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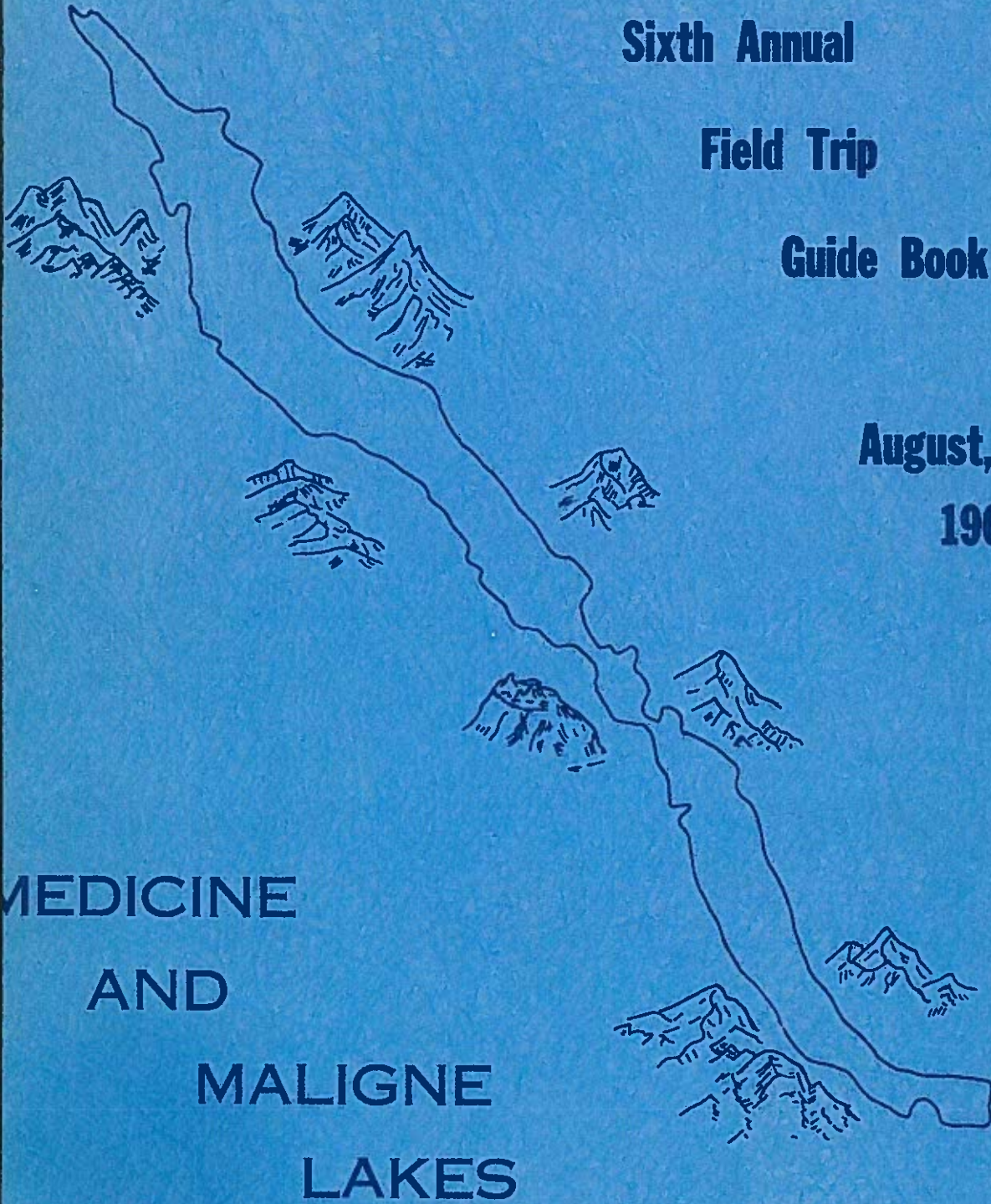
Sixth Annual

Field Trip

Guide Book

August,

1964



SOC. 6TH ANN. FIELD TRIP GUIDE BOOK MEDICINE AND MALIGNE LAKES

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Guide Book

MEDICINE & MALIGNANT LAKES,

JASPER PARK

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Edmonton Geological Society

EDMONTON GEOLOGICAL SOCIETY

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ROCKY MOUNTAIN FRONT RANGES BETWEEN ROCKY RIVER AND MEDICINE LAKE, JASPER NATIONAL PARK, ALBERTA¹

By

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ABSTRACT

The stratigraphy and structure in the vicinity of Medicine and Maligne Lakes are briefly outlined and reviewed. Strata exposed in this area range in age from Precambrian to Triassic. Precambrian strata outcrop in the Maligne Range west of Medicine Lake, Cambrian strata are most abundant around the south end of Maligne Lake, and Devonian, Carboniferous and Triassic strata outcrop in a belt along the east sides of both lakes.

The area includes parts of the western Front Ranges and eastern Main Ranges. It is underlain by portions of three major thrust sheets; the Colin, Chetamon and Pyramid.

INTRODUCTION

The stratigraphy and structure of the Front Ranges around Medicine and Maligne Lakes are briefly reviewed and outlined in this paper. No detailed geological survey has been made of the Medicine and Maligne Lake area. Information for this paper is based on detailed studies of the Miette area to the north (Mountjoy; 1960a, 1960b) and of the Mount Robson southeast area to the northwest (Mountjoy; 1962, 1964) carried out while the writer was with the Geological Survey of Canada. The Mountain Park area, whose southwest corner is about 6 miles northeast of Maligne Lake, was mapped by MacKay in 1929 and cross-sections from this map sheet have been used by Eardley (1962, p. 308) as examples of Rocky Mountain structure.

Additional information has been obtained from the geological mapping of R. D. Hughes (1955) of the area to the south, the Edmonton Geological Society map which appeared in the 1963 guidebook and a photo-geological study of this and surrounding areas.

The work of H.A.K. Charlesworth in conjunction with several theses problems (Charlesworth and Remington, 1960; Charlesworth, Evans and Stauffer, 1961; Charlesworth, Akehurst, Bielenstein and Weiner, 1963) has been of considerable assistance in determining

¹ Manuscript received July 22, 1964.

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FIGURE 1 - TABLE OF FORMATIONS

ERA	PERIOD OR EPOCH	GROUP OR FORMATION (Map Unit)	LITHOLOGY	THICKNESS (Feet)	
MESOZOIC	Lower Cretaceous	Luscar Fm	Sandstone, fine grained; greenish grey siltstone; shale; coal.	2,000+	
		Cadomin Fm	Conglomerate, chert & quartzite.	10 to 30	
		Disconformity			
	Lower Cretaceous and Jurassic	Nikanassin Fm	Sandstone; siltstone; silty mudstone dark grey.	1,000 to 2,000	
	Jurassic	Fernie Group	Shale, black and dark grey, concretionary; all members present.	700 to 900	
		Disconformity			
	Triassic	Whitehorse Fm	Carbonate, light grey breccias, red mudstone, gypsum.	100 to 1,500	
Sulphur Mountain Fm		Siltstone, dark brown grey; thin bedded silty mudstone.	600 to 1,000		
Disconformity ?					
PALAEOZOIC	Permian and/or Pennsylvanian	Rocky Mountain Fm	Massive grey chert; cherty brown sandstone.	0 to 220	
		Disconformity			
	Mississippian	Rundle Group	Mt. Head Fm	Dolomite, dense, cherty, medium bedded.	250 to 400
			Turner Valley Fm	Dolomite, brown, porous, coarse grained.	150 to 400
			Shunda Fm	Limestone, dark grey, fine grained, thin bedded.	200 to 360
			Pekisko Fm	Limestone, light grey, crinoidal, coarse grained, thick bedded.	115 to 300
		Banff Fm	Limestone and calcareous shale, dark brown, thin bedded.	500 to 760	
		Disconformity			
	Devonian	Palliser Fm	Limestone, dark grey, massive, fine crystalline, dolomitic.	700 to 900	
		Sassenach Fm	Sandstone, fine grained; siltstone, silty shale, silty carbonates.	100 to 600	
		Fairholme Group	Mount Hawk Fm	Limestone, brown grey, argillaceous; and brown calcareous shale.	250 to 700
			Perdrix Fm	Shale, black, fissile, thin limestone interbeds.	200 to 350
			Maligne & Flume Fms	Limestone, dark grey, thin-bedded, argillaceous, Limestone, dark brown, cherty, with stromatoporaids.	150 to 250
		Unconformity			
	Lower Ordovician	Sarbach Fm	Carbonates, cliff-forming.	0 to 800	
Chushina Fm		Limestone; calcareous shale; greenish-grey intraformational conglomerate.	0 to 700		
Upper Cambrian	Lynx Fm	Carbonates, silty, thin-bedded, argillaceous; intraformational conglomerate.	1,000 to 2,400		
Middle Cambrian	Arctomys Fm	Shale, silty, red and green; siltstone, brown.	600 to 800		
	Pika Fm	Limestone, calcareous; shale, thin-bedded.	500 to 700		
	Titkana Fm	Limestone, dark grey, massive dolomitic.	500 to 800		
	Shale Unit	Shale, green and red; argillaceous limestone. Limestone, dark grey, resistant.	1,400 to 1,800		
Lower Cambrian	Gog Fm	Sandstone, light grey; quartz, cross-bedded, fine to coarse grained, massive.	4,000		
	Disconformity ?				
P-C		Miette Group	Shale & phyllite, grey; sandstone, conglomeratic, poorly sorted; carbonate, arenaceous, with algal (?) markings	5,500+	

the structure and Precambrian stratigraphy in the vicinity of Jasper. The writer has only briefly visited the area.

Grateful acknowledgment is extended to the Geological Survey of Canada for information contained in this paper and for permission to publish this summary.

STRATIGRAPHY

The stratigraphy of this area is in general similar to that of the Athabasca valley which has been summarized in a number of articles (A.S.P.G., 1955; Mountjoy, 1961 and 1962; and various stratigraphic papers referred to below under each geological period). The area covered by Figure 2* includes four main thrust sheets. The three eastern thrust sheets, the Rocky River, Colin and Chetamon, consist for the most part of Palaeozoic strata with some Triassic and Jurassic strata occurring in the inter-montane valleys between the ranges. The western Pyramid thrust sheet consists of Precambrian and Lower Cambrian sediments west of Medicine Lake. Another thrust sheet consisting of Middle and Upper Cambrian, Ordovician and Devonian rocks occurs between the Pyramid and Chetamon thrust sheets near the south end of Maligne Lake and forms the ranges containing Mount Unwin, Llysfran Peak, Monkhead and Le Grand Brazeau (air photo interpretation and Hughes, 1955).

A summary of the stratigraphic units found in this and adjoining areas is shown in Figure 1. The stratigraphic names are those which are currently being used by the Geological Survey of Canada. In the following discussion the stratigraphy is very briefly outlined and only a few of the more important ideas are presented. The interested reader is referred to the literature cited for further information.

Precambrian

Miette Group

The Miette Formation was proposed by Walcott (1913) for a series of massive, grey sandstones and interbedded shales which outcropped beneath Lower Cambrian quartz sandstones in the vicinity of Yellowhead Pass. Miette was raised to group status by Mountjoy (1962) and redefined to include all the strata which occur beneath the Lower Cambrian Gog quartz sandstones in northern Jasper National Park. The Miette Group consists dominantly of recessive weathering shales and argillites with more resistant interbeds of arkoses, greywackes and conglomerates and locally algal carbonates. It outcrops extensively on the intermediate and lower mountain slopes on both sides of the Miette River valley and on the Maligne Range. These strata form distinct mappable units beneath the resistant Gog sandstones. Charlesworth and his students have found the Miette Group to be divisible into three formations totalling more than 5000 feet in thickness (Charlesworth, *et al.*, 1963). Farther northwest Mountjoy (1962, 1964) observed over 3000 feet of these strata near the head of the Snaring River.

The Miette Group replaces Hector Formation of Hughes (1955) and includes Hector and Corral Creek Formations and older strata near Lake Louise.

* in pocket

Cambrian

Cambrian rocks occur in the immediate hanging-wall portions of the Colin and Chetamon thrust sheets and the Pyramid thrust sheet. The Lower Cambrian Gog Formation outcrops along the crest of the Maligne Range extending to the southwest side of Maligne Lake. Middle and Upper Cambrian rocks outcrop east of the upper Maligne River and south of Maligne Lake and Upper Cambrian strata occur in the Colin and Chetamon thrust sheets.

Lower Cambrian

Gog Formation

The term Gog Formation has been extended northwestward from the Lake Louise area (Mountjoy, 1962) for massive quartz sandstones which occur below Middle Cambrian carbonates and above the recessive shales and sandstones of the upper part of the Miette Group. These rocks have previously been called Cavell for quartzites in the vicinity of Jasper (Raymond, 1930, p. 293) and Jonas Creek Formation in the area immediately to the south (Hughes, 1955). As well as outcropping in the Maligne Range extensive outcrops of Gog Formation occur farther southwest on both sides of the Banff-Jasper highway. Good accessible sections of Gog Formation occur at Mount Edith Cavell and Mount Kerkeslin. The formation consists of fine to coarse-grained, clean, quartzose, light grey sandstone. The formation is generally somewhat conglomeratic and arkosic in the basal 200 to 500 feet. Chert and quartz pebbles average between 1/2 and 1 inch in diameter and are well rounded. This lower conglomeratic part of the Gog Formation has been referred to the Jasper Formation by Charlesworth *et al.* (1961, 1963). Where exposed the contact with the Miette Group appears to be completely gradational over intervals of between 50 and 200 feet. No abrupt break or unconformable relationships are known to occur at this contact in the Jasper area. Good exposures of this contact are present on the north side of Mount Tekarra and the south side of Pyramid Mountain. In the Upper Bow Valley the Gog unconformably overlies Precambrian Hector Formation (Aitken, 1963; Gussow, 1957). Current bedding is relatively abundant in the coarser portions of the Gog Formation. A preliminary study of these structures indicates that they predominantly dip southwest, after rotation corrections to a horizontal plane, and thus are suggestive of a southwesterly direction of transport (Mountjoy and Aitken, 1963). This suggestion is supported by a general southwest decrease in grain size, or increase in argillaceous content, in Gog sections to west near Mount Robson.

Lower Cambrian fossils occur in the upper part of this formation in areas to the northwest (Mountjoy, 1962). Graphic thickness measurements indicate that the Gog is over 4,000 feet thick in the Jasper area (Hughes, 1955, p. 76 and Mountjoy, 1962, p. 7).

Middle Cambrian

Four lithologic units comprise the Middle Cambrian succession: a lower and unnamed, recessive-weathering sequence of greenish grey shales with a few thin but prominent limestone units herein called the Shale Unit (map unit 3 of Mountjoy, 1962); a

thick cliff-forming limestone - Titkana Formation; a thin, argillaceous, thin-bedded fossiliferous limestone - Pika Formation; and an upper recessive, varicoloured shale and siltstone unit - the Arctomys Formation.

Shale Unit (map-unit 3)

This unit forms a prominent recessive interval about 1400 feet thick between the resistant Gog and Titkana Formations. The lower contact is conformable and the upper contact is generally gradational over several tens of feet. The limestone units generally form distinct resistant horizons between 25 and 200 feet which are locally mappable. Southward the amount of shale in this formation gradually decreases with a corresponding increase in thickness and number of limestone units until in the upper Bow Valley only one shale unit remains - the Stephen Formation. A good section of the shale unit is located north of Jasper on Chetamon Mountain (Mountjoy; 1961, 1962). The lower part outcrops on Mount Kerkeslin and it also appears to be present on Monkhead and in the mountains south of Coronet Mountain (see Hughes, 1955). Albertella occurs in the lower third and Glossopleura occurs in the middle part of this formation. It becomes older westward since Olenellus has been collected near the base (Mountjoy, 1962).

The shale unit outcrops east of Coronet Creek on the lower slopes of Monkhead and Mount Warren at the south end of Maligne Lake.

Titkana Formation

The massive, dark grey, aphanitic limestones form relatively inaccessible Palliser-like cliffs. In isolated exposures these limestones are easily confused with those of the Palliser Formation as they contain prominent dolomitic and argillaceous mottling and laminae. Trilobite fragments are known to occur in these limestones but no good fossil collections have been obtained from them in the Jasper area. Strata of this formation were referred to the Sunwapta Peak Formation in the area immediately to the south (Hughes, 1955). It is approximately equivalent to the Eldon Formation of the Bow Valley area which is predominantly dolomite. The Titkana Formation forms the upper limestone cliffs of Monkhead and Mount Warren and outcrops immediately west of Coronet Creek on the lower slopes of Mount Mary Vaux.

Pika Formation

The Pika Formation has been extended to the Jasper area (Mountjoy; 1961, 1962) for a series of recessive-weathering limestone and shale interbeds, each between 10 and 40 feet thick. Thin layers of intraformational conglomerate also occur. Several of the upper layers of the limestone units contain abundant trilobite fragments. The lower contact is transitional over a few feet. The upper contact is generally sharp where these beds are overlain by green and red shales of the Arctomys Formation. In the area to the northwest this formation is about 600 feet thick. The abundant fossils appear to represent a late Middle Cambrian zone somewhat similar to those recently described by Robison (1964).

Arctomys Formation

Red and green silty shales, siltstones and minor carbonate form a distinct light yellow to orange brown, 700 foot recessive unit. The siltstones are finely laminated, cross-bedded and ripple marked and contain abundant salt-crystal pseudomorphs. This unit forms a distinct stratigraphic marker in much of Jasper and Banff National Parks.

Fossils are generally lacking in this formation. However some fossils have been found in the more western outcrops which indicate that the Arctomys Formation is of late Middle Cambrian (Greggs, 1962, 1963; and Mountjoy, 1964 and unpublished fossil data).

The Pika and Arctomys Formation appear to outcrop on the eastern slopes of Llysfran Peak and Mount Mary Vaux and form the middle recessive unit on the western slopes of Monkhead and Mount Warren.

Lynx Formation

The Lynx Formation consists of a series of light grey, thin bedded, fine-grained, silty carbonates varying in character and argillaceous and sand content. Finely laminated and cross-bedded carbonates and intraformational conglomerates are common. Westward near Mount Robson and southeastward towards the North Saskatchewan River (Greggs, 1963) portions of the Lynx Formation become more argillaceous. From North Saskatchewan River southward these argillaceous intervals and the intervening carbonates form a distinct series of four mappable units.

Typically the Lynx Formation is massive and cliff-forming. In the mountains east of Medicine Lake the Lynx Formation forms a series of ridges immediately east of the crests of these mountain ranges. North of Jasper the Lynx Formation is 2400 feet thick in the Chetamon thrust sheet thickening to 3800 feet on Rearguard Mountain near Mount Robson (Mountjoy, 1962, 1964). Fossils are generally rare and hard to find except in the more argillaceous sequences to the west near Mount Robson. Fossils representative of all the Late Cambrian fossil zones are present on Rearguard. (Mountjoy, unpublished fossil data)

Harker *et al.* (1954, p. 58) described a section on the ridges northwest of the south end of Medicine Lake. On the basis of regional stratigraphy the strata of this section beneath the Flume can be assigned to the Chushina Formation (upper 237 feet) and the upper part of the Lynx Formation (550 feet). The upper part of the Lynx Formation here consists of well-bedded, grey limestones and dolomites with ripple marks, current bedding, small scale slump structures and a few thin intraformational carbonate conglomerate beds (Harker *et al.*, 1954; McLaren, personal communication).

The Lynx Formation also outcrops extensively around the south end of Maligne Lake forming the highest cliffs of Monkhead, Mount Mary Vaux and Llysfran Peak and on the lower slopes of Mount Paul and Mount Charlton.

Lower Ordovician

Chushina Formation

The Chushina Formation has been extended from the Mount Robson area to the Jasper area (Mountjoy, 1962). This formation consists of greenish grey calcareous shales with thin carbonate and intraformational conglomerate interbeds. The upper part includes more massive and resistant weathering carbonates. On the Palisades the Chushina is about 700 feet thick but at the east end of Medicine Lake it is only 237 feet thick, (Harker *et al.*, 1954, p. 58) the upper part having been eroded. There it consists mainly of limestone with green shale and intraformational conglomerate interbeds. The distinctive early Ordovician (Canadian) *Bellefontia* sp. cf. *B. nonius* (Walcott) occurs 144 feet above the base (note - the green shale at the base of the Medicine Lake section was erroneously reported to be 141 feet thick; it is only 14 feet thick).

