calcite is present near breccia lenses. Up to 20 per cent of this unit is composed of ridge-forming, intraformational limestone breccia lenses which usually extend laterally for 200 to 300 times their maximum thickness. The thickest and most widespread breccia, near the base of the argillites, underlies the summit of Old Fort Point, where it is nearly 100 feet thick. Phenoclasts of pinkish grey, cryptocrystalline limestone identical to that in the Meadow Creek limestones, make up from 30 to 60 per cent of the rock, and range in length from a fraction of an inch to several feet but are never more than 3 inches thick. In this and higher breccias, fragment orientation is highly variable, and is interpreted as the result of both depositional and deformational processes. Breccia matrix typically consists of silt-sized quartz, albite, and books of chlorite with interleaved muscovite, in a groundmass of cryptocrystalline calcite, chlorite, muscovite, and siderite. Some thin breccias low in the succession have a limestone matrix. Phenoclasts are smaller in higher breccia lenses, reaching a maximum length of 10 inches, and generally make up a large proportion of the rock, but although pale grey in colour they are petrographically similar to phenoclasts in lower breccias. The matrix of these upper breccias has more quartz and albite and less fine-grained chlorite and muscovite, while the calcite is largely crystalline and twinned. Siltstone lenses, which comprise some 10 per cent of the breccia-bearing unit, reach a maximum thickness of 3 feet. Scour, slump, and pinch-and-swell structures, as well as cross-stratification, are all common. There appears to be a progressive increase in the proportion of the granular fraction, consisting mainly of well-sorted quartz and albite grains, from 50 per cent in the siltstones in the lower part of the unit to 90 per cent in those of the upper part. The matrix of the siltstones consists mainly of calcite, with very small grains and larger books of chlorite and muscovite, and minute rhombs of siderite. Towards the top of the member the siltstone matrix becomes progressively more calcareous until it consists almost entirely of calcite.

Dark bluish grey argillites overlie the breccia-bearing strata and their equivalents, and range from over 250 feet thick in the northeastern limb of the Jasper anticlinorium to a few feet in the other anticlinoria, where small thicknesses may be the result of tectonic thinning. The argillites, which weather rusty brown and have faint silty laminations several millimetres thick, are composed mainly of fine-grained muscovite and chlorite flakes developed parallel or sub-parallel to cleavage. Silt-sized quartz grains account for 10 to 20 per cent of the argillites, and rather large books of chlorite with interlayered muscovite make up 5, to 15 per cent, while up to 5 per cent may consist of minute siderite rhombs. Altered biotite is present as flakes in silt laminae and in some chlorite-muscovite books.

An intraformational quartzose limestone-breccia 5 to 15 feet thick occurs near the top of the dark bluish grey argillites, and contains up to 30 per cent of limestone phenoclasts of similar color in a matrix of coarse-grained calcareous sandstone. The phenoclasts have up to 15 per cent silt-sized albite with some quartz, in a ground mass of cryptocrystalline calcite and argillaceous material. The quartz and albite grains of the breccia matrix were originally well-rounded, but are now covered by irregular overgrowths and cemented with calcite. Several feet of dark bluish grey, thinly bedded limestone, similar to the phenoclasts in the quartzose breccia, underlie this bed in the southwestern limb of the Jasper anticlinorium. Neither the limestone nor the breccia is present in the northeastern limb, but the latter may be represented by a thin sandstone of very similar appearance to the breccia matrix. In the Muhigan Creek anticlinorium the breccia is overlain by over 20 feet of similar but coarser sandstone, with occasional phenoclasts which decrease in abundance towards the top.

The uppermost part of the Old Fort Point formation consists of about 150 feet of silty greenish argillites which become arenaceous near the apparently conformable contact with the overlying Miette formation. Dark bluish grey siliceous nodules, up to 10 inches in diameter,occur in a 10-foot zone near the middle of this unit. The association of chlorite, muscovite, quartz and albite continues in these strata, but the sands at the top are much richer in biotite than any other rock-type in the formation

Miette formation

The Miette formation is apparently divisible into a well exposed, primarily arenaceous lower part and a poorly exposed, primarily argillaceous upper part, both being about 2500 feet thick. Although the upper Miette has not been intensively studied, outcrops along Minaga Creek indicate that the dominant lithology is a bluish grey to greenish grey argillite.

The lower Miette formation consists of a large number of lenticular arenaceous and argillaceous units up to 300 feet thick, which often have gradational contacts. The arenaceous units are ridge-forming and well exposed, but the argillaceous ones are recessive and extensive outcrops are found mainly along road and railway cuts. The arenaceous units consist of sandstone, pebble-conglomerate, and some interbeds of silty argillite and argillite. Individual beds are rarely traceable more than 50 feet along strike. Graded bedding of the waning-current type is characteristic of most beds and consists of two kinds. The first involves a gradual decrease in grain size from the bottom to the top of a bed, which is usually between 3 and 6 feet thick. The second or discontinuous type is more common and involves up to four sudden reductions in grain size between the base and top of the bed. Beds with these characteristics range from 2 to 12 feet and the grain size units between 1 inch and 6 feet thick. Cross stratification is common in the Miette sandstones, with individual sets being 6 inches to 3 feet thick and 3 to 20 feet long. The attitudes of the sets suggest that the general stream flow was southwest. Load-casting commonly occurs where fine sandstones are overlain by several feet of pebble-conglomerate. The average cast width is about 1 foot, and downslope slumping has distorted some casts into flow-casts. Assuming that the peak of the flow-casts originally pointed up-slope, the depositional surface dipped southwest. Examples of scour-and-fill structures, ripple marks and pene-contemporaneous folding have also been found. Sandstones and conglomerates of the Miette formation are both usually greenish grey. Sorting is poor to moderate, and a slight increase in sorting with decrease in grain-size is discernible. The size range is from clay to pebbles 30 mm. in diameter, with an average of coarse sand. Angularity varies from sub-rounded for some pebbles to angular for most sand-sized grains. The mineralogical composition is quite consistent in both sandstones and conglomerates, with quartz averaging 65 per cent, mica 15 per cent, carbonate 10 per cent, albite 10 per cent, and accessory minerals (zircon, tourmaline, apatite, rutile, ilmenite, and magnetite) less than one per cent. Disregarding the carbonate the average composition of the rocks is that of a feldspathic greywacke. Argillite rock-fragments, usually parallel to bedding, are present in some conglomerates and coarse sandstones, and may be as large as 2 feet in diameter and 6 inches thick. In a few lenticular beds they make up more than 30 per cent of the rock. Authigenic pyrite cubes, ranging from microscopic to 3 inches wide, are common as scattered clusters. Exposed pyrites are usually badly weathered, and may be completely destroyed to form the patches of iron stain apparent in many outcrops. Most unweathered pyrite crystals have a recrystallized quartz rim and contain many rounded quartz inclusions. Growth of the pyrite apparently took place mainly by replacement of pressure-dissolved minerals other than the quartz grains, which were not able to dissolve as fast as the pyrite grew. Some apparently grew faster than the surrounding material dissolved, giving rise to compaction and wrinkling around the pyrite cubes.

The argillaceous units of the lower Miette formation consist of argillite and silty argillite, with some interbeds of siltstone, sandstone, and conglomerate up to 3 feet thick. Cross-stratification occurs in many of the fine sandstones and siltstones. Graded bedding is very common in varve-like beds from 1/10 inch to 1 inch thick. The base of a graded bed is usually olive-grey siltstone or silty argillite which grades up into dark or less silty argillite. Small-scale load-casting is not uncommon at the bottom of many graded beds. Fine-grained muscovite and chlorite make up most of the argillites, which have an extremely variable content of fine sand- and silt-sized quartz, averaging 15 per cent. Less than 5 per cent coarse-grained detrital muscovite is typically present, aligned with the bedding. Heavy varietal minerals are more abundant in the siltstones and silty argillites than in any other rocks in the Miette formation. Although cleavage is common, it is only rarely that enough muscovite and chlorite is present to cause a sheen.

Jasper formation

Comparatively few field or laboratory studies have been carried out on the Jasper formation, which is largely composed of coarse-grained sandstone and pebbly sandstone with subsidiary amounts of pebble-conglomerate. These rocks, although poorly sorted, do not contain nearly as much argillaceous and silty interstitial material as the Miette sandstones. Quartz is the dominant constituent, with up to 20 per cent feldspar, and limonite occurs sporadically. As the base the characteristic formational colour is yellowish grey, while higher in the succession reddish hues appear. At the top of the formation a series of grey argillites and dark grey and reddish carbonates occur, with algaloid structures common in the latter.

Depositional environment

Strata of the Old Fort Point formation may have been deposited under shallow-water marine conditions. The argillites at the base of the succession were either laid down some distance from land or at a time when only argillaceous material was available. The overlying beds may reflect a shallowing of the sea, if their purple colour is indicative of oxidizing conditions. The change to greens in the argillites interbedded with the succeeding limestones suggests less oxidizing conditions. Shallowing in the area of the Jasper anticlinorium may be indicated by the increase in siltstone towards the top of the basal Old Fort Point argillites. An incline in the depositional surface of the overlying beds is suggested by the presence of breccias (which may represent slumping), penecontemporaneous folding and sedimentary boudinage, while progressive shallowing of the sea is suggested by the increase in sorting of the siltstones. The 400 feet of strata between the bases of the lower breccia and dark blue argillites in the eastern part of Jasper anticlinorium are represented in the western part and in the other two anticlinoria by 60 feet of limestones and up to 200 feet of purple beds. The relationship between the two successions is not clear, but phenoclasts in the lower and upper breccias are of similar lithology to the lower and upper limestones respectively. The uniform lithology of the dark blue argillites suggests a return to quieter deposition throughout the entire area, perhaps in deeper water. The variation in thickness of the unit is, however, difficult to account for. The fairly uniform character and thickness of the quartzose limestone-breccia and its associated sandstones is difficult to explain other than by some kind of fairly rapid submarine downslope mass-movement. The limestone-phenoclasts probably came from within the area of deposition, since limestones of similar lithology underlie the breccia in the western part of the Jasper anticlinorium, but rounded sand grains probably came from a considerable distance to the northeast. Strata belonging to the upper Old Fort Point formation appear to record the transition from conditions represented by the dark blue argillites to those of the Miette formation.

Cross-stratification, waning-current graded bedding, lenticular beds and rapid lateral grain-size changes, all typical features of topset deltaic deposits, are present in the arenaceous units of the lower Miette formation. Except for a few occurrences of flow-casts, evidence of intrastratal flow and slumping is rare, so the site of deposition may have been quite flat. Interbedded argillites may have been deposited in interdistributary bays and lagoons. The argillite fragments present in sandstones and conglomerates are probably a result of flood redeposition of shale from dried up lagoonal areas or tidal flats. The poor sorting of these strata suggests rapid shallow-water marine deposition or fluviatile deposition, although the latter would probably have produced more cross-stratification than was observed. The angular nature of quartz and albite fragments in the Miette sands suggests rapid transportation and deposition of first cycle sediments derived from nearby. This feature contrasts with the rounded grains in the quartzose limestone-breccia of the underlying Old Fort Point formation.

The argillaceous nature of the upper Miette formation may reflect a deepening of the sea or non-availability of arenaceous sediment. The relatively homogeneous nature of the Jasper formation, together with the possible presence of algae in the carbonates, suggests shallow-water marine deposition.

Provenance

The existence of plutonic quartz and albite (probably originally calcic plagioclase and potash feldspar) in both the Old Fort Point and Miette formations suggests igneous and metamorphic rocks in the source-area. Composite grains of stretched quartz form the only metamorphic rock-fragments present. There are no detrital minerals from metamorphic rocks. The angularity of the quartz grains suggests that sedimentary rocks were absent from the source-area, while the angularity and coarseness of the grains may be indicative of a short period of transportation from source. Cross-stratification and flow-casts indicate that the source lay to the northeast, and thus within the metamorphic and igneous rocks of the Canadian Shield and its easterly extension under the interior plains.

Age and Correlation

The Old Fort Point, Miette and Jasper formations were deposited either in upper Precambrian or Lower Paleozoic times. Collet & Parejas (1932, p. 47) have suggested that the carbonates now placed at the top of the Jasper formation are upper Precambrian in age, and that the overlying quartzites now assigned to the Cavell formation are Lower Cambrian. If this is the case, the Old Fort Point, Miette and Jasper formations are all upper Precambrian in age.

The Old Fort Point formation is lithologically similar to the lower part of the Bow Valley Hector formation (Walcott, 1910, p. 428) which contains green and purple argillites, siltstones, limestone-breccias and quartzose limestone-breccias. Since the Jasper formation is lithologically similar to the lower part of the overlying St Piran formation, the Miette formation is apparently correlative with the upper Hector, which consists of comparable argillites. It thus appears that the uplift to the east responsible for the influx of sand after Old Fort Point time, was confined to the north. Structural remnants of the landmass involved may be represented by the Peace River High.

TECTONICS

The Precambrian strata of the Jasper-Geikie region are situated in the Pyramid thrust-sheet. The Pyramid thrust, which forms the boundary between the Main and Eastern ranges, can be seen in the south bank of Pyramid Creek, 1/4 mile northwest of the railway, where it strikes about north 60 degrees west and dips about 45 degrees southwest. The fault, which has a stratigraphic throw of about 10,000 feet, appears to flatten farther north (Collet & Parejas, 1932, p. 47). Movement along the thrust and deformation of the rocks within the thrust-sheet are both assumed to have taken place during the Lower Tertiary Laramide orogeny.

While the younger, more competent beds of the Jasper and Cavell formations are usually gently dipping, the older and less competent strata of the thrust-sheet are displayed in a seriesof tight anticlinoria, each of which consists of a number of minor anticlines and synclines cut by a number of faults. Within the Old Fort Point formation the maximum horizontal distance separating successive anticlines is about 1500 feet, and the maximum structural relief 1000 feet. Corresponding values for the Miette formation are 2500 and 3500 feet respectively. Folds of this magnitude appear to be absent from the Jasper and Cavell formations outside the map-area. The axial planes of all folds, which are often overturned to the northeast, trend northwesterly and generally dip steeply southwest.

Flow-cleavage is well developed within the argillites of the Old Fort Point formation and, to a lesser extent, in the more silty ones of the Miette formation. Since the orientation of the local stress-field to the argillites is controlled jointly by the attitude of the regional field, the dip of bedding, and the proximity of interbedded competent strata, the attitude of flow-cleavage is highly variable. Examples of fracture-cleavage, cleavage-boudinage and jointing are abundant.

Jasper anticlinorium

The Old Fort Point strata in the core of the Jasper anticlinorium are enveloped by Miette beds, while the Jasper formation occurs on the northeast limb. Northwest of the Athabasca River the anticlinorium trends about north 70 degrees west and plunges gently northwest. Southeast of the river the trend is north 48 degrees west and the plunge is southeasterly at the limits of the map-area. On the northeast limb of the anticlinorium, west of the Athabasca River, steep northeasterly dips predominate in the sandstones and conglomerates of the Jasper formation (the structure is undoubtedly more complex than shown on the map). East of the river the outcrop of these strata is displaced to the south, with carbonates, argillites and quartzites belonging to the upper part of the Jasper formation appearing between them and the Pyramid thrust. All outcrops of the Jasper formation east of the river dip comparatively gently southwest. The dissimilarity in structure across the valley is attributed to a southwesterly trending wrench-fault, the surface trace of which is unknown. This fault probably developed contemporaneously with other structures in the area and terminates downwards against the Pyramid thrust. It does not appear to cross the axis of the Jasper anticlinorium.

Rathlin Lake synclinorium

For most of its length the axial trace of the Rathlin Lake synclinorium lies in the lower Miette formation, although strata presumed to belong to the upper part of the formation appear in the extreme northwest. Its trend is sigmoidal, ranging from north 75 degrees west in the west, through north 55 degrees west, to north 70 degrees west in the southeast. The plunge is northwesterly in the northwest and southeasterly to horizontal in the southeast.

Muhigan Creek anticlinorium

The complex Muhigan Creek anticlinorium is located mainly in the lower Miette. In the northwest, however, these strata plunge beneath argillites belonging to the upper part of the formation, while to the southeast Old Fort Point strata appear. The average trend of the fold is about north 60 degrees west. For most of its length the plunge is northwesterly, although in the extreme southeast it appears to be southeasterly. The fold appears to decrease in magnitude towards the northwest, where it may merge with the Muhigan Creek and Minaga Creek synclinoria.

Minaga Creek synclinorium

The axial trace of the Minaga Creek synclinorium lies in the Miette formation. Although the plunge is apparently consistently northwest, the strike changes from about north 70 degrees west in the southeast to about north 50 degrees west in the northwest.

Meadow Creek anticlinorium

The complex Meadow Creek anticlinorium is as yet incompletely mapped and imperfectly understood. It exposes strata belonging to the Old Fort Point and Miette formations, which strike at about north 40 degrees west and plunge northwesterly. The structure is unusual in the occurrence of normal faulting and in the widespread occurrence of relatively gently dipping overturned strata in the northeast limb. Although the age of the normal faults is not known, the similarity of associated veins to those occurring elsewhere in the map-area suggests that faulting took place soon after the compressional phase of the Laramide orogeny.

METAMORPHISM

The Old Fort Point and Miette formations are within the quartz-albite-muscovite-chlorite subfacies of the greenschist metamorphic facies. Calcite and siderite apparently were stable during metamorphism, although recrystallized. The stability of quartz and albite is indicated by numerous overgrowths. The albite was probably formed, mainly by alkali metasomatism, from detrital potash and plagioclase feldspars, but some authigenic growth may have occurred in such favourable environments as the limestones of the Old Fort Point formation. Chlorite and

PLATE I

PRECAMBRIAN GEOLOGY OF THE JASPER-GEIKIE AREA

muscovite, the major constituents of the argillites and phyllites, form both a fine-grained groundmass and interleaved books up to 0.4 mm. in diameter. The books apparently resulted from the expansion and alteration of detrital biotite flakes.

The presence of quartz, albite, chlorite, and calcite in veins clearly indicates their stability during this phase of metamorphism. Veins in the Miette formation average about 80 per cent quartz, 10 per cent calcite, 10 per cent chlorite, and less than one per cent albite. Calcite and chlorite, though usually scattered throughout the veins, often occur in pods, singly or together. Veins in the Old Fort Point formation have about 65 per cent quartz, 30 per cent calcite, and 5 per cent chlorite, except near thrust faults, where quartz increases to 80 per cent and calcite drops to 15 per cent. Some evidence suggests that more than one period of veining, and some post-veining deformation, may have occurred.

REFERENCES

Allan, J.A., Warren, P.S. and Rutherford, R.L., 1932, "A Preliminary Study of the Eastern Ranges of the Rocky Mountains in Jasper Park, Alberta", Trans. Roy. Soc. Canada, Ser. 3, Vol. 26, Sec. 4, pp. 225-248.

Charlesworth, H.A.K. and Remington, D.B., 1960, "Precambrian Rocks in the Vicinity of Jasper, Alberta", Edmonton Geol. Soc., 2nd Ann. Field Trip Guidebook, pp. 11-18.

Collet, L.W. and Parejas, E., 1932, "Resultats de l'Expedition Geologique de l'Universite de Harvard dans les Montagnes Rocheuses du Canada (Jasper National Park), 1929", C.R. Soc. Phys. Hist. Natur. Geneve, Vol. 49, pp. 36-64.

McEvoy, J., 1901, "Report on the Geology and Natural Resources of the Country Traversed by the Yellowhead Pass Route from Edmonton to Tete Jaune Cache", Geol. Surv. Canada, Ann. Rept., 1898, Vol. 11, 44 pp.

Walcott, C.D., 1910, "Pre-Cambrian Rocks of the Bow River Valley, Alberta, Canada", Smithsonian Misc. Coll., Vol. 53, No. 7, pp. 423-431.

-------------, 1913, "Cambrian Formations of the Robson Peak District, British Columbia and Alberta, Canada", Smithsonian Misc. Coll., Vol. 57, No. 12, pp. 328-343.

ROCKY MOUNTAIN FRONT RANGES ALONG THE ATHABASCA VALLEY, JASPER NATIONAL PARK, ALBERTA (1)

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ABSTRACT

Strata exposed in Athabasca Valley, Alberta, range from Precambrian to Cretaceous in age. Lower Palaeozoic beds include the Lower Cambrian Gog formation, an interbedded shale and carbonate unit, Titkana and Pika formations of Middle Cambrian age, the Middle and Upper Cambrian Arctomys formation and the Upper Cambrian Lynx formation. Ordovician Chushina formation occurs in the southwest. Units above the Arctomys formation are progressively truncated from west to east beneath Devonian strata.

The area is subdivided tectonically into the Western Foothills, Eastern Front Ranges and Western Front Ranges, each containing two major thrust sheets, and Main Ranges. Available data suggest that the major thrusts remain separate at depth, and that regional decollement is absent. The geology of Athabasca Valley is outlined by two detailed maps and four cross-sections.

INTRODUCTION

Stratigraphy and structure of the Front Ranges along Athabasca Valley are outlined in this paper. Data were taken mainly from Geological Survey of Canada maps and reports of the Brule area (Lang, 1947), Miette (Mountjoy, 1960a, 1960b), Mount Greenock (Brown, 1952) and the Rock Lake and Snaring areas (Mountjoy, in press). Two maps with cross-sections illustrate the geology (Sheets 1 and 2, in pocket).

The Western Foothills and Eastern Front Ranges are shown on Sheet 1. Formations in the Miette area have been carried northwest, necessitating some revision of the southwest corner of the Brule area (Lang, 1947). Sheet 1 also illustrates the geology of the south end of the Bosche Range and its continuation across Athabasca Valley.

The remaining Front Ranges are shown on Sheet 2. Mapping units have been carried into the Jasper and Medicine Lake areas, largely by air photograph interpretation. Most formational contacts southwest of Snaring River and northwest of The Palisades are so interpreted, and thus require confirmation.

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Miette area was mapped during the summers of 1957 and 1958. The Snaring and Rock Lake areas were studied in 1959 and 1960, with work continuing in the former in 1961.

The capable help of numerous student assistants is very gratefully acknowledged. The writer is also grateful to W. MacKinnon, P. Smyth, J. Hargreaves and T. McCready for assistance with camps and pack horses, and for friendly assistance from Park Superintendents and Wardens. The writer is indebted to D.W. Gibson for assistance in re-drafting and compilation of maps and cross-sections.

PREVIOUS WORK

Reconnaissance mapping of Athabasca Valley was carried out by McEvoy (1900), Collet and Parejas (1932), and Allan et al (1932). More detailed mapping has been done by Dowling (1911, 1912), Lang (1947), MacKay (1929, 1955), Brown (1952), and recently by Mountjoy (1960, and in press), O'Brien (1960), and Ziegler (1960). A group of University of Alberta graduate students, under the direction of H.A.K. Charlesworth, are mapping and describing Precambrian rocks in the vicinity of Jasper (Charlesworth and Remington, 1960, Charlesworth, Evans and Stauffer, this volume).

STRATIGRAPHY

A stratigraphic summary is provided on Figure 1, and only some important observations are discussed here. For more detail the reader is referred to maps and reports by the writer, published or in press. There is a general southwest increase in age of exposed rocks across the area. Mesozoic rocks are mainly restricted to the Foothills and Eastern Front Ranges. The Front Ranges consist largely of Palaeozoic strata with some Jurassic and Triassic. Cambrian beds are restricted to the lower parts of the Miette, Colin and Chetamon thrust sheets and the region west of the Pyramid thrust. Several distinct mappable units occur in the Cambrian, and names for some of these have been extended from the Mount Robson and Upper Bow Valley districts (see Mountjoy, in press, for discussion and suggested correlations). These stratigraphic names have not been formally approved by the Geological Survey and are subject to revision.

Precambrian?

Miette group

The oldest rocks in Athabasca Valley occur southwest of the Pyramid thrust near Jasper. They have been variously referred to as Miette sandstones (Walcott, 1913), Jasper series (Allan et al 1932) and Hector formation (Hughes, 1955). Miette formation was proposed by Walcott (1913)

FIGURE 1 - TABLE OF FORMATIONS

ERA	PERIOD OR EPOCH	GROUP OR FORMATION (MAP UNIT)	LITHOLOGY	THICKNESS (FEET)
MESOZOIC	Lower Cretaceous	Luscar Formation KL	Sandstone, fine grained; greenish grey siltstone; shale; coal.	2,000 ±
		Cadomin Formation	Conglomerate, chert & quartzite.	10 to 30
		Disconformity		
	Lower Cretaceous and Jurassic	Nikanassin Fm Jn	Sandstone; siltstone; silty mudstone dark grey.	1,000 to 2,000
	Jurassic	Fernie Group Jf	Shale, black and dark grey, concretionary; all members present.	700 to 900
		Disconformity		
	Triassic	Whitehorse Fm Tw	Carbonate, light grey breccias, red mudstone, gypsum.	100 to 1,500
		Sulphur Mountain Fm Ts	Siltstone, dark brown grey; thin bedded silty mudstone.	600 to 1,000
		Disconformity ?		
PALAEOZOIC	Permian and/or Pennsylvanian	Rocky Mountain Group	Massive grey chert; cherty brown sandstone.	0 to 220
	Mississippian	Disconformity		
		RUNDLE GROUP: Formation D	Dolomite, dense, cherty, medium bedded.	250 to 400
		RUNDLE GROUP: Formation C	Dolomite, brown, porous, coarse grained.	150 to 400
		RUNDLE GROUP: Formation B	Limestone, dark grey, fine grained, thin bedded.	200 to 360
		RUNDLE GROUP: Formation A	Limestone, light grey, crinoidal, coarse grained, thick bedded.	115 to 300
		Banff Formation Bf	Limestone and calcareous shale, dark brown, thin bedded.	500 to 760
		Disconformity		
	Devonian	Palliser Fm Dp	Limestone, dark grey, massive, fine crystalline, dolomitic.	700 to 900
		Alexo Formation	Sandstone, fine grained; siltstone, silty shale, silty carbonates.	10 to 600
		Mount Hawk & Perdrix Fms Dm Dx	Limestone, brown grey, argillaceous; shale, dark grey, fissile.	550 to 1,100
		Southesk Fm Ds	Limestone, light grey, fine crystalline, medium-bedded.	0 to 650
		Cairn Fm Dc	Carbonate, brown, fine to medium crystalline with stromatoporoids.	0 to 900
		Maligne & Flume Fms F	Limestone, dark grey, thin-bedded, argillaceous. Limestone, dark brown, cherty.	150 to 250
		Unconformity		
	Lower Ordovician	Chushina Fm O	Limestone; calcareous shale; greenish-grey intraformational conglomerate.	0 to 700
	Upper Cambrian	Lynx Fm Єl	Carbonates, silty, thin-bedded, agillaceous; intraformational conglomerate.	0 to 2,400
	Upper and/or Middle Cambrian	Arctomys Fm Єa	Shale, silty, red and green; siltstone, brown.	600 to 800
	Middle Cambrian	Disconformity ?		
		Pika Fm Єp	Limestone, calcareous, shale, thin-bedded.	500 to 700
		Titkana Fm Єt	Limestone, dark grey, massive dolomitic.	500 to 800
		Shale Unit Єs	Shale, green and red; argillaceous limestone. Limestone, dark grey, resistant.	1,400 to 1,800
	Lower Cambrian	Gog Formation Єg	Sandstone, light grey; quartz, cross-bedded, fine to coarse grained, massive.	4,000
?		Disconformity ?		
P-Є		Miette Group M	Shale & phyllite, grey; sandstone, conglomatic, poorly sorted; carbonate, arenaceous, with algal (?) markings	5,500 +

for a series of massive, grey sandstones with interbedded shales beneath Lower Cambrian quartz sandstones in the vicinity of Yellowhead Pass. Jasper series was put forward by Allan et al (1932) for a similar series of quartzites, argillites, sedimentary breccias and slates with numerous conglomerate beds underlying Lower Cambrian sandstones near the foot of Pyramid Mountain near Jasper. There appear to be more similarities than differences between the strata at Pyramid Mountain and those near Yellowhead Pass. The term Miette consequently appears to have priority and is used here. In a report (Mountjoy, in press) Miette has been raised to group status and redefined to include all strata exposed beneath Lower Cambrian quartz sandstones in the Mount Robson district and adjoining parts of Jasper National Park, including the area near Jasper townsite.

For descriptions of the Miette group see Charlesworth & Remington (1960), Charlesworth, Evans & Stauffer (this volume) and Mountjoy (in press).

Cambrian

The Cambrian is poorly exposed in Athabasca Valley, but to the northwest can be divided into six mappable units. These are the Lower Cambrian Gog formation, the Middle Cambrian Shale Unit, Titkana and Pika formations, the Middle and Upper Cambrian Arctomys formation and the Upper Cambrian Lynx formation. Middle Cambrian formations thin to the northeast and the lower part becomes more argillaceous. Upper Cambrian is progressively truncated to the east at the sub-Devonian unconformity.

Lower Cambrian:

Gog formation

As with the Miette group, this thick, quartzose sandstone unit of Jasper Park area has been variously named. It has been referred to the Cavell formation or quartzite near Jasper (Raymond, 1930, p. 293) and to the Jonas Creek formation near Sunwapta Pass (Hughes, 1955). Near Mount Robson a distinctive carbonate and shale unit called the Mural formation divides equivalent sandstones into lower McNaughton and upper Mahto formations (Walcott, 1913, 1928, and Burling 1923, 1955). Correlative Lower Cambrian sandstones near upper Bow Valley have been named Gog formation (Deiss, 1940). Okulitch (1956) extended the Gog formation to the Lake Louise area.

The Lower Cambrian quartz sandstones of northern Jasper Park are assigned to the Gog formation because they occupy a corresponding stratigraphic position and can be traced northwest from Lake Louise to Jasper beneath Middle Cambrian carbonates east of the Banff-Jasper highway.

The most accessible sections of Gog formation near Jasper are at Mount Edith Cavell and Mount Kerkeslin. The lower part of the formation is well exposed at Athabasca Falls and on Pyramid Mountain. The upper part is exposed in the hanging-wall of the Chetamon thrust and outcrops may be examined beside the creeks on the southeast side of Chetamon Mountain.

In exposures northwest of Athabasca Valley the Gog formation consists of fine to coarse-grained, clean, quartzose, cross-bedded, very light grey sandstones. The formation coarsens towards the base, with chert and quartz pebbles one-half to one inch in diameter. These are associated with grains of feldspar. West of Blue Creek on the Snake Indian River graphic measurements indicate that the Gog formation is about 4,000 feet thick. It is of similar thickness in The Ramparts and Mount Edith Cavell.

Middle and Upper Cambrian Formations:

The most accessible outcrops of Middle and Upper Cambrian strata occur on Roche Miette and Chetamon Mountain. On the ridge crest northeast of the summit of Chetamon Mountain the following sequence can be observed (See Appendix A). Gog formation forms the lowest saddle, and is succeeded by the Middle Cambrian Shale Unit with three thin resistant carbonate beds. The Titkana formation makes up the overlying thick resistant cliff. Pika occurs on the dip slope above and the Arctomys formation outcrops to the base of the next cliff, which consists of Lynx. The latter formation extends down the southwest side of the mountain.

A less complete section is present northeast of the summit of the Miette Range, where only the upper part of the Middle Cambrian Shale Unit and younger beds up to the Arctomys formation are exposed (map-unit 1, Mountjoy, 1960a). The Middle Cambrian Shale Unit can be better observed northwest of Miette Hotsprings. Titkana formation (map-unit 2, Mountjoy, 1960a) weathers to a prominent light grey ridge northeast of Roche Miette (Plate III), and is also well exposed on the southeast slopes of Roche Ronde in a series of narrow folds (see Dahlstrom, 1960, Figure 5). Pika and Arctomys formations form a recessive orange to red weathering interval and are grouped together on Sheet 1 (map-unit 3, Mountjoy, 1960a). The Arctomys is overlain by Devonian Flume formation, and the Upper Cambrian Lynx formation is absent due to pre-Devonian erosion.

With the introduction of Mount Robson and Bow Valley area nomenclature, the Bosche, Chetamon and Snaring formations proposed by Raymond (1930) for the Mount Chetamon and Roche Miette sections appear to be superfluous.