The contact of the overlying Flume Formation is well exposed in the section described by Harker *et al.* (1954). A few feet of quartz sandstones rest on an irregular erosion surface, which is essentially parallel to beds above and below this contact.

The Chushina Formation is approximately stratigraphically equivalent to what geologists have called the "Mons" Formation of northern Banff National Park (Greggs, 1963) which is about the upper half of the type Mons (Walcott, 1928) at Glacier Lake.

Around the south end of Maligne Lake (Mounts Paul and Charlton for example) a prominent resistant cliff about 800 feet high occurs above the Chushina Formation and below beds assigned to the Flume. This cliff-forming carbonate unit is probably equivalent to strata referred to informally as Sarbach by Greggs (1963) and others. In comparison to the Beaver Lake section of Harker *et al.* (1954) these exposures indicate that about 1000 feet of additional strata occur between the Devonian and lower part of the Chushina Formation, marked evidence indeed for the sub-Devonian unconformity.

The sub-Devonian unconformity gradually truncates older strata northeastward across the mountain ranges. In the Colin thrust sheet Devonian beds rest directly on a part of the Lynx Formation and in the Miette Range they lie on Arctomys strata (Mountjoy, 1960b).

Devonian

The Devonian stratigraphy of the area near the south end of Medicine Lake has been fully described by McLaren (1956). All that is necessary is to bring the nomenclature up-to-date. McLaren's section 18 (1956, pp. 45-51) is accordingly revised as follows from bottom to top: 150 feet Flume Formation (units 1 to 14), 37-1/2 feet Maligne Formation (units 15 to 17), 350 feet Perdrix Formation, 252-1/2 feet Mount Hawk Formation, 601 feet Sassenach Formation, and 936 feet of overlying Palliser Formation. All of these units form distinctive easily mappable units. The most difficult formations to distinguish readily are the Mount Hawk and Sassenach especially when argillaceous. Because of similar lithology and sparse faunal control the true stratigraphic relationships between the Mount Hawk and Sassenach (previously Alexo) have been a

subject of considerable discussion (see references in McLaren and Mountjoy, 1962). While mapping the area north of Jasper the writer found a locality where the contact relationships are well exposed. This area was studied in detail by McLaren and Mountjoy (1962) who observed that the Sassenach Formation unconformably overlies the Southesk and Mount Hawk Formations. In a distance of about three miles the Sassenach gradually onlaps the underlying Southesk (thins from the bottom) thinning to less than 30 feet in thickness and over a large part of the Ancient Wall reef is not present (Mountjoy, 1962). A thin basal conglomerate is present locally. The Sassenach Formation is generally divisible into two members: a thick lower recessive interval of calcareous silty mudstones and argillaceous limestones and an upper resistant silty and sandy limestone about 100 feet thick.

Southeastward from the Ancient Wall reef the upper part of the Mount Hawk becomes more argillaceous and weathers much like the lower Sassenach and this contact becomes more difficult to map. Fortunately a thin phosphatic and pyritic siltstone and fine-grained sandstone between 10 and 30 feet thick forms a prominent marker unit at the top of the Mount Hawk Formation. It occurs in the Medicine Lake section (McLaren, 1956, p. 48 units 25 to 29) and has been observed on Mount Colin in the Miette area. It forms a thin marker unit on air photographs in the intervening area between these two localities.

Excellent outcrops of Fairholme and Sassenach strata may be seen on the north slopes of Mount Charlton and along the mountains on the east side of Maligne Lake.

No carbonate rocks are known to form reef or biostromal complexes near Medicine and Maligne Lakes. The nearest reefs are the Miette reef to the northeast (Mountjoy, in press) and the western margin of the Southesk reef which is exposed to the east in several thrust sheets near Southesk Lake, Mount Meda, and Mount MacKenzie (MacKenzie, 1964, this volume, and in press).

The Exshaw Formation is entirely absent from this area. The nearest Exshaw outcrops occur in the Miette Range 11 miles to the northeast. The Banff-Palliser contact on Proposal Mountain has been described by Harker and McLaren (1958, p. 258). They reported a cherty, phosphatic, conglomeratic sandstone less than 1/10 of an inch thick containing bone fragments and plant fragments.

Mississippian

Mississippian strata are relatively uniformly developed in much of Jasper National Park. The Mississippian is divisible into five units from bottom to top: the Banff Formation and the Pekisko, Shunda, Turner Valley and Mount Head Formations of the Rundle Group. The Pekisko consists of about 200 feet of resistant weathering coarse-grained encrinite; the Shunda consists of about 300 feet of dark grey, thin-bedded, recessive weathering, argillaceous carbonates; the Turner Valley consists of about 300 feet of massive, coral and crinoidal dolomite; and the upper Mount Head consists of 300 feet of cherty and argillaceous dolomite.

The sequence present near Beaver Lake appears to be similar to that of the Athabasca valley and is in turn similar to the Thornton Creek section of the Colin thrust sheet outlined in the accompanying paper by Walasko, Lerbekmo and Mountjoy.

Grey (1951) measured a section about 3 miles southeast of the south end of Medicine Lake opposite the big bend of the Maligne River. This information was summarized in a columnar section (Figures 4a and 4b, pages 25 and 26) from which approximate lithologies and thicknesses can be determined as follows: Pekisko 175 feet, Shunda 290 feet, Turner Valley 490 feet, Mount Head 335 feet, total Rundle Group 1290 feet. The section is normal except for the Turner Valley Formation which has the greatest thickness known in the Jasper area.

Permian

Rocky Mountain Formation and Group

In last year's guidebook McGugan and Rapson (1963) completely revised the Permian nomenclature of the Alberta Rocky Mountains proposing six new formations as part of the Ishbel Group. In the Jasper area two formations were suggested for the Permian strata — an upper sandstone unit named the Mowitch Formation and a lower phosphatic chert and siltstone named the Ranger Canyon Formation.

These units are difficult to map in the Jasper area and the writer prefers to follow previous workers and use Rocky Mountain Formation or Group for these strata. Regardless of original type section and redefinitions these strata are equivalent to the upper part of the type Rocky Mountain Group which thins northward through overlap. The Rocky Mountain Formation in some sections in the Jasper area is entirely chert, in others is chert overlying sandstone and in others is sandstone overlying chert. These changes occur rapidly along strike. Under such conditions it is not always possible to differentiate an upper Mowitch sandstone and a lower Ranger Canyon chert. Thus these units have limited distribution and should be given member status. A phosphatic pebble conglomerate is generally present at the base of the Rocky Mountain Formation and disconformably overlies the Mississippian Mount Head Formation. This formation varies between 100 and 200 feet thick and is absent in the area east of the Miette Range.

Mesozoic

No attempt is made here to review the Mesozoic stratigraphy summarized in Figure 1. Some Triassic rocks occur on the mountain slopes north of the north end of Maligne Lake. The dark brown weathering color indicate that these strata represent the Sulphur Mountain Formation. Some Whitehorse also appears to be present in this area. Farther east excellent exposures of Triassic rocks occur in the Colin thrust sheet near Helmet Mountain. There the three Sulphur Mountain subdivisions of Best (1958) can be recognized on the air photographs. The Whitehorse Formation in that area is overlain by dark shales of the Fernie Group (See Manko, 1960, for additional information on Triassic stratigraphy and Fربول, 1957, for information about Jurassic stratigraphy).

STRUCTURE

The Medicine-Maligne Lake area includes the western part of the Front Ranges and extreme eastern part of the Main Ranges. Two major thrust sheets, the Colin and Chetamon, form steeply southwest-dipping ridges which make up the Queen Elizabeth Ranges of the western Front Ranges. Except for a few minor faults and folds the structure of these thrust sheets are relatively simple. The hanging-wall strata of both the Colin and Chetamon thrust faults consists of lower to middle Lynx Formation. The trace of the Chetamon thrust is covered in the Beaver Lake valley but appears to follow the west side of the valley.

The eastern part of the Main Ranges here comprises the Pyramid thrust sheet and an unnamed thrust sheet at the south end of Maligne Lake. The Pyramid thrust sheet is more complexly faulted and folded especially near Jasper townsite. The trace of the Pyramid fault is not very well exposed or marked topographically but appears to follow the west side of the Medicine and Maligne Lake valley. Opposite Samson Peak the Pyramid thrust overlaps a major unnamed thrust sheet consisting of Cambrian, Ordovician and Devonian rocks. In the upper part of Maligne River valley southwest of Mount Unwin the Pyramid thrust appears to join with another major thrust which follows the east side of Endless Chain Ridge between Mount Hardisty and Poboktan Creek. The Pyramid thrust appears to dip more than 50 degrees to the southwest but structural data are poor because of poor exposures.

The structure and stratigraphy of the unnamed thrust sheet near the south end of Maligne Lake is complex and difficult to determine from the air photographs. Sufficient marker units can however be identified to outline the general geology. The Pyramid thrust appears to overlap a major thrust which passes beneath Maligne Lake and continues southeast beneath the ice fields on the east side of Mount Brazeau to Brazeau Lake (Fig. 2). This fault appears to extend southeastward beyond the North Saskatchewan River. South of Maligne Lake this thrust sheet forms the main part of Le Grand Brazeau. The principal structure is a broad anticline which mainly exposes Middle Cambrian strata and extends between Coronet Mountain and Brazeau Lake. It plunges gradually northwest until Devonian strata occur on the north side of Mount Charlton. As the anticline plunges northwestward it also becomes complexly folded and faulted. This complex structure is well displayed by the Pika, Arctomys, Lynx, Chushina and Devonian formations between Mount Mary Vaux and Samson Narrows. A major fault appears to follow Coronet Creek with the east side up relative to the west side. On the west side of this fault Upper Cambrian and younger strata have been folded into a series of narrow folds which plunge northwest. On the east side of this fault in the mountains between Monkhead and Valad Peak Upper and Middle Cambrian strata are gently folded (Fig. 2).

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THE SOUTHESK CAIRN CARBONATE COMPLEX

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INTRODUCTION

Since the discovery of commercial oil production from carbonate reservoirs in the Edmonton area Leduc Field in 1947, Devonian limestones and dolomites have been of particular interest to the oil industry. Large carbonate masses outcrop in the eastern foothills of the Rockies and are easily accessible for study.

The Southesk Cairn Carbonate Complex, with Southesk Cairn, an isolated topographic feature at the summit of Southesk Pass located near its geographic centre, is a small part of one such large carbonate body which may extend without interruption for many miles to the southeast (McLaren, 1955, Fig. 1).

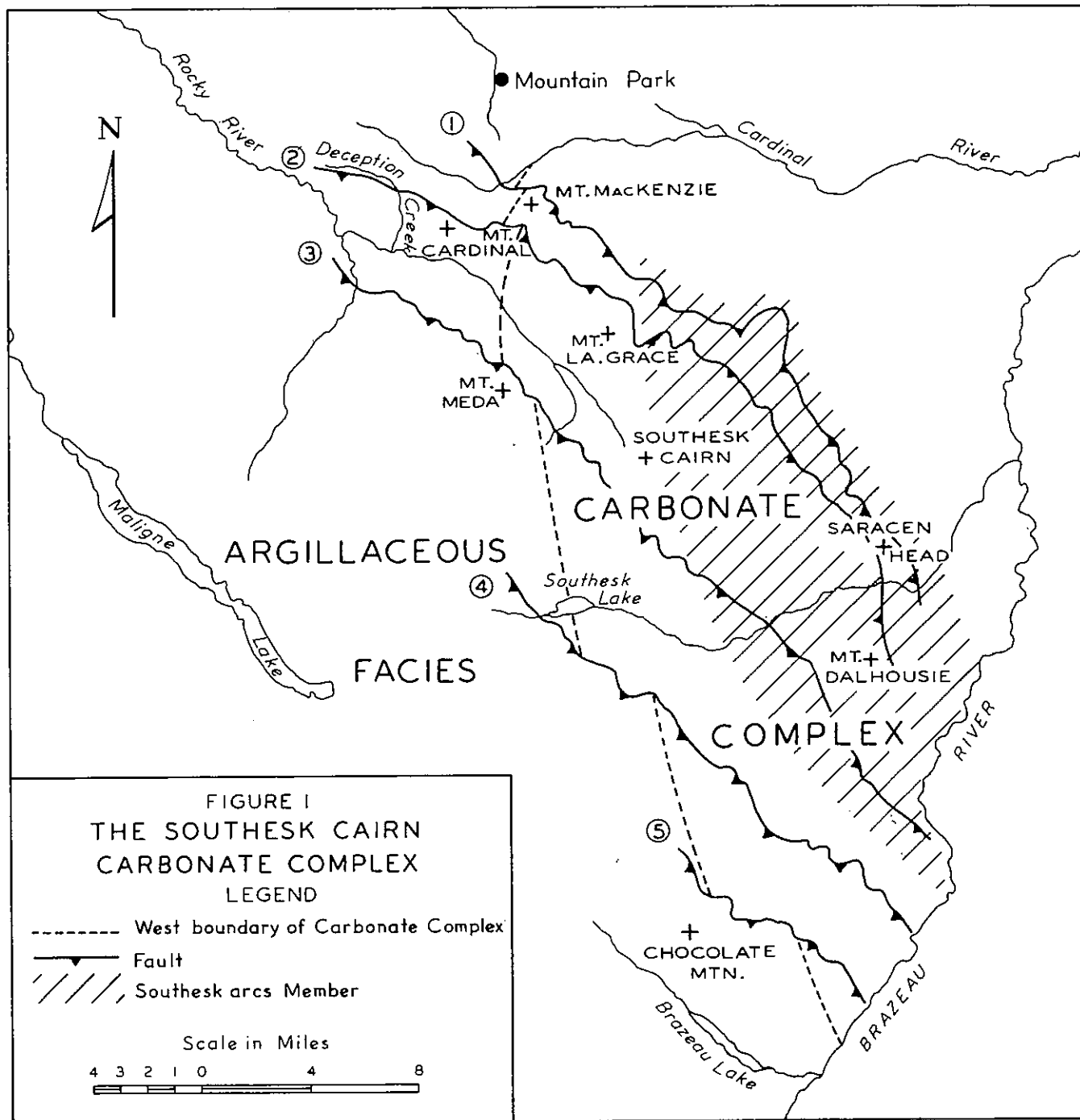
The following report comprises an examination of petrographic features of selected parts of the carbonate body, analysis of its constituent stratigraphic elements, and a study of the stratigraphic relationships between carbonate and equivalent argillaceous or basinal facies which are so important to interpretation of reef complexes under the Alberta Plains.

Location and Access

Mount MacKenzie, Saracen Head, the Brazeau River and the Brazeau-Maligne Lake valley are geographic features closely related to the boundaries of the study area which lies to the south of the abandoned coal mining town of Mountain Park (Fig. 1). It comprises a portion of eastern Jasper National Park as well as bordering lands to the northeast.

The report area may be reached by automobile from the town of Edson along a maintained gravel road (Highway 47) through Cadomin to a point some four miles south and east of Mountain Park. From here, the northern part of the report area (vicinity of Mount MacKenzie) can be reached on foot along cut seismic lines. Pack horses need to be used however to transport personnel and equipment into remote regions within the Park.

Short trips could be made by pack horse from camp sites farther east along the Cardinal River, to Mount Russel, Mount Lagrace, Ruby Mountain, Saracen Head and nearby areas. Other possible avenues of access, not explored by the writer, are via an improved gravel road northwest from Nordegg to within about five miles of the Brazeau River. (see Brazeau 83C, 1:250, 000 Map Sheet). From here, horses could be used to follow trails along the Brazeau southward into the eastern part of the report area.



Alternatively, from a point on Highway 93 near the Athabasca Glacier, pack horses could provide transportation northward along maintained Park trails in the Brazeau River valley into the southern and eastern part of the report area.

Terminology

Development of the generally accepted system of Devonian nomenclature now in current use began with what might be called the modern phase of exploration and Raymond's (1930) first use of formal formational terminology. Revision and modification has been a part of its continuing evolution. A recent contribution by McLaren and Mountjoy (1962) has further advanced understanding of the nature of Devonian sedimentation in the mountains. For brief descriptions of lithologic units mentioned in this report, the reader is also referred to McLaren (1955). Figure 2* shows intercorrelations, as interpreted within the report area, among constituent formations and members of the Devonian Fairholme Group.

Regional Setting

In the Front Ranges of the Rocky Mountains, Devonian strata rest with low-angle unconformity on a gently undulating surface of eroded Upper Cambrian rocks. Locally, beds on either side of the unconformity appear parallel but the youngest Upper Cambrian strata exposed below the unconformity change, to the southwest across the mountain ranges, from silty dolomite to light brown limestone and limestone conglomerate.

Paleozoic strata of the Front Ranges have been carried by thrusting over the Cretaceous to the northeast and broken by a series of sub-parallel, low-angle faults. Inter-fault slide surfaces were confined largely to horizons within the Upper Cambrian. Thick Devonian and Mississippian limestone members have acted as competent units within the thrust sheets so that fold deformation has been restricted to gentle warping.

The regional picture is one of a series of overlapping, relatively undeformed sheets of Paleozoic strata with their edges upturned to the east to form a series of sub-parallel mountain ranges. Lowermost Devonian strata rest disconformably on Upper Cambrian limestones and dolomites. There has been relatively little tectonic deformation to complicate the stratigraphy within individual thrust sheets.

STRATIGRAPHY

The Carbonate Complex

Figure 1 shows the probable western limit and distribution within the report area of the Southesk Cairn Carbonate Complex as well as regional thrust faults as they occur in and near it. Overthrusting toward the northeast of successive sheets of strata is the reason for offsetting of the overlapping layers. In this region and to the southeast,

Devonian carbonate strata are, with the exception of the upper part of the Southesk Formation in some areas, almost completely dolomitized. Many original textural features have as a consequence been obliterated and reconstruction of depositional environments made difficult. Major lithologic elements are conspicuous and constitute members and formations within the carbonate body. Their terminology is shown in Figure 2. For typical lithologic descriptions of individual units the reader is referred to McLaren (1955) and McLaren and Mountjoy (1962).

Figure 2 shows the areal and stratigraphic distribution of carbonate and adjacent argillaceous or basinal formations and members as they occur along the second thrust sheet (2), Fig. 1) between Deception Creek and Mount La Grace.

The transgressive nature of Devonian sedimentation is demonstrated here by progressive thinning and final disappearance of the Cairn Formation "lower dolomite" northwestward from the type area to Cardinal Mountain. In other areas this variation in thickness, though less regular, suggests deposition from Devonian seas transgressing over a rather rugged post-Upper Cambrian erosion surface. Topographic highs on this surface received little or none of the early sediment, thus accounting for the absence in some areas of the lower Cairn dolomite.

The overlying "cherty dolomite" is in the order of 100 feet thick and shows little variation within the report area. The combined "lower" and "cherty" dolomites are equivalent to the Flume Formation in areas adjacent to the carbonate build-up.

An "upper dolomite", frequently quite porous (Plate 1), and containing numerous *Amphipora* and large globular stromatoporoids (Plate 2) as quantitatively important rock-building elements, is the thickest of the three informally designated Cairn units. It represents the amount of Cairn Formation carbonate build-up that has taken place on the underlying more widely distributed Flume Formation and is probably analogous to "brown reef" build-up on the Cooking Lake Formation in the Redwater and Leduc areas of the Alberta Plains.

As represented in figure 2, the Cairn Formation extends laterally beyond the limits of the overlying Southesk. To the south however, in the vicinity of Chocolate Mountain (Fig. 1), it is less widely distributed so that tongues of upper Southesk Formation carbonates extend beyond its limits and overlie the Flume and intervening Maligne, Perdrix and Mount Hawk Formations.

The overlying Southesk Formation, composed of lower Peechee, Grotto, Arcs and upper Ronde Members is in the order of 600 feet thick within the report area. The Peechee Member, commonly of porous, coarsely crystalline, grey dolomite, rests on the Cairn with a sharp contact or, as in the neighbourhood of Saracen Head, by interfingering through more than 100 feet. The Peechee is less widespread than the underlying Cairn and appears to be restricted to those areas where the Cairn Formation approaches its maximum thickness.