Middle Cambrian:

1) Shale Unit

This map-unit lies conformably on the Gog formation and consists of recessive weathering greenish grey shales with several resistant limestone interbeds 25 to 200 feet thick. On Chetamon Mountain the unit totals 1386 feet.

Fossils of the Albertella zone appear to occur in the lower third, and of the Glossopleura zone in the middle part of this unit. The lowest beds may be early Cambrian, as Olenellus was collected elsewhere at one locality.

II) Titkana formation

The massive dark grey Titkana limestones (Walcott, 1913) are crypto-to microcrystalline. Prominent thin bands or laminae of dolomitic and/or argillaceous carbonate occur on the weathered surface. The formation varies from 400 feet at Miette Range to over 800 feet at, and northwest of, Chetamon Mountain. No fossils have been found in it in the Athabasca Valley area.

III) Pika formation

The Pika (Deiss, 1939) is a recessive weathering series of limestone, argillaceous limestone and shales with individual units 10 to 40 feet thick. The limestones contain thin intraformational conglomerates and abundant trilobite fragments. The formation in this area appears to be more argillaceous than at the type section north of Mount Eisenhower (Deiss, 1939). It varies from about 200 to 300 feet in the Miette Range to between 500 and 700 on Chetamon Mountain and the mountains to the northwest.

Fossils are abundant at several horizons, and according to Dr. B.S. Norford of the Geological Survey of Canada, are a previously undescribed assemblage related to the Thompsonaspis and later pre-Cedaria faunas (Denson, 1942).

Middle and Upper Cambrian:

Arctomys formation

Strata of the Arctomys formation (Walcott, 1920) form a distinct mapping unit, since they weather light yellow to orange, and contrast with the greys of other Cambrian formations. The beds consist of red and green, silty shales and siltstones. The latter are often finely laminated, cross-bedded and ripple marked. Salt crystal casts are prominent near the middle of the formation. The Arctomys formation has a thickness of about 700 feet. It is a most useful marker horizon for mapping purposes.

Upper Cambrian:

Lynx formation

The Lynx formation (Walcott, 1913) outcrops near Highway 16 on the low ridges at the base of The Palisades and also east of Cold Sulphur Spring. It consists of light grey to brown, fine grained, heterogeneous carbonates, of varying argillaceous, silt and sand content. Finely laminated and cross-bedded silty dolomites are common and so are intraformational conglomerates, particularly near the top and base of the formation.

The Lynx formation is typically cliff forming and makes the crest of the range northwest of Chetamon Mountain. Occasionally it is narrowly folded and more recessive. Two thousand four hundred feet were measured near Mount Strange. This is nearly half the thickness of the type section on Rearguard Mountain (Burling, 1955).

A few trilobite fragments collected northwest of the Athabasca Valley suggest a late Cambrian Dresbachian stage for the lower part of the Lynx formation. Fossils are however, rare in the formation.

In the western Front Ranges of Jasper Park the age of unfossiliferous pre-Devonian carbonates has been in doubt. These strata have lithologic characteristics similar to the Lynx formation and occupy a comparable stratigraphic position and have been so mapped.

Lower Ordovician

Chushina formation

A prominent recessive weathering interval occurs beneath Devonian beds and above the Lynx formation at the foot of The Palisades. This unit is assigned to the Chushina formation (Walcott, 1923) because it has similar lithology and fauna, and occupies the same stratigraphic position as type Chushina. It consists of thinly interbedded greenish grey, argillaceous limestone and calcareous shale. The upper part includes some resistant weathering carbonates. Intraformational conglomerates are also common. The formation is about 700 feet thick on The Palisades.

Early Ordovician fossils (Canadian) have been collected near Swift's ranch (see Sheet 2) by both Kindle (1929) and the writer, and along strike near Beaver Lake by Harker et al (1954). The Chushina formation appears to be stratigraphically equivalent to the upper half of the type Mons formation (Walcott, 1928) at Glacier Lake.

Sub-Devonian Unconformity

This is a major unconformity of considerable interest and importance. Along the mountain trend it generally remains within the same stratigraphic zones. In contrast, northeast across the strike from Chetamon Mountain this unconformity gradually truncates about 3000 feet of Lower Ordovician and Upper Cambrian strata, until in the Bosche and Miette Ranges Devonian carbonates rest on the Arctomys formation.

Devonian

Devonian strata are not discussed fully. The Maligne formation, proposed by Taylor (1957, p. 190) with type section at Cold Sulphur Spring, is a useful and widespread unit. Due to its thinness it has been combined with the Flume (revised) formation on the accompanying maps. DeWit and McLaren (1950) published a description of the Devonian near Cold Sulphur Spring and at adjacent Morro Peak and Mount Hawk.

The interesting and thick succession of silty and argillaceous carbonates referred to the Alexo formation by DeWit and McLaren (ibid) are easily accessible near Highway 16, where the contact with the overlying Palliser is sharp. Just south of the highway an outcrop of basal Alexo occurs where the silty carbonates form a large irregular 'flow fold'. It appears probable that the sediments were slumped when semi-consolidated. The contact with underlying Mount Hawk is covered.

The Alexo formation southeast of the Ancient Wall carbonate complex in the Colin and Chetamon thrust sheets is relatively thick. Stratigraphic relationships with the thinner Alexo in the Eastern Front Ranges is not known. Orr (1960) concludes that silts of Alexo type were deposited in upper Mount Hawk time, but several interpretations are feasible and no unique solution is possible. (Mountjoy, in press).

The southeast transition to a clastic facies of the Ancient Wall carbonate complex, which can be divided into Southesk and Cairn formations, occurs on Mount Haultain, northwest of Mount Rowand and immediately southeast of the Rajah (Mountjoy, in press).

Carboniferous

Mississippian strata of Athabasca Valley are similar in many respects to Mississippian successions along the Foothills and Eastern Front Ranges to the southeast near Nordegg (Brady, 1958) and Moose Mountain (Illing, 1959). Brown (1952) has described Carboniferous stratigraphy and palaeontology between Chetamon Mountain and Mount Greenock. Unfortunately he did not distinguish dolomites from limestones, making it difficult in some cases to determine formational contacts. The Mount Greenock pipeline section (Plate IV) is redescribed in Appendix B.

The Carboniferous is divisible into three major units referred here to the Banff formation, Rundle group and Rocky Mountain group (see other papers in this volume for further discussion). The Rundle group can be divided into four subordinate carbonate units, here designated Formations A, B, C and D. Formation A, at the base, consists of massive, crinoidal limestone, Formation B of dark grey, thin-bedded, argillaceous limestone, Formation C of porous, massive, dolomitic limestone, which is partly crinoidal, and Formation D of dense, cherty dolomite. The upper contacts of Formations

A and C are gradational and could be diachronic.

Formations A and B are probably equivalent to the Pekisko and Shunda formations respectively near Nordegg and further south, while Formations C and D may be equivalent to the 'Turner Valley' and 'Mount Head' formations.

Brown's (1952) lower Greenock formation member is roughly equivalent to Formation D and his upper and middle members can be assigned to the Rocky Mountain group. The chert and cherty sandstones of the latter in Athabasca Valley closely resemble the upper 50 to 100 feet of the Ishbel formation (McGugan and Rapson, 1961) in the Rocky Mountain group of the Banff area.

Triassic

Triassic stratigraphy of eastern Jasper National Park has recently been summarized by Best (1958) and Manko (1960). The latter author's stratigraphic units can be applied in most of this area.

The Triassic is divisible into a lower Sulphur Mountain formation of brown silty shales, siltstones and fine-grained sandstones with some black shales, and the Whitehorse formation of light colored silty carbonates, solution breccias and multi-colored silty mudstones.

Few good Triassic outcrops occur near the highway. Some road cuts provide exposures east of Cold Sulphur Spring and southwest of Talbot Lake, and on the southwest limb of Folding Mountain anticline. There are excellent outcrops beside Fiddle River, where Sulphur Mountain and Whitehorse formations outcrop above the mouth of Morris Creek. Good outcrops also occur upstream from the junction with Sulphur Creek (see Mountjoy, 1960a).

Jurassic

Well exposed Jurassic sections in Fiddle River and Snake Indian Valleys have been described by Frebold (1957). Faulted sections along Rocky River opposite Makwa Ridge have been referred to by Frebold, Mountjoy and Reed (1960). The glauconite and glauconitic shales (Green beds) at the base of the Oxfordian are an important Jurassic marker horizon.

Cretaceous

Cretaceous formations are very poorly exposed over most of this area, and no complete undisturbed sections occur near the highway.

STRUCTURE

Athabasca Valley transects the Foothills, Front Ranges, and a portion of the Main Ranges, providing one of the most accessible and well exposed cross sections of the Alberta Rocky Mountains. Between eight and ten parallel, southwest-dipping thrust faults have broken the stratigraphic sequence into a series of major and minor thrust sheets (Figure 2). Two major thrust sheets occur in the Foothills, while four are present in the Front Ranges. The Miette thrust is designated as the boundary between the Foothills and Front Ranges, and the Pyramid thrust as that between the Front and Main Ranges (see Sheets 1 and 2 and cross-sections).

Western Foothills

The Foothills are divisible into an eastern part with moderately deformed Upper Cretaceous and younger strata (Lang, 1947, Mountjoy, 1960a), and a western part composed of complexly deformed Mesozoic and Upper Palaeozoic beds. Only the Western Foothills, which lie west of the Folding Mountain thrust, will be considered here.

Folding Mountain and Boule are two closely associated Western Foothills thrust sheets. They are joined by connecting thrust faults south of Athabasca Valley (Mountjoy, 1960a). Both sheets are laterally extensive and show transitional characteristics to Front Range structures.

Folding Mountain Thrust Sheet

Strata within this sheet form the prominent Folding Mountain anticline with a Devonian core (Sheet 1). A nearly normal stratigraphic succession occurs across the thrust trace for much of its length. However, Jasper No. 1 well, on the southwest flank of the anticline, penetrated Devonian Cairn Formation thrust over Lower Cretaceous at a depth of 4,900 feet (1,200 feet sub-sea), showing that considerable lateral displacement is, in fact, present.

Boule Thrust Sheet

The Boule sheet forms the Boule Range northwest of Brule Lake and the Fiddle Range (including Roche a Perdrix) south of Athabasca Valley. These are the most easterly Mountain Ranges at this latitude. The Boule thrust sheet continues northwest to become essentially part of the Nelson thrust sheet (Mountjoy, in press).

Along Athabasca Valley, where this thrust is well exposed, Devonian strata lie upon contorted Nikanassin beds. The general structure

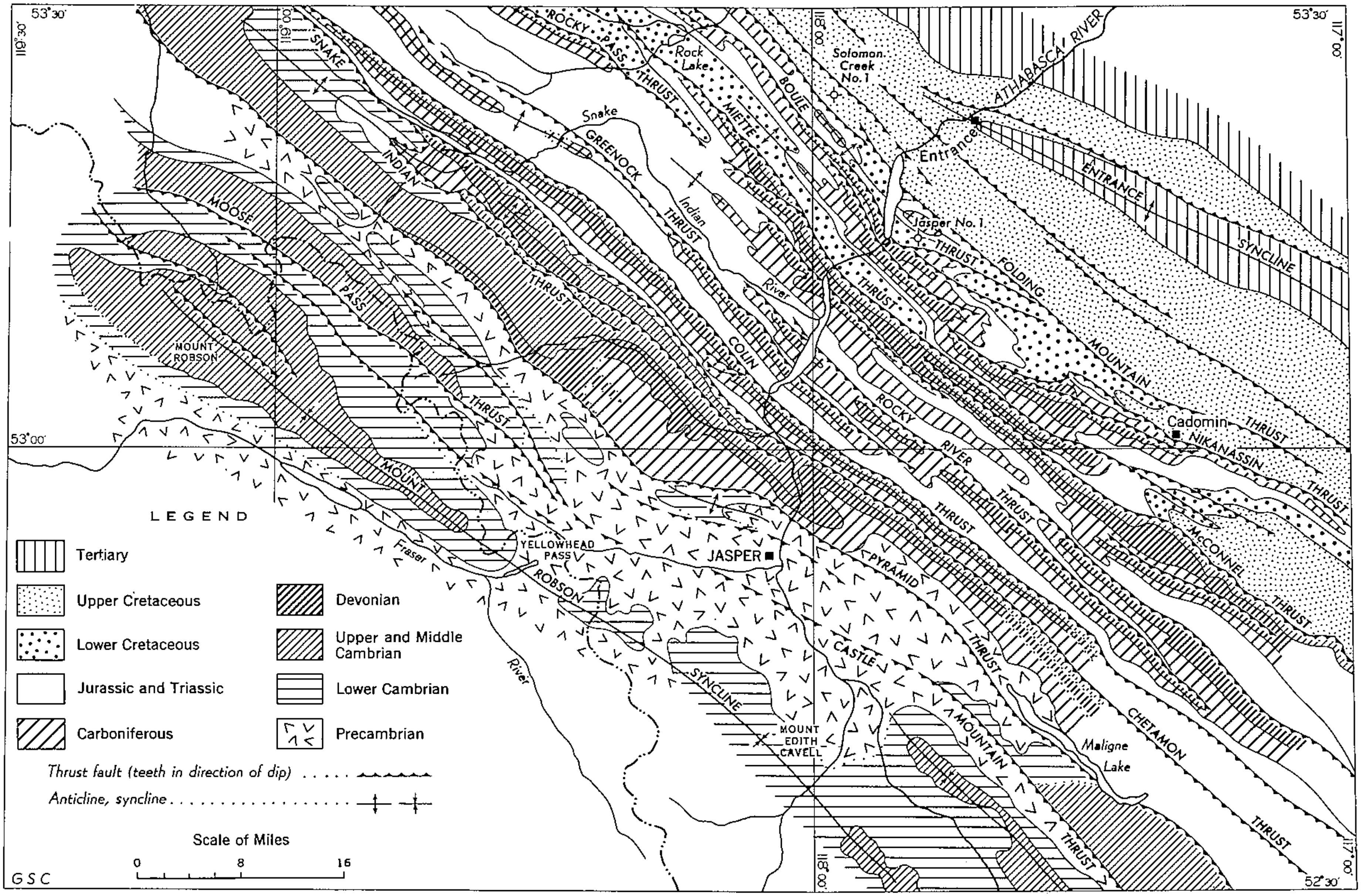

FIGURE 2 · REGIONAL STRUCTURE OF THE CENTRAL ALBERTA ROCKY MOUNTAINS AROUND JASPER is an anticline-syncline pair of folds, complicated by secondary thrusts, minor folds and disharmonic folding. Both folds are asymmetric and partly overturned to the northeast.

The Boule thrust dips at approximately 45° southwest beneath the southeast end of the Boule Range, but appears to be much steeper east of the Park gate. Further to the southeast on the ridge northeast of Roche a Perdrix, Rundle is flat-lying upon crumpled Nikanassin strata (Plate 1).

Near Boule Roche the thrust intersects younger strata in a southwest direction (Sheet 1 and Section A-B). Stratigraphic offsets and orientation of fold axes indicate that thrust sheets are displaced to the northeast relative to the foot-wall. The stratigraphic relationships along this part of the Boule thrust are, therefore, anomalous, and suggest that the thrust at least locally, truncated a pre-existing fold. This geometric relationship is unusual considering the general pattern of Foothills and Front Range thrusts.

It is probable that the Boule thrust intersects pre-Devonian strata at depth beneath the Perdrix anticline.

Ashlar Thrust

The southwest limb of the Perdrix anticline is repeated by the Ashlar thrust on both sides of Athabasca Valley, where this fault places Devonian, Mount Hawk or Perdrix above younger Upper Palaeozoic strata.

A striking southwest overfold (a fold with a northeast-dipping axial plane) named the Moosehorn Fold by Lang (1947), occurs in the Ashlar thrust sheet on the northwest side of Athabasca Valley. The structure is shown on Plate II and was well illustrated by Dahlstrom (1960). It is best observed from just west of Pocahontas on Highway 16.

The overfold can be seen to consist of two narrow anticlines with axial planes dipping at approximately 70° northeast. The southwest limb continues across the valley to the steep southwest-dipping Ashlar Ridge (Mountjoy, 1960a). The Moosehorn structure and adjoining syncline to the northeast are directly related spatially to changes in stratigraphic position of the underlying Ashlar thrust from a zone in the Cambrian to one in the Perdrix-Mount Hawk formations. Whether folding occurred before thrusting prior to folding cannot be determined. Folding and thrusting probably occurred together.

Front Ranges

The Front Ranges are divisible into the eastern Miette and Bosche Ranges underlain by the Miette thrust, the central Jacques and De Smet Ranges underlain by the Greenock thrust, and several western ranges including

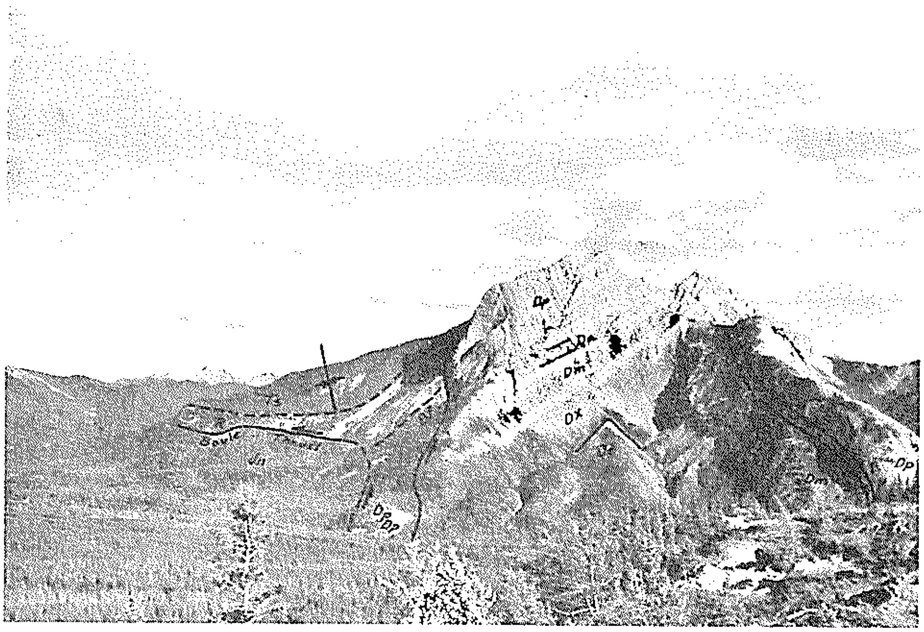

PLATE I - ROCHE A PERDRIX FROM SOUTH END OF BOULE RANGE, SHOWING DISHARMONICALLY FOLDED PERDRIX ANTICLINE AND POSITION OF BOULE THRUST.

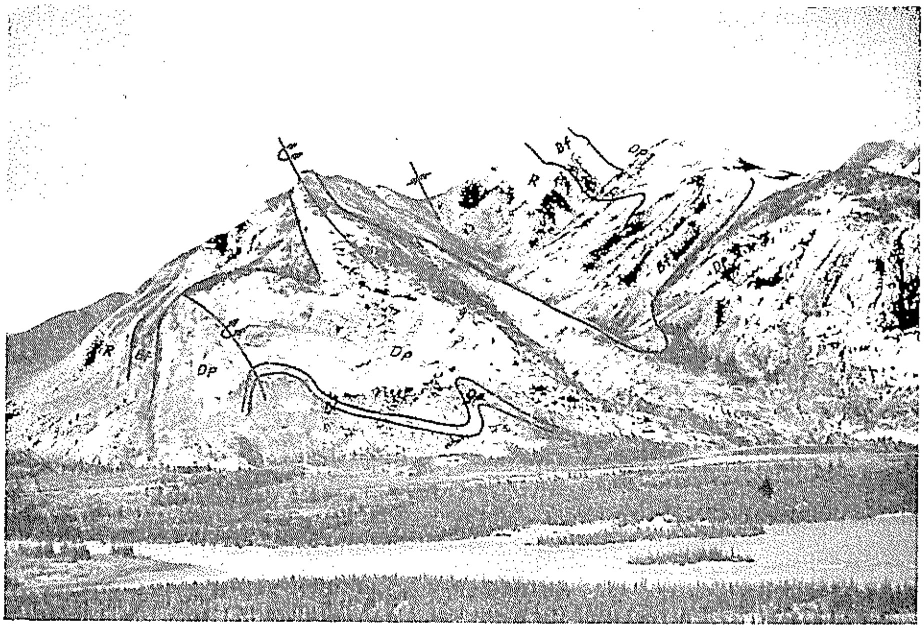

PLATE II - MOOSEHORN FOLD AND ASSOCIATED SYNCLINE IN HANGING WALL OF ASHLAR THRUST. NOTE NORTHEAST DIPPING AXIAL PLANES.

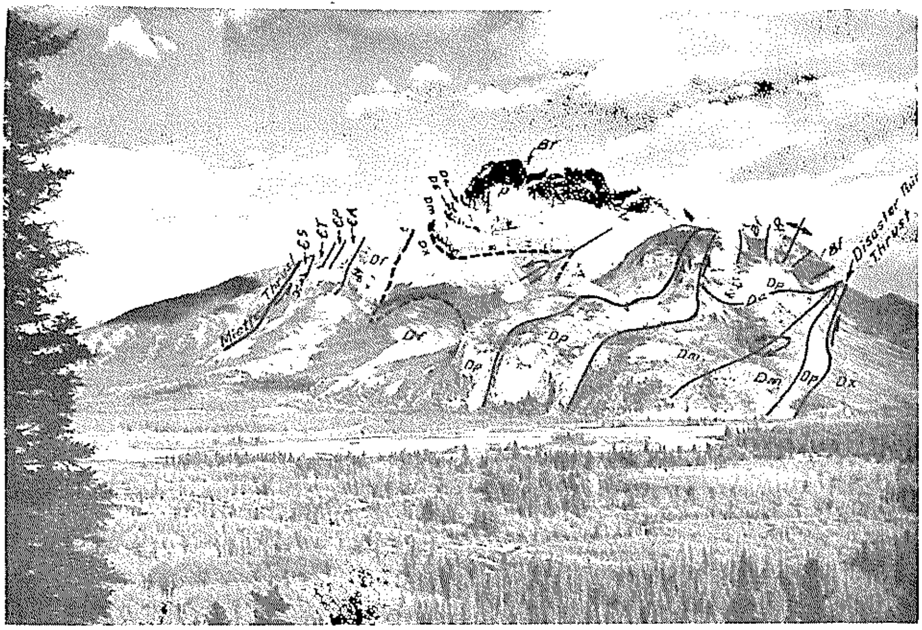

PLATE III - ROCHE MIETTE VIEWED FROM THE WEST-NORTHWEST SHOWING LOCATION OF MIETTE AND DISASTER POINT THRUSTS AND THE COMPLEX STRUCTURE BETWEEN THEM.

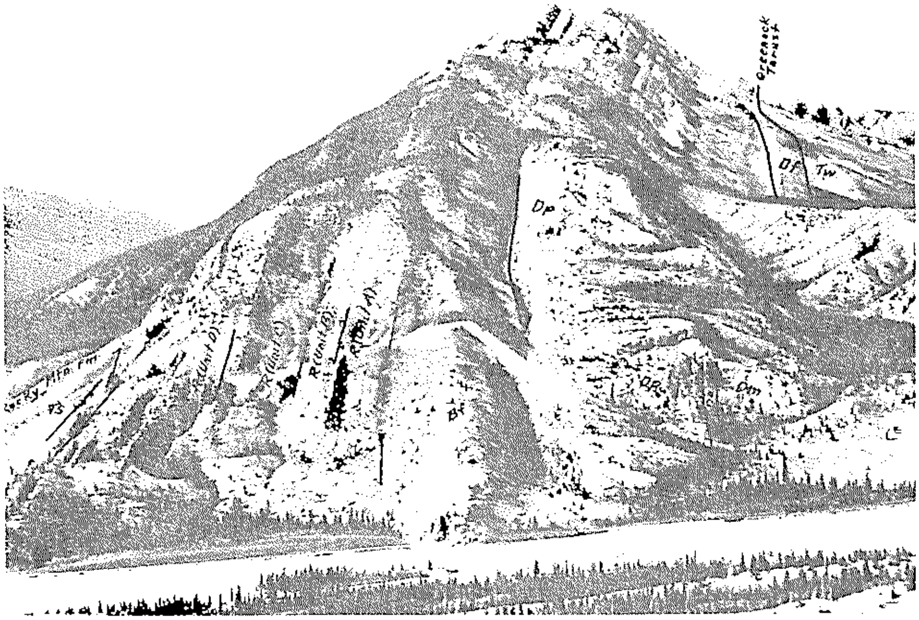

PLATE IV - MOUNT GREENOCK FROM ACROSS ATHABASCA VALLEY. PIPELINE RIGHT-OF-WAY, ALONG WHICH SECTION GIVEN IN APPENDIX B WAS MEASURED, IS VISIBLE ON LOW ONE THIRD OF THE MOUNTAIN. ACCESS ROAD RUNS NOT FAR ABOVE THE RIVER.

Colin and Victoria Cross Ranges, underlain by the Colin and Chetamon thrusts (Figure 2). Structures in the Victoria Cross Range plunge southeast to disappear beneath the Pyramid thrust north of Pyramid Mountain and in part are associated with the northwest termination of the Pyramid thrust.

Miette Thrust Sheet

This sheet is a continuation of the McConnell structural elements, although the trace of the McConnell thrust itself only extends as far north as Utopia Mountain near Miette Hot Springs (Mountjoy, 1960a). Roche Miette, Roche Ronde, and adjoining mountains provide excellent cross sections of the structure of the Miette sheet, which has been broken in two parts by the Disaster Point thrust. The latter fault slice underlies the southwest slopes of the Miette Range, and Roche a Boche and Coronach Mountain on the northwest side of Athabasca Valley.

The Miette thrust is not exposed near Athabasca Valley but probably occurs a short distance beneath the resistant Middle Cambrian Titkana limestone (Plate III). On the northeast spur of Roche Miette the thrust lies at about the middle of the Middle Cambrian Shale Unit. Southeast along Miette Range the thrust plane varies from near the base of the Shale Unit to within the overlying Titkana formation.

The Miette sheet is folded into an anticline-syncline pair with gradual northwest plunge. The folds are visible on both sides of Athabasca Valley. Disharmonic folding is obvious, since the Palliser syncline which forms the peak of Roche Miette directly overlies an anticline in Flume and older strata (Plate III and Sheet 1).

The Disaster Point thrust complicates the southwest limb of Miette anticline on the southwest side of the range. In some places four repetitions of Palliser formations may be observed. The foot-wall on Roche Miette is contorted into a paired anticline-syncline with northeast-dipping axial planes (Plate III). Similar dips in the associated thrust faults indicate that rotation occurred after most of the thrusting and folding had taken place.

The Miette and Greenock thrust sheets are topographically separated by Snake Indian and Rocky River Valleys. These valleys are underlain by the subordinate Makwa and Rocky River thrust sheets (Mountjoy, 1960a), which bring Mississippian rocks to the surface and are separated by a wide area of Fernie strata. The Snake Indian and Rocky Rivers have eroded channels in the softer Fernie rocks.

Greenock Thrust Sheet

In contrast to thrust sheets already discussed the Greenock sheet is essentially homoclinal, dipping at about 65° southwest (Plate IV).

Along much of its length the thrust occurs in either the Lynx or Flume formations. West of Mount Greenock a subordinate thrust repeats part of the Upper Palaeozoic succession.

Western Front Ranges

Colin Thrust Sheet

In the vicinity of Athabasca Valley the Colin thrust sheet is homoclinal and southwest dipping, like the Greenock sheet. Some structural complications occur to the northwest on Gargoyle Mountain where Devonian and Mississippian are repeated (Sheet 2). For much of its 175 mile length the thrust appears to follow a zone within the upper third of the Lynx formation.

Chetamon Thrust Sheet

On the northwest side of Athabasca Valley this is a homoclinal thrust sheet dipping 50° to 65° southwest (Section E-F). The thrust here faults upper Gog sandstones onto Devonian and Mississippian strata. Narrow folding, associated with a thrust fault which duplicates the Lynx formation on the southwest side of the range, occurs northwest of Chetamon Mountain. A subordinate thrust fault in the foot-wall repeats portions of the Devonian and Carboniferous strata.

The stratigraphic section and structure on the southeast side of Athabasca Valley are entirely different. No Lower or Middle Cambrian strata are present in the hanging-wall, and the basic structure is a large anticline-syncline pair. Northeast, at Roche Bonhomme, the Colin thrust occurs in the upper Lynx formation (Section G-H), about 5,000 feet stratigraphically higher than on the other side of Athabasca Valley. Obviously the thrust has changed stratigraphic position from a zone in the upper part of the Gog formation to one in the upper part of the Lynx formation. The anticline-syncline pair is spatially associated with this stratigraphic change in thrust position and is similar in this respect to the Ashlar fault slice.

The southwest slopes of The Palisades and the area to the immediate northwest have not been mapped in detail, but an overturned syncline of Devonian strata appears to be present beneath the Pyramid thrust (Section G-H). The Flume, Perdrix and Mt. Hawk outcrops on Highway 16, just east of the Jasper Lodge turnoff, are part of the overturned southwest limb of this syncline.

Main Ranges

Near Jasper the Main Ranges include Pyramid Mountain, parts of the Victoria Cross Range to the northwest, Maligne Range to the southeast, the Trident Range, the Ramparts, Mt. Edith Cavell, and other mountains to the south and west. The Main Ranges are in general less aligned than the Front Ranges and are underlain by much larger structures. Their most distinct feature is that they are mainly composed of Cambrian and Precambrian strata. They are deformed by several thrust faults west and northwest of Jasper (Figure 2), contrasting with the gently dipping and normal faulted strata of the Main Ranges near Lake Louise.

Pyramid Thrust Sheet

Pyramid Mountain comprises a nearly east-west trending anticline in Gog formation and Miette group. Miette strata are faulted over the southwest limb of this anticline near Elysium Pass. Northwest of Pyramid Mountain the Pyramid thrust apparently splits into two faults which rapidly decrease in stratigraphic throw to the northwest, and cannot be mapped beyond Buttress Mountain. This means that the Pyramid thrust sheet merges with the Chetamon thrust sheet and so cannot be considered a clear-cut boundary between the Front and Main Ranges (on Figure 2 the Pyramid thrust is incorrectly shown joining with another major thrust to the northwest).

Maligne Range southeast of Jasper appears to consist of Miette strata. In general, the mountain tops south and southwest of the Yellowhead road and Banff-Jasper Highway consist of Gog sandstones with the lower slopes and valleys underlain by Miette strata.

The detailed structure of part of Pyramid thrust sheet and related structures have been described by Charlesworth and Remington (1960), and Charlesworth, Evans & Stauffer (this volume).

Structural Interpretation

As already shown, the Foothills and Front Ranges in Athabasca Valley consist of six major thrust sheets, all of which dip moderately to steeply southwest. The three eastern sheets (Folding Mountain, Boule and Miette) are complexely faulted, with disharmonic folding and overfolds. This relative increase in folding to the east is largely related to the stratigraphic sequence there. As a result of pre-Devonian erosion, there is a close association of incompetent Devonian Mount Hawk and Perdrix formations with relatively incompetent Cambrian formations, compared with the Cambrian beds present further west (see Cambrian stratigraphy). The western thrust sheets (Greenock, Colin and Chetamon), overlain by more competent Cambrian beds, are homoclinal in character, with southwest dip generally greater than 60°.

In no cases can the stratigraphic position of any of these thrusts at depth be predicted with certainty. Some folded thrusts indicate that they gradually intersect older strata southwest across strike.

Many of the thrust faults of this region appear to follow specific stratigraphic zones. The Miette thrust occurs within or near the thick Middle Cambrian Shale Unit for approximately 32 miles. The Greenock thrust lies in upper Cambrian Lynx formation for about 11 miles, and the Colin thrust appears to be located in the middle to upper third of that formation for almost 200 miles. Middle Lynx is the horizon followed by the Chetamon thrust for about 80 miles southeast of Athabasca Valley, but the thrust also lies in upper Gog formation. Of the six major thrust faults of Athabasca Valley only the Miette thrust can be shown to occur largely in the Middle Cambrian Shale Unit, contrary to statements by O'Brien (1960). (In discussing the horizons at which thrusting occurs it should be remembered that the Lynx formation is approximately 2,500 feet thick, so that these zones can only be accurately determined when the formational stratigraphy has been worked out in detail).