The Peechee Member can be overlain either by dark brown Grotto Member dolomite or by light brown limestone of the Arcs Member which is stratigraphically higher in

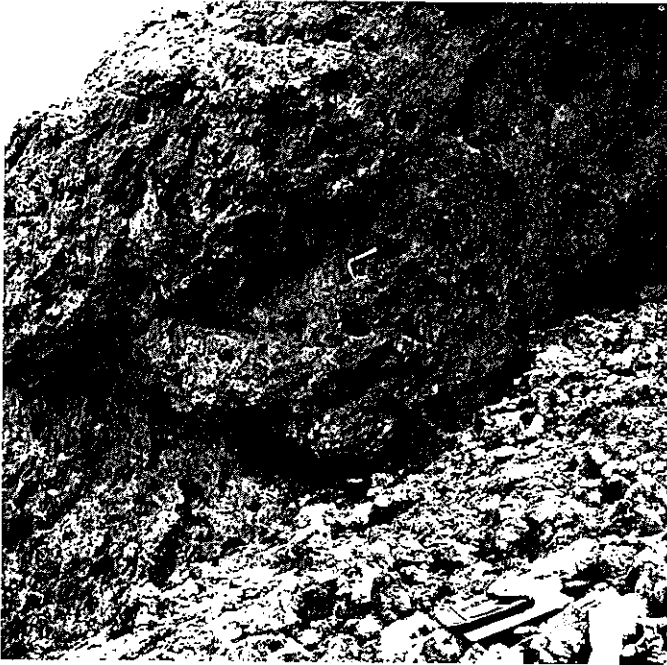


Plate 1. Porous Cairn Fm. "upper dolomite", vicinity of Mount MacKenzie.

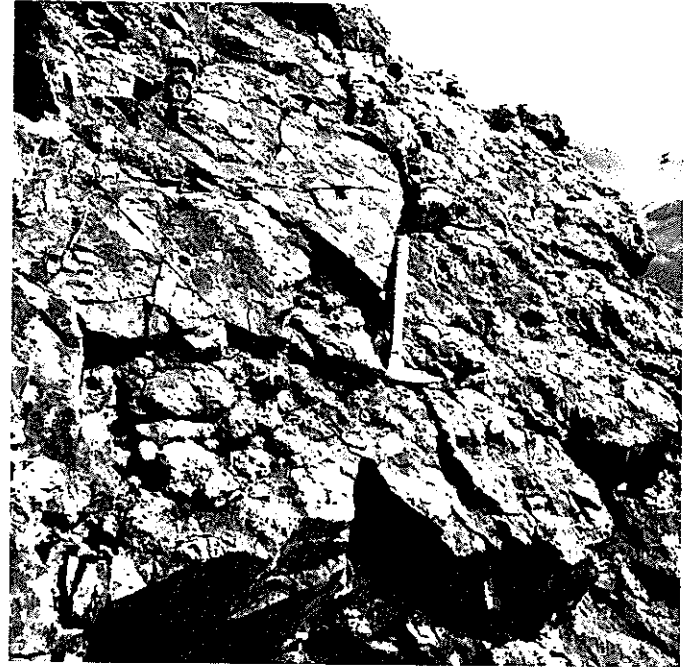


Plate 2. Abundant light-weathering globular stromatoporoids, Cairn Fm. "upper dolomite", vicinity of Mount Meda.



Plate 3. Good exposure of Southesk Fm. — Peechee, Grotto and Ronde Mbrs. near western margin of the Carbonate Complex, vicinity of Mount MacKenzie.

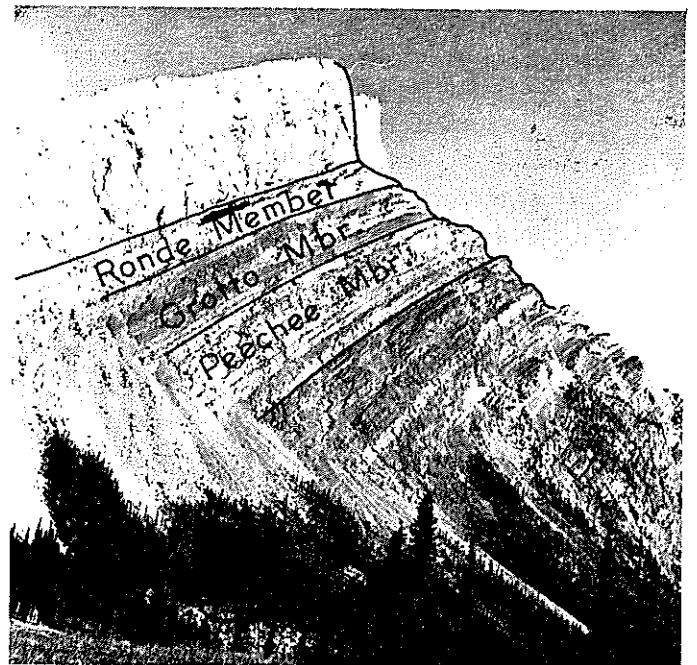


Plate 4. Good exposure of Southesk Fm. — Peechee, Grotto and Ronde Mbrs. near southern margin of the Carbonate Complex, Arete Mountain.

the sequence at the type locality. From Mount Dalhousie northwestward, a 45-foot Grotto Member thins progressively and disappears within a few miles. It reappears again and thickens to some 240 feet at the margin of the carbonate body (Fig. 2). Stratigraphic correlations carried southwestward across the mountain ranges show this same relationship of a Grotto Member with its maximum development in marginal areas and a thin layer or its total absence toward the interior of the carbonate body.

The Arcs Member attains its maximum thickness overlying the interior regions of the carbonate complex where it overlies Peechee Member dolomite or a thin Grotto Member. Toward argillaceous or basinal areas its lower contact rises stratigraphically until near the transition zone it has been entirely replaced by Grotto Member dolomite. Plates 3 and 4 show a stratigraphic succession of Peechee, Grotto and overlying Ronde Members with no Arcs present at marginal areas near Mount MacKenzie and Chocolate Mountain respectively.

The youngest lithologic unit of the Southesk Formation is the Ronde Member. As observed within the report area, it is underlain near transitional areas by the Grotto Member and in the interior by Arcs Member limestones. It is the most widespread of the Southesk Formation Members, extending beyond the limits of underlying members and in some areas beyond the limits of the underlying Cairn Formation.

Marginal Relationships

The transition zone from carbonate to equivalent basinal facies is not everywhere well exposed or easily accessible in the mountains. At Deception Creek, however, (Fig. 1), the change from Perdrix Formation to adjacent Cairn carbonate is well exposed and can be examined along the hillside on the east side of the creek (Plate 5). The change from shale and argillaceous limestone to dark brown Cairn dolomite is abrupt. There is no zone of gradual transition, although occasionally small tongues and isolated carbonate lenses do extend for a short distance outward into the enclosing shale and point to short periods of stability when carbonate deposition could extend itself laterally. The mound-like carbonate development shown on plate 5, continually decreasing in diameter upwards, suggests that carbonate deposition in these areas could not keep pace with that of the argillaceous facies so that the small mounds were soon completely covered. Such mound-like carbonate bodies may have been common in areas peripheral to the main carbonate build-up.

In contrast, members of the overlying Southesk Formation, where observed near Mount Meda, for example (Fig. 1), grade into adjacent argillaceous facies by a combined process of intertonguing and increase in clay content. The lower dolomites of the Southesk Formation become progressively more argillaceous, less resistant to weathering and finally lose their identity by intertonguing with adjacent Mount Hawk limestones. In general, this transition appears to be accompanied by an upward migration of the stratigraphic contact so that overlying members extend progressively farther beyond the main body of the reef (Fig. 2). Tongues of Grotto and Ronde Member dolomite in the neighbourhood of Chocolate Mountain extend far beyond the main body of the carbonate



Plate 5. Stratigraphic relationship between carbonate and argillaceous facies and mound-like Cairn Formation carbonate build-up, east side of Deception Creek.

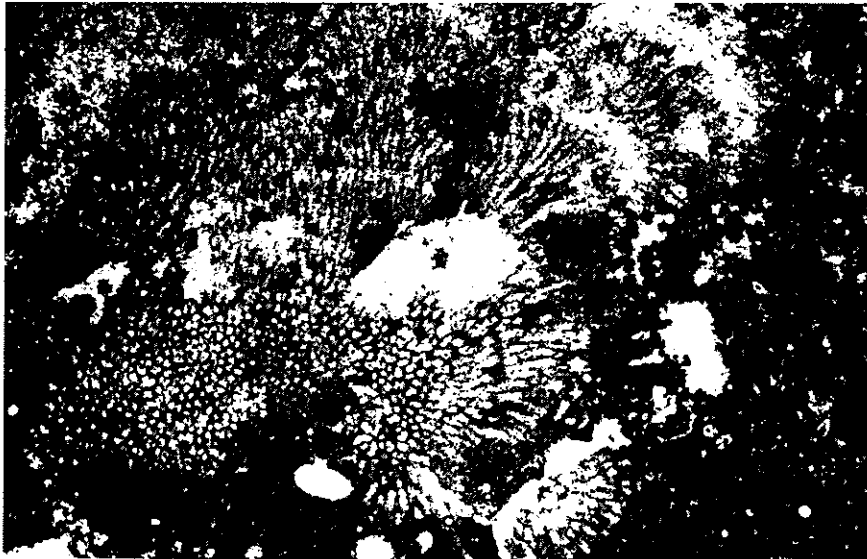


Plate 6. Parachaetetes sp., preserved in a dense microcrystalline limestone, Southesk Formation Arcs Member.

build-up. Belyea (1958), described tongues of Grotto extending beyond shelf margins into the Mount Hawk and Ireton of the Plains. Farther to the north, in the vicinity of Cardinal Mountain and Mount MacKenzie (Fig. 2), silty strata near the upper part of the Mount Hawk Formation can be traced eastwards into the carbonate body where they constitute silty horizons in the lower part of the Southesk Ronde Member. Thus the Ronde Member is stratigraphically equivalent to the upper part of the Mount Hawk Formation.

Overlying Strata

Maximum development of the overlying Sassenach Formation occurs in areas of clastic deposition away from the carbonate body. In these regions it consists of two members, a lower silty mudstone member and an upper sandy member (McLaren and Mountjoy, 1962). Approaching the carbonate body southeastward from Deception Creek, the formation changes by progressive thinning, from the base, of its lower silty mudstone member (Fig. 2). Thinning continues in this manner until only a thin remnant of the upper sandy member remains over the main body of the carbonate build-up. Closely spaced measured sections permit good assurance in tracing of the relatively thick upper sandy member beds from basinal areas to where they thin over areas of carbonate sedimentation. Again, on approaching the carbonate complex, southeastward from Mount Meda (Fig. 1), thinning of the Sassenach Formation takes place in the same manner. However, in this region, siltstone breccias occur in the upper part of the carbonate body near its margin and the Sassenach upper sandy member is absent locally, so that Palliser limestones are in contact with the highest Fairholme Group strata. In the southern part of the report area, the presence of stromatoporoid-bearing Southesk Ronde Member limestones immediately below grey, dolomite-mottled Palliser limestones precludes the presence of Sassenach Formation over large areas. Generally, the Sassenach Formation attains its maximum development overlying the argillaceous facies (Fig. 1), is quite thin overlying the carbonate body along thrust sheets (1), (2) and (3) and absent from large areas to the south along thrust sheets (4) and (5). In this area, the Palliser Formation rests directly on the underlying Fairholme Group strata.

PETROGRAPHY

Arcs Member

Light brown limestones, consisting of a series of closely related and intergrading microfacies, belong to the Arcs Member of the Southesk Formation and are restricted to interior regions of the carbonate body (Fig. 1). They can be separated into two groups of microfacies, a muddy facies in which burrowing organisms have been primarily responsible for stirring up and reworking of the sediment, and a calcarenitic facies in which water currents appear to have been the main agitating agent.

Of the muddy facies, pelleted microcrystalline rocks are the most abundant. They are commonly more coarsely crystalline than Folk's (1959) micritic rocks and contain whole

Explanation of Plates 7 - 10

- Plate 7: A bored and pelleted micritic rock. Coarsely crystalline calcite has infilled former void spaces. Southesk Formation Arcs Member.
- Plate 8: A laminated calcarenite with alternating laminae of dense micro-crystalline calcite and fine calcarenite, Southesk Formation Arcs Member.
- Plate 9: A broken mud-coated Amphipora fragment in medium calcarenite, Southesk Formation Arcs Member.
- Plate 10: A calcirudite of calcarenitic composite grains similar in texture to that of the surrounding matrix.

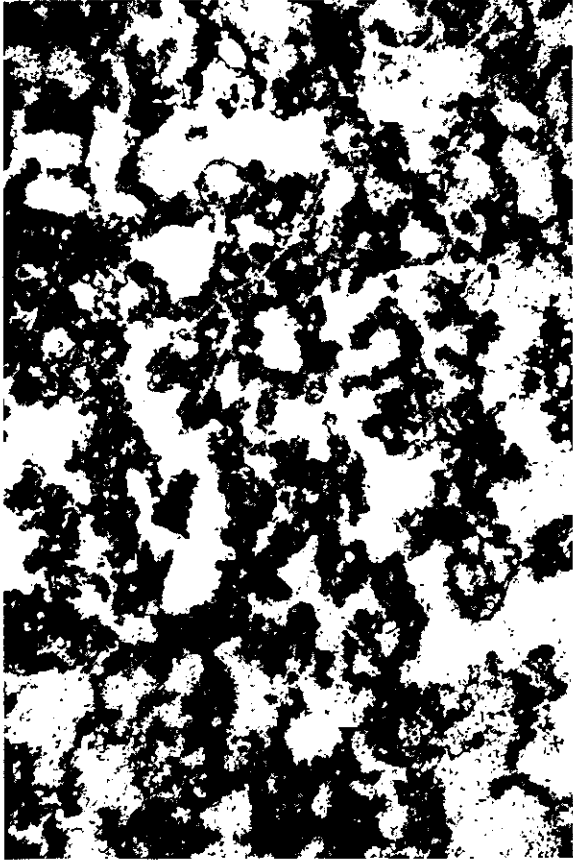


PLATE 7

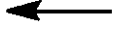


PLATE 8

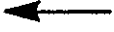


PLATE 9

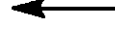
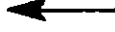


PLATE 10



and comminuted remains of small brachiopods, gastropods, ostracodes, stromatoporoids, calcispheres and algae. Plate 6 shows a Solenopore alga, Parachaetetes sp., preserved in one of the microcrystalline rocks. Their presence is probably good evidence for deposition in shallow water since light was required for their metabolism.

Micritic rocks which have been vigorously stirred by burrowing organisms, probably near the water-sediment interface, have been classified as bored and pelleted micrites (Plate 7). Coarsely crystalline calcite, which can constitute up to thirty per cent of the rock, has infilled burrows and other open spaces. This infilling by calcite must have taken place rather quickly or the loosely consolidated sediment would have collapsed under its own weight.

In addition to reworking of the sediment by animals, water currents have played a part in the breaking up and rearrangement of constituent limestone rock fragments of the calcarenite group of microfacies. Laminated calcarenites (Plate 8) are a distinctive rock type belonging to this group. Thin alternating beds of well sorted coarse and fine grains are evidence of periodic changes in current strength. Fine cross-bedding and localized areas of erosion suggest the presence of controls possibly in the form of plant and animal communities which affected water movement locally. Individual laminae are commonly of dense microcrystalline calcite with sharp upper surfaces and calcarenitic lower boundaries. These probably represent thin layers of algal-stabilized sediment which locally became separated from the substratum and which in some areas floated above it. Soft unconsolidated fragments dropped down from the underside of the algal-stabilized mat, were moved about locally, and finally were incorporated in a precipitated calcite cement.

Fossil remains are common in other calcarenitic rocks. Many of the skeletal remains were broken and mud-coated, as the Amphipora fragment in Plate 9, and appear to have been carried in from a distance to become incorporated with the limestone grains. Transported remains have no direct environmental significance but they do, because of their mud coating, suggest nearby contemporaneous quiet water.

Further sediment reworking produced coarser grained calcirudites (Plate 10), commonly made up of composite grains of essentially the same texture and composition as the enclosing calcarenite matrix. Such grains could have been produced by relatively weak currents that would have been unable to dislodge similar large fragments from a homogeneous fine-grained rock. Burrowing organisms may also have been a factor in breaking up the sediment.

The foregoing closely related microfacies compare with Klovan's (1963) back-reef facies of the Redwater oil field which was made up of similar closely related rock types. Their areal distribution (Fig. 1), confined to the central part of the carbonate body, supports the concept of an extensive lagoonal or back-reef type of deposit formed in shallow, generally calm water. Within this uniform habitat, plant and animal communities presumably influenced water movement locally to produce different textures in closely related microfacies. The foregoing rock types are commonly found in close association, and although individually subject to rapid local variation, as a group they constitute a laterally persistent unit which can be traced for long distances.

CONCLUSIONS

Construction of subsurface maps and interpretation of reef complexes under the Alberta Plains has in the past suffered from a lack of information on stratigraphic relationships near reef margins. Some of the preceding observed relationships may be significant in the continuing search for potentially productive carbonate reefs.

Fammenian Sassenach strata are separated from the underlying Frasnian Fairholme Group by a regional unconformity. There is a rapid decrease in thickness of Sassenach beds as the carbonate build-up is approached and they may be absent from large areas of the back-reef regions. Argillaceous Fairholme Group strata become increasingly calcareous toward the carbonate body and near it may contain isolated reef-like carbonate lenses in their upper levels.

Potential reservoir-forming porous dolomites occur in the Cairn Formation "upper dolomite" and in the lithologically similar Southesk Grotto Member dolomite which attains its maximum development in marginal areas. The interior regions of the complex are occupied by dense Arcs Member limestones and consequently are less attractive to the petroleum geologist.

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or correlated with the Banff, Pekisko, Shunda, Turner Valley and Mount Head Formations. The upper one has been referred to either the Rocky Mountain Group or the Tunnel Mountain Formation, but more recent work by McGugan and Rapson (1961) indicates that it is of Permian age.

In 1963, McKay and Green published the results of their studies on the Mississippian foraminifera of the Canadian Rockies. Included in their studies was a section on Morro Creek. This section is approximately three miles southwest of Mount Greenock and separated from the Greenock section by the Colin thrust and several minor faults. McKay and Green (1963) have found that the early Osage form, Endothyra tumula¹, extends at least two thirds of the way up into the "Turner Valley Formation" (see McKay and Green, Fig. 4). Although they were unable to find fauna in the upper part of the "Turner Valley", it is possible that E. tumula may extend that high in the section. However, McKay and Green place this upper part of the Morro Creek "Turner Valley" in the overlying Endothyra lanceolata range zone (Fig. 2, p. 5). Also on the basis of their foraminiferal studies (McKay and Green, Fig. 2, p. 5), they indicate that at least the lower part of the "Turner Valley" at Morro Creek is equivalent to the Shunda at Moose Mountain.

It can be seen from the foregoing that there is disagreement about the stratigraphy of the section at Mount Greenock and a lack of knowledge about the time-rock relationships. It is the purpose of this paper to throw some light on the anomalous nature of the section at Mount Greenock.

FIELD WORK

The sections of Mount Greenock, Mowitch Creek and Sulphur Forks were measured during the 1962 field season. Measurements were made with tape and compass and true thicknesses computed. Samples were taken at approximately five-foot intervals and field descriptions were augmented by binocular microscope and thin-section studies. In most instances enough ghost texture could be discerned in the dolomites to determine the original limestone type. Where ghost texture was indiscernible, the color and crystal size of dolomite were used as indications of original rock type.

The Jacques Lake section was measured in 1955 by L. W. Vigrass for The California Standard Company. Thicknesses were checked as closely as possible and the samples collected were re-studied by the authors. The section was observed in the field during the course of helicopter reconnaissance and no structural thickening was noted.

¹ The writers follow the terminology used by McKay and Green (ibid.) in this paper. The species is sometimes referred to as Plectogyra tumula and the reader is referred to McKay and Green, (ibid., 1963, p. 29) for a discussion of the nomenclature problem.