The Athabasca Valley structures have many characteristics in common with those of Southern Alberta, and these thrust sheets are probably similar at depth. The sheets differ from those in the Southern Alberta Rockies in their steep dip and are complicated by disharmonic folding and rotation. Surface observations and limited drilling in the Jasper area suggest that most of the major thrust sheets remain separate and superimposed at depth. This interpretation differs from O'Brien's (ibid) suggestion of a regional decollement beneath all the Front Ranges in Middle Cambrian beds. The following facts appear to support the present writer's interpretation.

1. Only the Miette thrust is known to occur in the Middle Cambrian Shale Unit at Athabasca Valley. The writer interprets beds at the bottom of Solomon No. 1 well as Mesozoic. Strata on the east side of the De Smet Range belong to the Triassic Whitehorse formation. O'Brien identified both occurrences as Cambrian. There is no proof that the thrust beneath the Boule Range lies in the Middle Cambrian, as O'Brien assumed.

2. O'Brien's interpretation requires the Lower Cambrian and Precambrian basement to rise to the southwest beneath the Foothills. Present drilling and structural data do not support this interpretation but suggest the very opposite, i.e., that the elevation of this basement decreases.

REFERENCES

Allan, J.A., Warren, P.S., and Rutherford, R.L., 1932, "A Preliminary Study of the Eastern Ranges of the Rocky Mountains in Jasper Park, Alberta", Trans. Royal Soc. Canada, 3rd Ser., Vol. 26, Sec. 4, pp. 225-249.

Best, E.W., 1958, "The Triassic of the North Saskatchewan-Athabasca Rivers Area", Alberta Soc. Petrol. Geol., Eighth Ann. Field Conf. Guidebook, pp. 34-49.

Brady, W.B., 1958, "Mississippian Stratigraphy of the Central Foothills and Eastern Ranges of the Nordegg Area, Alberta", Alberta Soc. Petrol. Geol., Eighth Ann. Field Conf. Guidebook, pp. 50-63.

Brown, R.A.C., 1952, "Carboniferous Stratigraphy and Palaeontology in the Mount Greenock Area, Alberta", Geol. Surv. Canada, Memoir 264.

Burling, L.D., 1923, "Cambro-Ordovician Section near Mount Robson, British Columbia", Bull. Geol. Soc. America, Vol. 34, pp. 721-748.

____________, 1955, "Annotated Index to the Cambro-Ordovician of the Jasper Park and Mount Robson Region", Alberta Soc. Petrol. Geol., Fifth Ann. Field Conf. Guidebook, pp. 15-51.

Charlesworth, H.A.K., and Remington, D.B., 1960, "Precambrian Rocks in the Vicinity of Jasper, Alberta", Edmonton Geol. Soc., Second Ann. Field Trip Guidebook, pp. 11-18.

Charlesworth, H.A.K., Evans, C.R., and Stauffer, M.R., 1961, "Precambrian Geology in the Jasper-Geikie Area", Edmonton Geol. Soc., Third Annual Field Trip Guidebook (this volume), pp. 3-13.

Collet, L.W., and Parejas, E., 1932, "Resultats de l'Expedition Geologique de l'Universite de Harvard dans les Montagnes Rocheuses du Canada (Jasper National Park), 1929", C.R. Soc. Phys. Hist. Natur. Geneve, Vol. 49, pp. 36-64.

Dahlstrom, C.D.A., 1960, "Concentric Folding", Edmonton Geol. Soc., Second Ann. Field Trip Guidebook, pp. 82-84.

Deiss, C.F., 1939, "Cambrian Formations of Southwestern Alberta and Southeastern British Columbia", Bull. Geol. Soc. America, Vol. 50, pp. 951-1026.

____________, 1940, "Lower and Middle Cambrian Stratigraphy of Southwestern Alberta and Southeastern British Columbia", Bull. Geol. Soc. America, Vol. 51, pp. 731-734.

Denson, N.M., 1942, "Late Middle Cambrian Trilobite Faunas and Stratigraphy of Alberta, Montana, Wyoming, and Utah", unpublished Ph. D. Thesis, Princeton University.

de Wit, R., and McLaren, D.J., 1950, "Devonian Sections in the Rocky Mountains between Crowsnest Pass and Jasper, Alberta", Geol. Surv. Canada, Paper 50-23.

Douglas, R.J.W., 1950, "Callum Creek, Langford Creek and Gap Map-Areas, Alberta", Geol. Surv. Canada, Mem. 255.

Dowling, D.B., 1911, "Coalfields of Jasper Park, Alberta", Geol. Surv. Canada, Summ. Report 1910, pp. 150-168.

____________, 1912, "Geology of Roche Miette Map-Area, Jasper Park, Alberta", Geol. Surv., Canada, Summ. Report 1911, pp. 201-219.

Frebold, H., 1957, "The Jurassic Fernie Group in the Canadian Rocky Mountains and Foothills", Geol. Surv. Canada, Mem. 287.

Frebold, H., Mountjoy, E.W., and Reed, R., 1959, "The Oxfordian of the Fernie Group in Western Canada", Geol. Surv. Canada, Bull. 53.

Harker, P., Hutchinson, R.D., and McLaren, D.J., 1954, "The Sub-Devonian Unconformity in the Eastern Rocky Mountains of Canada", Amer. Assoc. Petrol. Geol., Western Canada Sedimentary Basin, pp. 48-67.

Hughes, R.D., 1955, "Geology of Portions of Sunwapta and Southesk Map-Areas, Jasper National Park, Alberta, Canada", Alberta Soc. Petrol. Geol., Fifth Ann. Field Conf. Guidebook, pp. 69-116.

Illing, L.V., 1959, "Cyclic Carbonate Sedimentation in the Mississippian at Moose Dome, Southwest Alberta", Alberta Soc. Petrol. Geol., Ninth Ann. Field Conf. Guidebook, pp. 37-52.

Kindle, C.H., 1929, "An 'Ozarkian' Fauna from Jasper Park, Alberta", Can. Field Naturalist, Vol. 43, pp. 145-147.

Kindle, E.M., 1930, "Geological Story of Jasper National Park, Alberta", Canada Dept. Interior, National Parks Branch, Ottawa.

Lang, A.H., 1947, "Brule and Entrance Map-Areas, Alberta", Geol. Surv. Canada, Mem. 244.

McEvoy, J., 1900, "Report on the Geology and Natural Resources of the Country Traversed by the Yellow Head Pass Route from Edmonton to Tete Jaune Cache, Comprising Portions of Alberta and British Columbia", Geol. Surv. Canada, Ann. Rept. for 1898, Vol. 11, part D.

McGugan, A., and Rapson, J.E., 1961, "Stratigraphy of the Rocky Mountain Group (Permo Carboniferous) Banff Area", Jour. Alberta Soc. Petrol. Geol., Vol. 9, No. 3, pp. 73-106.

MacKay, B.R., 1929, "Brule Mines Coal Area, Alberta", Geol. Surv. Canada, Summ. Rept. 1928, part D, pp. 1-20.

____________, 1955, "Pocahontas-Moosehorn Creek Coal Basin, Jasper Park, Alberta", Alberta Soc. Petrol. Geol., Fifth Ann. Field Conf. Guidebook, pp. 131-145.

Manko, E.M., 1960, "The Triassic of the Rock Lake Area", Edmonton Geol. Soc., Second Ann. Field Trip Guidebook, pp. 24-42.

Mountjoy, E.W., 1960a, "Miette,Alberta", Geol. Surv. Canada, Map 40-1959.

____________, 1960b, "Structure and Stratigraphy of the Miette and Adjacent Areas, Eastern Jasper National Park, Alberta", unpublished Ph.D. Thesis, University of Toronto.

____________, 1960c, "Regional Structure of Rocky Mountains in the Jasper Area, Canada", Abstract, Bull. Geol. Soc. America, Vol. 71, p. 2045.

____________, 1961 (in press), "Discussion of the Structural Geology of the Boule and Bosche Ranges in the Canadian Rocky Mountains", Quart. Jour. Geol. Soc., London.

____________, 1961 (in press), "Mount Robson Southeast Quarter, Rocky Mountains of Alberta and British Columbia", Geol. Surv. Canada, Paper and Map.

O'Brien, C.A.E., 1960, "The Structural Geology of the Boule and Bosche Ranges in the Canadian Rocky Mountains", Quart. Jour. Geol. Soc., London, Vol. CXVI, pp. 409-436.

Okulitch, V.J., 1956, "The Lower Cambrian of Western Canada and Alaska", 20th Internat. Geol. Cong., Tomo II, Part II, pp. 701-734.

Orr, R.D., 1960, "The Upper Devonian Jasper Basin", Edmonton Geol. Soc., Second Ann. Field Trip Guidebook, pp. 19-23.

Raymond, P.E., 1930, "The Palaeozoic Formations in Jasper Park, Alberta", Amer. Jour. Sci., 5th Ser., Vol. 20, pp. 289-300.

Taylor, P.W., 1957, "Revision of Devonian Nomenclature in the Rocky Mountains", Jour. Alberta Soc. Petrol. Geol., Vol. 5, pp. 183-195.

Walcott, C.D., 1913, "Cambrian Formations of the Robson Peak District, British Columbia and Alberta, Canada", Smithsonian Misc. Coll., Vol. 57, No. 12, pp. 328-343.

____________, 1920, "Geological Formations in the Canadian Rockies", Smithsonian Misc. Coll., Vol. 72, No. 1, p. 15.

____________, 1923, "Cambrian Geology and Paleontology, IV: Nomenclature of Some Post Cambrian and Cambrian Cordilleran Formations", Smithsonian Misc. Coll., Vol. 67, No. 8, p. 458.

____________, 1928, "Pre-Devonian Palaeozoic Formations of the Cordilleran Provinces of Canada", Smithsonian Misc. Coll., Vol. 75, pp. 185-368.

Ziegler, W.H., 1960, "Die Uberschiebung der 'Castle Mountain Fault' Zone, Nordlich von Jasper, Alberta, Kanada", Eclogae Geol. Helv., Band 52, pp. 743-750.

APPENDIX A

Cambrian Section on Chetamon Mountain (53° 03' North and 188° 10' West)

Unit	Lithology	Thickness (feet)	Height above base (feet)
	Overlying beds Lynx formation, forming an inaccessible cliff.		
	<u>Arctomys formation</u> 591 feet		
15	Dolomite, silty, dark grey, pronounced fine cross-bedding and laminations, weathers yellow grey, resistant in beds 4-12 inches.	78	591
14	Shale, calcareous, dark red and green.	150	513
13	Limestone, argillaceous, medium grey, microcrystalline, weathers light yellow grey.	37	363
12	Shale, yellowish green and dark red, calcareous, fine laminations, some ripple marks.	179	326
11	Shale, green and dark red, fissile, in part calcareous, fine laminations and cross-bedding; ripple marks and salt crystal pseudomorphs in upper 90 feet.	147	147
	<u>Pika formation</u> 656 feet		
10	Limestone, dark grey, fine crystalline, weathers greenish grey in beds 1/2 to 1 inch.	13	656
9	Covered by talus, fossils collected from talus middle of unit, G.S.C. loc. no. 42573. "<u>Kochaspis</u>" sp. ?<u>Glyphaspis</u> sp. ?<u>Parehmania</u> sp.	140	643
8	Partly talus covered, small outcrops of limestone, dark grey, fine crystalline, argillaceous, weathers dark grey with yellow argillaceous partings. Some layers of intraformational conglomerate.	162	503

Unit	Lithology	Thickness (feet)	Height above base (feet)
7	Limestone, dark grey, microcrystalline, in thin nodular beds 1/2 to 2 inches, intraformational conglomerates prominent in lower half with fragments 1/4 to 2 inches long. Trilobite fragments from base, G.S.C. loc. no. 42580.	36	341
	?*Parehmania* spp.		
6	Shale, grey green calcareous	8	305
5	Limestone, dark grey, argillaceous, with some interbeds of recessive weathering calcareous mudstone. Trilobite fragments in upper 25 feet.	113	297
4	Shale, greenish grey, calcareous, fissile with a few thin interbeds of limestone, dark grey fine crystalline, argillaceous. Trilobite fragments near top.	49	184
3	Limestone, dark grey, medium crystalline, some intraformational conglomerate, brown weathering in beds 4 to 8 inches.	50	135
2	Limestone, dark grey, fine crystalline with several thin layers of intraformational conglomerate, fragments 1/4 to 4 inches long.	63	85
1	Limestone, grey, fine crystalline, fine laminations, weathers light yellow grey in beds 2 to 6 inches thick.	22	22
	Titkana formation. Limestone, medium to dark grey, microcrystalline, weathers light grey, resistant in beds 1 to 4 feet. Forms massive cliff. Thickness by graphic calculations.	850 approx.	
	Shale Unit 1386 feet		
12	Fourth shale - mostly covered; shale, green, with some argillaceous limestone beds.	270	1386
11	Upper limestone - dark grey, micro-to crypto-crystalline with thin interbeds of argillaceous limestone.	154	1116

Unit	Lithology	Thickness (feet)	Height above base (feet)
10	Third shale - mostly covered; some argillaceous limestone talus, trilobite fragments in lower 50 feet, G.S.C. loc. no. 42593 ?*Glossopleura* sp. *Iphidella* cf. *I. grata* Resser	116	962
9	Middle limestone - dark grey, micro-to cryptocrystalline, weathers light grey, some argillaceous partings give a mottled appearance to outcrops.	151	846
	Second shale -		
8	Shale, light green, mostly covered	62	695
7	Limestone, medium grey, cryptocrystalline, argillaceous, weathers light brown, trilobite fragments in upper 50 feet. G.S.C. loc. no. 42574. ?*Glossopleura* sp.	115	633
6	Covered; talus of argillaceous limestone, trace of trilobite fragments.	43	518
5	Lower limestone - dark grey, cryptocrystalline, with thin partings and layers of argillaceous limestone, weathers light grey, cliff forming.	224	475
4	First shale - covered; G.S.C. loc. no. 36753 collected at top of this unit in creek about 1 mile to southeast. *Vanuxemella* sp.	221	251
	Basal clastic unit -		
3	Dolomite, silty, microcrystalline, weathers light red to orange in beds 1 to 12 inches.	15	30
2	Covered.	14	15
1	Intraformational conglomerate of dolomite and shale in sandstone matrix, fragments angular,up to 1 1/2 inches long.	1	1
	Underlying beds Gog formation; Sandstone, quartzose, coarse-grained, grains well rounded, weathers light grey with limonitic stain.	100+	

APPENDIX B

Section of Rundle group on southeast spur of Mount Greenock, along pipeline right-of-way. (53° 05' North and 118° 04' West)

Unit	Lithology	Thickness (feet)	Height above base (feet)
	Overlying beds Rocky Mountain group. For description see Brown (1952, p. 32, Section 1A: upper and middle members of Greenock formation).		
	<u>Formation D</u> 335'		
	Covered	18	1192
34	Dolomite, cryptocrystalline, light grey, weathers light grey yellow in beds 2 inches to 2 feet. A few irregular dark grey chert lenses throughout, abundant in upper 2 feet.	35	1174
33	Partly covered - dolomite and argillaceous dolomite, light grey, microcrystalline, some chert, weathers light yellowish grey, recessive in beds 1 inch to 1 foot.	56	1139
32	Dolomite, microcrystalline, light grey, trace of fine laminations, abundant chert nodules, weathers very light grey, resistant in beds 1 to 3 feet.	18	1083
31	Dolomite, microcrystalline, medium grey, trace of crinoid and other fossil fragments, weathers light grey yellow in beds 1 to 2 feet. Upper 10 feet argillaceous.	109	1065
30	Dolomite, microcrystalline, medium grey, weathers light yellow grey, slightly recessive.	28	956
29	Dolomite, microcrystalline, light grey with abundant light grey chert lenses. Lenses contain abundant silicified brachiopods including <u>Dictyoclostus</u> sp. <u>Composita</u> sp. and abundant small <u>Spirifer</u> fragments (G.S.C. loc. no. 36754). This is the zone which contains Brown's (1952) <u>Spirifer</u> n. sp. A. The unit weathers light grey in beds 6 inches to 2 feet, and forms a distinct resistant unit on mountain.	23	928

Unit	Lithology	Thickness (feet)	Height above base (feet)
28	Dolomite, micro-to finely crystalline, light grey, occasional chert nodules at base, weathers light yellow grey in indistinct beds 1 to 2 feet, slightly recessive.	20	905
27	Dolomite, very fine crystalline, light brownish grey, weathers light grey, resistant. Contains thin light grey chert lenses and beds which weather light yellow to orange.	6	885
26	Dolomite, very fine crystalline, brownish grey, traces of fossil fragments, weathers light brownish grey in beds 1/2 to 2 feet.	17	879
25	Dolomite, microcrystalline, light to medium grey with abundant light grey chert nodules.	5	862
	<u>Formation C</u> 378 feet		
24	Dolomite, very fine crystalline, light grey, traces of fine porosity and weathers light yellow grey in beds 1 to 3 feet. Laminated and trace of fossil fragments in upper 10 feet.	50	857
23	Dolomite, very fine crystalline, medium grey, traces of coral and crinoid fragments abundant in some layers, weathers light grey brown in beds 2 inches to 2 feet.	92	807
22	Dolomite, crypto-to microcrystalline, light grey, with abundant light grey chert nodules, weathers light yellow grey in beds 1 to 3 feet.	12	715
21	Dolomite, microcrystalline, light brown to dark grey, some white chert, traces of colonial corals, some sedimentary breccia (?), weathers grey.	19	703
	Top of more porous recessive weathering dolomites and possible alternative contact between Formations C and D.		
20	Dolomite, fine crystalline, light brown, slightly calcareous and porous, trace of vugs, weathers grey, massive.	45	684
19	Dolomite, argillaceous, fine crystalline, dark grey, finely laminated, a few <u>Spirifer</u> and bryozoa, weathers light grey, recessive in	21	639

Unit	Lithology	Thickness (feet)	Height above base (feet)
	beds 1 to 6 inches.		
18	Limestone, dolomitic, very fine crystalline, light grey, trace of fine porosity, weathers light yellow grey, massive.	22	618
17	Dolomite, microcrystalline, light yellow grey, weathers grey in beds 2 to 3 feet.	10	596
16	Limestone, dolomitic, fine to medium grained, light brownish grey, loosely cemented abundant crinoid and fossil fragments, traces of fine laminations and porosity. Some small vugs near top. Weathers light grey in beds 1 to 3 feet.	85	586
15	Dolomite, calcareous, fine to medium grained abundant fossil fragments (mostly crinoid and brachiopod) loosely cemented, dark brown, weathers medium brown in 2-foot beds, moderately resistant. Basal bed coarsely crossbedded, suggesting current direction from northeast to southwest.	22	501
	<u>Formation B</u> 235 feet		
14	Dolomite, microcrystalline, medium grey, weathers light grey in beds 2 inches to 1 foot. Contact with overlying unit irregular. Overlying unit cuts up to 1 foot into this unit.	2	479
13	Mostly covered; dolomite, micro-to medium crystalline,dark grey in beds 2 to 4 feet thick, in part porous.	34	477
12	Dolomite, very fine crystalline, medium grey, weathers yellow grey in beds 1 to 2 feet. 3-foot bed of porous dolomite 5 feet above base.	20	443
11	Limestone, dolomitic, microcrystalline, brownish grey, trace of fine porosity, weathers light brown in beds 6 inches to 2 feet.	18	423
	Covered	27	405
10	Limestone, dolomitic, fine crystalline, dark brown grey, trace of fine laminations, some talus cover, weathers light brown grey. G.S.C. loc.	50	378

Unit	Lithology	Thickness (feet)	Height above base (feet)
	no. 36802 *Dictyoclostus* sp., *Spirifer* cf. *keokuk?* Hall and *Spirifer* cf. *forbesi?* Norwood and Pratten		
9	Limestone, microcrystalline, grey, with abundant specks of clear calcite, some pellets and pseudo-oolites, weathers light grey in beds 2 inches to 1 foot. Brachiopods and cup-corals. G.S.C. loc. no. 36798 25 feet above base *Dictyoclostus* cf. *gallatinensis* Girty, *Camarotoechia cobblestonensis* Brown, *Camarotoechia allan* Warren, *Composita* sp.	53	328
8	Limestone, finely crystalline, trace of fossil fragments, dark brownish grey, weathers medium grey, platy in beds 1/2 to 2 inches, recessive. A few thin interbeds of pelletoid limestone.	31	275
	Formation A 244 feet		
7	Limestone, alternate beds of fine and coarse grained, dark grey, abundant fossil fragments, weathers medium grey in beds 1/2 to 3 feet. G.S.C. loc. no. 36806 from top *Orthotetes* cf. *keokuk* Hall, and fragments.	71	244
6	Limestone, very coarse grained, grey, abundant rounded fossil fragments (mostly crinoid detritus), weathers light grey, resistant.	50	173
5	Limestone, fine to medium grained, argillaceous, weathers grey, recessive in beds 1 to 3 inches.	6	123
4	Limestone, medium to coarse grained, abundant fossil fragments (mostly crinoid detritus) cemented by clear calcite, grey, weathers light grey, resistant. G.S.C. loc. no. 36800 from middle of unit *Leptaena analoga* Phillips, *Dictyoclostus* cf. *burlingtonensis* (Hall) *D.* cf. *gallatinensis?* Shimer, *Spirifer rundlensis?* Warren, *Brachythris* sp.	52	117
3	Limestone, fine to coarse grained, light to dark grey, abundant fossil fragments, weathers light grey, resistant in beds greater than 5 feet.	33	65

Unit	Lithology	Thickness (feet)	Height above base (feet)
2	Limestone, micro-to fine grained, light to dark grey, with abundant fragments of crinoids, bryozoa, and corals, weathers light grey, massive, resistant. Numerous solitary corals in basal 2 feet.	16	32
1	Limestone, very coarse grained, dark grey, abundant fossil detritus, weathers light grey, resistant, massive.	16	16
	<u>Banff formation</u>		
	Siltstone, dark grey, finely laminated, weathers light grey yellow in beds 1/2 to 2 inches.	6	
	Covered. One outcrop near middle, limestone, dark grey, argillaceous.	124	
	Partly covered. Limestone, dark grey argillaceous, crinoidal, interbedded with calcareous shale in beds 1/2 to 3 inches. See Brown (1952, p. 35-38) for underlying strata and additional description of the Banff formation.	40	

DETAILED CARBONIFEROUS CORRELATIONS BETWEEN MOUNT GREENOCK AND BOX CANYON, SOUTHERN CANADIAN ROCKIES

by James. M. Drummond

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ABSTRACT

Carboniferous rock units correlate uniformly between Box Canyon near Nordegg and Mount Greenock near Jasper, Alberta, except for facies changes at the contacts of the Mount Head/Turner Valley and Shunda/Pekisko formations.

The Greenock formation is considered obsolete, and the two highest members referred to the Rocky Mountain group, while the lowest one is assigned to the upper part of the Mount Head formation. The Mount Greenock section is sub-divided into rock units used in the south of Alberta.

INTRODUCTION

Of the relatively large number of papers on the Carboniferous of the southern Rocky Mountains, most are detailed but localized, or regional but generalized. Type section localities are scattered, so that although about one dozen formal names are in use and adequate descriptions are available for any type section, it is rarely possible by direct reference to the literature to establish inter-section relationships. This paper attempts to improve the situation between Shunda type section at Box Canyon near Nordegg and Mount Greenock in the Jasper area. Several southern Alberta rock unit names are introduced at Mount Greenock for the first time, and it is suggested that the name "Greenock formation", presently applied in the Jasper area, is obsolete.

All section data presented here have already been published, but the sources are scattered. This paper summarizes lithologic data by the use of detailed symbols.

There were three main interpretive steps in developing the cross section (in pocket). Authors of papers in which the sections were described performed the initial field interpretation. Where the writer has introduced new data this is stated. Next, there was a certain amount of interpretation in drawing up the two composite end sections. Any arbitrary choices involved at this stage are explained in detail. The final correlation is the most interpretive step of all, and is the responsibility of the writer.

Overlying units:	Triassic Spray River formation, or Jurassic Nordegg or Fernie formations.
Rocky Mountain group:	Carboniferous and/or Permian.
Etherington formation:	Carboniferous (Not present on line of cross section)
Mount Head formation:	Mississippian.
Turner Valley formation:	"
Shunda formation:	"
Pekisko formation:	"
Banff formation:	"
Exshaw formation:	Mississippian and/or Devonian.
Underlying unit:	Palliser formation; usually accepted as Devonian.

Figure 1: General Carboniferous Succession. McGugan and Rapson (1960, 1961), break the Rocky Mountain into Carboniferous Tunnel Mountain and Kananaskis, and Ishbel formation of probable Permian age. The Turner Valley is locally divisible into Upper Porous, Middle Dense and Elkton members.

Appreciation is extended to Mobil Oil of Canada, Ltd. for permission to publish this paper, and to Mr. R.J. Skene and Mrs. Joan Checholik of that Company for drafting and typing respectively. Thanks are also extended to Dr. S.J. Nelson of the University of Alberta in Edmonton for invaluable criticism and advice.

GENERAL STRATIGRAPHY

Figure 1 outlines the relationships of Carboniferous rock units in this area.

Type Exshaw formation (Warren, 1937) in Bow Valley is predominantly black shale of Mississippian and/or Devonian age. Both its upper contact and age have been subject to controversy at various times (see Harker and McLaren, 1958). For convenience the Exshaw is here treated as though it was part of the Banff formation.

At Mount Rundle, type Banff (Shriner, 1926) of Mississippian age, consists mainly of fine grained argillaceous carbonates. Nelson and Rudy (1959) have shown that the Pekisko develops as a wedge within lateral equivalents of type Banff to the north, so that by this criterion the Pekisko and Shunda formations at Box Canyon could be considered correlative with upper type Banff (see Figure 1). It suffices to point out here that a major problem exists in delimiting the Banff formation from the overlying beds. In the Banff area the section interval between the Banff formation and Rocky Mountain group is referred to the Rundle group. Because of the difficulties associated with definition of the Banff/Rundle contact away from the type area, the name "Rundle" is not used here, except at Mount Greenock in the sense of Brown (1952). The unit identified as Banff on the cross section is often referred to as "plains" Banff.

The Pekisko was introduced by Douglas (1953) with member status. Penner (1957b) clarified the definition of the unit at what can be regarded as the type well (Devonian Test #1, 2-25-19-3 W5M). The Pekisko, in contrast to the units above and below, is primarily composed of encrinites.

Type Shunda formation (Stearn, 1956) at Box Canyon is fine grained, predominantly argillaceous, dolomites and limestones. Nearby subsurface sections contain appreciable amounts of anhydrite, and it is probably that some of the covered intervals at the type section represent leached anhydrite zones.

Devonian Test #1 at Turner Valley is regarded as the type well of the Turner Valley formation (Douglas, 1953, Penner, 1957b) which is broken down into Elkton, Middle Dense and Upper Porous members. The Middle Dense is principally fine grained dolomite, while the Elkton and Upper Porous are mainly dolomitized granular rocks of crinoidal origin. In places the Elkton retains its original lithology. Thomas and Glaister (1959) have discussed the relationships between the encrinites and the crystalline dolomites.

Penner (1958) demonstrated that the Turner Valley/Shunda contact carries from Box Canyon to the Westward Ho field and also showed (1957a) that the type Elkton in Elkton #16-13-31-4W5M correlated to Pine Creek #1 near Turner Valley. Thomas and Glaister (1959) amended Penner's interpretation of the upper part of the type well, but confirmed that the Turner Valley/Shunda contact carried to Turner Valley at Home Turner Valley #8-30. Thus, it has been fairly conclusively shown that this contact at Box Canyon will correlate with that in Devonian Test #1.

It is possible to break the Turner Valley at Box Canyon into three lithologic units which correspond to some extent to those at Devonian Test #1, although the Middle Dense is much thinner than at Turner Valley (see cross section).

The Mount Head formation is partly eroded in all sections discussed here, except perhaps at Mount Greenock, where the rock unit name is now formally introduced. Type Mount Head is at Highwood Gap (Douglas, 1953, Beales, 1950) and is typified by argillaceous fine grained limestones and dolomites, with occasional calcarenite horizons. Nelson and Rudy (this volume) correlate the Mount Head from the south to the lower member of Brown's (1952) Greenock formation at Mount Greenock. These authors demonstrate that the two upper members of the Greenock can probably be referred to the Tunnel Mountain formation (Beales, 1950) of the Rocky Mountain group (Dowling, 1907). The group name is retained here to allow for the possibility that Permian beds may be present at Greenock.

The Etherington formation (Douglas, 1953) does not occur on the line of cross section.

DEFINITIVE CHARACTERISTICS OF CARBONIFEROUS ROCK UNITS

Excluding the Etherington and Exshaw formations and the Rocky Mountain group, Carboniferous rock units in the southern Rockies have a common specific characteristic in that all can be distinguished by grade size. The Pekisko, Elkton, Upper Porous and Turner Valley units are typically medium to coarse grained, while the Banff, Shunda, Mount Head and Middle Dense, are essentially fine grained. When a contact is picked between any of these units it is placed between fine and coarser grained beds, regardless of other lithological factors. Definition of these rock units in this way is a slight simplification, since grade size is only one facet of lithology. However, although other lithologic characteristics may be distinctive locally, they do not carry everywhere, and grade size defined units do. This type of unit is shown on the accompanying cross section.

Although this is the first time, to the writer's knowledge, that the concept of grade size definition of Carboniferous units has been stated with more than limited application, it has been implied repeatedly since 1927, when Warren defined the Banff/Rundle contact as the horizon at which encrinites replaced argillaceous calcilutites in the sequence. For example, Brady (1958, page 54) improved upon Hemphill's (1957) original definition when he said that the subsurface

Turner Valley/Shunda contact is based upon the change from "medium-grained dolomite (or limestone) of the Turner Valley formation to the fine-to micro grained, darker coloured strata of the Shunda formation".

A study of the literature on any of the contacts between the Banff and Mount Head formations will show that grade size differences always occur, either as an implied or stated factor.

Referring to the Turner Valley/Shunda contact Penner (1958, page 65) stated: "The upper boundary of the Shunda in the Foothills area is placed at the change upwards from brown, lithographic limestone ('Black Lime' of the Turner Valley field) to coarsely crystalline limestone or dolomite of the Turner Valley formation. In the Plains area the top of the Shunda is placed at the change upwards from silty dolomite of the Shunda to coarsely crystalline limestone or dolomite of the Turner Valley. The 'Black Lime' bed of the Turner Valley field and Foothills region generally is not present in the Plains region".

A definition should have no exceptions, but although the "Black Lime" is fairly consistently developed, some Foothills wells do not contain this lithological unit. Penner (1957, Figure 2) showed the uppermost Shunda at Shell #5-7-1 at Jumping Pound as dolomite, not limestone. If the limestone/dolomite qualification is removed then the definition of the Foothills contact, like that of the plains, becomes essentially one based on grade size.

For the Shunda/Pekisko contact Penner (ibid) said: "The base of the Shunda formation is placed at the change upwards from brown, very finely crystalline, coarsely crinoidal or pelletoid limestone of the Pekisko to argillaceous and silty dolomite or sandstone of the Shunda formation". Exceptions invalidate this definition also unless it is changed to one based upon grade size differences. For example, under the Plains near the Pekisko subcrop the unit is often dolomite like the overlying Shunda, and the two have to be differentiated by grade size. Study of the cross section presented here between the Cadomin and Shunda sections will demonstrate that the Shunda/Pekisko contact could not be satisfactorily drawn using lime/dolomite relationships.

The Etherington and Exshaw formations, and the Rocky Mountain group are the only post-Palliser Upper Palaeozoic units not defined by grade size. The contact between the Rocky Mountain group and the underlying beds is defined by the presence of sandstones (see Drummond, 1959, page 260).