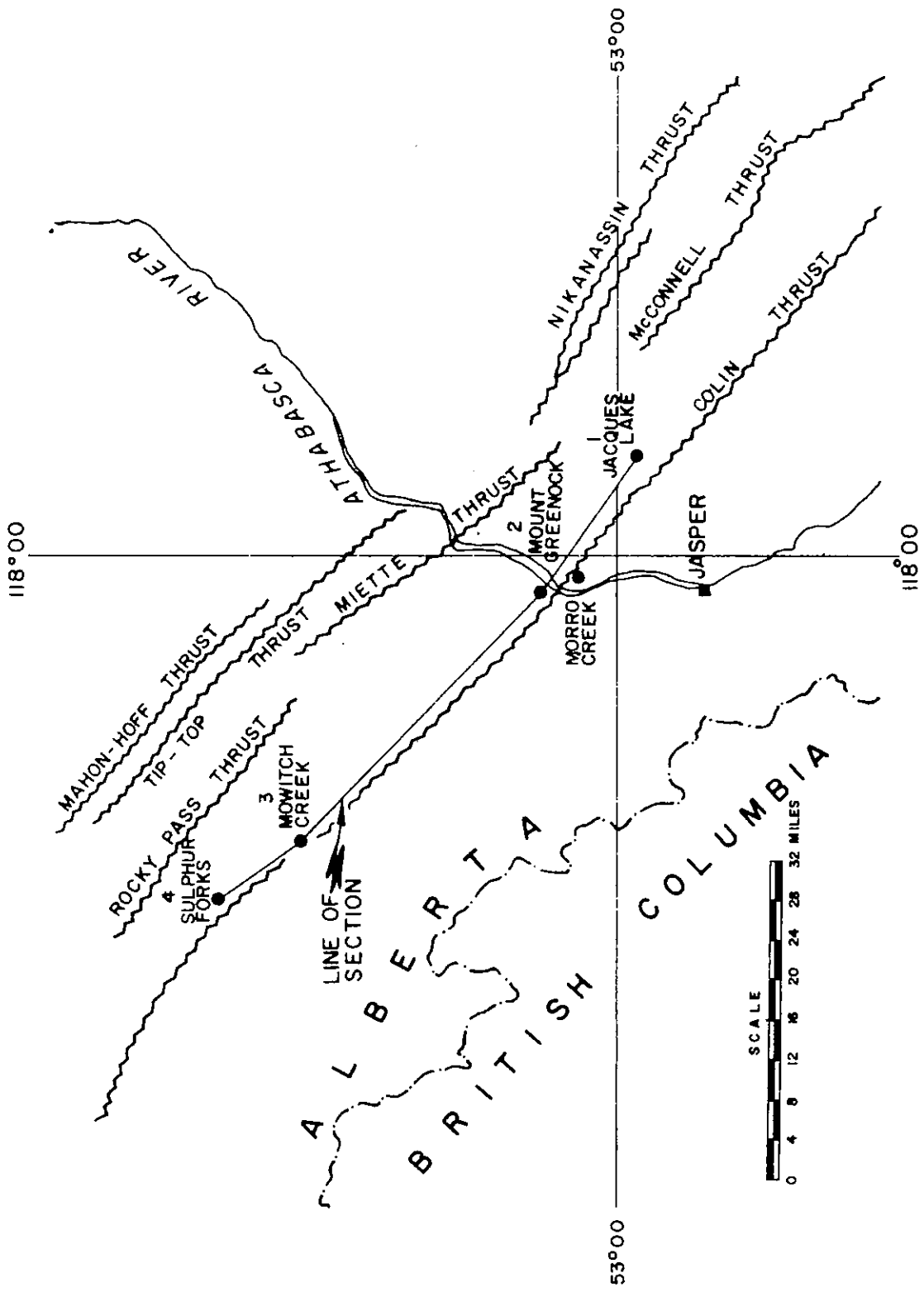


Figure 1. Index map

STRATIGRAPHIC RELATIONSHIPS¹

This section of the paper is a series of notes describing the accompanying stratigraphic cross-section (Fig. 2). A study of the cross-section at this point will make the following pages more meaningful to the reader.

The Permo-Carboniferous beds of the fault block immediately east of the Colin thrust, between the Sulphur and Maligne Rivers, can be subdivided into five units. These are, in ascending order, the Banff, Pekisko, Shunda and Debolt (?)² Formations and the Rocky Mountain Group. The Rocky Mountain Group can be further subdivided into units of formational status (see McGugan and Rapson, 1961).

The Banff, Pekisko, and Rocky Mountain beds are readily mappable (Fig. 2) and maintain their lithologic identity throughout the area.

Most of the Debolt (?) is dolomite throughout the area but there is a decrease in crystal size in the lower part toward the southeast. This seems to be due to a decrease in grain size and an increase in lump and pellet content of the pre-dolomite rocks. However, the change is not abrupt and a good crinoidal marker persists in the upper part.

Fossils collected by the writers from lower part of the Debolt (?) Formation at the Sulphur Forks section have been identified by E. W. Bamber of the Geological Survey of Canada who offered the following comments.

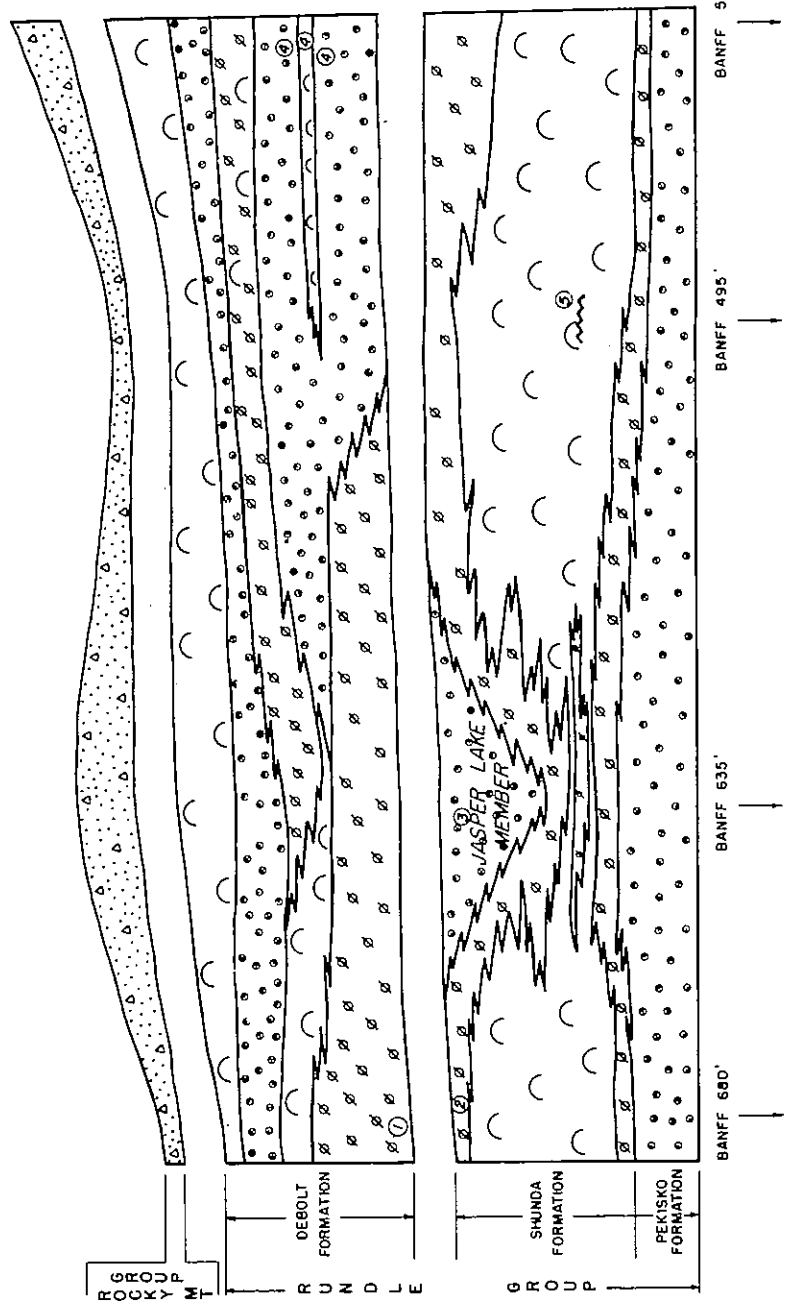
"At 524 feet below top of Paleozoic

Syringopora bassoï Nelson
Syringopora virginica Butts?
Vesiculophyllum sp.

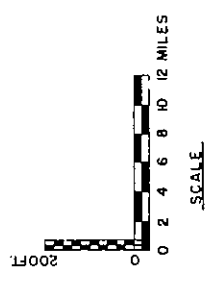
"S. bassoï is reported by Nelson to be restricted to the upper Livingstone and basal 150 feet of the Mount Head. S. virginica has a greater range, occurring from the upper Livingstone up into the lower Etherington, according to Nelson. This collection is

¹ The petrographic terminology used in this paper is essentially that of Folk (1959) with the addition of the term "lumps" as suggested by Wolf (1960). The terms are used only in a descriptive sense and do not necessarily imply the depositional conditions postulated by those writers.

² This unit may range in age from early Osage to Pennsylvanian and has previously been called "Mount Head". However, the resemblance is only superficial and correlation with the type Mount Head section is suggested only by stratigraphic position. The unit bears a closer resemblance to the Debolt and perhaps this is the name that should be used for it.



- LEGEND**
- SANDSTONE, SILTSTONE AND CHERT
 - CRINOIDAL LUMP PELSPARITE
 - CRINOIDAL BIOSPARITE AND BIOSPARRUDITE
 - DISMICRITE, THINLY BANDED MICRITE
- The rocks at ① are somewhat coarser and contain more crinoidal material than those at ②
- ③ Correlates with beds containing early Osage fauna at Morro Creek.
- ④ Late Osage to early Meramec fauna
- ⑤ Corrected for thrust.



— SOUTH-EAST — NORTH-WEST —

FIGURE 2

EXPLODED DIAGRAM SHOWING PRE-DOLOMITIZATION FACIES IN THE ATHABASCA RIVER AREA

probably late Osagean or early Meramecian in age.

"At 551 feet below the top of Paleozoic

Lithostrotion (Siphonodendron) oculinum Sando

"This species has been found in the upper 300 to 500 feet of the Rundle and Prophet Formations north of Wapiti Lake and from the top of Rundle B and middle and lower Rundle C in the Jasper region (see Mountjoy, G.S.C. Paper 61-31 where it is called L. (S.) cf. warreni Nelson. This species indicates a late Osagean to early Meramecian age.

"At 604 feet below the top of Paleozoic

Lithostrotion (Siphonodendron) oculinum Sando"
(see comments above)

The Shunda Formation presents many of the stratigraphic problems of this area. The base of this unit is diachronous and transitional from the underlying Pekisko through a thin zone of pelsparites. The base can be picked either at the base of the dismicrite zone (see Fig. 2), within the transition zone, or at the top of the biosparites. The latter is generally the better topographic break.

The upper contact is more difficult. The most obvious topographic and lithologic break lies at the top of the recessive dismicrite zone. However, this is a facies boundary. The important stratigraphic break appears to be the top of the overlying pellet-lump zone and we have drawn the contact there. This places it within a resistant series of beds. The basal beds of the overlying Debolt(?) are either dolomitized coarser pellet-lump rocks or crinoidal biosparites.

In the vicinity of the Athabasca River, the upper part of the Shunda changes rapidly from lump-pellet rocks and dismicrites to a dolomitized crinoidal biosparite. This crinoidal unit is herein called the Jasper Lake Member. All or part of this unit has previously been referred to the Turner Valley Formation. However, in view of the early Osage¹ dating by McKay and Green (1963) of similar beds at Morro Creek, and the Shunda thicknesses in adjoining sections, this assignment seems incorrect.

The Jasper Lake Member is composed of coarsely crystalline dolomite and is approximately 200 feet thick. The original rock is thought to have been crinoidal biosparites. The lower contact is not exposed at the type section on Mount Greenock.

¹ Osage is used in a manner similar to that of McKay and Green (1963) and publications of the Geol. Survey of Canada. Oswald (1963) assigns an early Meramec age to beds usually considered late Osage. McKay and Green (1963, p. 18) suggest a similar possibility. The late Osage-early Meramec problem is obviously beyond the scope of this paper.

The upper contact is drawn where the coarse dolomite gives way to medium crystalline dolomites of the Debolt(?). The Jasper Lake Member is interpreted as representing a local encroachment of more basinal conditions.

Much of the difficulty in interpretation of the Mount Greenock section stems from the fact that it has been compared with the easterly ranges in the Nordegg-Mountain Park area (Drummond, 1961; Green, 1962). The combined thickness of typical Shunda and Pekisko lithologies is almost identical in the two areas and this was the correlation usually made. However, Mount Greenock is considerably farther west and should thus contain a thicker Pekisko-Shunda section than that found in the Nordegg-Mountain Park area. If the Mount Greenock section is compared with adjacent sections along the structural strike, it becomes even more apparent that the interval containing beds of typical Pekisko and Shunda lithology is abnormally thin at Mount Greenock. The interpretation that the Jasper Lake Member is a local crinoidal development of the upper part of the Shunda, rather than a younger unit, resolves the abnormality, and may help to clarify the Mississippian stratigraphy of the Jasper area.

CONCLUSIONS

The Mount Greenock section is readily accessible and in many respects typifies the Carboniferous in the Jasper area. It does differ markedly in that a crinoidal facies equivalent to Shunda type beds to the north and south is found there. This crinoidal unit, which has been previously correlated with the Turner Valley Formation, is here called the Jasper Lake Member of the Shunda Formation, and Mount Greenock is designated as the type section of the member.

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PETROLOGY OF A PERMO-CARBONIFEROUS SECTION IN
NORTHERN JASPER NATIONAL PARK, ALBERTA¹

By

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ABSTRACT

A typical section of Permo-Carboniferous rocks at Thornton Creek in northern Jasper Park was examined to reconstruct the conditions of sedimentation and to investigate the diagenesis and alteration of these rocks. Depositional environments were interpreted from textural, mineralogic and faunal information.

Mississippian carbonate rocks reflect shallow-water shoal, intershoal and lagoonal environments. Uppermost Banff Formation sediments are alternating shallow-water limestones and dolostones formed in restricted environments. A shoal area with periodic restriction of the waters marked Pekisko time in the Jasper area. Shunda Formation sediments contain much mud; the area during this time was probably very similar to the protected shelf lagoons existing on the Bahama Banks today. Turner Valley and Mount Head Formations are highly dolomitized but were originally limestone.

Permian sedimentation began with the deposition of a basal conglomerate over an erosion surface, after which the sediments consist of a shallow-water deposit of spicular chert overlain by a quartzose sandstone.

INTRODUCTION

The sedimentary sequence studied is an unfaulted, well-exposed section of Mississippian and Permian rocks about 21 miles northwest of the town of Jasper in Jasper National Park at longitude 118°17'30" West and latitude 53°09'34" North (Fig. 1 and

¹ Manuscript received June 17, 1964.

Her Majesty the Queen, in right of Canada, reserves the right to reprint this article.

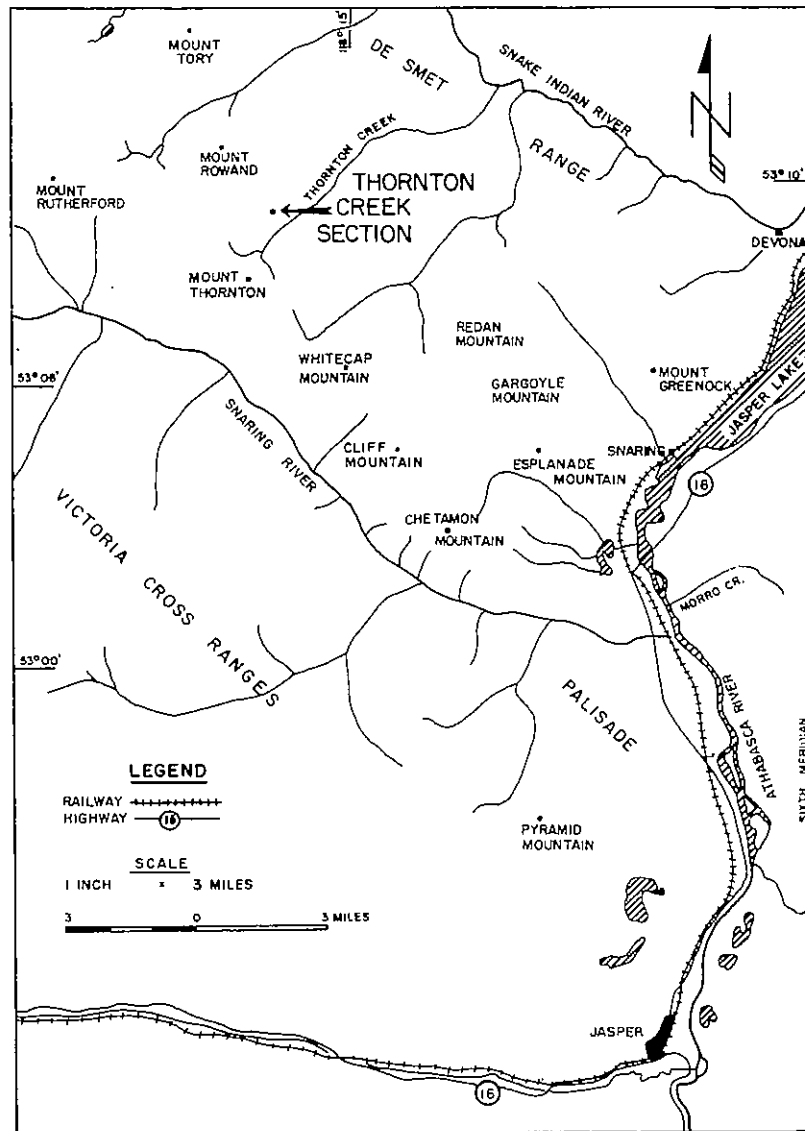


Figure 1. Map showing location of Thornton Creek section.

Plate 1) and is informally referred to as the Thornton Creek section.

The Thornton Creek section occurs in the hanging wall of the Colin thrust, which in this area contains strata ranging in age from Devonian (Flume and Cairn Formations) to Triassic (Sulphur Mountain Formation). To the southwest the succession is broken by the Chetamon thrust, and Lower Cambrian Gog sandstones occur in fault contact above Triassic rocks (Plate 1, also see Mountjoy, 1962).

Field work was done while Walasko was an assistant on a field party of the Geological Survey of Canada led by Mountjoy, who suggested the problem. Samples were collected from each distinct lithologic unit with additional samples selected from within the thicker units. These rocks were studied at the University of Alberta as part of

a M. Sc. program (Walasko, 1962) under the guidance of Lerbekmo. The principal objectives of the study were to investigate the petrography and diagenesis of these rocks and, from this, attempt to determine depositional environments.

Grateful acknowledgement is extended to the Geological Survey of Canada for supporting the field work and permission to publish this study. A special debt of gratitude is owed to the University of Alberta for the generous use of their facilities and to members of the staff of the University who offered valuable suggestions and assistance. Dr. E. W. Bamber of the Geological Survey of Canada kindly supplied the fossil determinations.

STRATIGRAPHY

The Carboniferous stratigraphy along the Athabasca Valley within Jasper National Park has received considerable study. Prior to 1950 much of the work was of reconnaissance nature but established a major three fold division of the Carboniferous rocks, that is, a basal shale and argillaceous limestone (Banff Formation), a middle carbonate (Rundle Formation) and an upper chert and sandstone (Rocky Mountain Formation) (Allan *et al.*, 1932; Lang, 1947). This subdivision and nomenclature was based on comparisons with the Carboniferous of the Banff area. The detailed stratigraphy and palaeontology of Brown (1952) established the principal stratigraphic and biostratigraphic relationships of three successive thrust sheets near Mount Greenock. Woodward (1955) and Moore (1958) demonstrated that the Rundle Formation was divisible into four units similar to units already established in southern Alberta. They employed the same names for these units on the basis of stratigraphic position and lithologic similarity but without establishing the relationships or continuity between the two regions. From bottom to top these formations are Pekisko, Shunda, Turner Valley and Mount Head.

More recently several geologists have studied the Carboniferous rocks of the Jasper area. Mountjoy (1960, 1961, 1962) has shown that the four fold division of the Rundle is mappable throughout most of northern Jasper Park, but informally referred to these formations by letter: Formations A to D from oldest to youngest. McGugan and Rapson (1961, 1963) have recently contributed important data on the Rocky Mountain Formation. Permo-Carboniferous nomenclature in general use is shown in Figure 2.