The Exshaw was first defined on faunal as well as lithologic grounds, and only the latter could be acceptable. In this area Brady (1958) referred to seven feet of Exshaw near Box Canyon and to 6.5 feet at Chungo Creek. Brown (1952) did not pick any at Mount Greenock because, he said, (page 17) "as the typical fauna of the Exshaw shale was not found in the area covered by this report, the name is not used".

Nelson and Rudy (this volume) differentiate the Etherington carbonate unit by its lack of argillaceousness, in which it contrasts with the underlying Mount Head. They do not carry the Etherington formation to Mount Greenock, and their interpretation agrees with that shown on the cross section.

GRADE SIZE IDENTIFICATION

A single grade size scale has not yet been generally accepted for carbonates. Of the section descriptions used here only those by Brown (1952, page 29) have grade size terms defined. This lessens the acceptability of the present interpretation, since as already discussed, correlations are based on grade size units.

On the other hand, most diagnostic Carboniferous carbonates are either coarse encrinites or fine grained calcisiltites, and are easily differentiated. Further, most geologists refer to rocks as fine, medium or coarse grained in an approximately similar way, and in practice grade size descriptions are generally reasonably consistent.

DISCUSSION OF OUTCROP SECTIONS

Box Canyon (Shunda type section)

Stearn (1956) has given the most detailed data on this section. The exposures are incomplete both above the Shunda and below the Pekisko. It is possible to estimate the Palliser top fairly accurately at the location, but it is necessary to use information from nearby sections if the upper part of the Carboniferous is to be shown.

Stearn (ibid) gave adequate descriptions of 829 feet between a point 46 feet above the base of the Turner Valley and the lowermost Banff exposure, which is a 12 foot encrinite. The underlying covered interval was not measured by Stearn. (The 12 foot figure in his descriptions should refer to the encrinite.) The present writer estimated the covered section between the encrinite and the top of the Palliser at 150 feet, giving 558 feet for the Banff/Exshaw total. Douglas (1956, page 16) reported 577 feet for the latter interval in Box Canyon neighborhood, and so confirms that the 150 foot estimate was reasonable.

The lower Turner Valley and Pekisko lithologies on the present log are slightly more detailed than those given by Stearn, while a few thin beds described by him within larger covered intervals could not be found, and are omitted. Apart from these minor points Stearn's descriptions are followed closely, and his thicknesses precisely. None of the supplementary data affects the correlations to any extent.

The Allan Memorial Mississippian Committee moved Stearn's pick for the Shunda 33 feet upwards. This change was formally noted by Penner (1958). The committee accepted Stearn's definition of the Shunda and Pekisko bases. It can be noted that the finalized picks are all based upon grade size differences.

The missing upper portion at the section was supplemented by data from Brady (1958, pages 51, 54) who outlined this part at Dizzy Creek two miles southeast of the Saskatchewan Gap, or about eight miles southeast of Box Canyon. Brady there refers to 126 feet of Turner Valley overlain by 127 feet of Mount Head. An uppermost dolomite unit varies from zero feet at Dizzy Creek to 50 feet further north, and an arbitrary figure of 25 feet is assigned to this unit as being probably representative of Box Canyon. In this way 278 feet of beds are shown between the base of the Turner Valley and the top of the Carboniferous. On the basis of Brady's grade size descriptions, the top of the Turner Valley is elevated here from his pick at the top of a 126 foot unit (page 54) to the top of a 56 foot unit (page 51) to include another 84 feet of section. This change is consistent with both a grade size definition of the Turner Valley and its thicknesses further south.

Chungo Creek Section

Data was obtained from Brady (1958, page 55). The Banff formation cannot be shown in detail because of generalized descriptions.

Brief comment is necessary on the 10.3 foot conglomerate bed which occurs above the Mount Head at Chungo Creek. From its stratigraphic position this unit could be of any age between Mississippian and Triassic. In nearby Eastern Ranges, where the Carboniferous approximates twice the thickness of that at Chungo Creek the strata assignable to the Rocky Mountain group are thin. For example, at Job Creek (Brady, pages 58, 59) about 2000 feet of section occur between the base of the Exshaw and Rocky Mountain compared with 1200 feet at Chungo Creek. This clearly indicates that the conglomerate at the latter locality is divorced from Carboniferous sedimentation. It may be either Permian Rocky Mountain or basal Triassic Spray River.

Brady (ibid, page 55) described a bed 88 to 120 feet within his Mount Head as fine grained but porous. This unit is here included with the Turner Valley. Apart from this change Brady's descriptions and choices of contacts are adhered to strictly.

Cadomin Ridge Section

Section data was given by the Road Log Committee in the 1959 Edmonton Geological Society Cadomin Guidebook. Descriptions and interpretation are followed implicitly, except in that the Mount Head/Turner Valley contact is here lowered by 130 feet (page 24) and the Pekisko/Shunda contact by 60 feet (page 25).

Mount Greenock Section

Brown's (1952) excellent study of the Greenock area contains one minor defect, in that he did not differentiate between dolomite and limestone. This has been rectified in part here, but it is emphasized that the re-evaluation is only partial, and that many of the beds may be more dolomitic than indicated.

Brown's work was performed when the Jasper area was still geologically isolated, and his Greenock formation now requires revision. He separated out this formation from the underlying sequence stating (ibid, page 24) "First, as mentioned above, the reliable sections in the area show that the Greenock formation contains three distinctive members. Such a division has not been recognized in the type area of the Rocky Mountain formation. Secondly, the age of the Rocky Mountain formation, although still in doubt, is thought to be Pennsylvanian or Permian by those who have studied it, but the only fossils obtained from the Greenock formation indicate that at least its lower member is of Mississippian age".

At Mount Greenock on the cross section the upper Greenock member is the 42 foot sandstone at the top, and the middle one the remainder of the Rocky Mountain group including the 5.5 foot covered interval at the base. The lower member is the upper 305.5 feet of the Mount Head formation, down to the base of the chert-rich unit 126 feet above the Turner Valley.

It is not difficult to analyze the steps which led Brown to propose the Greenock formation. First, he was influenced (ibid, page 24, para. 2) by earlier workers like Raymond (1930) who had referred this interval to the Rocky Mountain formation. Because of the relative abundance of chert in the lower Greenock member, compared with that in corresponding strata at Banff, this miscorrelation was understandable. Secondly, the cherty carbonates, cherty and sandy carbonates, and sands, seem to form a natural unit. When Brown found Mississippian fossils in the lowermost cherty carbonates, classifying the three together as members of a formation seemed logical. The writer is inclined to think, in the absence of contradictory palaeontological data, that Brown was correct in assuming depositional continuity and hence a Mississippian age for all three members.+ The chert in Brown's lowest member at Mount Greenock, whatever its origin, is not associated with sandstone, however, and the Rocky Mountain is defined essentially by this lithology.

A pertinent reason for questioning Greenock formation validity is the difficulty of picking the lower contact, since even within the type area the base is not clearly defined. Brown (1952, page 22) states that the contact between his Rundle* and Greenock is transitional and "would be undoubtedly difficult to trace through several successive mountain ranges without a series of measured sections".

The cross section demonstrates that southern Alberta rock unit names can be successfully used at Mount Greenock. Although the name Greenock formation has priority, the facts that the unit is essentially local in expression, and cannot even be clearly separated within the Jasper area, seem enough to suggest that it should be discarded, and that its members should be referred to the Rocky Mountain group and Mount Head, as here.

* Brown's Rundle is the interval between his Greenock formation and Banff.

\+ Since time of writing, McGugan and Rapson (this volume) seem to have produced such evidence.

Nelson and Rudy (this volume) show two alternative horizons for the base of the Mount Head at Mount Greenock. The higher is the base of Brown's Greenock formation. The lower is chosen in this paper on a grade size basis. Beneath the Mount Head the Turner Valley, Shunda and Pekisko formations are distinguished on the same basis.

The section shown here is composite, since Brown traced beds along strike to get complete exposures. The following refers to Brown's descriptions:

Section 1A, page 32.

The interval used was all Brown's Greenock formation, totalling 485.5 feet. The uppermost 180 feet (his middle and upper members) are now referred to the Rocky Mountain group, as already explained. The Rocky Mountain/Mount Head contact could equally well be drawn at the top of the 5.5 foot covered interval, making the Rocky Mountain group 174.5 feet thick.

Section 1B, pages 34 - 35.

Here all Brown's Rundle formation, totalling 782.5 feet, was used. Data was abstracted from Section 1A for the 26 foot covered interval at the top of Section 1B and the 6 foot interval 79 feet further down. The Mount Head/Turner Valley contact is placed 10 feet above the base of the 20.5 foot bed 126 feet within Brown's Rundle, on the basis of the crinoidal content of the lower half of the bed. The 136 foot interval above this point, together with the 305.5 foot lower member of the Greenock formation, are now referred to the Mount Head formation, with a total thickness of 441.5 feet. The Turner Valley/Shunda contact appears to occur at the base of the 18 foot bed 391.5 feet within Brown's Rundle, giving the Turner Valley a thickness of 265.5 feet. The Shunda/Pekisko contact is placed at the top of the 4 foot bed 137 feet above the top of the Banff, resulting in thicknesses of 254 and 137 feet for the Shunda and Pekisko formations respectively.

Section 1C, pages 36 - 37.

385 feet of section assigned by Brown to an upper member of the Banff formation were used from this section interval. (Brown's upper and lower Banff members may have significance since it is possible, for example, to identify apparently correlative units at Cadomin Ridge.)

Section 1D, pages 37 - 38.

A total of 207.5 feet, or Brown's lower Banff member, completes the section. With Section 1C this gives a total of 592.5 feet for the Banff formation. Brown does not identify an Exshaw in this area, but either the lowermost 6 or 35.5 feet of section could be so named.

DISCUSSION OF CROSS SECTION

Palliser to Exshaw and Banff is a change from rocks showing hundreds of feet of clastic-free carbonate deposition to an equally great thickness of clastic-rich beds. The contact sometimes represents a minor diastem, as proved by a thin basal Exshaw sand at many localities, including Mount Greenock, but there is no evidence of significant amounts of erosion. The post-Palliser environmental change can only be due to a new and continuing flood of clastics, therefore, and explosive volcanism in the west (towards which the Exshaw thickens) is a logical source explanation. This conclusion is supported by Exshaw bentonites near Box Canyon (Folinsbee and Baadsgaard, 1958). If this argument is correct, the Exshaw/Palliser contact should be regionally isochronous.

In the absence of pertinent palaeontological evidence, it is necessary to use lithologic data to postulate time-rock relationships. Other things being equal, similar thicknesses of rock will represent equal periods of deposition. On this cross section, the Exshaw/Palliser horizon can be assumed isochronous, on the basis of its origin, and all contacts which parallel it should also be isochronous, including the datum at the base of the Pekisko.

The Cadomin section shows some divergence from parallelism for post-Pekisko time-rock interpretation, and it may be significant that over 100 feet of covered section occurs in the Shunda there. Covered intervals are difficult to measure accurately, and may conceal minor folds or faults. Either factor could result in over-measurement of Shunda thickness.

If the isochronous interpretations shown are correct, the upper boundaries of the Turner Valley and Pekisko formations, as defined, have to be diachronic.

One point could be disputed among the correlations suggested. It is possible to correlate three chert-rich horizons at Cadomin to three successive horizons at Greenock, instead of correlating the middle horizon at Cadomin to the lower one at Greenock, as shown here. The alternative seems less acceptable to the writer.

REFERENCES

Beales, F. W., 1950, "The Late Paleozoic Formations of Southwestern Alberta", Geol. Surv. Canada, Paper 50-27.

Brady, W. B., 1958, "Mississippian Stratigraphy of the Central Foothills and Eastern Ranges of the Nordegg Area, Alberta", Alberta Soc. Petrol. Geol., Eighth Ann. Field Conf. Guidebook, pp. 51-63.

Brown, R.A.C., 1952, "Carboniferous Stratigraphy and Palaeontology in the Mount Greenock Area, Alberta", Geol. Surv. Canada, Memoir 264.

Douglas, R.J.W., 1953, "Carboniferous Stratigraphy in the Southern Foothills of Alberta", Alberta Soc. Petrol. Geol., Third Ann. Field Conf. Guidebook, pp. 68-88.

-------, 1956, "Nordegg, Alberta", Geol. Surv. Canada, Paper 55-34.

Dowling, D.B., 1907, "Report on the Cascade Coal Basin, Alberta", Geol. Surv. Canada, Pub. 949, pp. 1-37.

Drummond, J.M., 1959, "Major Diachronism in Carboniferous Deposits of the Bow Valley, Alberta", Jour. Alberta Soc. Petrol. Geol., Vol. 7, No. 11, pp. 260-266.

Folinsbee, R.E., and Baadsgaard, H., 1958, "An Absolute Age for the Exshaw Shale", Alberta Soc. Petrol. Geol., Eighth Ann. Field Conf. Guidebook, pp. 69-73.

Harker, P., and McLaren, D.J., 1958, "The Devonian-Mississippian Boundary in the Alberta Rocky Mountains", Jurassic and Carboniferous of Western Canada Symposium, Amer. Assoc. Petrol. Geol., pp. 244-259.

Hemphill, C.R., 1957, "Sundre, Westward Ho and Harmattan Oil Fields", Jour. Alberta Soc. Petrol. Geol., Vol. 5, No. 10, pp. 232-247.

McGugan, A., and Rapson, J.E., 1960, "Stratigraphy of the Norquay Formation, Rocky Mountain Group, Banff Area, Alberta", Jour. Alberta Soc. Petrol. Geol., Vol. 8, No. 1, pp. 1 - 12.

----------, 1961, "Stratigraphy of the Rocky Mountain Group (Permo Carboniferous) Banff Area, Alberta", Jour. Alberta Soc. Petrol. Geol., Vol. 9, No. 3, pp. 73-106.

Nelson, S.J., and Rudy, H.R., 1959, "Stratigraphic Position of the Shunda Formation", Jour. Alberta Soc. Petrol. Geol., Vol. 7, No. 11, pp. 257-259.

--------, 1961, "Tunnel Mountain-Rundle Relationships, Carboniferous of the Southern Canadian Rocky Mountains", Edmonton Geol. Soc. Field Trip Guidebook, (this volume), pp. 56-70.

Penner, D.G., 1957a, "The Elkton Member", Jour. Alberta Soc. Petrol. Geol., Vol. 5, No. 5, pp. 101-104.

--------, 1957b, "Turner Valley Oil and Gas Field", Alberta Soc. Petrol. Geol., Seventh Ann. Field Conf. Guidebook, pp. 131-137.

--------, 1958, "Shunda Formation", Alberta Soc. Petrol. Geol., Eighth Ann. Field Conf. Guidebook, pp. 65-68.

Raymond, P.E., 1930, "Paleozoic Formations in Jasper Park, Alberta", Am. Jour. Sci., 5th Ser., Vol. 20, pp. 289-300.

Shriner, H.W., 1926, "Upper Paleozoic Faunas of the Lake Minnewanka Section, near Banff, Alberta", Geol. Surv. Canada, Bull. 42, pp. 1-89.

Stearn, C.W., 1956, "The Exploration Desk: Type Section of the Shunda Formation", Jour. Alberta Soc. Petrol. Geol., Vol. 4, No. 10, pp. 237-239.

Thomas, G.E., and Glaister, R.P., 1959, "Facies and Porosity Relationships in the Mississippian Elkton Carbonate Cycle", Alberta Soc. Petrol. Geol., Ninth Ann. Field Conf. Guidebook, pp. 113-121.

Warren, P.S., 1927, "Banff Area, Alberta", Geol. Surv. Canada, Mem. 153.

------, 1937, "Age of the Exshaw Shale in the Canadian Rockies", Am. Jour. Sci., Vol. 33, pp. 454-457.

ADDENDUM

As author of "Detailed Carboniferous Correlations between Mount Greenock and Box Canyon, Southern Canadian Rockies", the editor proposed his own views of the best criteria for subdividing Carboniferous strata. D. G. Penner, who specified the characteristics by which he subdivides some of the Carboniferous rock units discussed, was as a result subject to mild criticism.

Penner (private communication) disagrees with a grade size definition of Carboniferous units as follows: "As I understand it, you propose to establish formational contacts on the basis of grade size. In the past I have shown grade size on the left hand side of logs in publications, but did not use it as the prime criterion for drawing contacts. Factors other than grade size, such as crystallinity or silt and shale content, are of greater concern to me in identifying the top or bottom of a formation. A case in point is the Cadomin section. I have logged that outcrop, and place the Mount Head/Turner Valley contact 170 feet below the top. This horizon is close to that shown in the Edmonton Geological Society Cadomin Guidebook. Underlying beds are finely crystalline, but acid gives little or no clastic residue. These beds are therefore more characteristic of Turner Valley than of Mount Head. Surely this radical change can be shown more realistically by a facies map than by reducing Turner Valley thickness from a normal 200 to a mere 70 feet. I therefore disagree with the statement, 'When a contact is picked between any of these units it is placed between fine and coarser grained beds, regardless of other lithological factors'. Other statements such as 'under the plains near the Pekisko subcrop the unit is often dolomite like the overlying Shunda, and the two have to be differentiated by grade size', fall in the same category".

As both author and editor, I respect this interpretation of the lithologic features of the Cadomin section, and have little doubt that chronostratigraphically the Turner Valley top at Greenock is the same as Penner's Turner Valley top at Cadomin. It is so shown on the cross section.

Most differences of opinion on Carboniferous rocks can be referred back to time-rock interpretation. In the Mountains only sections along depositional strike, like the one discussed here, are relatively free of diachronism. In the plains, by contrast, diachronism is weakly developed. Differences of time-rock interpretation, and the related problem of deciding on the best criteria for subdividing the rocks, should both be resolved in time.

Editor

TUNNEL MOUNTAIN-RUNDLE RELATIONSHIPS, CARBONIFEROUS OF THE SOUTHERN CANADIAN ROCKY MOUNTAINS

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ABSTRACT

The apparently conformable contact between carbonates of the Rundle group and the overlying silty-sandy beds of the Tunnel Mountain formation is traced by means of 10 sections in the Canadian Rocky Mountains from Mount Darrah in the Flathead area, north to Mount Greenock near Jasper, Alberta, a distance of about 300 miles. The line of section is north-northwesterly, approximately paralleling the trend of the mountains.

The Tunnel Mountain-Rundle contact is considered to become diachronically older from south to north, and (with less evidence) from west to east. In the south the contact is interpreted as being Early Pennsylvanian in age. Further north at Mount Rae (=Storm Creek) and Tunnel Mountain (Banff area) it straddles the Mississippian-Pennsylvanian boundary. East and north of Tunnel Mountain the contact becomes early Chesterian or late Meramecian.

INTRODUCTION

This report traces the diachronic Tunnel Mountain-Rundle contact in the southern Canadian Rocky Mountains from Mount Darrah in the Flathead area of British Columbia northward to Mount Greenock near Jasper, Alberta, a distance of about 300 miles. Ten critical sections are chosen to illustrate the various faunal and lithologic aspects of the problem, although more have been studied and used for corroborative evidence. Location of sections is shown on Figure 1, and lithologic and faunal control on Figure 2.

It should be stressed that the line of section is north-northwesterly, approximately paralleling the mountain trend. The third dimension, at right angles to the mountains, in most cases is not shown. Lake Minnewanka and Dormer River are the exceptions. The reader is referred to Drummond (1959) for discussion of this last dimension.

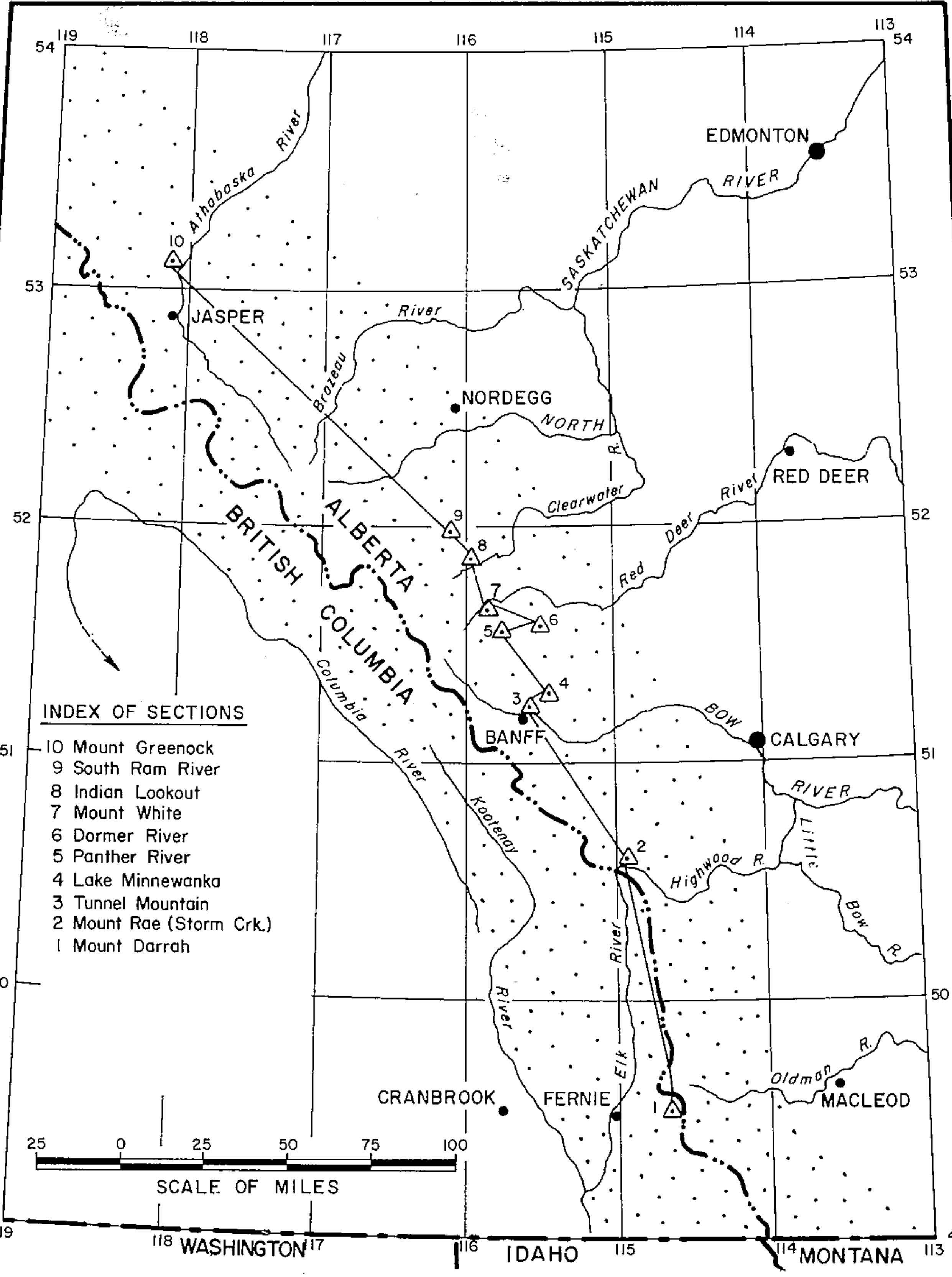


Figure I. — Map showing locations of sections on Figures 2 and 3. Stippled area represents approximate extent Rocky Mountains.

ACKNOWLEDGEMENTS

The writers wish to extend their very sincere thanks to officials of the British American Oil Company, Limited, particularly Dr. A.D. Baillie, for help and encouragement during field and laboratory aspects of this study.

Grateful acknowledgement is also made to co-workers in the field. In 1955 these were J. Cundill and R. Greggs; in 1956, R. Cote; and in 1957 J. Hamilton, D. Basso, J. Twyman and A. Grunder.

J.M. Drummond of Mobil Oil Company, Edmonton has helped the writers by both discussion and argument.

Financial assistance has been given by The British American Oil Company, the University of Alberta, and the National Research Council of Canada.

STRATIGRAPHIC CONTROL

Evidence used in this paper is based upon field work done by the authors over the period from 1955 to 1957, while with Canadian Gulf Oil Company (1955) and the British American Oil Company field parties (1956, 1957). During this time detailed fossil and lithologic collections were made from 27 mountain sections extending from near the International Boundary to the Jasper area of Alberta. The first author was concerned mainly with faunal and the second with lithologic control.

Most sections studied are in two areas. One is from Crowsnest Pass south to near the Boundary, and the other from Banff north to Jasper. Except for Mount Rae (Storm Creek), no sections have been examined in the area between Crowsnest Pass and Banff, although information has been gained from those measured by other British American Oil Company field parties.

Lithologic control is based upon samples collected at one foot intervals from each section. Faunal control for Figure 2 is from approximately 350 very large collections, most of which were made by the first author, or under his supervision.

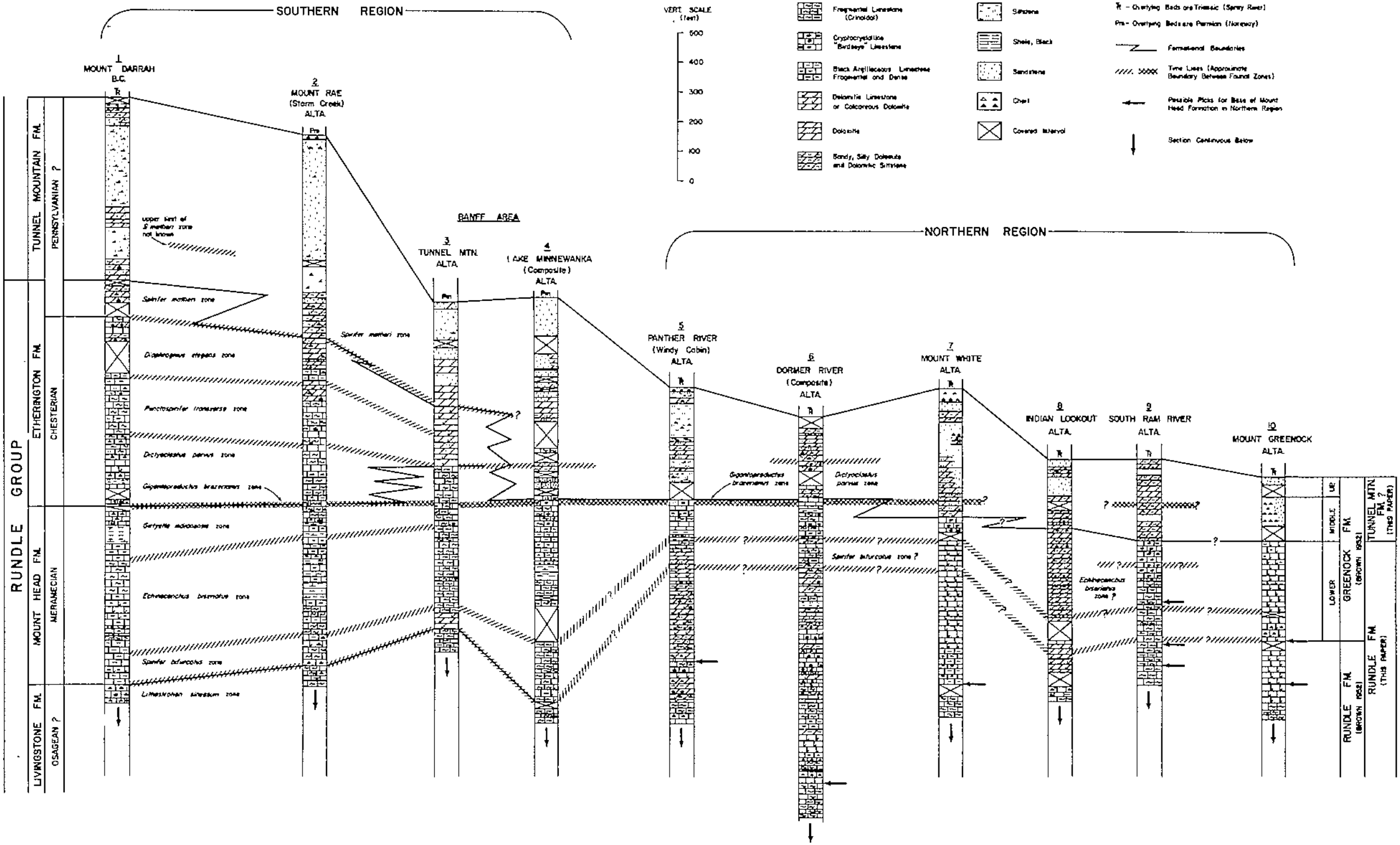
STRATIGRAPHY

The Permo-Carboniferous succession in the southern Canadian Rockies consists, in ascending order, of the Banff formation, and the Rundle and Rocky Mountain groups. The reader is referred to Moore (1958) for history of nomenclature.

The type Banff formation and its lateral equivalents is a rather

FIGURE 2

TUNNEL MOUNTAIN - RUNDLE RELATIONSHIPS
CARBONIFEROUS OF THE SOUTHERN CANADIAN ROCKIES



recessive shaly carbonate sequence generally between 1000 and 1500 feet thick, spanning Kinderhookian and the lower part of the Osagean stage (Kindle, 1924; Warren, 1927; Beales, 1950; Nelson and Rudy, 1959; Nelson, 1960, 1961). It is underlain by a thin black shale unit called the Exshaw formation of Devonian and/or Mississippian age.

The Rundle group consists of the Livingstone (s. l.), Mount Head and Etherington formations (Kindle, ibid; Beales, ibid; Bostock, Mulligan and Douglas, 1957; Nelson, 1960, 1962). The Livingstone is probably Osagean in age and is 1500 to 2000 feet of rather resistant, light coloured, predominantly crinoidal carbonates. It is overlain by the Meramecian Mount Head formation which is generally 500 to 600 feet thick. This latter unit tends to weather recessively and is typically composed of dark shaly carbonates and shales. The Etherington formation is more resistant, with light weathering limestones and dolomites, 600 feet or less thick, as the predominant lithology. The age of the Etherington is mainly Chesterian but at Mount Darrah the uppermost beds (Nelson, 1958) may be Pennsylvanian (see Figures 2 and 3).

Formations of the Rundle group are best displayed in the Rocky Mountains south from Tunnel Mountain. North and east of there the Etherington disappears by grading laterally into the silty beds of the Tunnel Mountain formation, leaving only Mount Head and Livingstone equivalents within the Rundle (Nelson, 1958; Rudy, 1958). Differentiation between these last two formations is often difficult in this northern region, so that they are referred to as the "Rundle formation" on Figure 2. Where possible, lithologic picks for the base of the Mount Head formation are indicated by horizontal arrows. Because of the rather subtle differences in lithology these picks are arbitrary. Rudy (1958) has given a detailed discussion of the various rock types.

The Rocky Mountain group is a clastic sequence of siltstone and sandstone with dolomitic and cherty admixtures (Warren, 1956; Raasch, 1954, 1956, 1958; Nelson; 1958; McGugan and Rapson, 1960, 1961). The lower unit of the group is the Tunnel Mountain formation of silty, sandy and dolomitic beds several hundred or more feet thick. The type section is on Tunnel Mountain at Banff, Alberta (Warren, 1956). The contact with the underlying Rundle carbonates is placed where sand and silt make their first appearance in force. The age of the Tunnel Mountain has been the subject of considerable controversy, largely because of its unfossiliferous nature (Warren, ibid.; Raasch, ibid.; Nelson, 1958, 1961; McGugan and Rapson, ibid.). Until recently regional stratigraphic interpretations were hindered by Raasch's Permian dating of lateral equivalents at Mount Rae-Storm Creek (essentially his Norquay and Storm Creek formations). Most workers now regard the Tunnel Mountain as being Chesterian and/or Pennsylvanian in age.

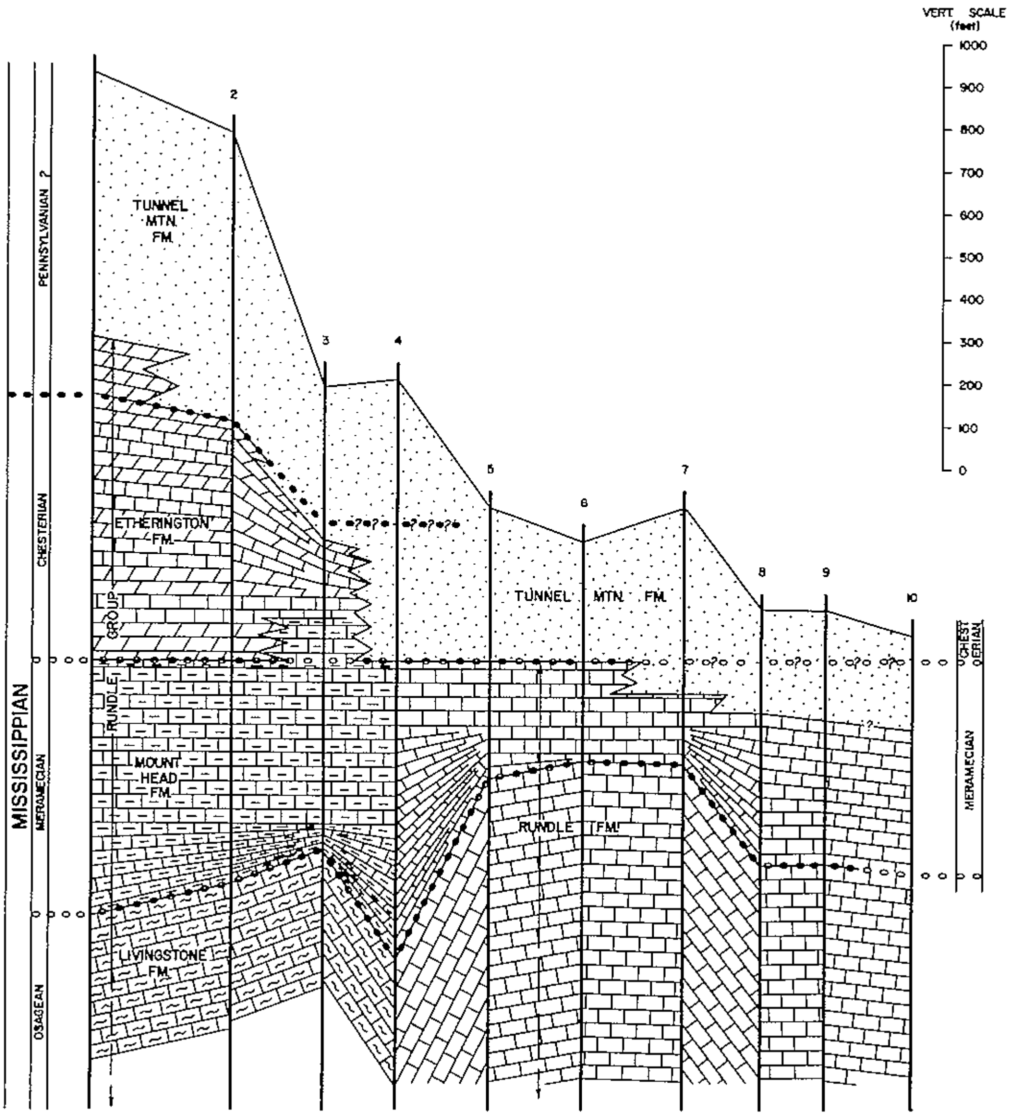
The writers suggest that the lower beds of the formation become diachronically older northward, with the basal contact ranging in age from Pennsylvanian in the south to mid-Meramecian in the north (see Figure 3).

The Norquay formation has a silt and dolomitic content similar to that of the Tunnel Mountain but is usually differentiated by its much more cherty nature. Previously it was considered Permian (Warren, 1956; Raasch, 1956, 1958). McGugan and Rapson (1961) have recently made a very detailed study of the unit both at its type section on Tunnel Mountain and in other areas. They concluded that the Norquay actually contains two distinct horizons. The lower, called the Kananaskis formation, is lower Middle Pennsylvanian, and the upper or Ishbel formation Lower

FIGURE 3

DIAGRAMMATIC CROSS - SECTION
SHOWING
TUNNEL MOUNTAIN – RUNDLE RELATIONSHIPS FROM MOUNT DARRAH (No. 1)
IN THE SOUTH TO MOUNT GREENOCK (No. 10) IN THE NORTH.

SEE FIGURES 1 AND 2 FOR LOCATIONS AND DETAILED STRATIGRAPHY, RESPECTIVELY.



or Middle Permian in age. Thus McGugan and Rapson define the Rocky Mountain group to consist of the Tunnel Mountain, Kananaskis and Ishbel formations.

Some of the sections of the Tunnel Mountain formation portrayed on Figure 2 may contain Kananaskis or Ishbel equivalents in the upper beds. These sections were described and measured before McGugan and Rapson's excellent study, and before these authors' criteria for differentiation were available.

FAUNAL ZONES

Introduction

Faunal zones discussed here are those presented by the first author in 1958 (Nelson, 1958) although one--the Lithostrotion sinuosum zone--was described later (Nelson, 1960). The lithologic interval occupied by these zones and pertinent to a discussion of the Tunnel Mountain-Rundle contact extends from upper Livingstone to Tunnel Mountain. A detailed description of these and lower zones, along with illustrations of characteristic fossils, will shortly be published by the Geological Association of Canada (Nelson, 1961).

Most species listed below have previously been discussed by Raasch (1954, 1958), Harker and Raasch (1958) and Nelson (1958, 1960). The references to the various groups of Syringopora, an extremely valuable fossil in broad correlation, are based upon a paper by Nelson (1959). A detailed description of the various species of this genus is at present in press (Nelson, 1962).

The faunal succession and its stratigraphic implications will be discussed for two regions. The first, here referred to as the "southern region", extends from Lake Minnewanka, to Mount Darrah in the Flathead area. In this region the palaeontology and stratigraphy of the upper Livingstone-Tunnel Mountain interval is fairly well known. The second, called the "northern region", is between Panther River and Mount Greenock. Strata here are usually unfossiliferous, so that a great deal of interpretation is necessary in determining the age of the Tunnel Mountain-Rundle contact. Species pertinent to stratigraphic interpretation in the northern region are indicated below with asterisks.

Zonation

Southern Region

Lithostrotion sinuosum Zone

The Lithostrotion sinuosum zone was named for an interval occupying approximately 400 feet of the upper Livingstone formation as exposed at Tunnel Mountain, Alberta. Elsewhere the zone is usually difficult to recognize because of its unfossiliferous nature. It is tentatively referred to the Upper Osagean stage.

The fauna consists of *Syringopora virginica* Butts (=S.group 2 Nelson)*, S. group 9 Nelson*, *Lithostrotion sinuosum* (Kelly)*, "*Buxtonia*" *setigerus* (Hall), *Dictyoclostus burlingtonensis* (Hall) and *Girtyella* sp. The zone may be equivalent to Harker and Raasch's (1958) *Spirifer keokuk* zone, the major elements of which are *Spirifer keokuk* Hall, *S. washingtonensis* Weller, "*Buxtonia*" *setigerus* (Hall) and *Myalina keokuk* Worthen.

Spirifer bifurcatus Zone

The *Spirifer bifurcatus* zone is somewhat arbitrarily defined, generally spanning an interval of about 100 feet in the lower Mount Head formation and is approximately equivalent to Nelson's (1960) *Lithostrotionella bailliei* zone. Strata contained by the zone appear to thicken at Lake Minnewanka. In part this may be caused by errors in measurement there, due to the poorly exposed nature of shoreline outcrops. Another possibility is that Crickmay's (1955) bed 14, here referred to the lower part of the zone, may actually belong in the underlying *Lithostrotion sinuosum* zone.

Corals, particularly the colonial *Lithostrotion*, *Lithostrotionella* and *Syringopora* are very useful in defining the zone. Most important species are: *Amygdalophyllum* (=*Ekvasophyllum*) *inclinatum* (Parks), *Lithostrotion warreni* Nelson*, *L. arizelum* (Crickmay), *L. sinuosum* (Kelly)*, *Lithostrotionella bailliei* Nelson*, *L. shimeri* (Crickmay)*, *Syringopora virginica* Butts (=S. group 2 Nelson)*, S. group 5 Nelson*, S. group 9 Nelson*, *Spirifer bifurcatus* Hall, *Composita trinuclea* (Hall), *Dictyoclostus altonensis* (Norwood and Pratten) and *Linoproductus ovatus* (Hall).

Echinoconchus biseriatus Zone

The *Echinoconchus biseriatus* zone extends through approximately 300 feet of beds belonging to the middle Mount Head formation. Like the underlying *Spirifer bifurcatus* zone there is a suggestion that it may thicken at Lake Minnewanka, again possibly due to errors in measurement.

The *Echinoconchus biseriatus* zone is roughly equivalent to Nelson's (1960) *Lithostrotionella astraeiformis* and the lower half of the *Lithostrotion whitneyi* zone. The combined fauna of the *Spirifer bifurcatus* and *Echinoconchus biseriatus* zones suggest an interval equivalent to that spanned by the Warsaw, Salem and St. Louis formations of type Meramecian in the upper Mississippi Valley region (see Nelson, 1958, p. 49). Finer correlation, however, is not yet possible.

Species diagnostic for the zone are *Amygdalophyllum* (=*Ekvasophyllum*) *turbineum* (Parks), *Turbophyllum multiconum* Parks, *Lithostrotion whitneyi* Meek*, *Lithostrotionella astraeiformis* (Warren), *L. shimeri* (Crickmay)*, *L. pennsylvanicum* (Shimer), *L. americana* Hayasaka?, *L. banffensis* (Warren), *Syringopora virginica* Butts (=S. group 2 Nelson)*, *Spirifer bifurcatus* Hall, *Cleiothyridina sublamellosa* (Hall)?, *Productella indianensis* (Hall), *Dictyoclostus tenuicostus* (Hall), *Echinoconchus biseriatus* (Hall), *E. genevievensis* Weller, *Rhynchopora? banffensis* Warren, and *Girtyella turgida* (Hall).

As a rule the cerioid lithostrotionids belonging to the various species of *Lithostrotionella* listed above are most diagnostic for the lower part of the zone, and the fasciculate *Lithostrotion whitneyi* for the upper part.

Girtyella indianensis Zone

The *Girtyella indianensis* zone is usually difficult to recognize in the southern region because of the common lack of diagnostic species and/or the unfossiliferous nature of the containing strata. Often it is delimited by stratigraphic position, with respect to over- and underlying zones. In the area between Mount Rae and Mount Darrah it occupies an interval of between 100 and 200 feet in the upper Mount Head formation. At Tunnel Mountain, and at nearby Mount Norquay (not discussed or shown on Figure 2), the *Gigantoproductus brazerianus* zone is relatively very close to the upper beds of the *Echinoconchus biseriatus* zones. This suggests that the strata contained by the *Girtyella indianensis* zone are thinning northward. The possibility has to be considered that the thinning is due to non-deposition or erosion, and that an unconformable or diastemic relationship is present within the upper Mount Head. As will be discussed later, section condensation in this interval is very apparent in the northern region between Panther River and Mount White.

The poorly exposed and unfossiliferous nature of the upper Mount Head at Lake Minnewanka has prevented definite recognition of the zone.

The *Girtyella indianensis* zone is tentatively referred to the Ste. Genevieve (Upper Meramecian) of the upper Mississippi Valley on the basis of one species, *Girtyella indianensis*. The fauna is as follows: *Syringopora virginica* Butts (= *S.* group 2 Nelson)*, *S.* group 7 Nelson, *Turbophyllum* (=*Faberophyllum*) *leathemanense* (Parks), *Turbophyllum* spp. *Lithostrotion whitneyi* Meek*, *L. arizelum* (Crickmay), *Pugnoides parvulus* Girty, *Composita deltoides* Hernon, *Gigantoproductus brazerianus* (Girty)* and *Girtyella indianensis* (Girty). The most diagnostic elements are *Syringopora* group 7, the various species of *Turbophyllum* (=*Faberophyllum* sensu Parks, 1951), *Lithostrotion whitneyi* and *Girtyella indianensis*. The *Girtyella indianensis* zone roughly corresponds to the upper half of Nelson's (1960) *Lithostrotion whitneyi* zone, and the *Lithostrotion arizelum* zone.

Gigantoproductus brazerianus Zone

The *Gigantoproductus brazerianus* zone is essentially a thanatacoenosic marker bed rather than a faunal zone, and is indicated by cross-hatched lines on Figure 2. In most sections where recognized, the zone spans about 20 feet or so of strata and consists of densely packed, almost coquinoid masses of the brachiopod *Gigantoproductus brazerianus* (Girty)* to the exclusion of all other species. Commonly it is associated with recessive green bentonitic shales of volcanic origin (see Nelson, 1958; 1961) and it is thought that the abundance of this brachiopod is due to either poisoning of the water or super-fertilization during ash falls. Although *Gigantoproductus brazerianus* does occur in over- and underlying zones it is nearly always rare. The species is indigenous to the Cordillera and hence cannot be dated with respect to the type Mississippian System.

Between Mount Rae and Mount Darrah this zone generally marks the Mount Head-Etherington contact. At Tunnel Mountain (and also at Mount Norquay), however, it occurs approximately 120 feet below it (see Nelson, 1958, p. 50), or approximately 300 feet below the Rundle-Tunnel Mountain boundary. As will be explained under the following *Dictyoclostus parvus* zone, the upper part of the Mount Head formation becomes diachronically younger toward the Banff area from Mount Rae.

At Lake Minnewanka the *Gigantoproductus brazerianus* zone has been recognized in upper Mount Head immediately below the Tunnel Mountain-Rundle contact. Faunal evidence from the lower part of the Tunnel Mountain (see below) suggests that this unit becomes diachronically older from Banff eastward toward Lake Minnewanka. A similar diachronic progression occurs northward from Lake Minnewanka, so the *Gigantoproductus brazerianus* zone becomes incorporated within the Tunnel Mountain formation (see Figure 2).

Dictyoclostus parvus Zone

The *Dictyoclostus parvus* zone occupies the lower 200 to 300 feet of the Etherington formation between Mount Rae and Mount Darrah. Northward, strata of the zone thin to about 100 feet at Tunnel Mountain and belong in the upper Mount Head formation (see Nelson, 1958). At Lake Minnewanka the zone has been identified in strata immediately above the Tunnel Mountain-Rundle contact (Nelson, ibid.) indicating that the former unit is becoming diachronically older from Banff eastward to Lake Minnewanka.

The *Dictyoclostus parvus* and the succeeding *Punctospirifer transversa* and *Diaphragmus elegans* zones all bear predominantly Chesterian brachiopod species (Nelson, ibid., p. 49) but closer correlation with the type Chesterian stage is not possible at present. The first zone is approximately equivalent to the *Lithostrotion genevievensis* zone of Nelson (1960) and may be in part upper Meramecian.

Diagnostic fossils are *Syringopora virginica* Butts (= *S.* group 2 Nelson)*, *S.* group 7 Nelson, *Lithostrotion genevievensis* Easton*, *L.* sp., cf. *L. pauciradiale* (McCoy), *Spirifer leidyi* Norwood and Pratten*, *Composita trinuclea* (Hall), *Orthotetes kaskaskiensis* (McChesney), *Dictyoclostus inflatus* (McChesney), *D. parvus* (Meek and Worthen), *Gigantoproductus brazerianus* (Girty)*, *Echinoconchus rodeoensis* Hernon?, *Linoproductus ovatus* (Hall), *Rhipidomella cascadensis* Warren, *Dielasma shumardanum* (Miller) and *Girtyella brevilobata* (Swallow).

Punctospirifer transversa Zone

This zone spans the middle portion of the Etherington formation between Mount Rae and Mount Darrah, an interval of about 200 feet. To the north at Tunnel Mountain containing strata thin to about 100 feet and are placed in the lower Etherington formation. This and the younger zones have not been definitely recognized in sections of the northern region.

The fauna of the *Punctospirifer transversa* zone comprises the species *Pleurodictyum meekanum* (Girty)?, *Spirifer arkansanus* Girty, *Orthotetes kaskaskiensis* (McChesney), *Echinoconchus rodeoensis* Hernon?, *Linoproductus ovatus* (Hall), *Punctospirifer transversa* (McChesney) and *Dielasma shumardanum* (Miller).

Diaphragmus elegans Zone

The *Diaphragmus elegans* zone was originally called the *D. cestriensis* zone by Nelson (1958). The new name is used here to conform with recent taxonomic changes. Essentially it is equivalent to Nelson's (1960) *Lithostrotionella stelcki* zone.

In sections studied this zone occupies the upper 200 feet of the Etherington formation southward from Mount Rae. At Mount Darrah, however, a still younger Etherington fauna, the *Spirifer matheri* zone is present. North at Tunnel Mountain the *D. elegans* zone spans the upper Etherington formation, an interval of about 100 feet, and may extend into the basal beds of the overlying type Tunnel Mountain formation. The zone has not been recognized at Lake Minnewanka or to the north. Its significance in dating the Tunnel Mountain-Rundle contact will be discussed in the following *Spirifer matheri* zone.

The fauna of the *Diaphragmus elegans* zone consists of *Syringopora* sp., *Lithostrotionella stelcki* Nelson, *Spirifer cavecreekensis* Hernon*, *S. leidyi* Norwood and Pratten*, *Torynifer setigera* (Hall), *Composita subquadrata* (Hall), *Orthotetes kaskaskiensis* (McChesney), *Diaphragmus elegans* Norwood and Pratten, *Dictyoclostus coloradoensis* (Girty)?,*Echinoconchus rodeoensis* Hernon?, *Linoproductus ovatus* (Hall) and *Eumetria vera* (Hall).

Spirifer matheri Zone

When proposed, (Nelson, 1958), the *Spirifer matheri* zone was known from only one locality. This is at Mount Darrah, in the upper 100 feet of the Etherington formation. Recently McGugan and Rapson (1961, p. 81) reported representatives of the zone in the lower beds of the Tunnel Mountain formation at Mount Rae, i.e. in the "Norquay" and "Storm Creek" formations of Raasch (1954, 1955, 1958), which he dated as Permian. Upper limits of the zone, both on Mount Darrah and Mount Rae, are not known.

The zone is one of the more interesting in the Carboniferous of the Canadian Rockies in that it appears to bear a Lower Pennsylvanian brachiopod called *Spirifer matheri* Dunbar and Condra*, in association with the Mississippian *Spirifer cavecreekensis* Hernon* and *Composita subquadrata* (Hall). In addition, McGugan and Rapson (ibid.) have reported *Punctospirifer* sp.?,*Cleiothyridina* sp. and *Streblascopora* sp. from the zone.

The first author originally referred this zone to the Pennsylvanian with reservations (Nelson, 1958, p. 52), and these reservations still hold. The stratigraphic position of the zone at Mount Darrah suggests that the Tunnel Mountain-Rundle contact there is Lower Pennsylvanian in age. Northward at Mount Rae the contact appears to become diachronically slightly older, and straddles the Pennsylvanian-Chesterian boundary with the *Diaphragmus elegans* zone below and the *Spirifer matheri* zone above. At Tunnel Mountain the contact is about the same age as at Mount Rae. The highest zone recognized on Tunnel Mountain is the Chesterian *Diaphragmus elegans* zone within the Upper Etherington. On the basis of stratigraphic position with respect to this zone, the overlying type Tunnel Mountain is thought to belong within the *Spirifer matheri* zone and to be Lower Pennsylvanian in age (see Nelson, 1958).

Crickmay (1960, p. 2) has criticized the first author's Pennsylvanian age determination of type Tunnel Mountain by stating:

> "Nelson (1958) stated very positively in the abstract of a paper on brachiopod zones that 'Type Tunnel Mountain formation is thought to be Pennsylvanian in age, not Chesterian as commonly asserted', which might be very valuable if supported, though neither such a statement nor any support for it is to be found in the body of his article."

The comment is inaccurate in two ways. First, the statement quoted cannot be regarded as "very positive", as anyone who objectively read the paper will be aware. In the second place, the statement is supported in the body of the paper in discussion of the Diaphragmus cestriensis (now D. elegans) zone (Nelson, 1958, p. 52). The tentative, not positive, dating of the type Tunnel Mountain formation, then as now, is based upon the laws of stratigraphic succession and of faunal succession, by correlation with Mount Rae and Mount Darrah.

Northern Region

Previously the discussion has dealt with faunal zones and their stratigraphic position in the relatively well known southern region extending from Lake Minnewanka to Mount Darrah. In the northern region most strata are unfossiliferous or contain relatively poorly preserved and undiagnostic species. The following discussion will deal only with those species found which appear to be significant in zoning. The writers wish to stress the highly interpretive nature of their correlations in this region.

Three sections to the north of Lake Minnewanka will be discussed first (see Figure 2). These are Panther River, Dormer River and Mount White. In the first two the Gigantoproductus brazerianus zone is at the Tunnel Mountain-Rundle contact, indicating that this contact is about the same age as at Lake Minnewanka. At Mount White the zone is within the lower part of the Tunnel Mountain formation, suggesting that the unit is becoming diachronically older northward.

Corroboratory evidence for the dating of the contact has been found at Dormer River where Syringopora virginica, Lithostrotion genevievensis var. and Spirifer leidyi, an association indicative of the Dictyoclostus parvus zone, occur in the basal 100 feet of the Tunnel Mountain formation.

As mentioned previously under the Girtyella indianensis zone, there appears to be a tendency for the strata of this zone to thin northward from Mount Darrah to Tunnel Mountain. The three sections north of Tunnel Mountain, on Panther River, Dormer River and Mount White, all show the same tendency but to a much more marked degree. Here the Spirifer bifurcatus zone is only about 130 feet below strata containing the Gigantoproductus brazerianus zone, whereas sections in the southern region have 400 to 500 feet of beds separating the two zones. Fossils identified as belonging to the Spirifer bifurcatus zone from these three sections (see Figure 2) are Syringopora group 9 (section 5), Lithostrotion warreni (sections 5, 7), Lithostrotionella shimeri? (sections 5, 6) and L. bailliei? (section 6).

These condensed relationships over the three sections in the northern area suggest that strata of the Girtyella indianensis zone and probably the Echinoconchus biseriatus zone have either drastically thinned, or else are absent by erosion or non-deposition. A peninsular or high area may have extended over this area during middle and upper Mount Head time (i.e. E. biseriatus and G. indianensis zones), because evidence to the north of here suggests a more normal stratigraphic interval between the *Spirifer bifurcatus* and the *Gigantoproductus brazerianus* zone.

Indian Lookout, the section immediately north of Mount White, is almost completely unfossiliferous. No sign of the recessive bentonitic beds indicative of the *Gigantoproductus brazerianus* zone have been noted. The zone, however, is interpreted as falling within the lower part of the Tunnel Mountain formation because of its proximity to Mount White.

The upper 50 feet of the Tunnel Mountain on Indian Lookout contains very poorly preserved spiriferids belonging to the *Spirifer leidyi-S. cavecreekensis* group. These brachiopods suggest an interval spanned by the Chesterian *Dictyoclostus parvus* to *Diaphragmus elegans* zones. Closer calibration is not possible. The only other fossil found was a *Syringopora* sp. about 400 feet below the Tunnel Mountain-Rundle contact. The coral is very poorly preserved but the large size of corallites suggest *Syringopora* group 9 of the *Spirifer bifurcatus* and (less probably) *Lithostrotion sinuosum* zones. Presuming it indicates the former zone, there is then a suggestion that the interval between the *Spirifer bifurcatus* and *Gigantoproductus brazerianus* (position interpreted) zones is becoming thicker north from Mount White.

South Ram River is stratigraphically similar to Indian Lookout in that it has about the same thickness of Tunnel Mountain. The middle portion of this unit contains bentonitic beds interpreted as belonging within the *Gigantoproductus bragerianus* zone. No sign of the index fossil, however, was noted. The interpretive nature of this zonal positioning is stressed, since unfossiliferous bentonitic beds (in sections such as Panther River and Mount Norquay) are known to occur higher than the *G. brazerianus* zone and there is a possibility the South Ram River bentonites may belong to one of these higher horizons.

Assuming, however, that these beds represent the *Gigantoproductus brazerianus* zone, then the Tunnel Mountain-Rundle contact is older than that at Mount White. At the latter section the contact is about 50 feet below while at South Ram River it is 120 feet below the zone.

The Rundle formation on South Ram River has yielded only one fossil, about 200 feet below the base of the Tunnel Mountain formation. It is a seemingly aberrent colonial coral interpreted as a *Diphyphyllum* genomorph of *Lithostrotion whitneyi* and belonging within the *Echinoconchus biseriatus* zone. Although no representatives of the lower *Spirifer bifurcatus* zone are present it is placed in Figure 2 on the basis of stratigraphic position.

Mount Greenock in the Jasper area is the most northerly section discussed. Brown (1952) originally divided the upper part of the succession into the Rundle and Greenock formations. The latter contained lower, middle and upper members. In the present writers' opinion the lower Greenock formation belongs in the Rundle. The middle and upper members are probably homotaxial with the Tunnel Mountain formation, judging by the stratigraphic and faunal evidence from the area further south.

The only diagnostic fossil found at Mount Greenock is *Syringopora* group 5, about 290 feet below the postulated Tunnel Mountain base. This horizon is in the basal part of Brown's (1952) lower Greenock formation. The coral is diagnostic for both the *Spirifer bifurcatus* and *Lithostrotion sinuosum* zones. Statistical evidence (Nelson, 1962, text-figure 7) suggests that the chances of it representing the former zone are about double that of it representing the latter. Thus, assuming it is within the *Spirifer bifurcatus* zone, the distance between this horizon and the base of the Tunnel Mountain tallies with the interval interpreted for the South Ram River and Indian Lookout sections and the Tunnel Mountain-Rundle contact may be of the same age over these three areas, i.e. mid- or late-Meramecian. This conclusion is, of course, highly tentative. Brown (1952), using a different line of approach, gave approximately the same date to this contact in his excellent but neglected work.

REFERENCES

Beales, F.W., 1950, "The Late Palaeozoic Formations of Southwestern Alberta," Geol. Surv. Canada, Paper 50-27.

Bostock, H.S., Mulligan, R., and Douglas, R.J.W., 1957, "The Cordilleran Region," pp. 283-392; *in* Geology and Economic Minerals of Canada, Geol. Surv. Canada, Econ. Geol., Ser. 1, 4th Ed.

Brown, R.A.C., 1952, "Carboniferous Stratigraphy and Palaeontology in the Mount Greenock Area, Alberta, Canada," Geol. Surv. Canada, Mem. 264.

Crickmay, C.H., 1955, "The Minnewanka Section of the Mississippian," Published by the Author, Imperial Oil Ltd., Calgary, Alberta.

____________, 1960, "The Pennsylvanian Age of the Pennsylvanian of Alberta," American Assoc. Petrol. Geol.-Alberta Soc. Petrol. Geol., Regional Meeting, Banff, Alberta (preprint).

Drummond, J.M., 1959, "Major Diachronism in Carboniferous Deposits of the Bow Valley Area, Alberta," Jour.. Alberta Soc. Petrol. Geol., Vol. 7, No. 11, pp. 260-266.

Harker, P., and Raasch, G.O., 1958, "Megafaunal Zones in the Alberta Mississippian and Permian," American Assoc. Petrol. Geol., Allan Memorial Volume, pp. 216-231.

Kindle, E.M., 1924, "Standard Paleozoic Section of Rocky Mountains near Banff, Alberta," Pan American Geol., Vol. 42, No. 2, pp. 113-124.

McGugan, A., and Rapson, J.E., 1960, "Stratigraphy of the Norquay Formation, Rocky Mountain Group, Banff Area, Alberta," Jour. Alberta Soc. Petrol. Geol., Vol. 8, No. 1, pp. 1-12.

____________, 1961, "Stratigraphy of the Rocky Mountain Group (Permo-Carboniferous) Banff Area, Alberta," Jour. Alberta Soc. Petrol. Geol., Vol. 9, No. 3, pp. 73-106.

Moore, P.F., 1958, "Late Paleozoic Stratigraphy in the Rocky Mountains and Foothills of Alberta -- a Critical Historical Review," American Assoc. Petrol. Geol., Allan Memorial Volume, pp. 145-173.

Nelson, S.J., 1958, "Brachiopod Zones of the Mount Head and Etherington Formations, Southern Canadian Rockies," Roy. Soc. Canada, Trans., Vol. 52, Sec. 4, pp. 45-53.

__________, 1959, "Mississippian Syringopora of Western Canada," Jour. Alberta Soc. Petrol. Geol., Vol. 7, No. 4, pp. 91-92.

__________, 1960, "Mississippian Lithostrotionid Zones of the Southern Canadian Rocky Mountains," Jour. Paleont., Vol. 34, No. 1, pp. 107-126.

__________, 1961, "Mississippian Faunas of Western Canada," Geol. Assoc. Canada, Special Paper No. 2 (in press).

__________, 1962, "Analysis of Mississippian Syringopora from the Southern Canadian Rocky Mountains," Jour. Paleont., (in press).

__________, and Rudy, H.R., 1959, "Stratigraphic Position of the Shunda Formation," Jour. Alberta Soc. Petrol. Geol., Vol. 7, No. 11, pp. 257-259.

Parks, J.M., 1951, "Corals from the Brazer Formation (Mississippian) of Northern Utah," Jour. Paleont., Vol. 25, No. 2, pp. 171-186.

Raasch, G.O., 1954, "Carboniferous Section at Highwood Pass, with Correlations to Banff and Mount Head," Canadian Stratigraphic Service, Limited, Calgary, Alberta.

__________, 1956, "The Permian Rocky Mountain Group in Alberta", Alberta Soc. Petrol. Geol., Sixth Ann. Field Conf., Guide Book, pp. 114-119.

__________, 1958, "Upper Paleozoic Section at Highwood Pass, Alberta," American Assoc. Petrol. Geol., Allan Memorial Volume, pp. 190-215.

Rudy, H.R., 1958, "Permo-Carboniferous Stratigraphy of the Banff-Jasper Area, Alberta," University of Alberta, M.Sc. thesis.

Warren, P.S., 1927, "Banff Area, Alberta," Geol. Surv. Canada, Mem. 153.

__________, 1956, "Age and Subdivision of the Rocky Mountain Formation in the Canadian Rockies," Jour., Alberta Soc. Petrol. Geol., Vol. 4, No. 11, pp. 243-248.

PERMIAN STRATIGRAPHY, AND THE POST-CARBONIFEROUS UNCONFORMITY, JASPER AREA, ALBERTA

by

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ABSTRACT

Uppermost Palaeozoic beds in the vicinity of Jasper, Alberta, consist of a sandstone unit between 20 and 100 feet thick, of Permian and/or Triassic age, underlain by a Permian chert unit 15 to 100 feet thick. A distinctive basal Permian conglomerate contains derived materials ranging from Upper Mississippian to Permian in age, and lies upon unevenly eroded Upper Mississippian or Pennsylvanian strata.

The Permian Ishbel formation of the Banff area appears correlative with the Jasper area chert unit and basal conglomerate, and hence with a chert interval at Wapiti Lake in the Rockies of Northeastern British Columbia. Lower Permian beds at the latter locality appear to be absent in Athabasca Valley but probably occur as derived fragments in the basal conglomerate at Deer Creek 15 miles to the north.

INTRODUCTION

This preliminary report, based on current field work, presents new data on the Rocky Mountain group for the area around Jasper, Alberta, and an interpretation of the stratigraphic relationships within and beneath this group for the area between Banff, Alberta and Wapiti Lake, British Columbia (Figure 1).

The most important publication to date on the late Palaeozoic rocks flanking Athabasca Valley near Jasper is by Brown (1952) who described the stratigraphy and megafaunas of these rocks. More regionally, the Permo-Carboniferous of the Canadian Rockies has been discussed by Crickmay (1955), Douglas and Harker (1958), Drummond (1959), Halbertsma (1959), Halbertsma and Staplin (1960), McGugan and Rapson (1960, 1961), Nelson (1958, 1960), Norris (1957), Raasch (1954, 1956, 1958) and Warren (1947, 1956).

The Permo-Carboniferous of the Jasper area is of particular interest. To the south near Banff, a thin section of Pennsylvanian (Lower Atokan) and Middle Permian rocks is now recognized, while to the north, in the subsurface of the Peace River area, a thick succession of Pennsylvanian and Permian rocks is developed. In addition, at Wapiti Lake 110 miles northwest of Jasper, Lower Permian (Wolfcampian) fusulinids are present (Forbes and McGugan, 1959) in beds beneath a chert and sandstone series containing a Middle Permian Arctic *Waagenoconcha* fauna. Lower Permian fusulinids also occur at Winnifred Pass between Wapiti Lake and Jasper, but details of the section there are not yet available.