Several correlations between Banff and Jasper have been suggested (Moore, 1958; Nelson and Rudy, 1961; Drummond, 1961; and Green, 1962) but all have been proposed without study of rather vast intermediate areas between Jasper and Nordegg and between Nordegg and Banff. Essentially the four fold subdivision of the Jasper area Rundle Group is approximately equivalent (or homotaxial) with the Mount Head, Turner Valley, Shunda and Pekisko Formations near Nordegg (Brady, 1958) and Moose Mountain (Illing, 1959). Palaeontological control, especially in the upper part of the Rundle, is still insufficient and not refined enough to establish beyond doubt good correlations. Until more detailed stratigraphic and palaeontological studies have been made particularly in the region between Banff and Jasper the true temporal relationships between the Rundle divisions in

GENERALIZED PERMO-CARBONIFEROUS NOMENCLATURE IN WESTERN CANADA								
SYSTEM	STAGE	SASK. BRINDLE 1962	SOUTHERN PLAINS OF ALBERTA PENNER 1958	BANFF NELSON 1961 MCGUGAN 1961	JASPER DRUMMOND 1961 MCGUGAN AND RAPSON 1961 GREEN 1962	NORTH WESTERN ALBERTA MACAULEY 1958 HALBERTSMA 1959 HALBERTSMA AND STAPLIN 1960		
PERMIAN				ROCKY MTN. GP. ISHBEL FM.	ROCKY MOUNTAIN FM.	BELLOVY FM.		
PENNSYLVANIAN				KANANASKIS FM. TUNNEL MTN. FM.		TAYLOR FLAT FM.		
MISSISSIPPIAN	CHESTERIAN			ETHERINGTON FM.		KISKATINAW FM.		
	MERAMECIAN	POPLAR BEDS	MOUNT HEAD FM.	MOUNT HEAD FM.	MOUNT HEAD FM.	GOLATA FM.		
	OSAGEAN	RATCLIFFE BEDS	RUNDLE GROUP	TURNER VALLEY FM.	LIVINGSTONE FM.	TURNER VALLEY FM.	DEBOLT FM.	
		MIDALE BEDS		SHUNDA FM.	UPPER MBR.	SHUNDA FM.		SHUNDA FM.
		FROBISHER-ALIDA BEDS		PEKISKO FM.	MIDDLE MBR.	PEKISKO FM.		PEKISKO FM.
	KINDERHOOKIAN	TILSTON BEDS		BANFF FM.	BANFF FM.	BANFF FM.	BANFF FM.	
		SOURIS VALLEY BEDS						LOWER MBR.
MISSISSIPPIAN OR DEVONIAN		BAKKEN FM.	EXSHAW FM.	EXSHAW FM.	EXSHAW FM.	EXSHAW FM.		

Figure 2. Permo-Carboniferous nomenclature in western Canada

the various areas cannot be firmly established.

While mapping the Miette and Mount Robson map-areas for the Geological Survey of Canada, Mountjoy has made a semi-detailed study of over 20 sections. Brief summaries of some of this work have been published (Mountjoy, 1960, 1962) but much of this data is in preparation or being edited for publication.

One of these sections is at Thornton Creek. It has been studied in detail by Walasko (1962) and is illustrated in Figure 3.* The Banff Formation at this locality is 743 feet thick, but only the upper 120 feet were studied. It consists of a sequence of rhythmically interbedded calcareous shales and crinoidal limestones or dolostones. The Rundle Group is 1210 feet thick. The Pekisko Formation consists of 210 feet of thick-bedded, resistant, light grey, coarse-grained crinoidal limestone and argillaceous and microcrystalline, calcareous dolostones. Recessive, relatively thin-bedded, light to dark grey, argillaceous dolostones and limestones of the Shunda Formation are 280 feet thick.

* in pocket

The Turner Valley Formation is 367 feet thick and consists of very fine-crystalline, in part crinoidal, dolostone and cryptocrystalline limestone. In part cherty, microcrystalline and argillaceous dolostones form the Mount Head Formation, which is 353 feet thick. The upper part of the Mount Head and Etherington equivalents are not present and appear to have been eroded prior to deposition of the Rocky Mountain Formation. All formations have been distinguished on a basis of lithology and most contacts are gradational. The bases of both the Turner Valley and Pekisko Formations form the most reliable horizons for correlation purposes. They may even approximate time lines in the Jasper area, especially the base of the Pekisko. Interbeds of crinoidal carbonates extend upward into both the Shunda and Mount Head Formations making the choice of an upper contact for the Pekisko and Turner Valley Formations much more difficult.

Thick-bedded spicular cherts and light brown weathering, quartz sandstones of the Rocky Mountain Formation disconformably overlie the Rundle Group. They form a distinct, resistant, dark grey weathering unit above the light grey Rundle carbonates (Plates 1 and 2). The Rocky Mountain Formation is overlain disconformably by siltstones and sandstones of the Triassic Sulphur Mountain Formation.

The lithology and thickness of the Thornton Creek section are reasonably representative of the thicker part of the Carboniferous succession of northern Jasper Park (Fig. 4). The Rundle Group thins progressively northeastward from 1200 feet to 800 feet in the foothills. This is the cumulative result of thinning of all the units except the Shunda Formation, which in some parts of the region thickens slightly in an eastward direction. The thickest section of the Pekisko Formation occurs at Mount Greenock (244 feet, Fig. 4) where the Shunda Formation is also correspondingly thinner (235 feet). The Shunda Formation varies in thickness from about 210 to 290 feet in this area, the Thornton Creek section being the thickest. The thickness of the Turner Valley Formation varies from 300 to 400 feet. The Mount Head Formation is somewhat more variable in thickness changing from 260 to 350 feet. This variation probably reflects differential erosion of the upper part.

PETROGRAPHY

Introduction

Folk's (1959) classification of carbonate rocks is the basis for the one used by the writers. Allochemical constituents, including intraclasts, bioclasts, pellets and oolites provide the structural framework of the rock; interstitial calcite mud and sparry calcite cement are called orthochemical constituents. These constituents, combined with texture, provide a basis upon which depositional environment may be deciphered.

Modifications of Folk's classification proposed herein stem from the recognition of the intermediate silt grade as an important size entity. Table 1 shows the terminology proposed by the writers for limestones containing silt-sized grains and matrix; the terms

THORNTON CREEK

ROCHE DE SMET

MOUNT GREENOCK

6 miles

4 miles

53° 19 1/2'

118° 17'

53° 09'

118° 08'

53° 05 1/2'

118° 04'

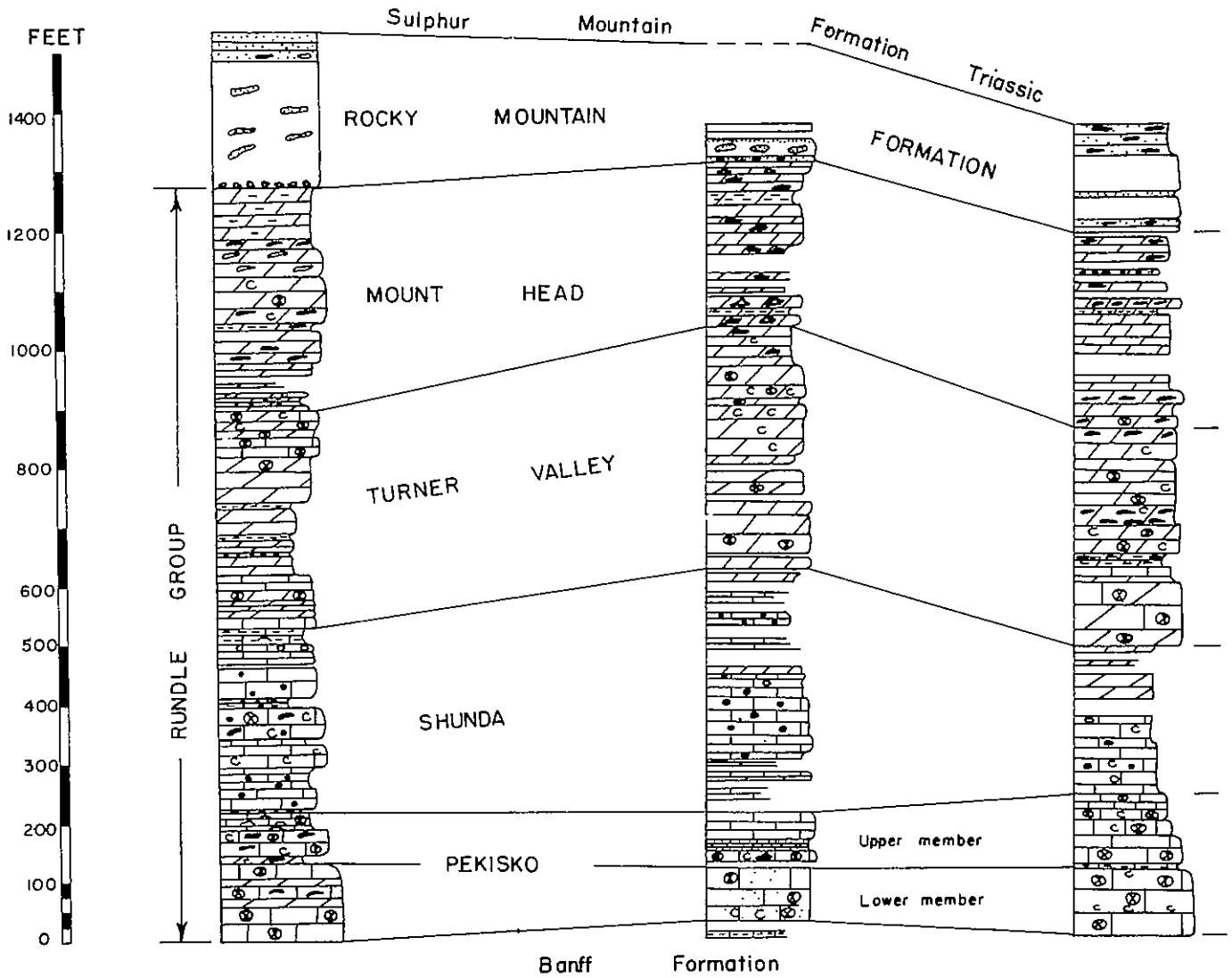


FIGURE 4
PERMO-CARBONIFEROUS COLUMNAR SECTIONS

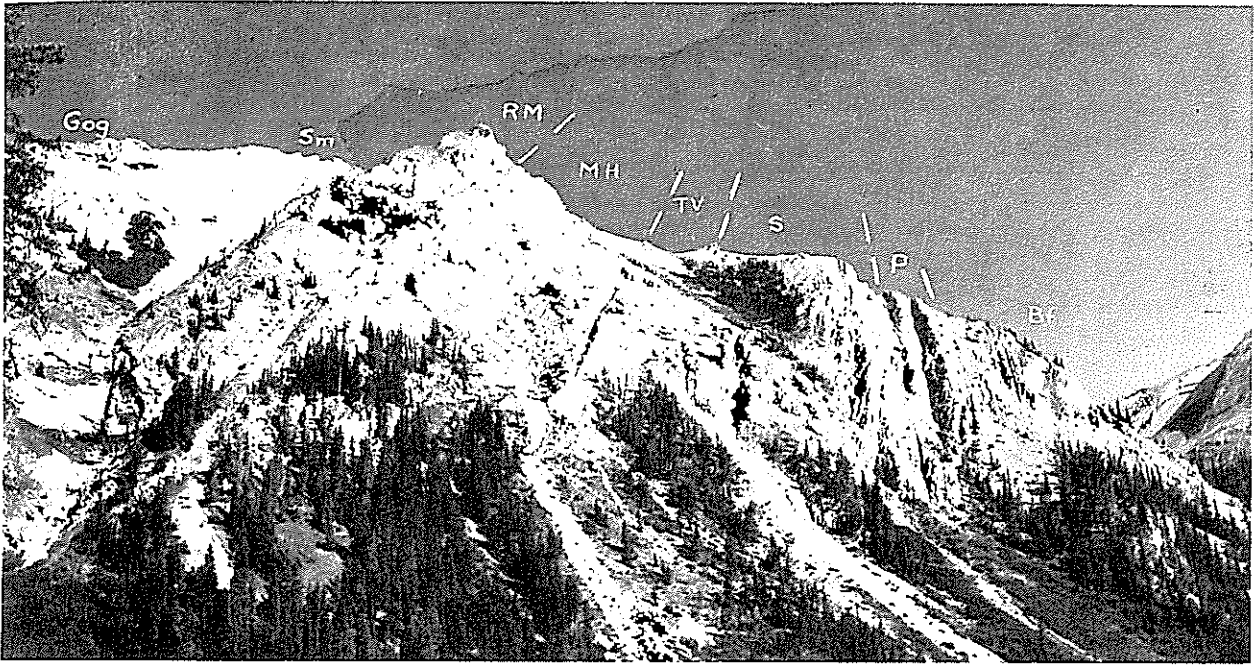


Plate 1. Thornton Creek section on southwest spur of Mount Haultain as viewed from Thornton Creek valley. The Carboniferous succession dips about 60 degrees to the southwest. On the left Lower Cambrian Gog Formation of the Chetamon thrust sheet occurs in fault contact above Triassic Sulphur Mountain Formation (GSC Photo EWM 60, 10-5,6).

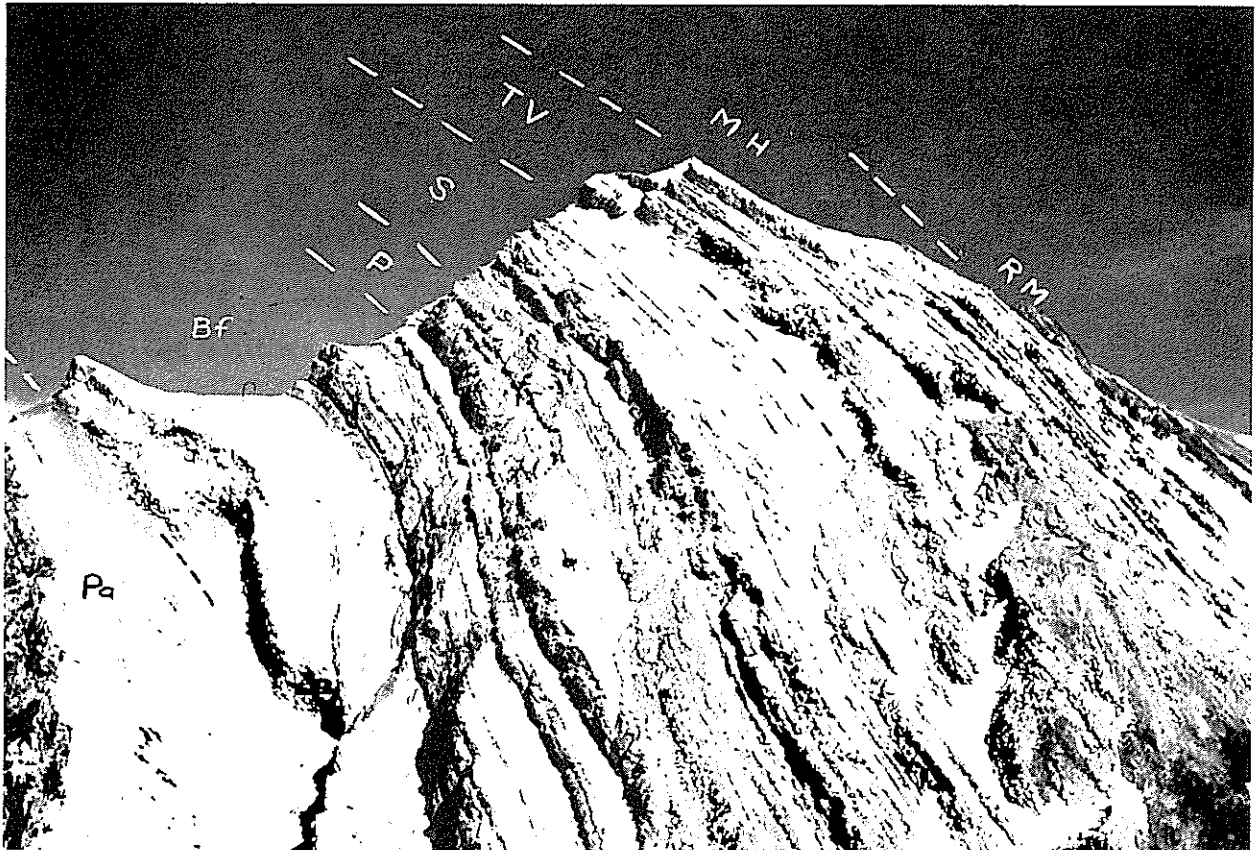


Plate 2. South side of Thornton Creek illustrating Carboniferous sequence opposite Thornton Creek section (GSC Photo EWM 60, 8-8).

CLASSIFICATION OF CARBONATE ROCKS																
LIMESTONE AND PARTLY DOLOMITIZED LIMESTONE											REPLACEMENT & PRIMARY DOLOSTONE					
>10% ALLOCHEMS											<10% ALLOCHEMS					
SILT-SIZE CALCITE < SPAR CEMENT >MUD											SPAR CEMENT <SILT-SIZE CALCITE >MUD		SPAR CEMENT <MUD> SILT-SIZE CALCITE			
SILT-SIZE CALCITE < MUD >											MUD > SILT-SIZE CALCITE		SILT-SIZE CALCITE < MUD >		MUD > SILT-SIZE CALCITE	
UNDIS- TURBED BIO- HERMS											ALLOCHEM GHOSTS		NO ALLO- CHEM GHOSTS		PRIMARY DOLO- MITE	
VOLUMETRIC ALLOCHEMICAL COMPOSITION	>75% INTRACLASTS	>75% OOLITES	3:1	INTRASPARITE	INTRASILTITE	INTRAMICRITE	INTRACLAST- BEARING CALCISILTITE	INTRACLAST- BEARING MICRITE	INTRACALCISILTITE	CALCISILTITE	MICRITE AND DISMICRITE	BIOLITHITE	INTRACLASTIC DOLOSTONE	DOLOSTONE	DOLOMICRITE	
				OOSPARITE	OOSILTITE	OOMICRITE	OOLITE- BEARING CALCISILTITE	OOLITE- BEARING MICRITE	OOCALCISILTITE				OOLITIC DOLOSTONE			
	<25% INTRACLASTS	<25% OOLITES	1:3-3:1	BIOSPARITE	BIOSILTITE	BIOMICRITE	FOSSIL- IFEROUS CALCISILTITE	FOSSIL- IFEROUS MICRITE	BIOCALCISILTITE	CALCISILTITE	MICRITE AND DISMICRITE	BIOLITHITE	BIOGENIC DOLOSTONE	DOLOSTONE	DOLOMICRITE	
				BIOPELSPARITE		BIOPELMICRITE	PELLET- BEARING CALCISILTITE	PELLET- IFEROUS MICRITE	PELCCALCISILTITE				PELLETOID DOLOSTONE			
	<25% INTRACLASTS	<25% OOLITES	1:3		PELSILTITE											
				PELSPARITE		PELMICRITE										

Figure 5. Scheme of petrographic classification of carbonate rocks (modified after Folk, 1959).

are easily incorporated into Folk's classification (Fig. 5). Intracalcisiltite, biocalcisiltite, oocalcisiltite and pelcalcisiltite were coined by Kent (1961) but were used with different quantitative limits. Calcisiltite would in general accumulate in slightly less agitated water than would calcarenite.

The Wentworth size grade scale was used for both mechanical and authigenic textures. Dolostone is used as the rock name for those carbonate rocks in which the mineral dolomite predominates (Shrock, 1948). Folk's rock type dolomicrite, the primary dolostone, is a separate class of dolostone in the classification adopted. Cayeux's (1935) classification of calcite-dolomite mixtures has been adopted.

Table 1. Nomenclature for Carbonate Rocks Composed of Silt-size Grains

SIZE DISTRIBUTION	TYPE OF SILT	ROCK TYPE
<1% sand-size allochems; silt-sized calcite framework	any	calcisiltite
	bioclasts	biocalcisiltite
	intraclasts	intracalcisiltite
	oolites	oocalcisiltite
	pellets	pelcalcisiltite
1-10% sand-sized allochems; silt-sized calcite matrix	bioclasts	bioclast-bearing calcisiltite
	intraclasts	intraclast-bearing calcisiltite
	oolites	oolite-bearing calcisiltite
	pellets	pellet-bearing calcisiltite
>10% sand-sized allochems; silt-sized calcite matrix	bioclasts	biosiltite
	intraclasts	intrasiltite
	oolites	oosiltite
	pellets	pelsiltite

Allochemical Constituents

Allochemical constituents include intraclasts, oolites, pellets and bioclasts, and are of intrabasinal origin. Intraclasts are intrabasinal calcareous rock fragments and particles formed by erosional, aggregational and recrystallization processes. Those observed in the present study are spherical to irregularly rounded homogeneous bodies of light to dark grey-brown cryptocrystalline calcite. Material comprising intraclasts is often identical to that of matrix. Intraclasts may contain earlier deposited materials such as bioclasts, smaller intraclasts and detrital quartz in addition to authigenic constituents such as dolomite rhombohedra and quartz. Some algae and foraminifera are wholly or

partly recrystallized, the result is intraclasts of dark cryptocrystalline calcite.