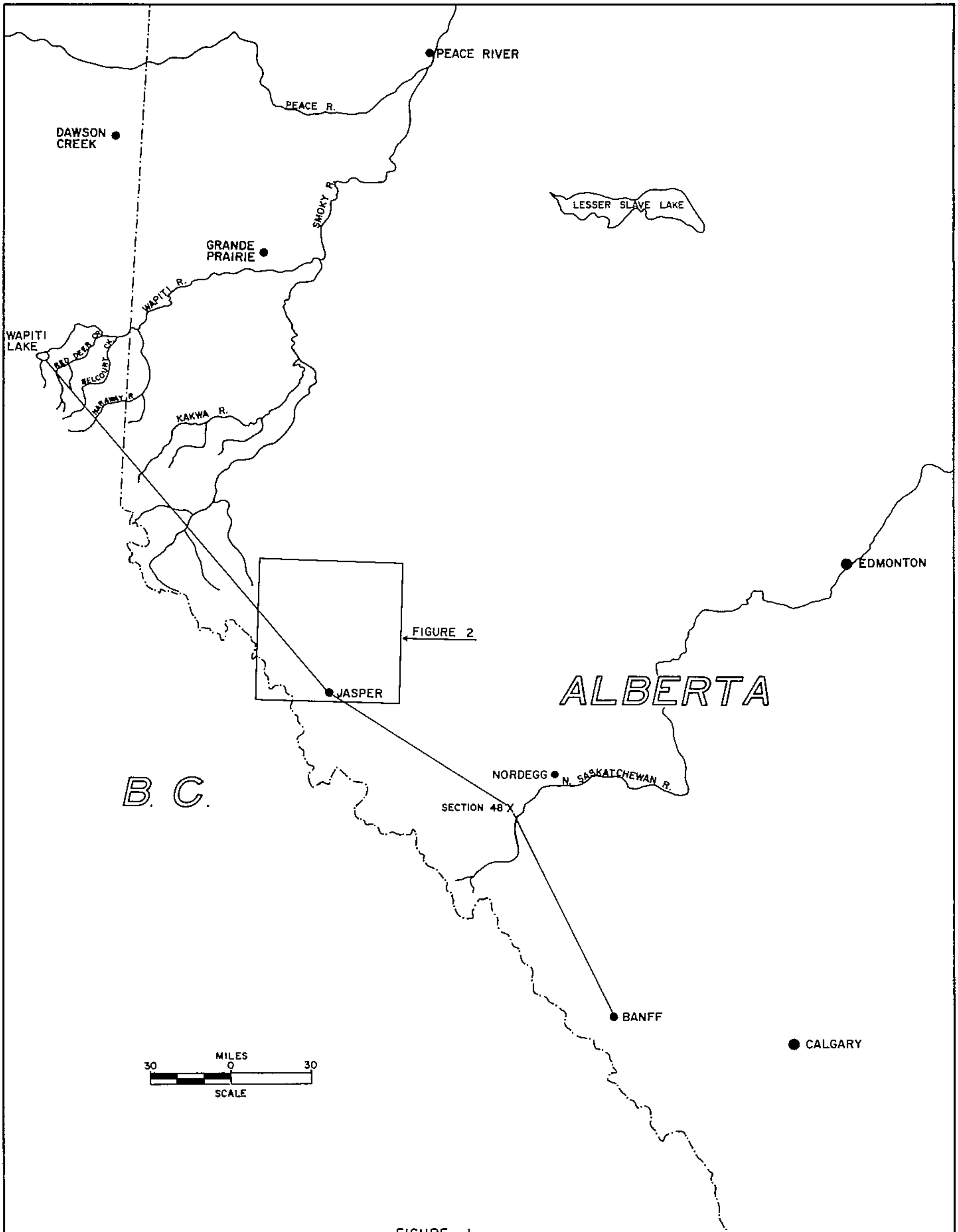


FIGURE 1

SKETCH MAP SHOWING LOCATION OF JASPER AREA

AND WAPITI LAKE - BANFF CROSS SECTION (FIG. 6)

It can be seen that the relationship between these previously unrelated north and south areas is fundamental to the understanding of the Permo-Carboniferous stratigraphy of Western Alberta.

STRATIGRAPHY AND PALAEONTOLOGY

Figure 2 shows the location of outcrop sections near Jasper and Figure 3 is a generalized composite section of the Permo-Carboniferous sequence there.

Permian

Permian strata at Jasper and for some distance north and south can be recognized by a distinctive basal conglomerate. In the Jasper area, this unit occurs at the base of Brown's (1952) middle member of the Greenock formation, and varies from a few inches to seven feet thick. It contains elements varying from rounded to angular and from granule size to boulders two feet in diameter. The elements represent a wide lithic range, and come from varying Carboniferous horizons (See Figures 5a and 5b). Many distinctive younger Carboniferous levels are lithologically recognizable and fragments of Carboniferous fossils are occasionally found. Fusulinids of Permian age occur in derived chert pebbles in the conglomerate at Deer Creek headwaters (Section 60).

Several specimens of conglomerates and conglomeratic sandstones were examined from each of the fourteen localities shown on Figure 2, enabling statistically reliable pebble counts to be made. The nature and variation of components are summarized in tabular form on Figure 4. Five are recognized. In order of frequency and significance these are: Chert types identical with those found in situ in Carboniferous limestones and dolomites; black sandstones, siltstones, shales, and spicular cherts lithologically similar to those in the Ishbel formation in the south (McGugan and Rapson, 1961); dolomites, light colored sandstones and siltstones comparable to those of the Tunnel Mountain formation; and finally, insignificant quantities of reworked quartz material.

The conglomerate matrix is always a sandstone rich in black chert and siltstone, phosphate and glauconite, with pyrite, iron oxides and subordinate quartz. Two types of cement occur. The first is a black, opaque, extremely fine grained phosphatic or bituminous substance with abundant pyrite, which is lithologically similar to the cement of the breccias and conglomerates in the Ishbel formation. This cement, where present, occurs in the basal two to six inches of the conglomerate. The second cement type, found in the upper parts, is siliceous.

There is interesting variation in maturity within the conglomerate, A considerable proportion of very angular fragments and less stable rock materials such as black siltstone, shale and dolomite, are present in the basal parts, which are thus strictly breccio-conglomerates (See McGugan & Rapson, 1961, page 83). This indicates immaturity with rapid accumlation and preservation. The upper parts of the conglomerate, by contrast, are more mature, with a high proportion of rounded chert pebbles and boulders. Thus, an initial period of rapid accumulation was followed by one of reworking, both being represented within the one widespread conglomerate.

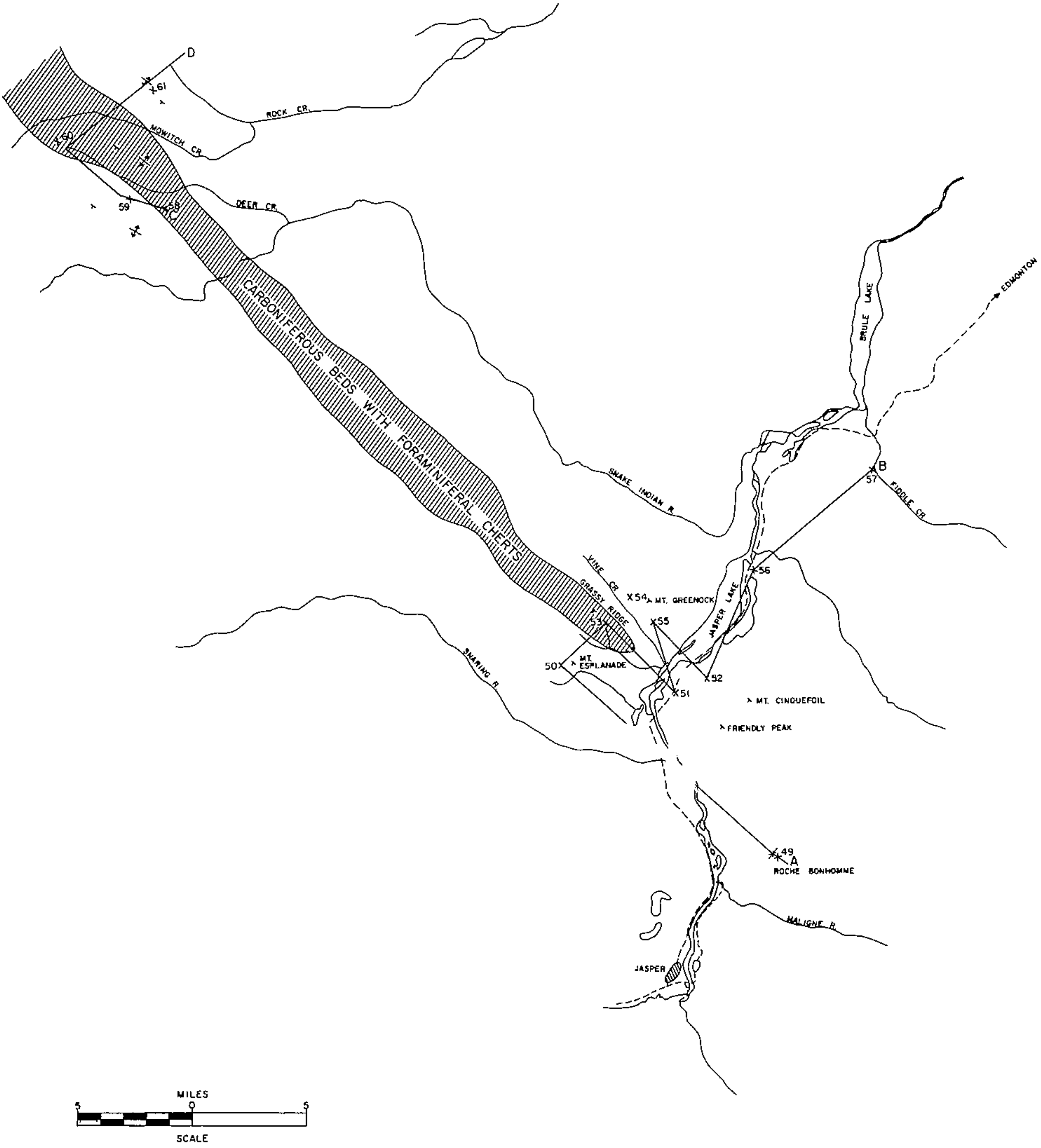


FIGURE 2

LOCATION MAP OF JASPER AREA

SHOWING SECTIONS EXAMINED AND POSITION OF CROSS-SECTIONS AB AND CD

Two rock units (1 and 2) may be distinguished in the interval between the basal Permian conglomerate and the Triassic Spray River formation in the Jasper area. These correspond to the middle and upper members of Brown's (1952) Greenock formation. The lower unit (1) consists of 15 to over 100 feet of massive grey chert, which normally weathers white. Scattered zones of brecciation occur through the chert. Irregularly distributed sandstone and dolomite inclusions, which may result in large-scale vugs and cavernous weathering, are also found. At Wapiti Lake and further north, apparent correlatives of this unit contain the Middle Permian Arctic Waagenoconcha fauna.

The upper unit (2), which follows concordantly and possibly gradationally, is a brown-weathering, grey quartzitic sandstone with subsidiary chert. Grey siliceous carbonate bodies are present in it at various levels and characterize the uppermost few feet. These bodies, which are considered to be derived carbonate blocks, are well exposed at the top of the Mount Greenock section (Sections 54 & 55). At Deer Creek headwaters (Section 60), Unit 1 totals 100 feet in thickness, and consists of sandstone beds containing locally derived blocks of carbonate interbedded with laminated and cross bedded sandstones. The thickness of this unit varies from 20 to 100 feet, and averages 40 feet.

The following tentative hypotheses can be advanced on the genesis of the Permian beds in the Jasper area on the basis of field observations to date: The basal conglomerate apparently marked the initiation of a period of marine transgression during which carbonates with interlenses of fine clastic debris were laid down. The carbonate beds were then lithified and elevated to form a karstland topography. Pot holes and other surface irregularities, as well as intraformational breccias, resulted. A second transgression then caused deposition of the upper sandstone unit (2) with its sorted clastic debris; these clastics infilled the karstland surface, cemented the breccias, and gave rise to varying thicknesses of beds, some containing large blocks of locally derived carbonate debris. Irregular silicification some time after deposition resulted in replacement of the lower carbonate unit (1) by chert, and silification of the upper sandstone (2). Compaction formed cone-in-cone structures and large scale stylolitic intergrowths. Extensive fracturing also took place.

No fossils have been found in either Units 1 or 2 in the Jasper area, where these beds are overlain without obvious disconformity by low weathering platy Spray River siltstones.

Carboniferous

Various Carboniferous erosion levels are encountered beneath the basal Permian conglomerate near Jasper, depending on locality. Lithologic criteria assist in determining the horizon present. Of these, the two most distinctive are buff-weathering platy sub-lithographic grey dolomites, and an underlying, probably less wide-spread horizon, with rusty-weathering, large ramifying and rounded grey chert nodules in grey dolomite (Figures 5a and 5b).

Fossils are sparse in the uppermost Carboniferous of the Jasper area. At Roche Bonhomme (Section 49), a brachiopod and coral fauna, including Spirifer cf matheri of probable Morrowan age, underlies the basal Permian conglomerate. At Deer Creek headwaters (Section 60) bryozoa and brachiopods, of as yet undetermined age, occur approximately 20 feet below the eroded Carboniferous top.

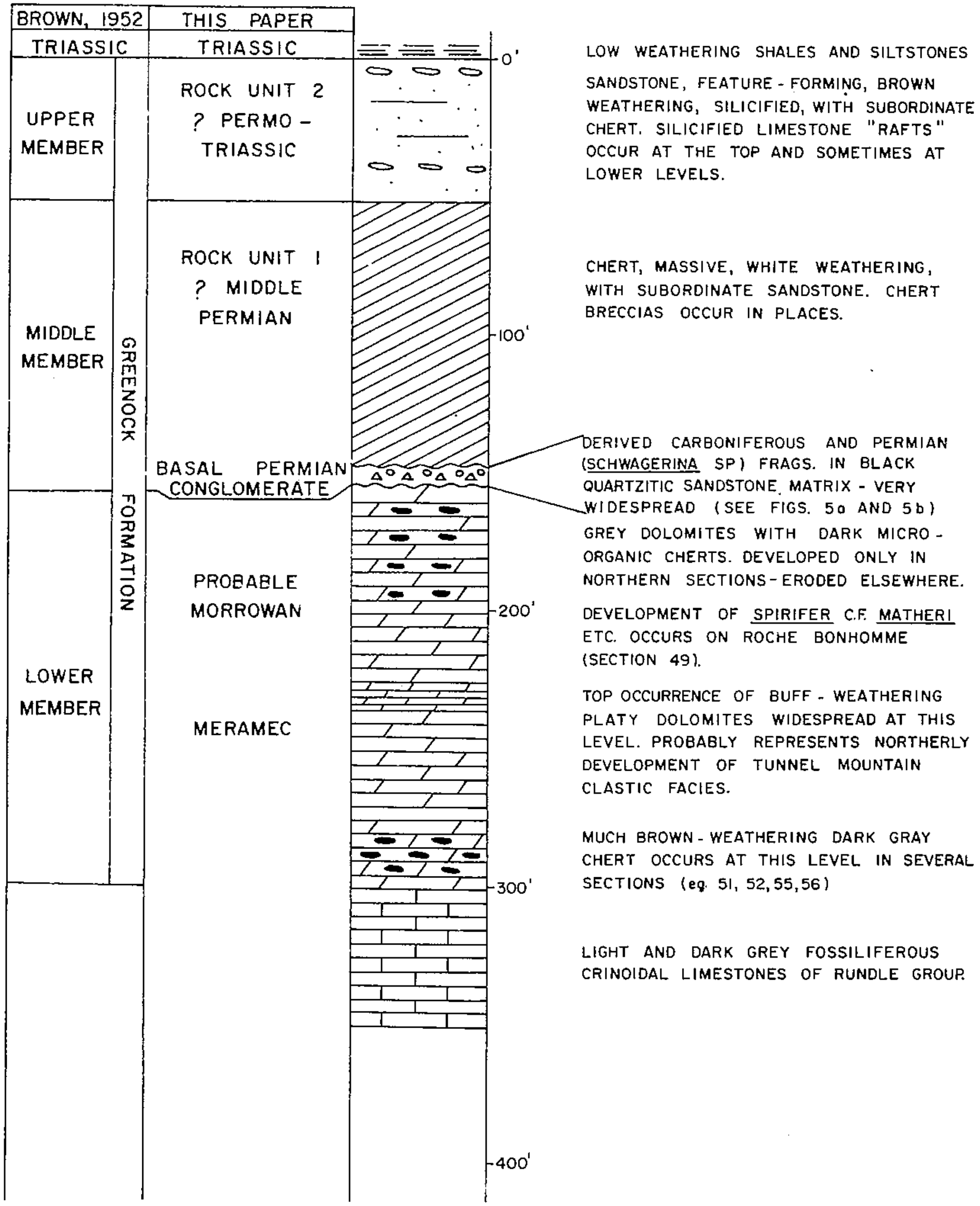


FIGURE 3

GENERALIZED COMPOSITE SECTION, JASPER AREA

Foraminifera are present in dark grey to black nodular cherts at three separate localities; (1) Grassy Ridge (Section 53) has chert nodules with rare, poorly preserved, small primitive coiled foraminifera, in the highest Carboniferous present, and fragments of similar chert occur in the overlying Permian conglomerate; (11) Deer Creek (Section 58) displays a similar but much better preserved microfauna of Morrowan aspect; (111) At Deer Creek headwaters (Section 60), several horizons of probable Morrowan foraminiferal cherts occur 50 to 80 feet below the top of the Carboniferous, which has here the least eroded section of the Jasper area. The overlying conglomerate contains derived brachiopods, bryozoa, gastropods and cherts with small Permian fusulinids showing fluted septae. Dr. C. L. Forbes, of Sedgwick Museum, Cambridge, England, reports on the Carboniferous foraminifera as follows:

"The genera present are *Plectogyra* sp., *Eostaffella* sp., *Millerella* sp?, and represent an earlier fauna than that in the Kananaskis formation at Banff. They are approximately of Morrow age." Forbes also identifies the fusulinids from the overlying conglomerage as Permian *Schwagerina* sp.

At Friendly Peak (Section 51) Brown (1952) reported *Tetracamera subcuneata* (Hall) from just above the highest buff-weathering platy dolomite. Ostracods are also abundant in this bed, which was given a low Middle Carboniferous (Meramec) age. The lower member of the Greenock formation was referred to the Visean by Brown (ibid) from the presence of *Brachythyris* n. sp., *Spirifer* n. sp., *Eumetria* sp., *Cleiothyridina* sp. and Productids. *Perditocardinia dubia* (Hall) was also reported from one locality.

LOCAL CORRELATIONS

Figure 5a correlates the Permian and uppermost Carboniferous in the Athabasca Valley, and Figure 5b in the Deer Creek area, both along an east-west line. It will be seen that the basal Permian conglomerate is developed in every section, although it was rarely reported by previous workers. This is probably because the bed weathers back and it is usually necessary to go above treeline for exposures. The conglomerate is of maximum thickness and coarseness in Section 56, where erosion of the Carboniferous was relatively great. Further east, at Fiddle Creek (Section 57), it is a polygenetic concentrate of well reworked elements and is the only representative of the late Mississippian, Pennsylvanian and Permian time intervals.

Variation in thickness, facies and erosional level of Carboniferous strata beneath the Permian unconformity cannot be fully explained with data accumulated to date. For example, foraminiferal cherts were not found at Mount Greenock (Sections 54 & 55) although there appears to be slightly more Carboniferous section remaining at that locality than at others in the Athabasca Valley. The Mount Greenock sediments may have been deposited outside the zone of foraminiferal cherts. The possible limits of foraminiferal chert development are indicated on Figure 2.

Figure 5b displays a consistent overall pattern. Foraminiferal cherts generally occur where erosion of the Carboniferous is least. The cherts also occur along strike at Grassy Ridge (Section 53, Figure 5a).

COMPONENTS	SOURCE	VARIATION	HIGHEST PERCENTAGE
CHERT (a) Organic; at 53,60 these include foraminiferal cherts.	Some may be Permian Carboniferous	2 - 17% Absent in 4 localities	South and East (54, 53, 56, 52, 59). Also North (60), and upper (61) where organic cherts are frequent.
(b) Dark coloured		7 - 29% Absent in 3 localities	
(c) Light coloured		26 - 100% Always present	
DOLOMITE & SILTY DOLOMITE	Tunnel Mountain Clastics	4 - 62% (4 Localities)	South & West.(50, 51, 49).
LIGHT COLOURED SANDSTONE & SILTSTONE		Less than 10% (3 Localities)	Insignificant
BLACK very fine grained SANDSTONE, SILTSTONE & SHALE	Lower (?) Permian	1 - 42% (8 Localities)	North & West (60, 61, 59, 50) Also South.(48).
Quartz	Reworked; original source uncertain	3 - 6%	Insignificant. South & West 6%(51), 3%(49).

Figure 4. Constituents of Conglomerates.
(51) etc., refer to Section numbers.

FIGURE 5a: EAST-WEST CORRELATION OF PERMO-CARBONIFEROUS, JASPER AREA (ATHABASCA VALLEY)

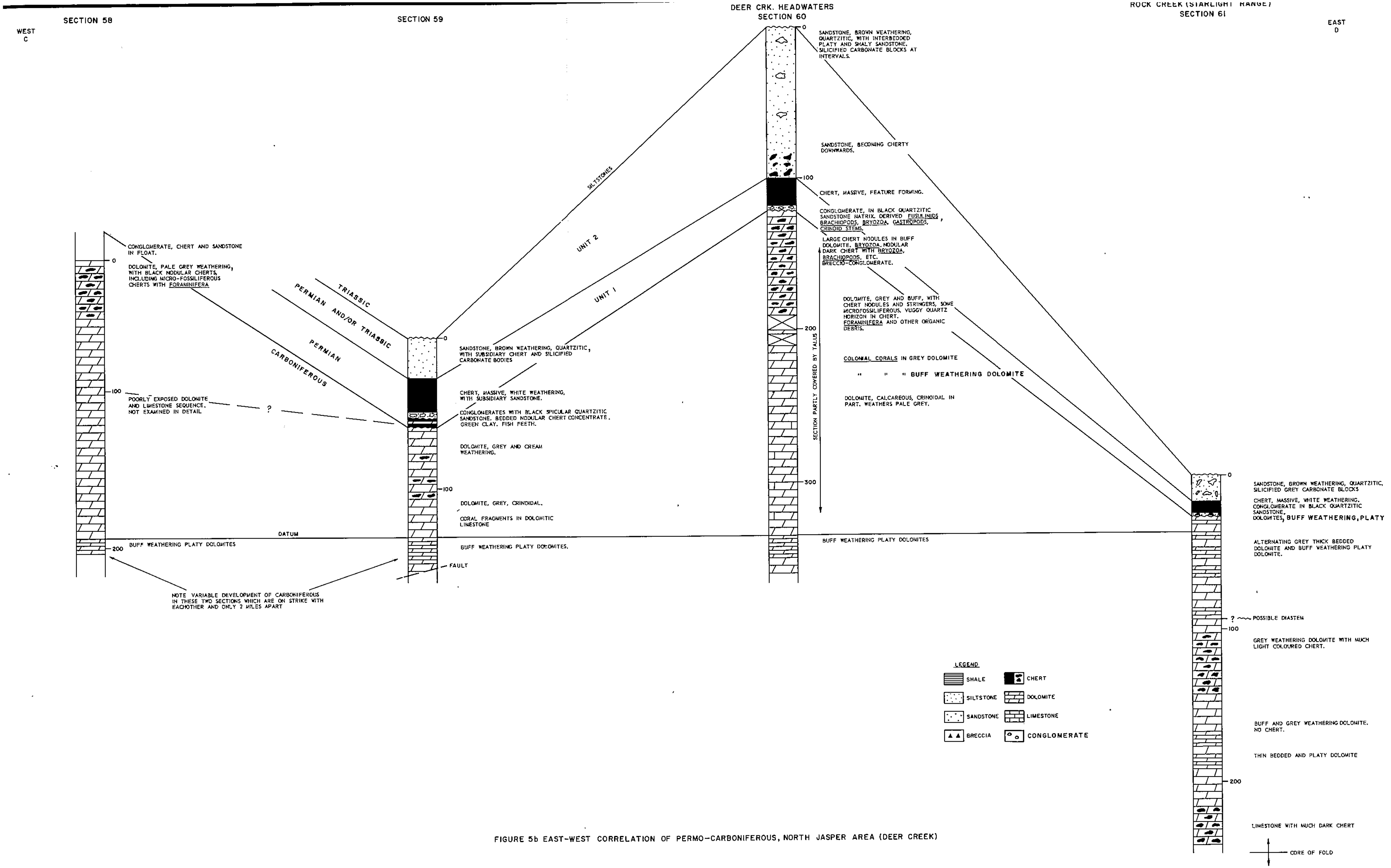


FIGURE 5b EAST-WEST CORRELATION OF PERMO-CARBONIFEROUS, NORTH JASPER AREA (DEER CREEK)

Figure 5b also demonstrates interesting irregular erosion of the Carboniferous surface between Sections 58 and 59, which are only two miles apart along strike. In Section 58, foraminiferal cherts occur approximately 40 feet below the top of the Carboniferous and 160 feet above the buff-weathering platy dolomites. In Section 59, these cherts are absent and only 90 feet of Carboniferous beds overlie the platy dolomites. The fact that the basal Permian conglomerate is thicker than usual in Section 59 would appear to correspond with the greater erosion there.

A careful search of conglomerate components is presently being made in section samples to identify, in particular, derived foraminiferal cherts (particularly fusulind ones), similar to those already known from Grassy Ridge (Section 53) and Deer Creek headwaters (Section 60.)

REGIONAL CORRELATIONS

Figure 6 is a tentative north-south correlation between Wapiti Lake, Jasper and Banff. More control is required to positively establish the relationships shown, but it is believed that they will need, at most, only minor subsequent alterations. The outcrop on the North Saskatchewan River near Windy Point (Section 48, Figure 1) is most important to the cross section, in linking the Banff and Jasper areas. Not far east of Windy Point, Permian beds are absent due to erosion and/or non-deposition.

The Helicoprion-bearing Middle Permian chert unit of the Upper Ishbel formation is the probable equivalent of the chert (Unit 1), and of the Wapiti Lake chert unit of the same age. The upper sandstone (Unit 2) is represented by only a few feet of beds at the top of northerly sections in the Banff area. The age of this unit at Jasper is problematic, but may be Permian and/or Triassic.

Correlation of Lower Ishbel dark, fine-grained clastics with the basal Permian conglomerate and siltstones of the North Saskatchewan River, and with the basal conglomerate of the Jasper area is supported by both lithologic evidence and the relative stratigraphic position of these units. The relationship between the Jasper area conglomerate and the Wapiti Lake section is still uncertain.

The northern expression of clastics of the Carboniferous Tunnel Mountain formation of the Banff area is dealt with in some detail by Nelson and Rudy (this volume), with whom the present writers are in essential agreement for the area nearest Banff. This is not so at Mount Greenock, however, where Nelson and Rudy tentatively refer the beds, here classed as Permian, to the Tunnel Mountain formation. The Windy Point exposures on the North Saskatchewan River (Section 48) present good evidence on the extent of the Tunnel Mountain lithofacies. At that locality clastics typical of the formation are reduced to 20 feet in thickness beneath a basal Permian conglomerate of Jasper area type. The Tunnel Mountain, here as elsewhere, appears conformable on underlying beds. On the basis of the North Saskatchewan section, it is the present writer's opinion that the Tunnel Mountain clastics do not occur any distance north of that point. They may be replaced by carbonate rocks of similar age, and some erosion of the upper beds may also occur. It is probable that the distinctive buff=weathering platy dolomites of the upper Carboniferous at Jasper (Figures 5a and 5b) at least partly represent a diachronically older northerly carbonate equivalent of Tunnel Mountain clastics.

At Wapiti Lake, where the Carboniferous is again represented by carbonates, the breccio-conglomerate 70 feet below the top of the Palaeozoic represents a break between Permo-Pennsylvanian and Chesterian deposition. The magnitude of the break is uncertain, as Pennsylvanian strata have not been definitely recognized at this locality.

Detailed correlation of the sections described above with the subsurface "Permo-Pennsylvanian" succession of the Peace River area must await further surface and subsurface studies.

REFERENCES

Brown, R.A.C., 1952, "Carboniferous Stratigraphy and Palaeontology in the Mount Greenock Area, Alberta", Geol. Survey Canada, Mem 264.

Crickmay, C. H., 1955, "The Minnewanka Section of the Mississippian," Imperial Oil Limited, Calgary.

_______________, 1960, "The Pennsylvanian Age of the Pennsylvanian of Alberta," Preprints, Frontiers of Exploration in Canada, A.A.P.G.-A.S.P.G. Regional Meeting.

Douglas, R. J. W., and Harker, P., 1958, "Mississippian Succession in Mount Head Area, Alberta," in Jurassic and Carboniferous of Western Canada, Symposium, Amer. Assoc. Petrol Geol., Tulsa, pp. 177-189.

Drummond J. M., 1959, "Major Diachronism in Carboniferous Deposits of the Bow Valley Area, Alberta," Jour. Alberta Soc. Petrol. Geol., Vol. 7, No. 11, pp. 260-266.

Forbes, C.L., and McGugan, A., 1959, "A Lower Permian Fusulinid Fauna from Wapiti Lake, B.C.," Jour. Alberta Soc. Petrol. Geol., Vol. 7, No. 2, pp. 33-42.

Halbertsma, H. L., 1959, "Nomenclature of Upper Carboniferous and Permian Strata in the Subsurface of the Peace River Area," Jour. Alberta Soc. Petrol. Geol., Vol. 7, No. 5, pp. 109-118.

_______________,and Staplin, F.L., 1960, "The Mississippian-Pennsylvanian Boundary from the Peace River Area to the Williston Basin," Jour. Alberta Soc. Petrol. Geol., Vol. 8, No. 12, pp. 363-373.

McGugan, A., and Rapson, June E., 1960, "Stratigraphy of the Norquay Formation, Rocky Mountain Group, Banff Area, Alberta," Jour. Alberta Soc. Petrol. Geol., Vol. 8, No. 1 (errata, Vol. 8, No. 2, p. 79.)

____________________, 1961, "Stratigraphy of the Rocky Mountain Group (Permo-Carboniferous) Banff Area, Alberta," Jour. Alberta Soc. Petrol. Geol., Vol 9, No. 3.

Nelson, S. J., 1958, "Brachiopod Zones of the Mount Head and Etherington Formations, Southern Canadian Rockies," Trans. Roy. Soc.

FIGURE 6. TENTATIVE CORRELATION, WAPITI LAKE, B.C. TO BANFF, ALTA.

Nelson, S. J., 1960, "Mississippian Lithostrotionid Zones of the Southern Canadian Rocky Mountains," Jour. Paleont., Vol 34, No. 1.

Norris, D. K., 1957, "The Rocky Mountain Succession at Beehive Pass, Alberta," Jour. Alberta Soc. Petrol. Geol., Vol. 5, No. 10, pp. 248-254.

Raasch, G. O., 1954, "Carboniferous Section at Highwood Pass, with Correlations to Banff and Mt. Head," Canadian Stratigraphic Service Ltd., Calgary, Alberta.

____________, 1956, "The Permian Rocky Mountain Group in Alberta," Alberta Soc. Petrol. Geol. Guidebook, 6th Ann. Field Conf., pp. 114-119.

____________, 1958, "Upper Paleozoic Section at Highwood Pass, Alberta," in Jurassic and Carboniferous of Western Canada, Symposium, Amer. Assoc. Petrol. Geol., pp. 190-215.

Warren, P. S., 1947, "Age and Subdivisions of the Rocky Mountain Formation at Banff, Alberta," (Abstract), Bull. Geol. Soc. America, Vol. 58, No. 12, Pt. 2, p.1238.