Two types of oolites were noted; one has a light microcrystalline calcite nucleus and a darker laminated calcite rim, and has a diameter of about 0.1 mm; the other is larger, has both concentric and radial structure, has a diameter of about 0.9 mm, and the oolite material is identical to matrix.

Pellets are generally believed to be aggregate bodies produced as animal excrement. No grains of definite pellet origin were recognized in this study.

Folk (1959) classified all fossils and fossil fragments, other than those which grew in situ, as bioclasts, and this definition is used here. Crinoids, bryozoans, algae, echinoids, brachiopods, gastropods, ostracodes, sponge spicules, foraminifera, corals and calcispheres were observed in the present study.

Crinoid columnals and calyx plates are the most common bioclasts. Crinoid skeletons have a porous structure which becomes filled with clear secondary calcite cement. The characteristic perforations of plates and cellular structure is often preserved. The peripheries of some columnals contain dark cryptocrystalline calcite which filled rotted or dissolved portions as the columnal was rolled on a mud sea floor. The debris is generally abraded and denticulated; attached columnals are uncommon.

Well-preserved echinoid spines are present with arrangements of septa and interseptal tissue forming distinctive and varied patterns.

Fronds and stemlike colonies of bryozoans are common in varying degrees of preservation and fragmentation. Spines, some of which are pyritized, are present on some walls.

Algae are present in layered, encrusting, tubular and cylindrical club-shaped forms. Dark cryptocrystalline calcite with irregular laminae of light crystalline calcite characterize the layered and encrusting forms. These forms may be partly recrystallized. Tubular forms have a core of clear microcrystalline calcite surrounded by dark cryptocrystalline calcite. Cylindrical, club-shaped forms are characterized by clear microcrystalline calcite walls with dark microcrystalline calcite filling radial perforations and center portions.

Brachiopod shells have a fibrous undulating or non-undulating habit; some have, in addition, a thin outer prismatic layer; punctae are uncommon. These shells tend to have a larger size than the other bioclasts, hence are fragmented and extensively abraded.

Gastropod shells are high-spired forms in which the original light brown fibrous shell is generally recrystallized and exterior portions are commonly dissolved. Chambers are filled with cement, allochems and matrix.

The calcite fibres comprising ostracode carapaces are oriented normal to the shell

surface. Carapaces have distinctive hinge and free margin structures.

Calcispheres are small spherical bodies of unknown origin, attributed to the genus Calcisphaera by Williamson (1880). They are characterized by a nucleus of clear microcrystalline calcite surrounded by a dark cryptocrystalline calcite wall of variable structure. Wall structures include radial transections, coronas, laminae and homogeneous layering.

Foraminifera are present as both planispiral and rectilinear types. Planispiral endothyrid types have a dark cryptocrystalline calcite wall and chambers filled with calcite cement or matrix. Occasionally endothyrids form nuclei around which calcite mud is compacted, the microfossil showing various stages of recrystallization. Rectilinear non-endothyrid foraminifera are both septate and non-septate. The walls of these types are composed of light and dark microcrystalline calcite and the chambers are generally filled with matrix. Some bioclasts identified as non-septate foraminifera could possibly be hollow or solid brachiopod spines.

Sponge spicules occur in some chert nodules. Most tend to be "resorbed" and are difficult to separate distinctly from the encompassing silica matrix; only monaxonic types were noted.

Orthochemical Constituents

Orthochemical constituents are mainly calcite mud and sparry calcite cement. Calcite mud is defined as calcite grains less than 3.9 microns in diameter; characteristically it has a turbid brown-grey color. Calcite mud, as used here, is synonymous with lime mud. Folk (1959) considered it to form mainly by chemical or biochemical precipitation in sea water, and only in minor quantities by comminution of allochems. The writers believe that abrasion dust may reach significant proportions occasionally. Calcite cement precipitates in original pore space and as such may be responsible for a complete loss of primary porosity. Cement is distinguished from calcite mud by its clarity and coarser crystal size, which in these rocks ranges from microcrystalline to very coarsely crystalline. Two generations of cement are evident in some cases; an uneven thin layer of prismatic crystals normal to shells and other grain surfaces was observed to be deposited before the main portion of the pores were filled with calcite anhedra.

Other Constituents

Clay minerals, detrital and authigenic quartz, chert and pyrite are the most important non-carbonate constituents. Very light to dark brown-grey clay minerals are the most dominant and persistent terrigenous materials, occurring as discrete laminae or disseminations within matrix. Detrital quartz, mainly of silt size, is a minor terrigenous constituent. Authigenic quartz subhedra and euhedra of silt size replace allochems and matrix, and overgrowths occurring on detrital quartz also produce better defined crystal shapes. Chert composed of microgranular quartz occurs as nodules and disseminations.

Pyrite, in all stages of alteration to limonite and hematite, is an ubiquitous constituent; a finely disseminated and/or framboidal texture is common; nodules and replacement occurrences are rarer. Pyrite also forms nuclei of some dolomite rhombohedra.

Minor non-carbonate constituents include collophane, detrital potash feldspar and plagioclase feldspars, tourmaline, mica, glauconite and carbonaceous organic material, and occur mainly in samples of the Banff Formation.

ROCK TYPES OF THE THORNTON CREEK SECTION

Fourteen rock types are recognized in the Thornton Creek section, the dolostones are of secondary replacement origin and are divided into two types. The distribution of rock types and the interpreted energy index of the depositional site (Plumley *et al.*, 1962) are shown in Figure 3.

Dolostone - Type A

Appearance in thin section: Fine-microcrystalline to fine-crystalline dolomite rhombohedra in alternating layers of varying crystal sizes and a high terrigenous content characterize this rock type. Irregular laminae rich in clay minerals, quartz and dolomite are common. Calcite is mainly calcite mud; when present, bioclasts include crinoids, brachiopods, algae, foraminifera and calcispheres. Chert in a few samples preserves some traces of spicules and crinoids. Pyrite may be locally concentrated or disseminated.

Interpretation: Type A dolostones are characteristic of the Banff, Pekisko and Shunda Formations and occur alternately interbedded with limestones. The paucity of bioclasts, high terrigenous and dolomite contents and relationships with overlying and underlying strata suggest that this rock type is formed in shallow, restricted environments similar to those envisaged by Edie (1958) for certain Mississippian dolostones of southeastern Saskatchewan. Contrarily, a microfacies of similar description in the Mississippian Rundle Group between Jasper and Banff was considered by Walpole and Carozzi (1961) to have formed in the greatest relative depth of water of five microfacies present. The abundance of terrigenous material may be interpreted as, a) representing uplift or proximity of source causing a more rapid influx of detritus, or b) change of conditions in the depositional basin suppressing chemical activity to the extent that terrigenous materials accumulated by default.

Most of the Mississippian rocks of southern Alberta and Saskatchewan represent a broad, often shallow, epicontinental sea (Edie, 1958; Illing, 1959; Thomas and Glaister, 1960). Such a regional setting also appears applicable to the Jasper area. Near the eastern boundary of Jasper Park anhydrite occurs through most of the Shunda Formation in the Jasper No. 1 well at Folding Mountain (Lang, 1947, p. 47) and the Solomon Creek well (Mountjoy, 1962, p. 31). Thus during parts of Shunda time salinities were high. Some limestones formed under open marine conditions have textures almost obliterated by

dolomitization (Plate 3, Fig. 1). Dolomitization fronts in some of these rocks provide evidence that solutions with a high magnesium concentration permeated through them, probably at an early diagenetic stage.

Dolostone - Type B

Appearance in thin section: This is a fine-microcrystalline to fine-crystalline dolostone with a porphyroblastic or patchy texture commonly containing two distinct crystal sizes; dolomite rhombohedra replacing mud are smaller than those replacing bioclasts. Calcite content represents relict brachiopods, bryozoans, crinoids and some traces of mud. Terrigenous material includes disseminated clay minerals and traces of detrital quartz. Chert and pyrite are often present. Porosity developments are confined to this rock type.

Interpretation: Type B dolostones are characteristic of the Turner Valley and Mount Head Formations. This rock type was originally a lithified limestone and the relict structures indicate it probably contained bioclasts in considerable amounts.

Biomicrite

Appearance in thin section: Crinoids, bryozoans, algae, brachiopods and foraminifera are distributed in a calcite mud matrix. There are subordinate amounts of other bioclasts; intraclasts and oolites are not common. Most bioclasts are disarticulate and somewhat abraded. Clay mineral content is variable and detrital quartz is present in a few samples. Pyrite is ubiquitous, both disseminated in the matrix and replacing parts of bioclasts. Most samples tend to have isotropic fabric and poor sorting.

Interpretation: The presence of calcite mud, poor sorting and isotropic texture suggest a poorly agitated environment. Fine sediment accumulation takes place where there is shelter from currents in any depth of water. Some allochems were subjected to bottom traction as indicated by abraded and fragmented shells. It is suggested that some grains are not indigenous to the environment in which they accumulated.

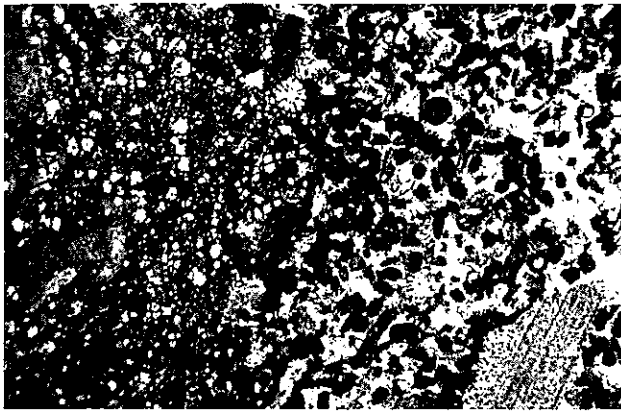
Biosparite

Appearance in thin section: This rock type is predominantly composed of bioclasts cemented with clear calcite. Crinoidal debris predominates with the remainder comprised of bryozoans, algae, echinoids, brachiopods, gastropods and ostracodes; intraclasts and oolites are also common. Clay minerals and detrital quartz are characteristically present in minor amounts and calcite mud may be present interstitially, in cavities or in axial canals of columnals. Dolomite is minor or absent and preferentially replaces matrix and intraclasts distinct from cement. These biosparites show good to fair sorting with isotropic fabric, and usually exhibit only a moderate degree of packing.

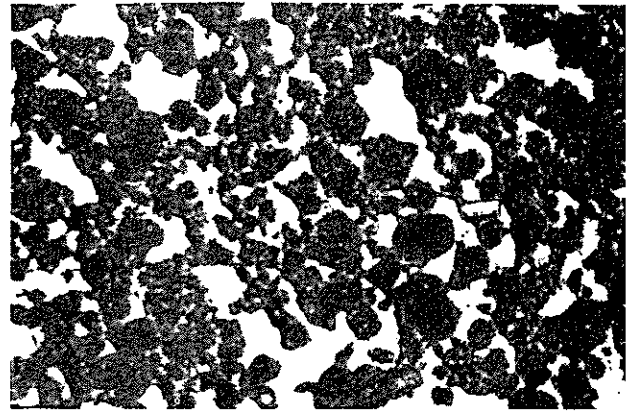
PLATE 3

Photomicrographs of Thin Sections

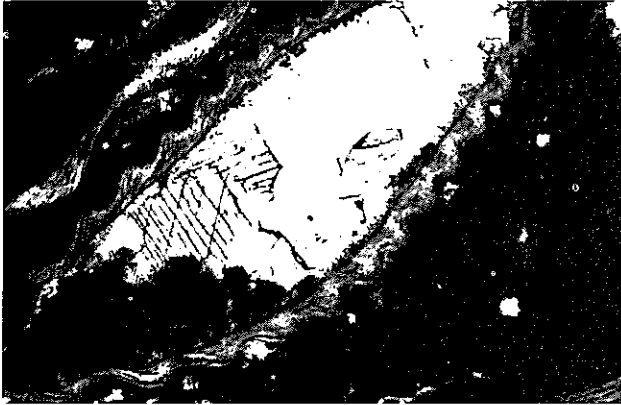
- Figure 1: Intrasparite; TC 18, Pekisko Formation, very fine-grained intrasparite with dolomitization "front" on left obliterating textural features. (x25), plane polarized light.
- Figure 2: Intrasparite; TC 28b, poorly sorted intraclasts cemented with clear calcite. Note merging of grain boundaries. (x25), plane polarized light.
- Figure 3: Biomicrudite; TC 17-22, Pekisko Formation, articulate brachiopod showing geopetal accumulation of sediment in cavity. Matrix of dark calcite mud. (x25), plane polarized light.
- Figure 4: Biosparite; TC 13b, Pekisko Formation, well-sorted bioclasts cemented with clear calcite. Partly rotted grains, gastropod shell in upper left, foraminifer in lower right. (x25), plane polarized light.
- Figure 5: Dolostone; TC 46, Mount Head Formation, type B displaying granoblastic texture. Clay minerals concentrated on microstylolite trace. (x25), plane polarized light.
- Figure 6: Dolostone; TC 12, Banff Formation, type A displaying non-uniformly sized rhombohedra and clay mineral-rich lamina. (x25), plane polarized light.
- Figure 7: Conglomerate; TC 52, Rocky Mountain Formation, colloform structure of silica (white) and phosphatic matrix (dark) with relict spicules and detrital grains. (x25), plane polarized light.
- Figure 8: Sandstone; TC 54, Rocky Mountain Formation, well-sorted, very fine-grained sandstone, silica overgrowth structures. (x170), crossed nicols.



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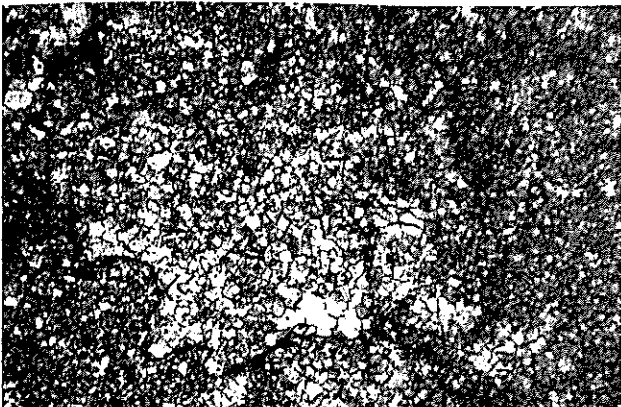
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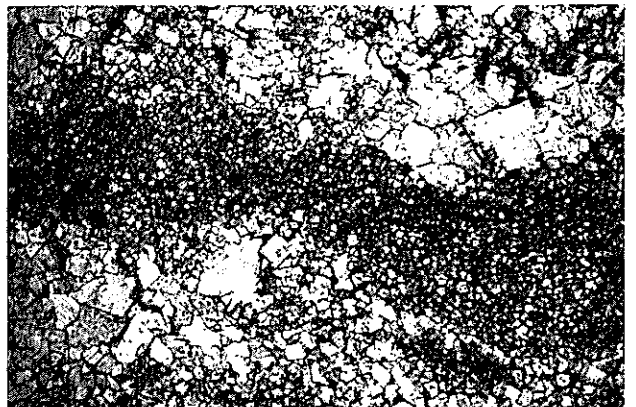
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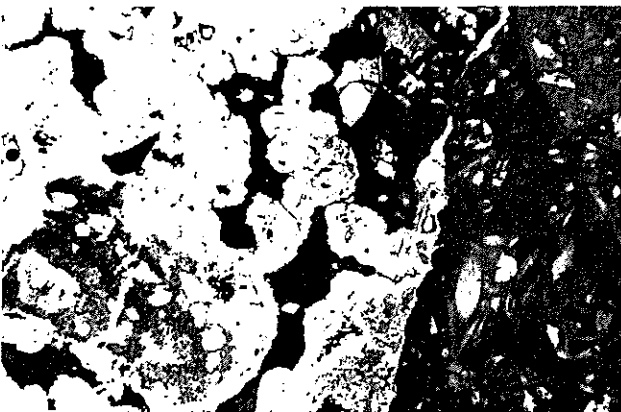
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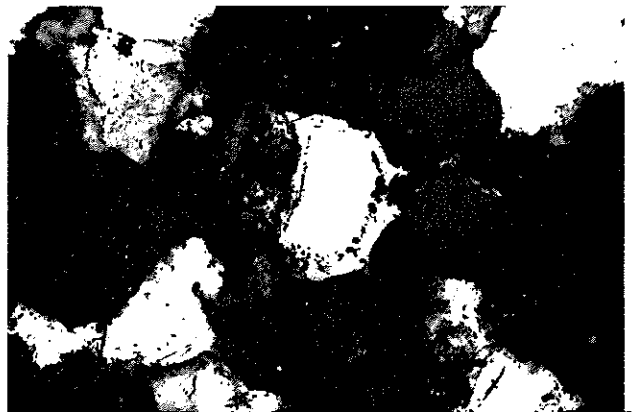
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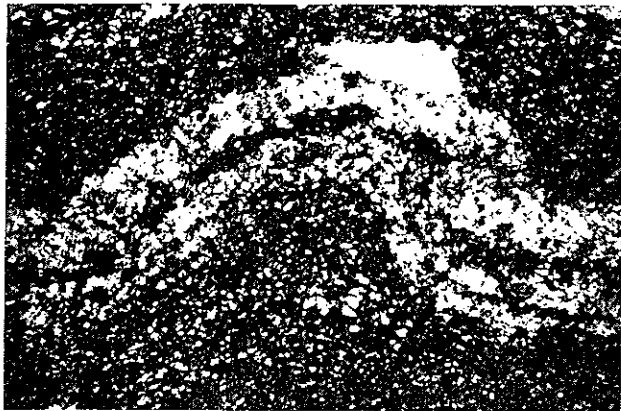


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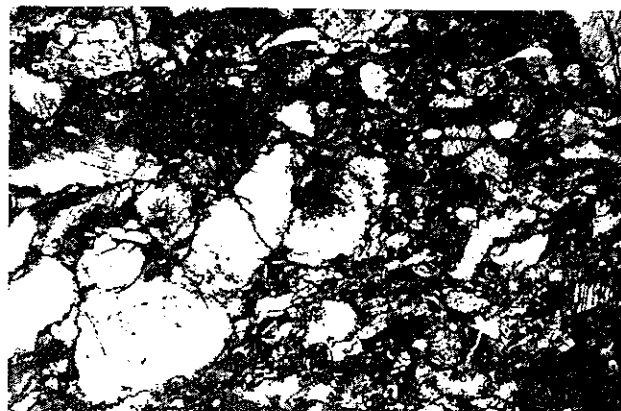
PLATE 4

Photomicrographs of Thin Sections

- Note: all photomicrographs x25, plane polarized light.
- Figure 1: Mudstone; TC 3, Banff Formation, laminae rich in detrital quartz (white) showing fold structure formed penecontemporaneously with deposition.
- Figure 2: Biosiltite; TC 16, Pekisko Formation, poorly sorted crinoid debris in matrix of silt-sized, comminuted fossil debris. Pressure-solution welding of grains.
- Figure 3: Oosparite; TC 11, Banff Formation, oolites cemented by clear sparry calcite, high bioclast content including ostracod carapace filled with cement in lower left. A well-sorted rock.
- Figure 4: Micrite; TC 31, Shunda Formation, calcite mud containing scattered dolomite porphyroblasts.
- Figure 5: Oomicrite; TC 32, Shunda Formation, poorly sorted oolites in mud matrix. Microstylolite traces seen by clay mineral concentrations show pressure solution effects in rock.
- Figure 6: Intramicrite; TC 20B, Shunda Formation, poorly sorted intraclasts in mud matrix. Composite nature of intraclasts shown.
- Figure 7: Biomicrite; TC 17-13, Pekisko Formation, unsorted fossil debris in mud matrix. Algae (dark) encrusting brachiopod shell at left.
- Figure 8: Biomicrite; TC 14, Pekisko Formation, matrix preferentially dolomitized.