____________, 1956, "Age and Subdivision of the Rocky Mountain Formation of the Canadian Rockies," Jour. Alberta Soc. Petrol. Geol., Vol. 4, No. 11, pp. 243-248.

ROAD LOGS

Compiled by G. M. Smart.

Shell Oil Company of Canada, Limited.

Road log Number 1 covers the route for the first day of the field trip along Highway 16 east of Jasper to Pocahontas, then up the side road to Miette Hot Springs. The first portion of the route can be followed on the geological maps of Athabasca Valley (Sheets 1 and 2, in pocket).

Road log Number 2 should be used on the morning of the second day during examination of the Precambrian west of Jasper.

Road log Number 3, for the afternoon of the second day, covers a portion of the north side of the Athabasca Valley including the Mount Greenock section, and should be used in conjunction with geological map Sheet 2.

Thw writer wishes to thank Dr. E. W. Mountjoy, Geological Survey of Canada, and Dr. H. A. K. Charlesworth, University of Alberta in Edmonton, for invaluable assistance with the road logs.

ROAD LOG NO. 1 - JASPER TO MIETTE HOT SPRINGS

0.0	Signpost at eastern outskirts of Jasper Town.
0.3	North - Terrace of lacustrine sands, 150 feet above the road or approximately 400 feet above present river level.
0.5	Canadian National Railways underpass.
0.6	Branch road to Cottonwood Creek camp ground and cabins.
0.8	Southeast - Signal Mountain (7397 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.
1.1	Northeast - The Colin Range demonstrates outcrop expression of Devonian and Carboniferous strata. Triassic forms the peak of Roche Bonhomme. (See sketches at mile 10.1).
1.3	Southwest - Good view of Mt. Edith Cavell (11,033 feet), a prominent pyramidal peak, composed of about 4000 feet of Lower Cambrian and Proterozoic sediments. The Proterozoics lie beneath the treed slopes.
1.8	Branch road to Jasper Park Lodge on east side of highway.
2.0	West - Road and railroad outcrops of sandstones and conglomerates of Jasper formation, overlying Miette argillites. (See Charlesworth, Evans and Stauffer in this Guidebook for terminology.

2.4 Culvert of Pyramid Creek on approximate surface position of Pyramid fault, in which Jasper formation strata are thrust upon Upper Palaeozoics.

2.5 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.

3.4 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 cut in or at the top of Palliser limestones.

4.0 West - Gently dipping Palliser strata, exposed beside the railway, represent the southern end of The Palisades.

5.2 East - Gorge in northwest ridge of Roche Bonhomme is cut in the axial zone of a syncline.

5.6 West - The Palisades. The upper cliffs are Palliser formation; middle slope is shale facies of the Fairholme Group (Alexo, Mt. 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 Athabasca Valley, are located in the foot wall of Pyramid fault and form the westernmost Front Range here.

5.9 Good view of Pyramid Mountain (9076 feet) through gorge in The Palisades.

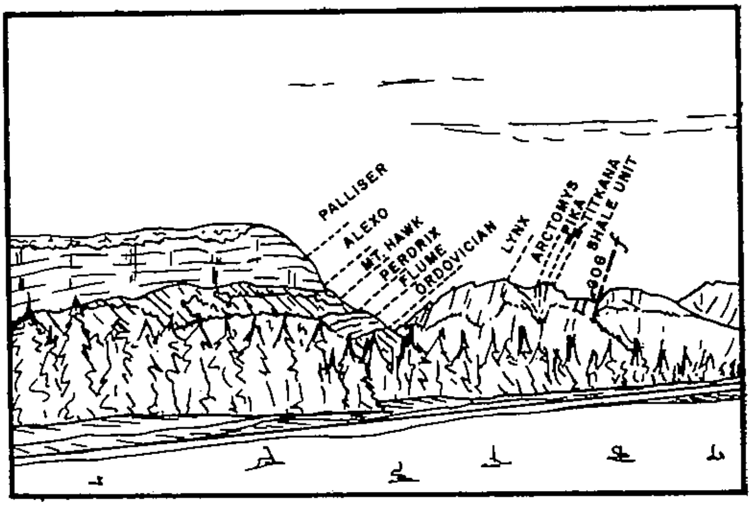
6.1 West - Branch road to Palisades Motel and Lodge. This is the old Swift Ranch, near which Kindle (1929) obtained a Lower Ordovician Bellefontia fauna.

6.2 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. (See 10.1 for sketch.)

6.5 Branch road to Jasper airport on east side of highway.

6.7 Canadian National Railways underpass.

6.8 Chetamon Mountain and The Palisades (See Mile 9.0 for further sketches and maps).



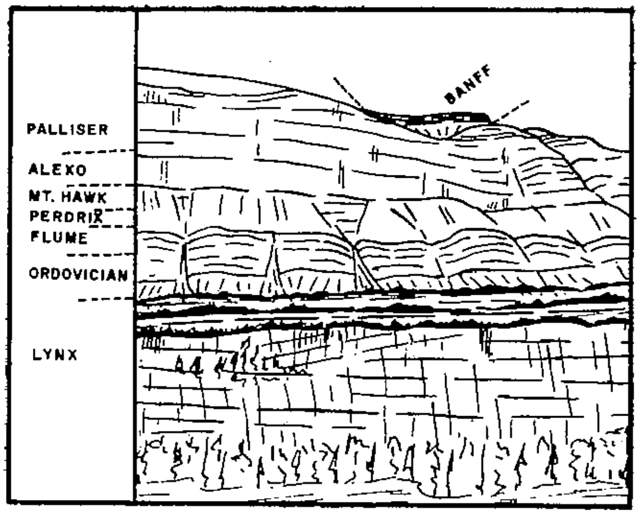
View of The Palisades and Chetamon Mountain
from Mile 6.8

6.9 The road is here cut in Pleistocene lacustrine sands.

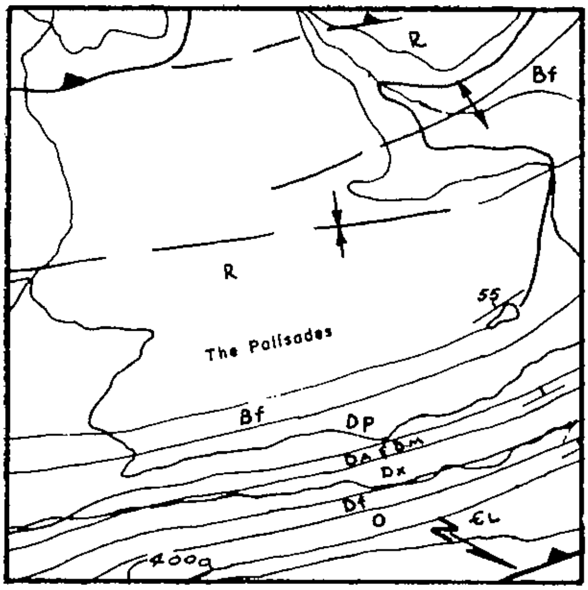
7.3 East - Garonne Creek gorge in Devonian limestones on west slopes of Colin Range. Mount Colin is on the south side of gorge, and Mount Hawk on the north. These mountains form a single structural unit, and are separated from the Roche Bonhomme structure by the Chetamon fault, which brings Ordovician to the surface at Beaver Lake.

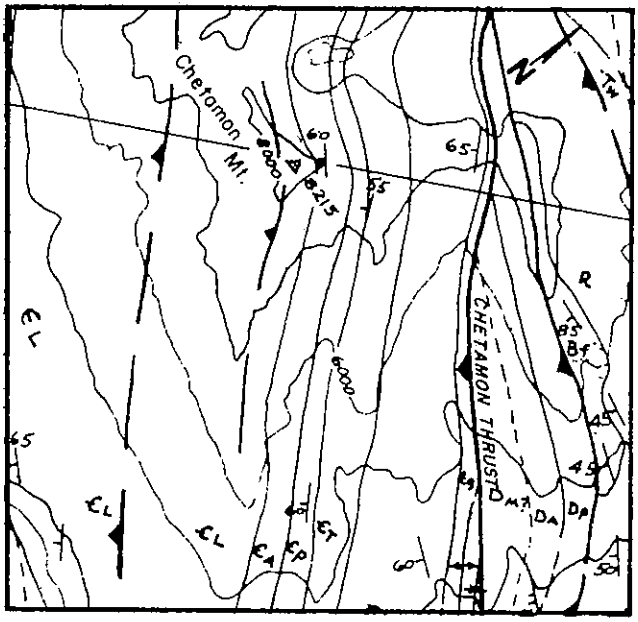
7.7 - 9.0 West - Cliff at foot of The Palisades is composed of Lynx formation which is hard, light grey limestones and dolomites interbedded with intraformational conglomerates and yellow-weathering, silty limestone with rare sandstone. The cliff is continuous with the west peak of Chetamon Mountain where there is about 5000 feet of faulted Upper Cambrian strata between the Arctomys and Lower Ordovician. The true thickness of these beds is in the order of 2500 feet.

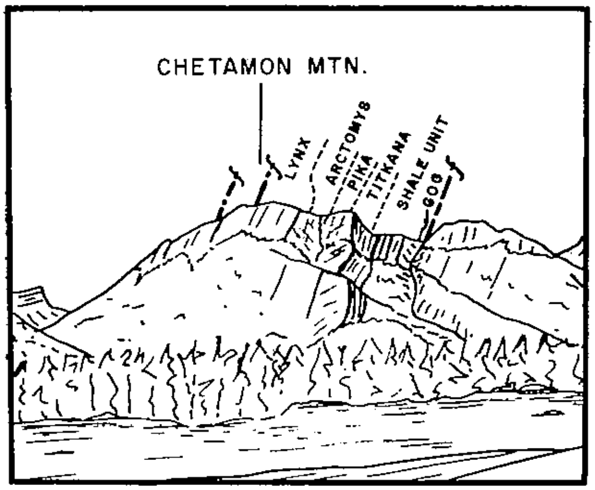
9.0 Stop No. 1. View of The Palisades and Chetamon Mountain.



The Palisades from Mile 9.0.







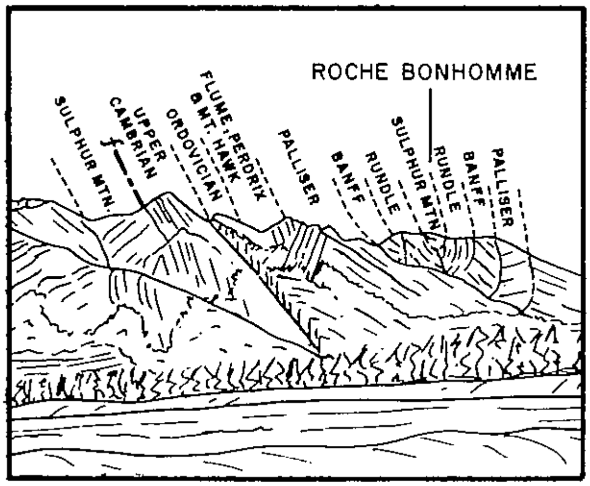
Chetamon Mountain from Mile 9.0.

9.3 East - Mount Hawk: The peak is Palliser limestone with Banff and Rundle on the west slopes.

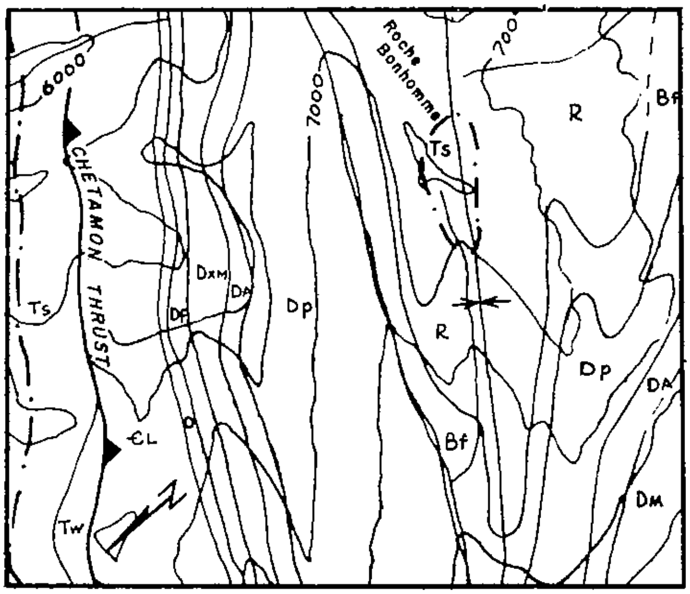
West - Chetamon Mountain and The Palisades.

10.1 Stop No. 2. Bridge across Snaring River.

Southeast - Good view of Roche Bonhomme structure. The Colin Range is associated with two parallel thrust sheets, of 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 and Devonian overlying Cambrian strata. In the Roche Bonhomme unit Ordovician strata are present, and Triassic Sulphur Mountain formation is preserved in the syncline forming the peak of Roche Bonhomme.



View of Roche Bonhomme from Mile 10.1



11.1 Approximate surface trace of Chetamon thrust.

11.9 Canadian National Railway crossing.

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

12.0 North - Gargoyle Mountain, on strike with Esplanade Mountain, shows folding on its western flank.

12.1 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.

12.3 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.

12.4 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.

12.5 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.

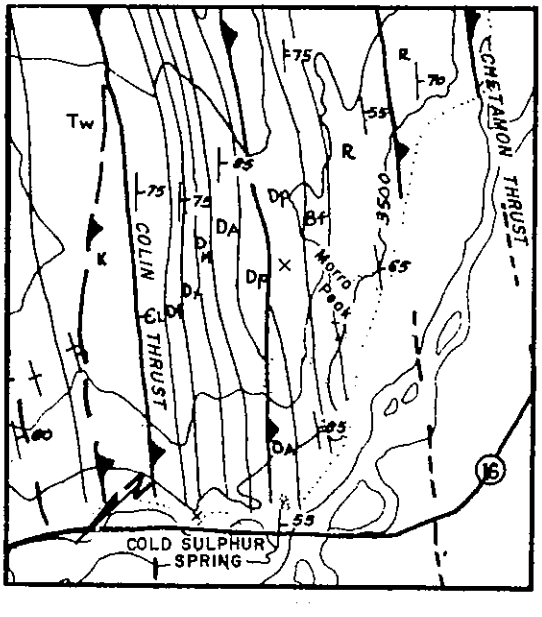
12.6 South - Mount Hawk limestones are exposed on the ridge above the east end of pond.

12.7 South - Perdrix shales underlie a forested saddle to the east of Morro Peak, south of the road.

12.8 Stop No. 3. 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 fossilferous type Eleutherokomma jasperensis zone is in the upper one foot of limestone directly below the black shales. The Devonian base lies approximately 60 feet west of the retaining wall.

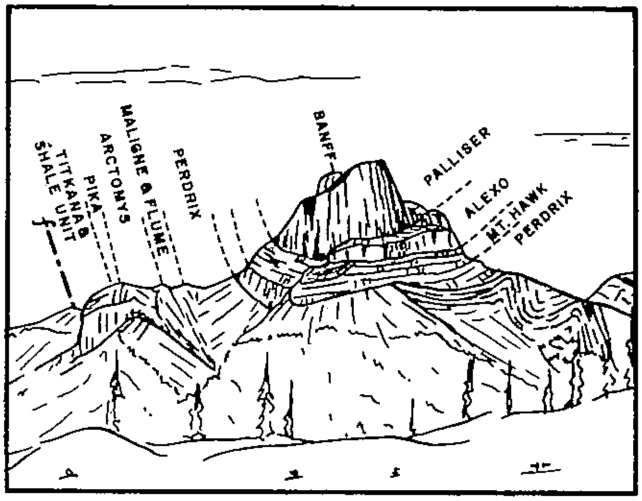
From this stop point, a short climb allows examination of formations between the Perdrix and Palliser. A trail which follows a gully in the Perdrix and cuts across onto Mount Hawk and Alexo formations, is possibly part of the old Jasper Trail. Continuous outcrops can be seen on upper Morro Peak on strike with those traversed. An interesting, highly contorted slump(?) block is present in the Mount Hawk formation, and the Palliser is fault-thickened.



12.9	South - Approximate surface position of Colin thrust. Cambrian (Lynx formation) thrust on Rundle and Whitehorse strata at this fault. North - The strata in the Colin thrust sheet can be traced across the river onto the east slopes of Esplanade Mountain.
13.3	A road outcrop displays Triassic Sulphur Mountain siltstones and shales.
13.4	South - Outcropping Rocky Mountain group is underlain by Rundle group, Banff and Palliser formations.
13.5 - 13.8	South - The Rundle weathers to a forested slope on the far side of the marsh area. Near the road, argillaceous Banff and Palliser limestones are located in the axis of an anticline, of which both limbs are visible. This anticline continues to Grassy Ridge in the north, where a gulley displays the Banff/Palliser contact.
14.1	South - Cinquefoil Mountain (7412 feet), is composed of rocks of Devonian to Triassic age.
15.2	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 Range.
15.3	The contact between dark Rocky Mountain and pale Rundle is visible on the north spur of Cinquefoil Mountain.
15.4	South - The Banff/Palliser contact is directly east of the small gully, with Banff on the peak above.
15.5	North - Jasper Lake is four miles long and one mile wide, but is shallow and partly silted up. Wind blown sand bars separate it from Edna Lake.
15.9	Approximate surface position of Greenock thrust, where Cambrian and Palaeozoic sediments are thrust onto Mesozoics: Cinquefoil Mountain and Mount Greenock are in the hanging wall.
16.0	North - Mount Greenock (6881 feet), a part of the De Smet Range, is on strike with Cinquefoil Mountain on the Athabasca south bank. Their physiography, stratigraphy and structure are all similar. The approximate position of the Greenock thrust can be observed on the east slopes of the range.
16.6	Stop No. 4. South - Road outcrops consist of Rocky Mountain beds and fossiliferous upper Rundle. (Mount Head, Turner Valley and Shunda formations).

17.0	The road is built for the next 3 miles upon the wind-blown sand between Jasper Lake and Talbot Lake to the south.
17.2	North - A complexity of small structures can be seen in Rundle, Banff and Palliser beds on the north bank of Athabasca River.
18.1	Stop No. 5. Talbot Lake Picnic Grounds. Observe the repeated Palliser and folded Carboniferous strata on the ridges of Miette Range. The Bosche Range north of the river is a structural continuation of the Miette one.
19.7	Roche a Bosche (6966 feet), and Roche Ronde (7014 feet), comprise the south end of the Bosche Range.
20.0	South - Muskeg Valley of the Rocky River is probably underlain by Triassic and Jurassic strata. The valley is physiographically and structurally similar to the Snake Indian Valley on the north side of the Athabasca.
20.9	North - The roadside monument commemorates the second site of Jasper House (1826 - 1884). The first Jasper House was established in 1801 near the mouth of Solomon Creek at the north end of Brule Lake, and the second after the merger of the Hudson's Bay Company and the Northwest Company.
21.7	The bridge here crosses the channel of Rocky River. Approximately five miles upstream, the river forms a long canyon over 500 feet deep in folded Mississippian strata.
23.2 - 23.4	South - Outcrops beside the road consist of argillaceous limestones of the lower Rundle group and upper Banff formation, in the overturned west limb of an anticline.
23.4 - 23.8	South - At the roadside Palliser limestone and a thin Alexo overlie Mount Hawk formation. The beds are vertical or overturned on the west limb of a large anticline. Note the slickensiding along bedding planes in the limestone.
23.9	South - Disaster Point Alpine Hut.
24.0 - 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.
24.6 - 24.7	South - Outcrop of poorly fossiliferous Mount Hawk limestone occurs in the near-vertical east limb of an anticline.

24.8 Stop No. 6 Gravel Pit. Southeast - Roche Miette (7599 feet), marks the north end of Miette Range. The massive cliff is Palliser limestone, underlain by Alexo and Mount Hawk and folded Perdrix shales. Maligne and Flume limestones represent the lowest Devonian strata. These overlie Cambrian sediments of the Arctomys, Pika and Titkana formations and part of the Cambrian Shale Unit, (Mountjoy, this volume) which is thrust upon Mesozoics.



Roche Miette, from Gravel Pit, Mile 24.8

25.5 North - Moosehorn Basin in the strike valley of Moosehorn Creek, is underlain by folded Mesozoic strata.

26.7 South - The slack pile marks the site of the abandoned Jasper Colliery. Lower Cretaceous Luscar formation seams were mined from the foot wall of Miette fault.

26,9 Pocahontas Warden Headquarters.

27.1 Turn right onto Miette Hot Springs road.

27.4 Crossing Mountain Creek.

28.1 Punch Bowl Falls. The Cadomin-Blairmore contact is just south of road, and the falls are cut in a dip slope of Cadomin.
Northeast - The tectonic setting of the Moosehorn - Pocahontas Basin, Roche Ronde and Roche Miette is well displayed from the top of the gravel terrace to the east of the road.

28.5 On this terrace level, some old dwellings and Indian graves can be seen to the east.

29.1 Blairmore Luscar formation outcrops east of the road at the hairpin bend.

29.5 West-Roche Miette and the Miette thrust, which places Cambrian over Nikanassin. Intermittent Blairmore exposures occur on the east side of the road for the next half mile.

31.5 Intermittent outcrops for the next half mile are Nikanassin.

31.8 Good ripple marks in the Nikanassin are visible.

32.1 Ahead - The dip slope of Ashlar Ridge is formed by Palliser, Banff, Rundle and Triassic beds.

32.5 Nikanassin and Fernie are exposed in Morris Creek.

32.9 Viewpoint. Ashlar Ridge lies above Fiddle Creek Gorge. The Fiddle River runs along the uppermost Rundle, Rocky Mountain or Sulphur Mountain beds. The Fernie is covered but Nikanassin is exposed in Morris Creek.
West - The eastern side of the Miette range is well displayed here.

33.2 The lower Nikanassin and Fernie Passage Beds outcrop intermittently for the next 1.2 miles.

34.0 Bedrock is covered by moraine on the west side, but Sulphur Mountain outcrops just east of the road.

34.1 East - Giant ripple marks are present on the Sulphur Mountain rock face above the river.

34.6 Villeneuve Creek.

35.4 West - Outcrop of Fernie Passage Beds.

35.7 Sulphur Creek enters Fiddle River.

35.9 The deeply incised Fiddle Creek Gorge has Rocky Mountain and Triassic along its banks. Fernie Passage Beds and Nikanassin are exposed on the west side of the road.

36.7 Northeast - Prominent Sulphur Mountain beds lie across Sulphur Creek.

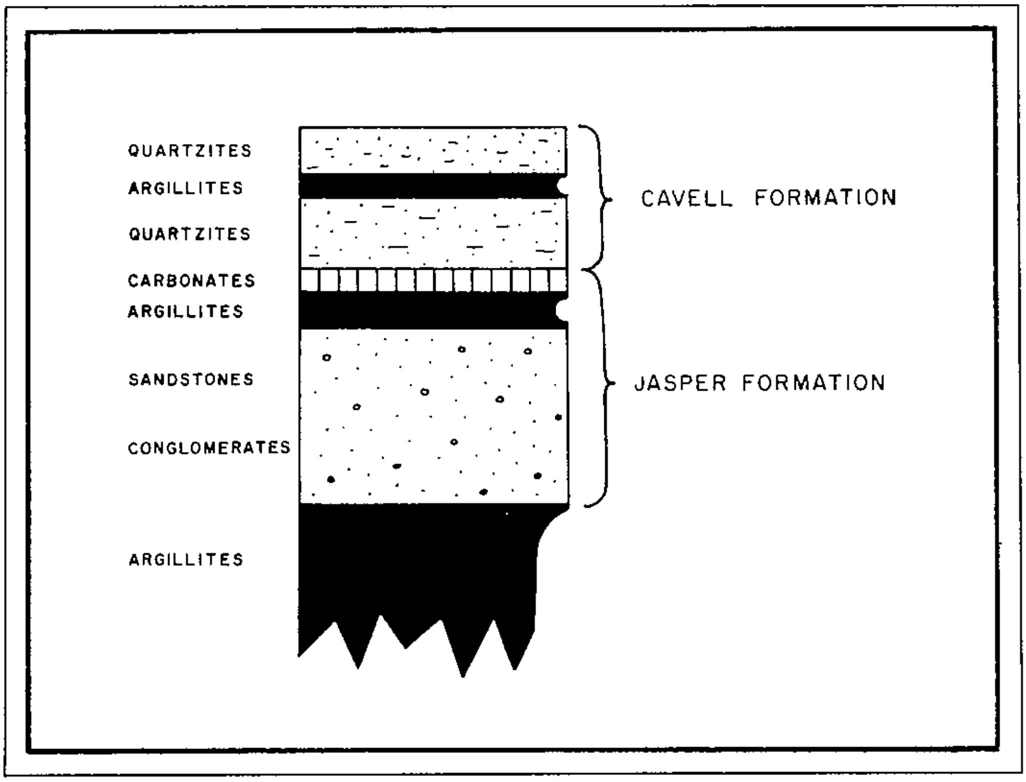
36.9 Sulphur Creek gorge is cut into Sulphur Mountain formation. Numerous ripple marks are exposed on dip surfaces.

37.1	The road cuts through a small Sulphur Mountain outcrop.
37.2 - 37.4	Sulphur Creek bridge. Ripple marked Sulphur Mountain outcrops continuously along side the road.
38.4	Motels and camp ground.
38.6	Rundle can be examined on the left side of the road. Sulphur Mountain beds outcrop 100 yards downstream.
38.7	Bath house and hotsprings. Elevation 4518 feet.

ROAD LOG NUMBER 2
JASPER VICINITY TO BEYOND GEIKIE STATION, ON THE YELLOWHEAD HIGHWAY

Proceed to end of Pyramid Lake road.

Stop No. 1 - View of Pyramid Lake and Mountain. Outcrops of sandstone and conglomerate along the lake shore belong to the Jasper formation. The trace of the Pyramid thrust can be observed to the northeast. Precambrian and Cambrian are present in the hanging wall. The hanging wall succession on Pyramid Mountain, which lies on the eastern limb of the Jasper anticlinorium, can be identified from the sketch below.



Return to Jasper.

0.0.	Canadian National Railways crossing, near southern outskirts of Jasper, on Jasper-Banff Highway.
0.1	The Yellowhead Highway follows the abandoned Canadian Northern Railways grade from this point as far as Geikie station.
1.2	Outcrops to the right, above the railway, are southerly dipping lower Miette sandstones and conglomerates on the southwest limb of Jasper anticlinorium.
1.4	Southwest - The Whistlers and Indian Ridge are both composed of conglomerates, sandstones and argillites of the lower Miette formation, capped by upper Miette argillites.
1.5	A road outcrop displays southerly dipping conglomerates, sandstones and argillites of the lower Miette formation.
1.7	Stop No. 2. The lower Miette here consists of interbedded arenaceous and argillaceous units. The first are resistant, dominantly feldspathic sandstones and conglomerates with graded bedding, cross stratification, ripple marks, etc. The argillaceous units are mainly recessive weathering cleaved argillites.
2.1 - 2.3	Further exposures of lower Miette occur on the side of the road.
2.9	Wynd station to the right.
3.0	Caledonia Creek, at the approximate axial position of Rathlin Lake synclinorium.
3.3	The Trans-Mountain pipeline and Miette River.
4.3	This road outcrop of northeast dipping lower Miette sandstone is in the southwest limb of the Rathlin Lake synclinorium.
4.7	Sandstones of the lower Miette formation exhibit tight folds,
4.9 - 5.0	Vertical basal Miette sandstones.
5.1 - 5.4	Old Fort Point formation in the core of Muhigan Creek anticlinorium consist of an uppermost 200 feet of laminated greenish grey argillites, followed by 35 feet of coarse grained calcareous sandstones, grading down into a quartzose limestone breccia. One foot of dark blue argillites overlies the basal exposures of 40 feet of interbedded limestones and calcareous argillites. All of these units can be identified in the roadside outcrops.

5.4 Crossing Muhigan Creek.

5.7 Northwest - The northwesterly plunging Muhigan Creek anticline lies just south of the burnt patch of hillside.

5.7 - 6.8 Sandstones, conglomerates and argillites of the lower Miette formation can be seen in the southwest limb of the Muhigan Creek anticlinorium.

5.9 Crossing Conifer Creek.

6.8 This point lies on the axis of Minaga Creek synclinorium.

7.2 - 8.2 Road outcrops of tightly folded lower Miette sandstones, conglomerates and argillites are not part of the southwest limb of the Minaga Creek synclinorium.

8.2 Crossing Meadow Creek.

8.4 Geikie station to south.

8.8 Miette River, a main tributary of the Athabasca.

8.9 - 9.5 This road outcrop is overturned, southwest dipping sandstones, conglomerates and argillites of the lower Miette.

9.5 - 9.8 The Old Fort Point beds here lie on the overturned northeast limb of Meadow Creek anticlinorium, where the succession is as follows:

<u>Overlying beds: Miette formation</u>

Old Fort Point fm.

200'	green argillites
5'	quartzose limestone breccia
10'	dark blue argillite
60'	interbedded limestones and calcareous argillites
200'	purple argillites
100'	green argillites
350'	blue argillites

Underlying beds; un-named coarse clastics.

All but the blue argillites may be examined on this stretch of road. Note the crinkling of cleavage planes in the argillites.

9.65 South - Across Miette River at the railway cut, purple argillites of the Old Fort Point formation are separated from white weathering sandstones of the Miette formation at the top of the cut by a southwest dipping normal fault.

10.00 The cliffs ahead are composed of Miette beds in the hanging wall of the normal fault. The trace of this fault is crossed about 500 feet further on.

10.1 Miette sandstone, conglomerates and argillites are here tightly folded.

10.4 Stop No. 3. Outcrops of Old Fort Point formation along the north side of the road form the core of the northwesterly plunging Meadow Creek anticlinorium. Cleaved purple argillites are the lowermost strata exposed. All units thin on the northeast limb of this anticline.

The next seven miles to Yellowhead Pass have discontinuous exposures of the lower and upper Miette formation.

Return to the Jasper - Banff Highway, turn right and then left onto Lake Beauvert road and proceed to Old Fort Point, at northeastern end of bridge crossing Athabasca River.

Stop No. 4. Old Fort Point. See map on following page. At this locality Old Fort Point beds outcrop in the northeastern limb of the Jasper anticlinorium, where the succession is as follows:

Overlying beds; Miette formation.

150'	green argillites and siltstones
15'	quartzose limestone breccia
150'	dark blue argillites
550'	interbedded green argillites, siltstones and limestone - breccias.
200'	blue argillites

The outcrops here belong to the 550-foot interbedded unit. The beds are overturned to the southwest. Cleavage in the argillites is less steep than the bedding.