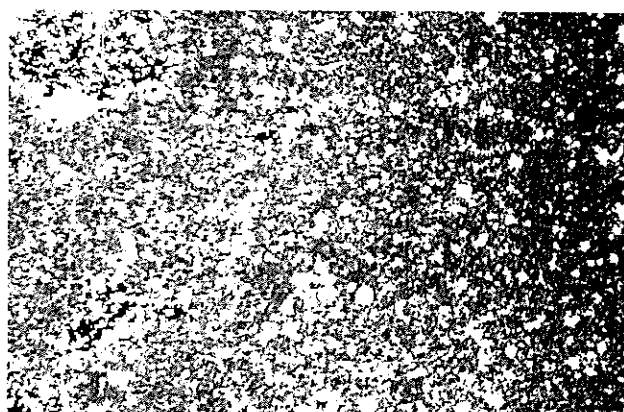
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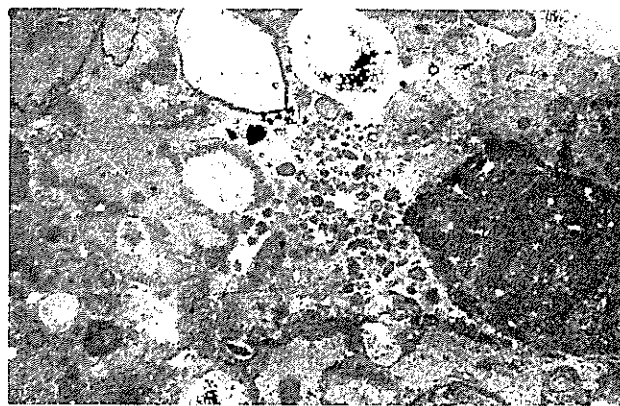
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Interpretation: High agitation is responsible for winnowing out most of the calcite mud, which remains only as fillings in rotted portions of columnals, cavities of gastropods and bryozoans and as minor amounts trapped interstitially among grains. The comparatively low clay mineral content is indicative of a highly agitated current environment in which clay minerals were winnowed out with the calcite mud. The high bioclast content shows that this rock type forms mainly in open marine environments and the abundant crinoids and algae, at least, are indicative of relatively shallow water (Illing, 1954; Johnson, 1961).

Oosparite

Appearance in thin section: Oolites, including superficial oolites, lithified by calcite cement constitute oosparites. The well-sorted oolites are admixed with crinoidal debris, foraminifera, ostracodes, bryozoans, echinoids and intraclasts. Calcite cement is preferentially replaced by dolomite.

Interpretation: The lack of mud matrix and low clay mineral content, together with evidence from recent sediments, indicates that oolites form in highly agitated, shallow waters saturated with calcium carbonate.

Mudstone

Appearance in thin section: Laminae alternately rich in quartz and clay minerals are mixed with a few bioclasts. Quartz, both strained and unstrained, predominates over clay minerals, and dolomite is more commonly associated with clay minerals.

Interpretation: More rapid accumulation of terrigenous materials than calcareous sediments took place. A restricted environment with increased salinity is suggested by the lack of bioclasts.

Biosiltite

Appearance in thin section: Abundant crinoids with a matrix of comminuted bioclast debris and calcite of silt size make up most of this rock. Calcite mud fills crinoid columnal axial canals; otherwise it is replaced by dolomite, which occurs in small quantities. Minor amounts of intraclasts, clay minerals and quartz are present. The sorting is poor, packing is moderate and fabric is isotropic.

Interpretation: The lack of calcite mud suggests an environment in which active winnowing took place. Precipitation of silt-sized calcite and its accumulation with comminuted bioclasts is indicated. Some silt-size calcite grains believed to be of precipitated origin could conceivably be recrystallized comminuted bioclast fragments.

Intrasparite

Appearance in thin section: By definition intrasparite consists of more than 25 per cent intraclasts cemented together with calcite cement. Varying amounts of bioclasts include crinoids, brachiopods, algae, bryozoans, foraminifera, calcispheres and ostracodes. Dolomite rhombohedra are confined to interstitial matrix. Oolites are present in a few samples; terrigenous material is confined within intraclasts. Fair to poor sorting, isotropic fabric and moderate to loose packing are the textural features of intrasparites.

Interpretation: Intrasparites are formed in highly agitated, shallow-water environments which have strong or persistent currents of sufficient strength to winnow calcite mud and produce intrabasinal rock fragments. Winnowing of the calcite mud provided pore space in which sparry calcite cement was precipitated.

Biomicrodite

Appearance in thin section: Biomicrodite consists of bioclast constituents with an average diameter greater than two millimeters in a calcite mud matrix. The rudaceous constituents in this rock type are articulate brachiopods and encrusting algae. Bryozoans, crinoids, echinoids, foraminifera and intraclasts are subordinate and of smaller size. A considerable clay mineral component is present in the calcite mud. The framework is poorly sorted, loosely packed and has isotropic fabric.

Interpretation: This rock is a shallow, moderately quiet water deposit since much interstitial mud remains and algae are present. The fine-pebble size of the brachiopods results from their articulate nature.

Micrite

Appearance in thin section: Allochem constituents make up less than 10 per cent, the bulk of the rock being calcite mud. The bioclasts consist of crinoids, foraminifera, ostracodes, calcispheres, brachiopods and gastropods. Bryozoans and oolites are absent but intraclasts are present. Clay content varies but only a few grains of detrital quartz are generally present. Dolomitization occurs both in patches and disseminations.

Interpretation: Micrites accumulate in weakly or little agitated waters. The calcite mud is probably in part physiochemically precipitated from waters supersaturated with calcium carbonate. Biochemical precipitation is considered to have been less important. Calcite mud produced by submarine attrition of allochems may be significant although absolute amounts are indeterminable. This interpretation approximates recent estimates determined for a portion of the Bahama Banks (Cloud, 1962, p. 104).

Intramicroite

Appearance in thin section: Intraclasts with interstitial calcite mud make up this rock type. Minor amounts of crinoids, calcispheres, brachiopods, gastropods, foraminifera and ostracodes occur. Clay minerals are disseminated. Textural features include poor to good sorting, isotropic fabric and loose packing.

Interpretation: This rock type probably occurs in a transitional interval between areas of predominant calcite mud and predominant intraclasts.

Oomicrite

Appearance in thin section: Oolites, commonly mixed with intraclasts, occur in a calcite mud matrix with some sparry calcite. Clay minerals are present in minor amounts. The texture is poorly sorted and loosely packed with an isotropic fabric.

Interpretation: This lithology is probably transitional between areas containing abundant oolites and predominant calcite mud. The lack of bioclasts may be an indication of above normal salinities.

Conglomerate

Appearance in thin section: Phenoclasts of poorly sorted chert pebbles (containing sponge spicules, microgranular quartz and chalcedony), detrital quartz and sandstone rock fragments occur in a matrix of brown cryptocrystalline phosphatic material.

Interpretation: This rock is a basal conglomerate laid down by the transgressing Permian sea after a considerable depositional hiatus.

Chert

Appearance in thin section: Abundant relict spicules are preserved as nearly colorless microcrystalline to cryptocrystalline quartz. Much of the silica is redistributed into a mosaic of microcrystalline quartz.

Interpretation: This type of chert probably represents a thick accumulation of sponge spicules deposited in a quiet, shallow-water environment.

Sandstone

Appearance in thin section: Well sorted, clear quartz grains are mixed with a few grains of phosphatic material.

Interpretation: A highly agitated environment is responsible for these well-sorted sandstones.

MINERAL COMPOSITION

Percentages of dolomite of total carbonate in 75 samples from the Thornton Creek section were determined by X-ray diffraction techniques comparing the areas under the 104 peaks of calcite and dolomite, following the procedures outlined by Weber and Smith (1960). A standard calcite-dolomite calibration curve was prepared from a series of known mixtures of the Iceland Spar variety of calcite and coarsely crystalline dolomite (Walasko, 1962). The weight per cent dolomite in each sample is plotted on Figure 3. The preponderance of dolomite in the Turner Valley and Mount Head Formations is strikingly evident.

Six selected insoluble clay residues (one each from the Banff and Pekisko Formations and two each from the Shunda and Mount Head Formations) were identified from X-ray diffraction powder patterns. Illite is the only clay mineral present in identifiable quantities in the residues. Extrapolation of d_{020} gives values of d_{060} of less than 1.50 Å indicating that the illite is dioctahedral (MacEwan, 1950). These results are in agreement with Weaver (1958a, 1958b), who stated that illite is generally the dominant clay mineral in limestones and dolostones, and that most of the Palaeozoic illites in limestones are the dioctahedral type. However, any acid soluble chloritic type minerals present may have been destroyed during acidization (Peterson, 1962).

DIAGENETIC ALTERATION IN ADDITION TO DOLOMITIZATION

Silicification

Redistributed silica occurs throughout the Thornton Creek section. Most silica is present as chert nodules but some is present as overgrowths on detrital quartz. Some chert is pore filling, some is distributed in fracture veins and some has silicified bioclasts preserving original structures. Silt-sized authigenic quartz euhedra and subhedra are common in rocks containing calcite mud. Some chert nodules contain rhombohedral-shaped bodies of later chert, showing that carbonate was leached before a second stage of silicification. Trapped rhombohedra are evidence that silicification occurred later than dolomitization in certain rocks, whereas Illing (1959) has shown that silicification (believed to be penecontemporaneous with sedimentation) preceded dolomitization in the Turner Valley Formation at Moose Mountain.

Siliceous sponge spicules, witnessed by relict structures, are the probable source of most of the silica. A mechanism of chertification proposed by Lowenstam (1942) can be applied to these rocks. He suggested that chert nodules may form in the host rock

through lateral movement of siliceous solutions enveloping undissolved spicules. The sandstone nodules in the chert and chertification of the overlying sandstone suggests that part of the silica of the Rocky Mountain Formation was derived from solution of quartz in these sands or some external silica-rich solutions.

Carbonate Cementation

Sparry calcite cement, an important lithifying agent, is precipitated in intergranular pore space and in cavities of fossils. The cement is probably derived from interstitial solutions contained at the time of burial, and from solution of shell fragments after burial. Geopetal accumulation of mechanically deposited grains in pore spaces was followed by two stages of cementation. The earlier stage is a layer of prismatic calcite coating the cavity, the later stage fills the remainder of the internal cavity. This situation is analogous to that described by Sander (1951, p. 171).

Sparry calcite cement of this study is not recrystallized calcite mud because: (1) no relict structures are present, (2) it occurs as structurally continuous overgrowths on crinoid columnals, (3) no rocks containing widely spaced allochem occurrences are cemented by clear calcite, and (4) cement has sharp boundaries with grains and no transsections of allochems by clear calcite takes place; in addition, there are no continuous gradations of crystal sizes from cement into mud.

Solution

Solution denticulates some bioclasts and has dissolved the exterior portions of some gastropod shells. Some porosity is developed by solution of bioclast relicts in the Mount Head Formation. Insoluble constituents such as clay minerals are often concentrated along microstylolitic surfaces which parallel the bedding mainly. The microstylolites are a few millimeters in length, occur in both fine and coarse carbonates, and have relief of the order of a few millimeters only. Numerous examples of pressure-solution welding of framework particles occur.

DEPOSITIONAL HISTORY OF THORNTON CREEK SECTION

A detailed study of one stratigraphic section is insufficient to determine the complete depositional history of an area. However, since the character of this section is reasonably representative of the Carboniferous sequence of the region, such a study can provide a general outline of the sedimentation.

Epicontinental seas during Mississippian time in western Canada allowed the accumulation of relatively shallow-water carbonate rocks. Depositional environments in the Jasper area interpreted from textural, mineralogic, gross faunal and stratigraphic information are considered to be shallow-water shoals, intershoal areas and lagoons.

During latest Banff time in the Jasper area several sea level fluctuations resulted in the alternation of normal marine, very shallow-water limestones and dolostones formed in restricted environments.

Pekisko time was marked by shoal environments in which crinoid life abounded. The depth of water in early Pekisko time was probably very shallow.

The Shunda Formation is characterized by an abundance of calcite mud. An environment with few organisms, but otherwise similar to that present on the interior of the Bahama Banks today, is envisaged. Evaporites, which occur east of Thornton Creek, are indicative of restricted environments for a portion of Shunda time.

The sedimentary record of the Turner Valley Formation is largely obliterated by dolomitization but similar conditions of deposition to those existing during Pekisko time is suggested by relict fossils and dolomite displaying the porphyroblastic texture of biogenic limestones.

The Mount Head Formation is largely dolostone but relict fossils suggest shoal conditions existed during a portion of this time.

After a period of erosion (relief of about five feet occurs along the Mississippian-Permian contact at Thornton Creek), a basal conglomerate was laid down by a transgressing Permian sea. The lowest Permian beds in this area consist of thickly bedded spicular chert suggesting a shallow-water environment. Well-sorted sandstone overlies the chert.

In addition to dolomitization and silicification, carbonate cementation and solution are the most significant diagenetic changes; the rocks are otherwise relatively unaltered. Dolomitization in the Banff, Pekisko and Shunda Formations probably took place at an early diagenetic stage and may be the result of magnesium-rich solutions caused by evaporitic concentration of normal sea water in restricted environments.

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DEVONIAN SECTION ON BEAVER RIDGE

(from Geol. Surv. Canada Bull. 35)

ALEXO FORMATION

Member C

The lowest beds of the Palliser are exposed on the south-west side of "Beaver Ridge", and the uppermost beds of the Alexo form the steep dip-slope of the ridge itself. The ridge may be climbed on this side by any of the numerous gullies.

<u>Unit No.</u>		<u>Thickness in feet</u>
49	Limestone, grey, sandy and silty; thick-bedded; thin rubbly weathering	25
48	Sandstone, brown, strongly calcareous, formed of small rounded quartz grains; thin-bedded; weathers yellowish brown; fucoid markings on bedding planes; at 20 feet from base, a 3-inch grey limestone bed with <u>Camarotoechia</u> and <u>Athyris</u> spp.	23
47	Sandstone, quartzose, calcareous, and limestone, sandy and silty, both yellowish brown to light grey; thin flaggy bedding; bedding planes covered with coarse fucoid markings up to 12 inches long, all aligned approximately north-south	68
	Thickness of member C	116

Member B

46	Limestone, medium grey, fine- to medium-grained; regular medium bedding (18 inches to 2 feet), breaking up into thinner rubbly beds on weathering; richly fossiliferous, mainly small forms: <u>Aulopora</u> sp., <u>Camarotoechia</u> sp., <u>Pugnoides</u> sp., <u>Cyrtospirifer</u> sp., <u>Athyris</u> sp., gastropods, and nautiloids; some larger forms: <u>Schuchertella</u> sp., <u>Camarotoechia banffensis</u> Warren subsp. nov., productellids	34
	The following unit forms a prominent feature along most of the ridge crest.	
45	Sandstone, grey, strongly calcareous, grading upwards into very sandy limestone; thin-bedded; rubbly buff weathering; fucoid markings on bedding planes; a few fossils near top of unit: <u>Aulopora</u> sp., small <u>Cyrtospirifer</u> sp., <u>Athyris</u> sp., and large nautiloids	20

Measured down the scarp slope of the ridge, the following units are all prominent on the hillside.

- | | | |
|----|--|-------|
| 44 | Sandstone, pale brownish grey, very calcareous; thick-bedded; a few nodules of grey sandy limestone; fucoid markings common | 11 |
| 43 | Limestone, grey, very sandy and silty; thin-bedded; laminated silty stringers enclose small limestone nodules; silt content decreases downwards | 7-1/2 |
| 42 | Limestone, grey, silty, fine-grained; thin-bedded (1 inch to 3 inches); weathers brownish yellow; fossiliferous throughout: <u>Aulopora</u> sp., <u>Schuchertella</u> sp., <u>Chonetes</u> sp., <u>Leioproductus</u> sp. and other productellids. <u>Camarotoechia banffensis</u> subsp. nov., <u>Pugnoides</u> sp., <u>Cyrtospirifer</u> cf. <u>portae</u> Merriam, small <u>Athyris</u> sp. (abundant), <u>Leptodesma</u> sp. and other pelecypods, "Bellerophon" sp., cf. <u>Bactrites</u> sp., <u>Camarotoechia</u> spp. are particularly abundant between 25 and 35 feet above the base: the " <u>Camarotoechia zone</u> "

The base of unit 42 forms a prominent feature along the hillside. | 46 |
| 41 | Limestone, similar to unit 42; bedding planes ripple-marked; fossiliferous: <u>Aulopora</u> sp., <u>Schuchertella</u> sp., <u>Pugnoides</u> ? sp., <u>Cyrtospirifer</u> sp., <u>Athyris</u> sp., gastropods, nautiloids, well-preserved carapaces of <u>Echinocaris</u> sp. | 32 |
| 40 | Limestone, dark grey, very fine-grained; rhythmically inter-bedded with yellow calcareous silty stringers; fragmentary fossils: <u>Pugnoides</u> sp., <u>Cyrtospirifer</u> sp., straight nautiloids | 20 |
| 39 | Limestone, grey, rubbly; a single bed; abundantly fossiliferous, mainly <u>Schuchertella</u> sp. with rare <u>Pugnoides</u> sp., and <u>Cyrtospirifer</u> sp.; shells all red-stained | 1-1/2 |
| | Thickness of member B | 172 |

Member A

- | | | |
|----|--|----|
| 38 | Limestone, grey, argillaceous, silty; nodular bedded; inter-bedded with thin, fissile, silty layers (2- to 3-inch alternations); few fossils: <u>Aulopora</u> sp., <u>Cyrtospirifer</u> sp. | 15 |
| 37 | Limestone, similar to unit 38 but more massive; richly fossiliferous especially near middle: <u>Orbiculoidea</u> sp., <u>Nudirostra gibbosa walcotti</u> (Merriam), <u>Pugnoides</u> sp., <u>Cyrtospirifer</u> cf. <u>portae</u> Merriam, <u>Leptodesma</u> sp.; "the <u>Nudirostra zone</u> " | 35 |
| 36 | Limestone, similar to unit 38 but more thinly bedded; scattered fossils: <u>Nudirostra gibbosa walcotti</u> (Merriam), small <u>Pugnoides</u> sp., <u>Cyrtospirifer</u> sp., <u>Athyris</u> sp. | 20 |

35	Limestone, light to dark grey, slightly argillaceous; bedding obscure; curved fracture surface: weathers yellowish brown; sparingly fossiliferous similar to unit 36	48
34	Limestone, dark grey, strongly argillaceous, silty; vaguely thick-bedded; fossiliferous: <u>Lingula</u> sp., <u>Chonetes</u> sp., <u>Nudirostra gibbosa walcotti</u> (Merriam), <u>Cyrtospirifer</u> sp., <u>Leptodesma</u> sp.	40
33	Limestone, similar to unit 34; irregular bedding; fossiliferous: <u>Chonetes</u> sp., <u>Nudirostra</u> sp., small <u>Cyrtospirifer</u> sp., pelecypods, " <u>Conularia</u> " sp.	35
32	Limestone, similar to unit 34; irregular, thin- to medium-bedded, fissile; fossiliferous: abundant " <u>Styliolina</u> ", rare <u>Nudirostra</u> and pelecypods	15
31	Limestone, black to dark grey, argillaceous, slightly silty, very fine-grained; thin-bedded, fissile, becoming thicker bedded upwards; conchoidal fracture; grades down into unit 30; sparingly fossiliferous throughout: " <u>Styliolina</u> " sp., <u>Nudirostra gibbosa walcotti</u> (Merriam)	25
30	Limestone, black to dark grey, strongly argillaceous; very thin shaly bedding, fissile, becoming a little thicker upwards; residue pale brownish grey	80
	Thickness of member A	313
	Total thickness of Alexo formation	601

MOUNT HAWK FORMATION

29	Sandstone, grey, dolomitic, silty, slightly calcareous; thin-bedded, laminated; yellowish brown weathering; <u>Tentaculites</u> and rare conodonts	9
28	Limestone, dark grey, silty and argillaceous; very thin-bedded, fissile; yellow weathering	10-1/2
27	Sandstone, quartzose, dark grey to black, calcareous, argillaceous, fine-grained, laminated, with silty stringers; medium-bedded at base, increasingly thin and fissile upwards; weathers light brownish yellow	7-1/2
26	Sandstone, similar to unit 27; medium-bedded with two prominent bands of pyritic nodules and one thin argillaceous band	3-1/2
25	Sandstone, similar to unit 27; thin-bedded and fissile; at base a 2-inch bed of irregular, nodular, argillaceous and phosphatic limestone pebbles in a sand and siltstone matrix	2-1/2
24	Limestone, dark grey, argillaceous and silty; medium-bedded, alternating with thin, fissile, calcareous and argillaceous siltstones	10

23	Limestone, black to dark grey, argillaceous; medium-bedded at base; becoming increasingly fissile and argillaceous upwards	5-1/2
22	Limestone, similar to unit 23; medium-bedded at base, becoming increasingly fissile upwards	19
21	Limestone, black to dark grey, argillaceous; 3-inch beds alternating with 2 inches of fissile, platy, limestone; becomes increasingly argillaceous in the top 15 feet; rare pelecypods indet., and flattened tapering rod-like bodies (up to 3 inches long)	155
20	Limestone, black, argillaceous, nodular, alternating in bands (2 to 6 inches) with fissile, calcareous shale; grades upwards from lower unit and into higher	30
	Total thickness of Mount Hawk formation	252-1/2

PERDRIX FORMATION

19	Shale, grey to black, calcareous, fissile; grades upwards from unit 18	60
18	Shale, black, pyritic, fissile; mainly non-calcareous, but calcareous bands increase upwards; a few thin beds of nodular argillaceous limestone; " <u>Styliolina</u> ", fairly common in bands	290
	Total thickness of Perdrix formation	350

The remainder of the section was measured in the gully that runs down from the open hillside above and cuts the lower, wooded slopes of 'Beaver Ridge', immediately above the south end of Beaver Lake.