ROAD LOG NUMBER 3
CELESTINE LAKE ROAD TO MOUNT GREENOCK

0.0 Junction of Highway 16 and branch road 10.7 miles east of Jasper, to Celestine Lake.

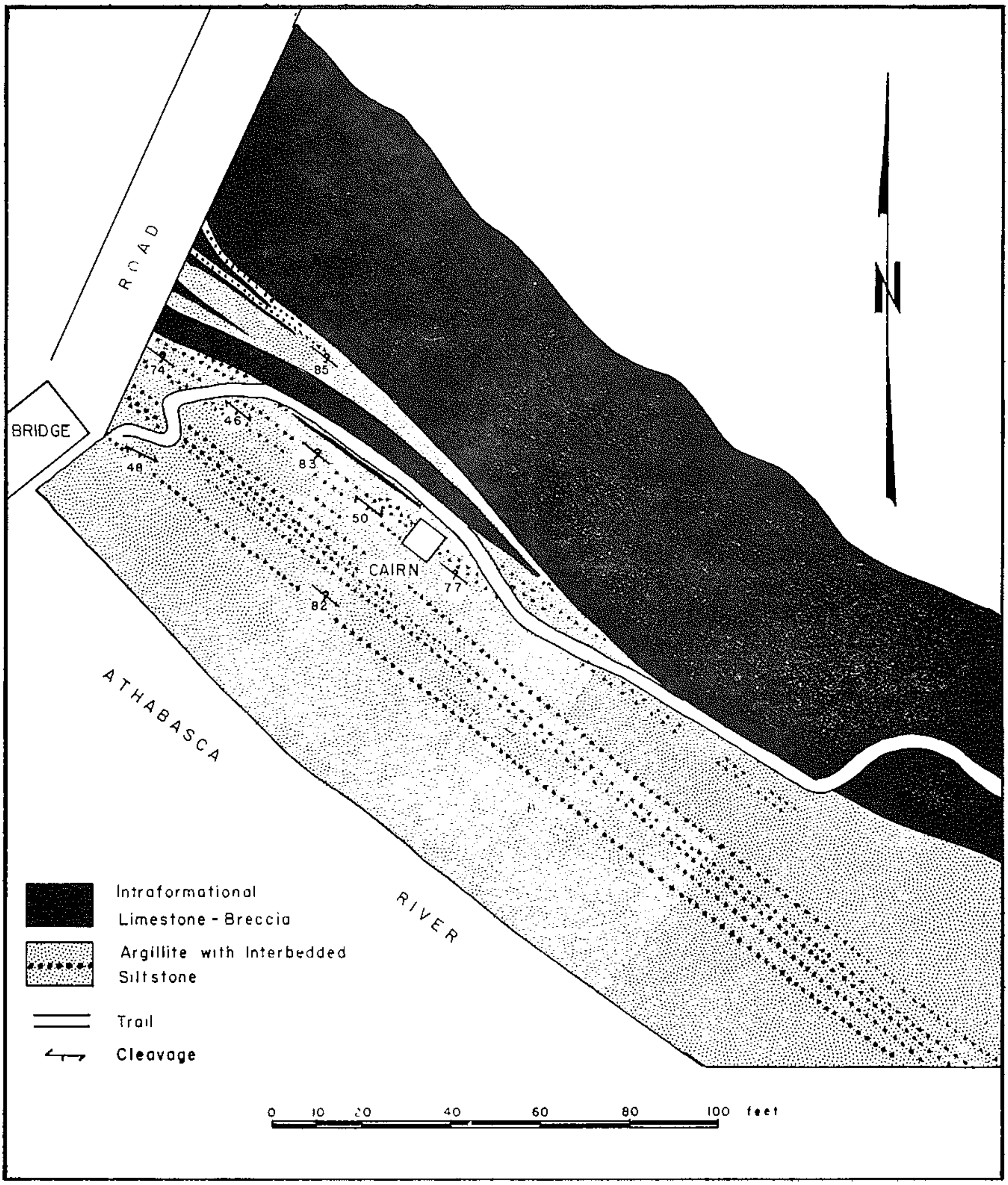
Southwest - The Palisades, which are on strike with Chetamon Mountain, and Snaring Mountains to the north.

.4 West - Buttress Mountain, visible behind The Palisades, is composed of Jasper and Miette sandstones and argillites, and is on strike with Pyramid Mountain.

1.8 Crossing approximate surface trace of Chetamon thrust.

DETAILED GEOLOGY OF OLD FORT POINT

EXPOSED AT STOP NO. 4



C.R.Evans, Unpublished MSc. Thesis, U of A

3.3 North - Esplanade Mountain. Peaks are Banff and Palliser strata. Gargoyle Mountain, Esplanade Mountain, and Morro Peak on the south side of Athabasca Valley, are all on the same thrust block.

3.6 Stop No. 1. Large meadows.

North - the valley of Corral Creek lies in front of Gargoyle Mountain. Grassy Ridge, on the east side of the valley, is composed of southwest dipping Rundle, Banff, Palliser and Mount Hawk.

3.7 Crossing Trans-Mountain Pipeline.

3.8 Corral Creek Bridge.

3.9 North - Branch road to Warden's Headquarters. The large meadows here are called Moberley Flats. Good view of Esplanade Mountain.

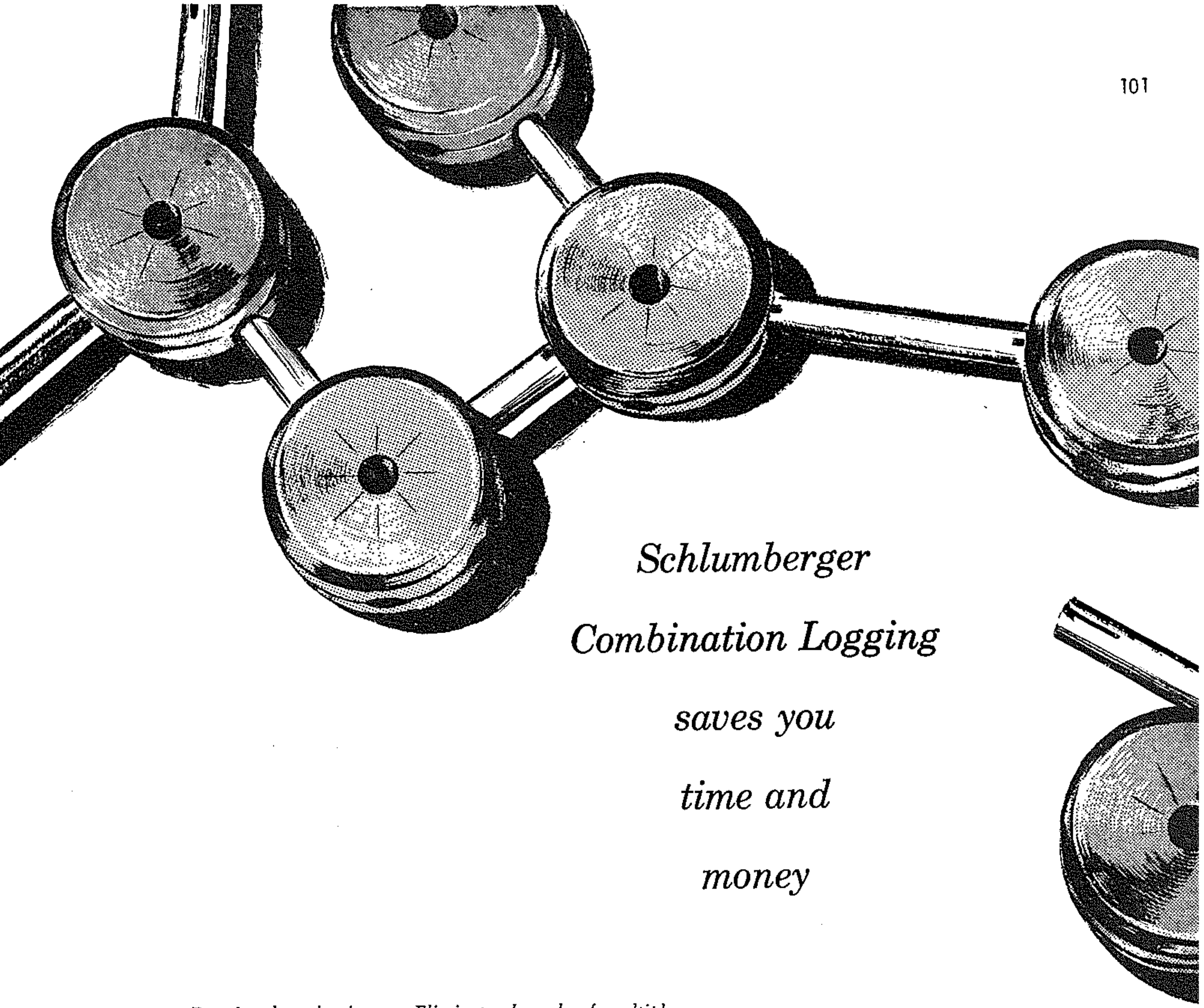
4.0 Crossing approximate surface trace of Colin thrust. The high terrace of lacustrine sediments to the north is at least 350 feet above present river level.

4.2 Good view of Gargoyle Mountain.

5.0 Crossing Spring Creek bridge.

5.7 Crossing Vine Creek. De Smet Range is to the east.

6.1 Stop No. 2. The Trans-Mountain Pipeline right of way cuts across the lower spurs of Mount Greenock, providing an excellent section through Triassic, Rocky Mountain, Rundle, Banff, Palliser, Alexo, Mount Hawk, Perdrix, Flume and Lynx strata, faulted over Triassic Whitehorse formation by the Greenock thrust.



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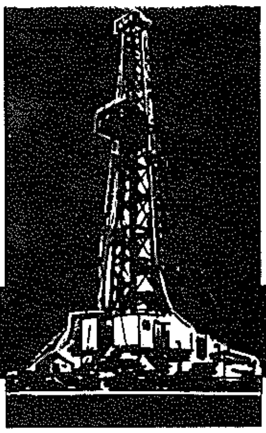

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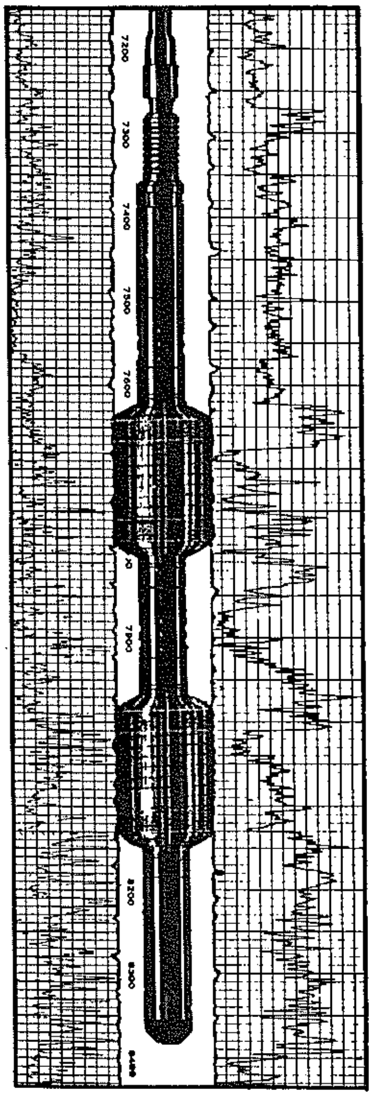

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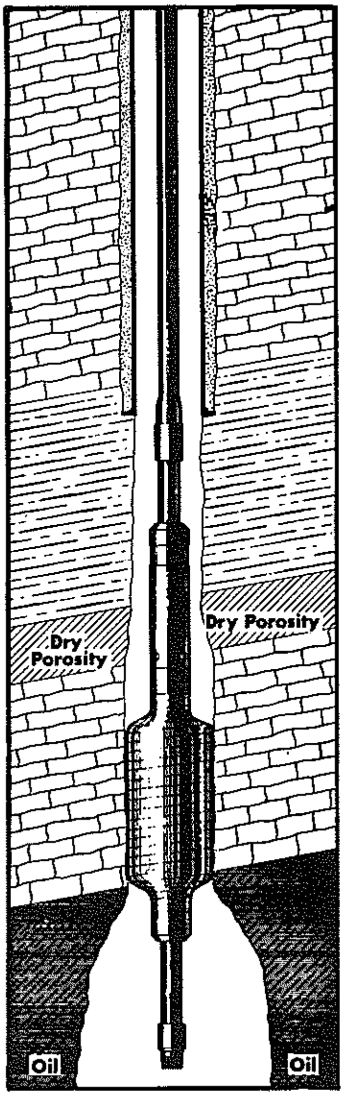

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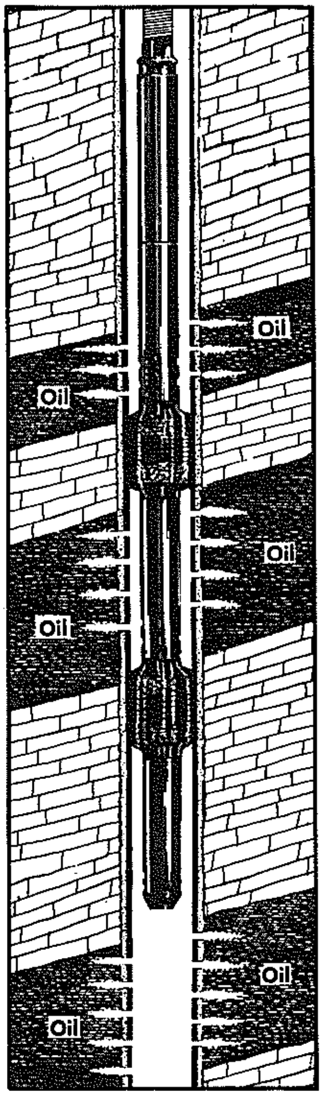

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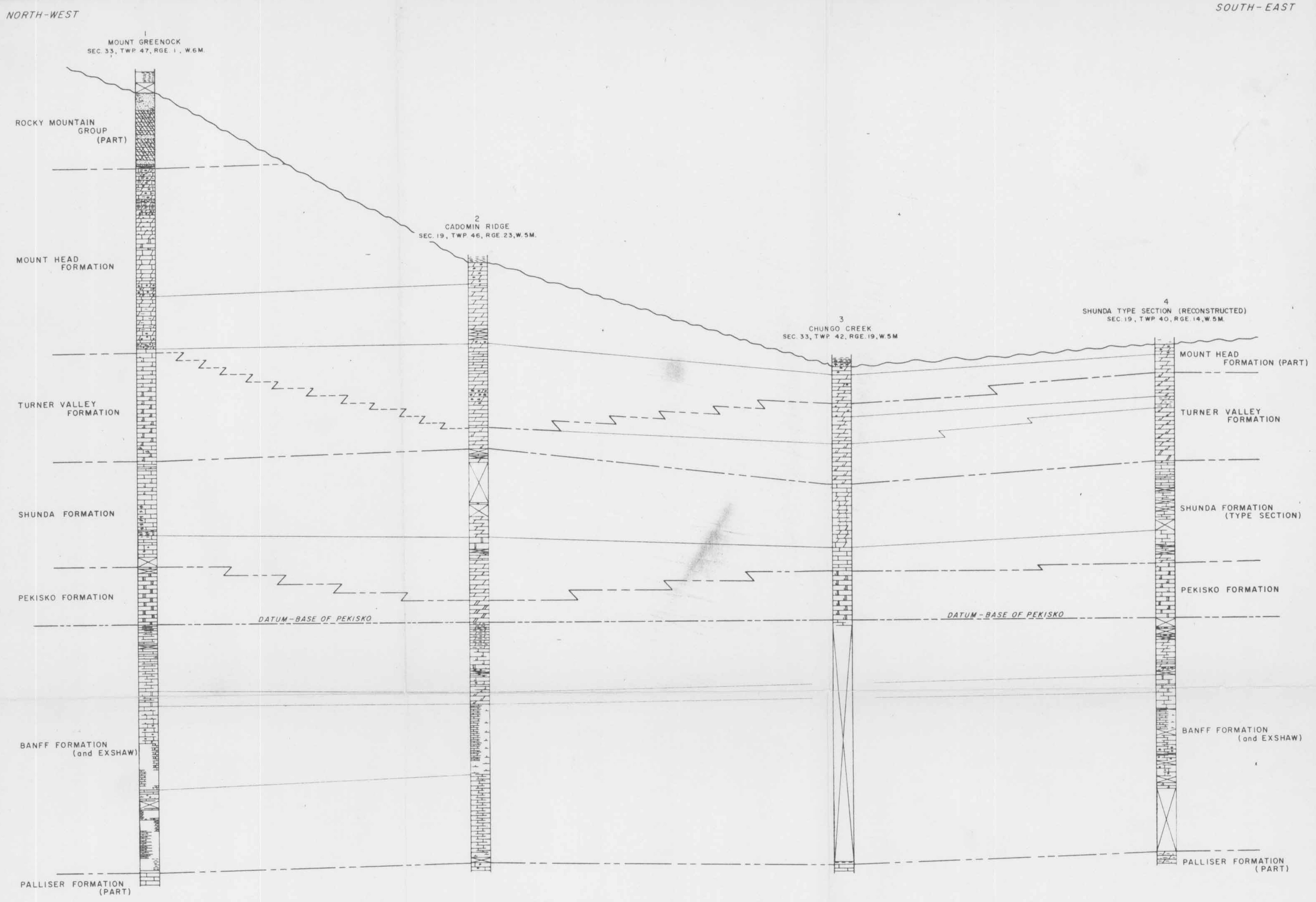

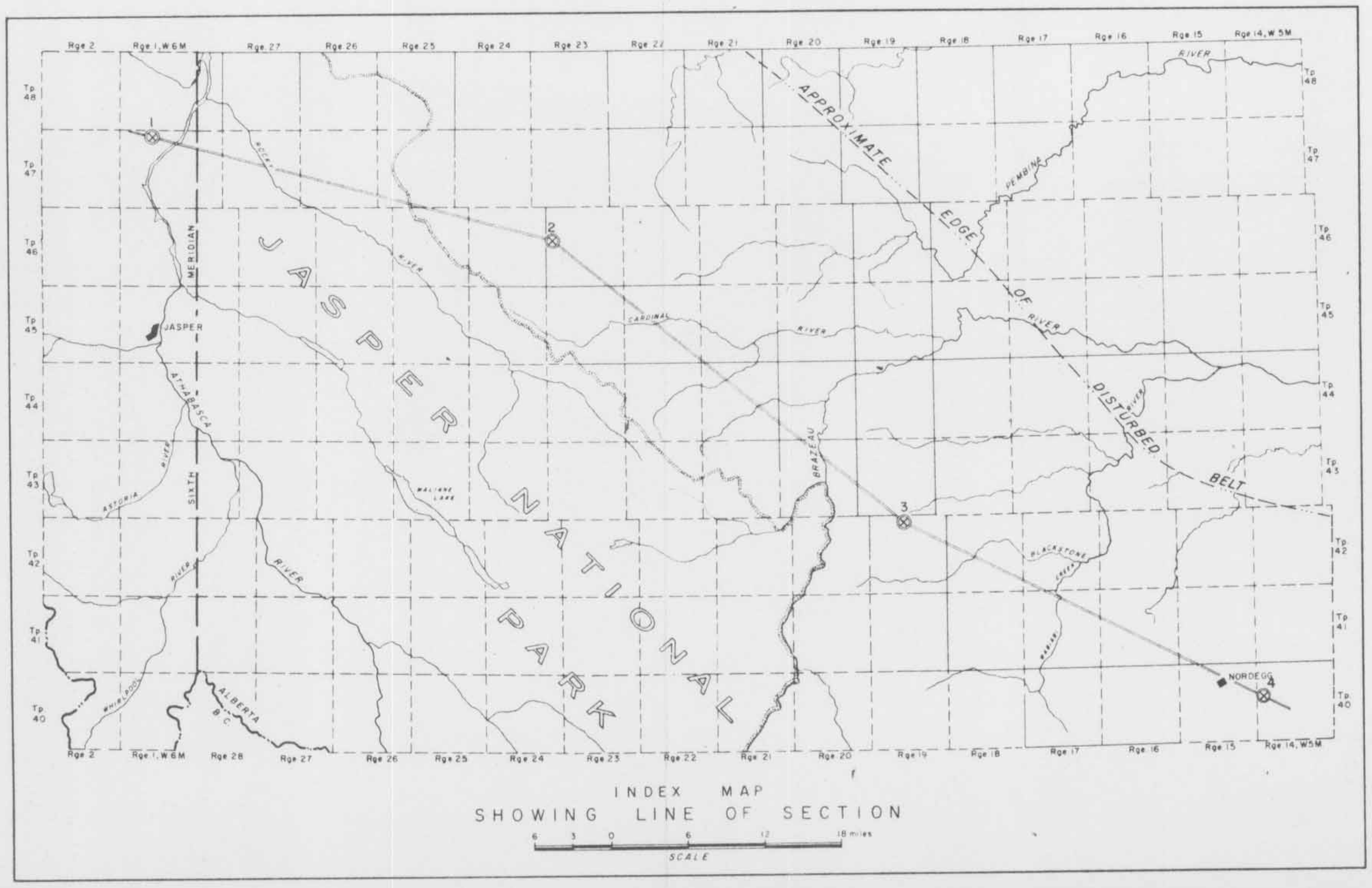

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SHOWING LINE OF SECTION

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MOUNT GREENOCK TO SHUNDA TYPE SECTION

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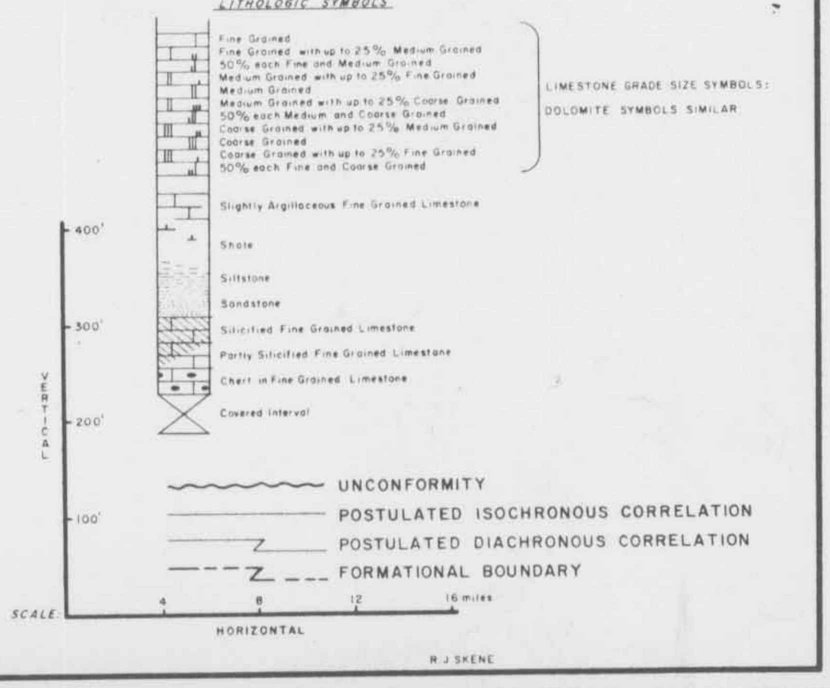


R J SKENE

GEOLOGY OF THE
ATHABASCA VALLEY

SHEET I

By

E.W. MOUNTJOY

Geologist

GEOLOGICAL SURVEY OF CANADA

1 1/2 0 1 2

SCALE OF MILES

FIELD TRIP STOPS

(5) First Day

LEGEND

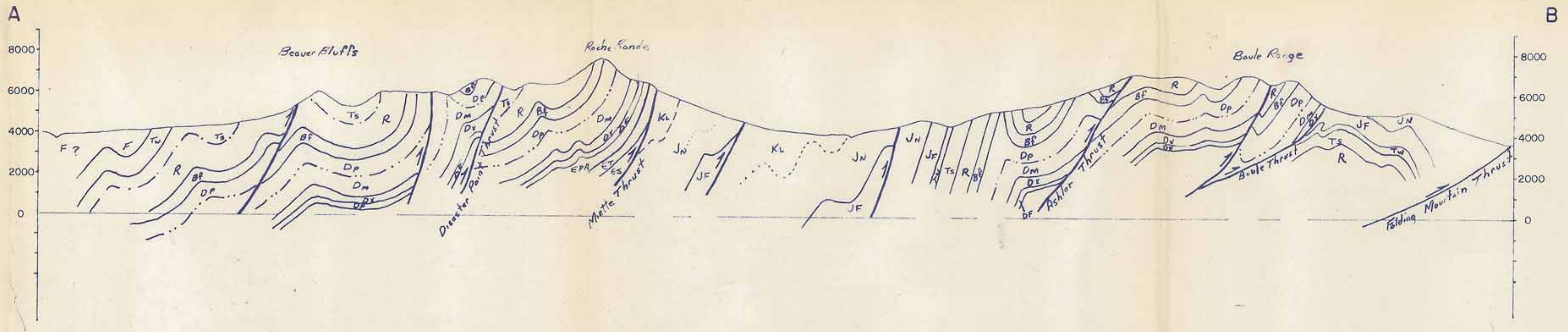
	CRETACEOUS
KL	Luscar formation ····· coal seams
---	Cadomin formation
	JURASSIC
Jn	Nikanassin formation
Jf	Fernie group
	TRIASSIC
Tw	Whitehorse formation
Ts	Sulphur Mountain formation
	PERMIAN
—·—	Rocky Mountain Group
	MISSISSIPPIAN
R	Rundle group
Bf	Banff formation
---	Exshaw formation
	DEVONIAN
Dp	Palliser formation
Da	Alexo formation
Dm	Mount Hawk formation
Dx	Perdrix formation
Df	Flume formation
Ds	Southesk formation
Dc	Cairn formation
	ORDOVICIAN
O	Chushina formation
	UPPER CAMBRIAN
ЄL	Lynx formation
	UPPER & MIDDLE CAMBRIAN
ЄPA	Arctomys & Pika formations
	MIDDLE CAMBRIAN
ЄT	Titkana formation
ЄS	Shale unit

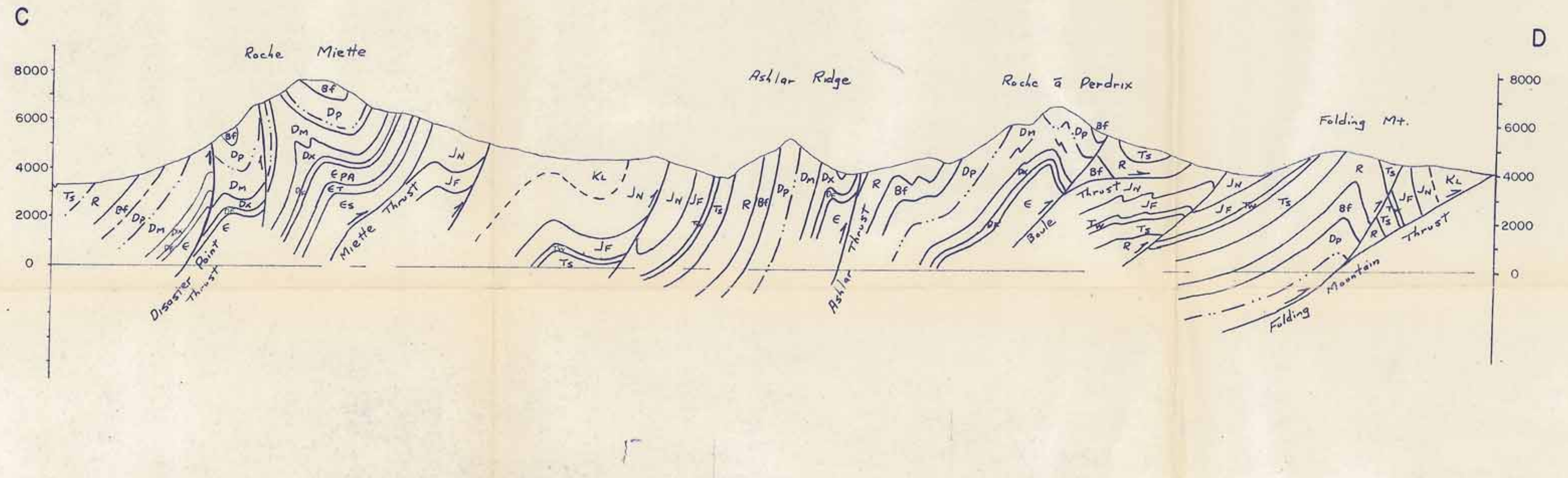
Thrust fault defined

Thrust fault projected and assumed

Contact defined

Contact projected and assumed

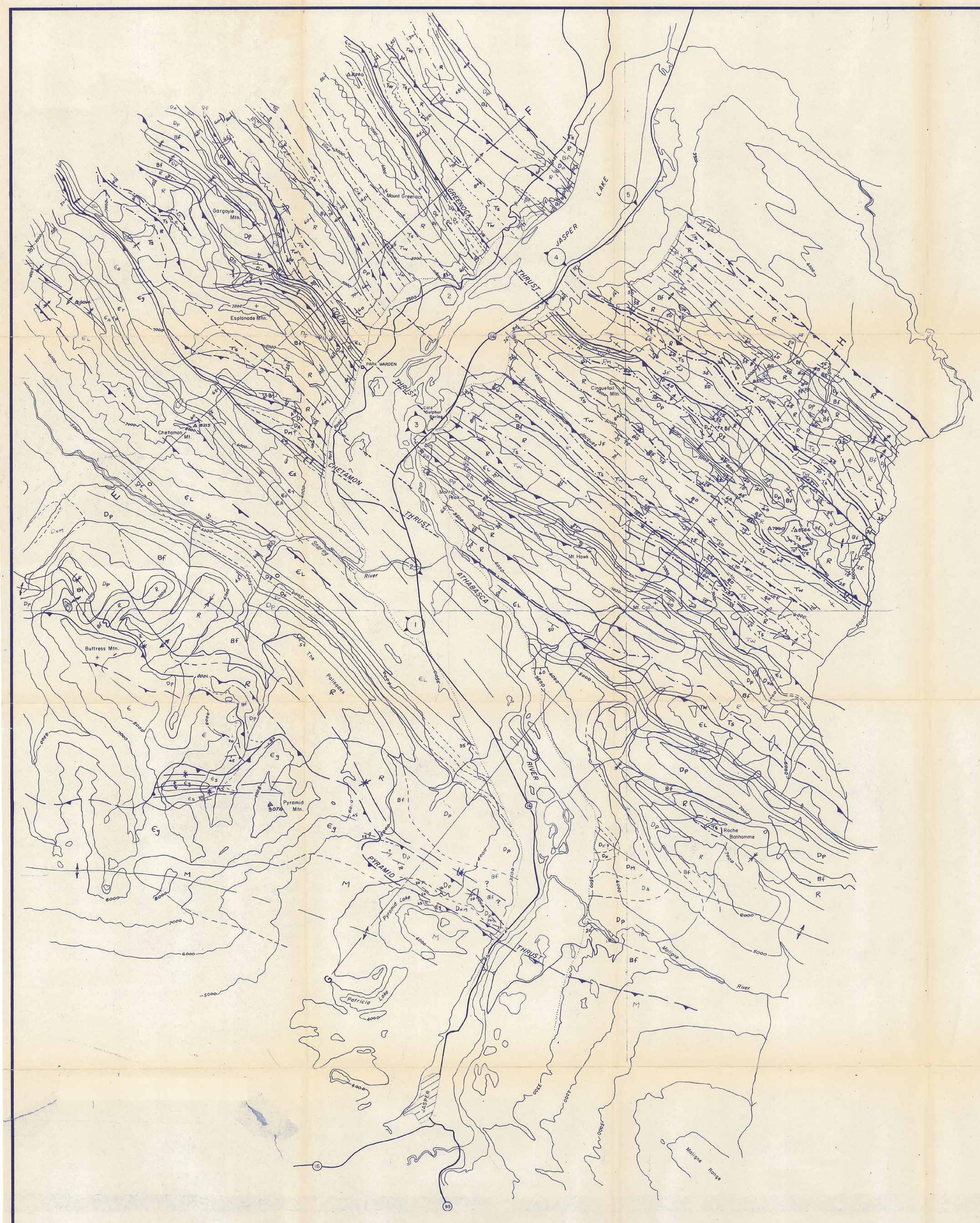




GEOLOGY OF THE
ATHABASCA VALLEY

SHEET 2
By
E.W. MOUNTJOY
Geologist
GEOLOGICAL SURVEY OF CANADA

1/2 0 1 2
SCALE OF MILES



FIELD TRIP STOPS

○ 1	First Day
⬡ 1	Second Day

LEGEND

Jf	Fernie group
	TRIASSIC
Tw	Whitehorse formation
Ts	Sulphur Mountain formation
	PERMIAN ?
—·—	Rocky Mountain formation
	MISSISSIPPIAN
R	Rundle group
Bf	Banff formation
- - -	Exshow formation
	DEVONIAN
Dp	Palliser formation
Da	Alexo formation
Dm	Mount Hawk formation
Dx	Perdrix formation
Df	Flume formation
	ORDOVICIAN
O	Chushina formation
	UPPER CAMBRIAN
ЄL	Lynx formation
ЄA	Arctomys formation
	MIDDLE CAMBRIAN
ЄP	Pika formation
ЄT	Titkana formation
ЄS	Shale unit
	LOWER CAMBRIAN
ЄG	Gog formation
	LOWER CAMBRIAN and EARLIER
M	Miette group
Є	Cambrian undivided
—▼—▼—	Thrust fault defined
—▼— —▼—	Thrust fault projected and assumed
——	Contact defined
– – –	Contact projected and assumed