FLUME FORMATION

Upper Member

17	Limestone, black, argillaceous, fetid; thin-bedded with shale partings; richly fossiliferous: <u>Productella</u> sp., <u>Nudirostra athabascensis</u> (Kindle), <u>Ambothyris</u> sp., <u>Eleutherokomma jasperensis</u> (Warren), <u>Athyris</u> sp., <u>Buchiola</u> sp., <u>Leiopteria</u> sp., and other pelecypods, <u>Bactrites</u> sp.	6-1/2
16	Limestone, dark grey, argillaceous, fine- to medium-grained, poorly medium-bedded, rubbly; richly fossiliferous: <u>Nudirostra athabascensis</u> (Kindle), <u>Atrypa</u> sp., <u>Eleutherokomma jasperensis</u> (Warren)	30
15	Limestone, grey, argillaceous, rubbly, fine-grained, transitional from underlying dolomite; abundant <u>Eleutherokomma jasperensis</u> (Warren)	1

	Thickness of upper member	37-1/2
	<u>Lower Member</u>	
14	Dolomite, dark grey to brown, argillaceous, bituminous odour, medium- to coarse-grained; medium- to thick-bedded	24
13	Dolomite, black to dark brown, medium-grained; very thin-bedded and laminated at base, becoming thicker bedded higher up; chert abundant in bands; scattered stromatoporoids throughout and <u>Amphipora</u> band (4 inches) at top	17
12	Dolomite, black, coarse-grained; weathers chocolate-brown; medium-bedded; black chert bands at several horizons	8-1/2
11	Dolomite, light to medium grey, medium- to coarse-grained; medium-bedded; scattered silicified <u>Allanaria</u> cf. <u>allani</u> (Warren) and <u>Athyris</u> sp.	18
10	Dolomite, grey, medium- to coarse-grained; medium-bedded; vuggy; scattered chert nodules, some after stromatoporoids; irregular erosion surface at base and thin (6-inch) silty dolomite bed at top	10
9	Dolomite, black, fetid, coarse-grained; thin-bedded	1-1/2
8	Dolomite, grey and brown, fine- to medium-grained; thick-bedded; sporadic thin silty bands and thin <u>Amphipora</u> horizons; basal bed strongly bituminous; rare stromatoporoids and silicified <u>Athyris</u> sp.	23
7	Dolomite, silty, laminated; thin-bedded	1
6	Dolomite, grey and brown, medium-grained; massive; 18-inch <u>Amphipora</u> bed at top	4-1/2
5	Dolomite, dark grey, medium-grained; medium-bedded; scattered large rounded quartz grains throughout; erosion surface at base	9-1/2
4	Dolomite, dark grey to brown, bituminous odour; thin- to medium-bedded; several 1-inch silty beds	13-1/2
3	Dolomite, black, argillaceous; thin, shaly bedding	1-1/2
2	Dolomite, dark grey, argillaceous, medium-grained; medium-bedded; black chert band in middle of unit; erosion surface with channelling at base; large <u>Eleutherokomma</u> ? sp. in top 10 inches	10
1	Dolomite, dark grey, coarse-grained; massive; scattered large rounded quartz grains; grades downwards into coarse dolomitic quartzose sandstone, with some lenses of pure sandstone at bottom; very variable in thickness, thinning to 4 feet in less than 20 feet along strike, overlies erosion surface, bored and	8

channelled and filled with sand grains; richly fossiliferous with beekitized broken shells: zaphrentid corals, Allanaria cf. allani (Warren), Athyris sp.

Thickness of lower member	150
Total thickness of Flume formation	187-1/2

SUB-DEVONIAN

Ordovician and Underlying Beds of Uncertain Age

9	Dolomite, dark grey, argillaceous and calcareous; some silty bands; conglomeratic, with pebbles of similar rock; worm trails on bedding planes	4-1/2
8	Shale, dark grey, slightly calcareous	1/2
7	Dolomite, grey, argillaceous, fine-grained; medium-bedded; upper part of each bed conglomeratic with flat disk-shaped pebbles of dolomite in a similar matrix. Some thin beds of green, calcareous shale	36
6	Limestone, grey, fine-grained; medium-bedded; inter-bedded with green, calcareous shale	22
5	Limestone and dolomite as above, interbedded with thin beds of shale; trilobite fragments including <u>Bellefontia</u> cf. <u>nonius</u> (Walcott)	85
4	Conglomerate, intraformational, flattened dolomitic pebbles in more calcareous mudstone matrix; unbedded	22
3	Limestone and shale, regularly interbedded in 6-inch to 1-foot alternations	53
2	Shale, green, calcareous; a few thin beds of limestone throughout	141
1	Dolomites and limestones; well-bedded; with sporadic conglomerate beds becoming fewer downwards; much evidence of currents: ripple-marks, fine current bedding, and small-scale slump structures; continuing down to last outcrop in gully	550
	Total exposed thickness of sub-Devonian	914

ROAD LOG — JUNCTION, HIGHWAY NO. 16, TO BEAVER CROSSING
 (reprinted from A.S.P.G. Fifth Ann. Field Conf. Guidebook, 1955, p. 165-166)
 SUMMARY

The route trends southeast along the strike valley of the tributary Maligne River. Colin Range, the westernmost Front Range, is located east of the route; Maligne Mountains, the easternmost Main Range, is located west of the route. Pyramid fault (Castle Mountain fault zone) is located in the forested slopes of Maligne Mountains. A spectacular gorge at mile 5.7, (9.1), cut in Palliser limestone, illustrates clearly the geomorphic process of headward erosion of steep-graded mountain rivers. Outcrops along the route are poor and expose upper Palliser, lower Banff and Rundle strata.

- 0.0 Junction of Highway No. 16 and branch road to Fish Hatchery, Jasper Lodge, Maligne Canyon and Medicine Lake.
- 0.1 Bridge crossing Athabaska River.
- 0.2 North—Branch road to Fish Hatchery.
- 0.9 South—Branch road to Jasper Lodge.
- 1.2 South—Annette Lake.
- 1.6 North—Edith Lake.
- 2.3 North—Branch road, Edith Lake circular drive.
- 3.0 North—Branch road to lower part of Maligne Canyon.
- 3.4 - 4.2 Road outcrop of poor exposures of Banff limestone.
- 4.6 North—Excellent view of Pyramid Mt. on north side of Athabaska River valley. Pyramid Mt., like the Maligne Mountains directly west of our route, is composed of Lower Cambrian and/or Proterozoic quartzites and argillites. These mountains are located directly in the hanging wall of Pyramid fault (Castle Mt. fault zone). They form the easternmost range of Main Ranges sub-province.
- 5.4 West—View of Maligne Canyon. Thin limestones of Banff Formation in upper part of gorge.
- 5.5 Viewpoint—Canyon cut in massive gray limestones of Palliser Formation.
- 5.6 Northeast—Roche Bonhomme, composed of Carboniferous and Devonian strata.

- 5.7 Bridge crossing Maligne River. Channel on south is on bedding planes of Palliser limestone. From this point, Maligne River descends almost 500 feet in less than one mile. The canyon, which in places is 200 feet deep with adjacent walls only a few feet apart, may be viewed from the fenced-off area directly northeast of bridge. The canyon is cut along joint planes in Palliser Formation. Partly obliterated pot holes within the walls of the canyon indicate plainly the process by which the canyon has been carved. The canyon is the result of headward erosion of the waterfall which spilled over wall of Palliser limestone cliffs on Athabaska River.
- 5.9 East—Road outcrop of upper Palliser Formation.
- 6.5 Roadside exposures of boulder till. Maligne valley has been deepened and widened to U-shaped cross-section by a large valley glacier.
- 7.5 - 8.4 Road outcrop of Palliser limestone.
- 8.6 Bridge crossing Two Valley Creek. Gorge cut in Palliser limestones.
- 9.1 South—Excelsior Mt. (9,100 feet).
- 11.5 North—Basal Banff shales exposed in road materials pit.
- 12.0 North—Anticline of Palliser limestone in Colin Range. This range, westernmost Front Range at this latitude, occurs in foot wall of Pyramid fault.
- 14.5 South—Landslide talus, Maligne River flows underground for about 1/2 mile.
- 14.7 South—Outcrops of Rundle Group (Pekisko) limestones in dry river bed.
- 15.0 Northwest end of Medicine Lake.
- 16.7 - 17.1 Road outcrops of Palliser limestone.
- 17.3 - 19.0 Road outcrops of Palliser limestone.
- 19.2 Beaver Crossing.

N.B. No road log could be constructed for the section from Beaver Crossing to Maligne Lake, as the road is under construction and the bus route changes from day to day. Bedrock outcrops are relatively few, however, and consist of Palliser (?) limestones, Rocky Mountain Formation cherty beds and reddish-brown Triassic siltstones. The succession rises from Beaver Crossing to Maligne Lake.



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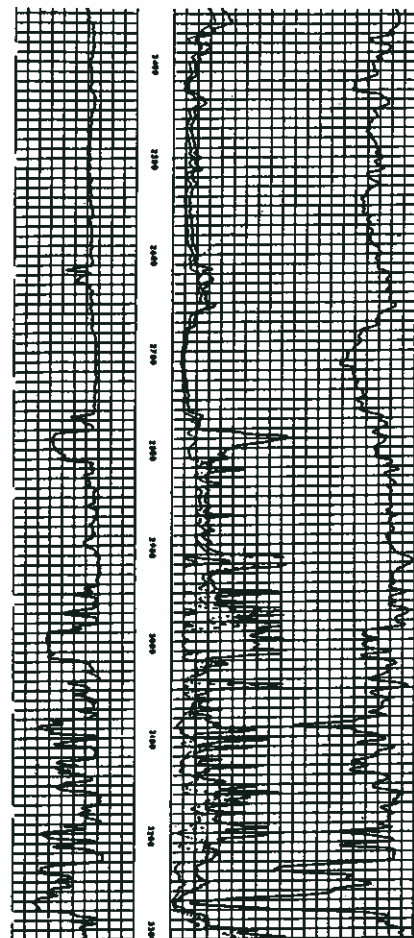
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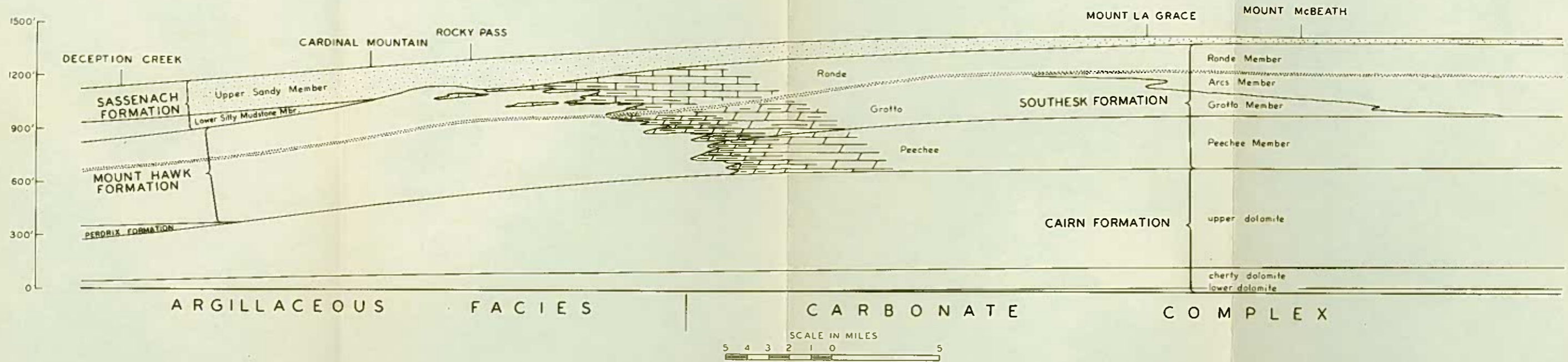
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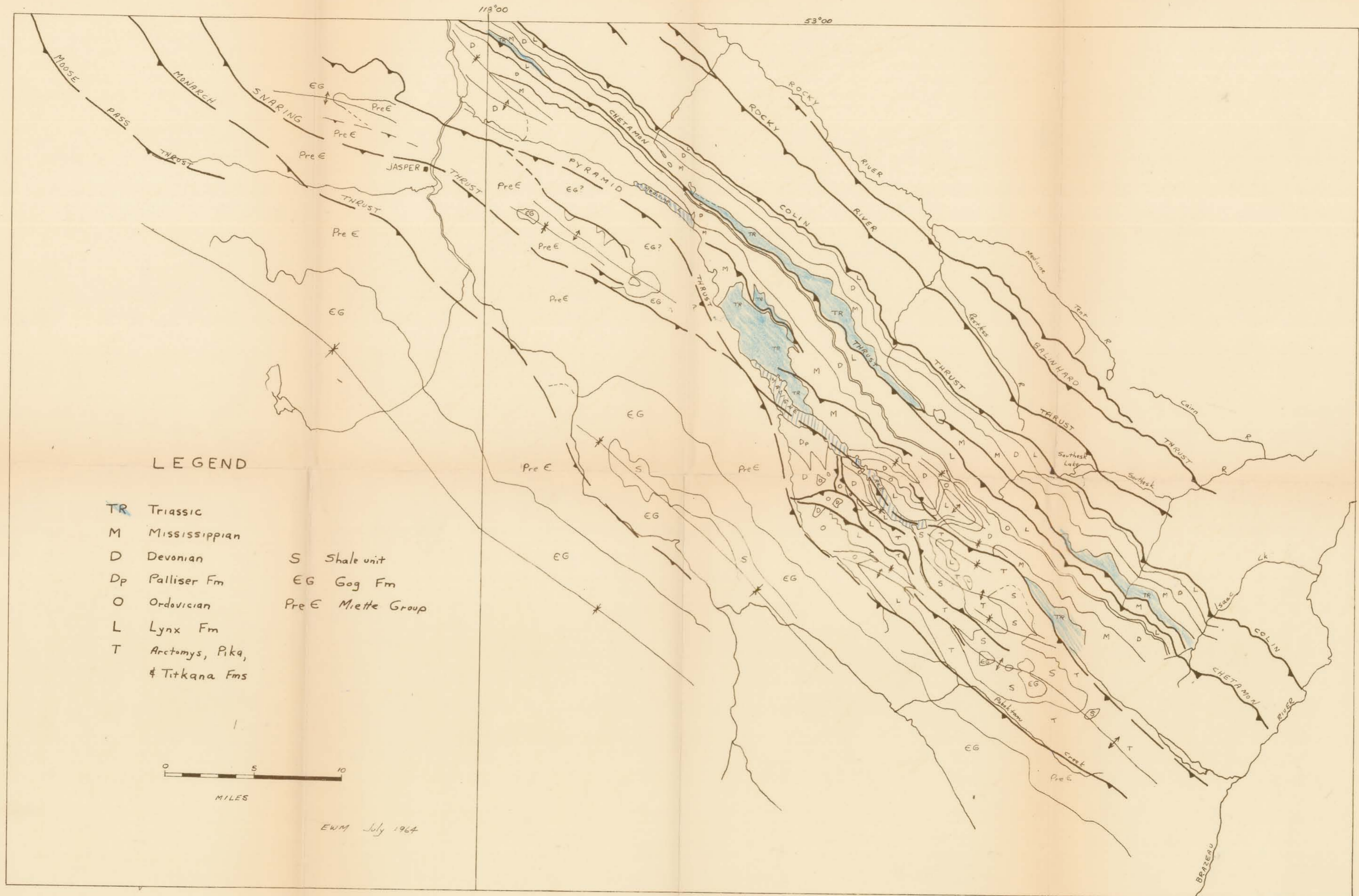
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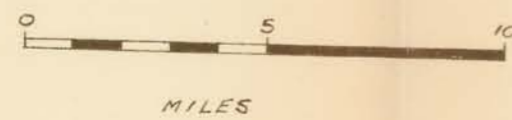
FIGURE 2
 THE SOUTHESK CAIRN CARBONATE COMPLEX
 Stratigraphic correlation between
 DECEPTION CREEK AND MOUNT LA GRACE





LEGEND

- | | | | |
|----|----------------------------------|-------|--------------|
| TR | Triassic | S | Shale unit |
| M | Mississippian | EG | Gog Fm |
| D | Devonian | Pre E | Miette Group |
| Dp | Palliser Fm | | |
| O | Ordovician | | |
| L | Lynx Fm | | |
| T | Arctomys, Pika,
& Titkana Fms | | |



EWM July 1964

FIGURE 2. GENERAL GEOLOGY; ROCKY MOUNTAINS OF JASPER-MALIGNE LAKE AREA

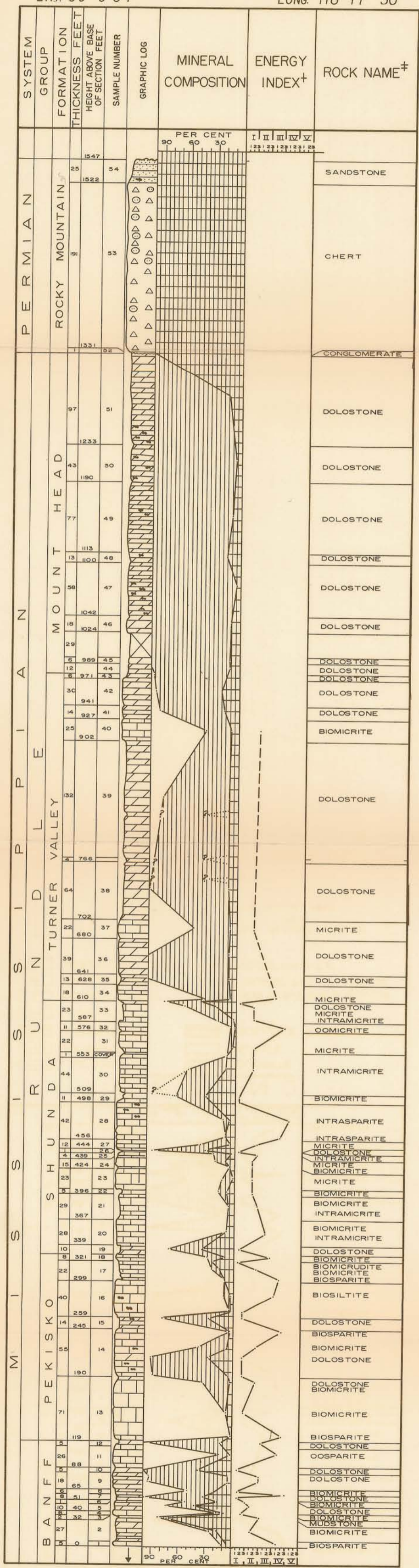
FIGURE 3

STRATIGRAPHIC COLUMNAR SECTION

THORNTON CREEK SECTION

LAT. 59° 9' 34"

LONG. 118° 17' 30"



LEGEND

- [Horizontal lines] LIMESTONE
- [Diagonal lines /] DOLOSTONE
- [Horizontal lines -] MUDSTONE
- [Cross-hatch] COVERED
- [Triangle] BEDDED CHERT
- [Circle with dot] NODULE CHERT
- [Circle with dot] SANDSTONE LENS
- [Vertical lines] DOLOMITE
- [White box] CALCITE
- [Grid] INSOLUBLE RESIDUE
- [Down arrow] SECTION CONTINUES BELOW
- [Dashed line with question mark] NO QUANTITATIVE VALUE
- [Wavy line] UNCONFORMITY

0
25
50
VERTICAL SCALE
IN FEET

+ AFTER PLUMLEY, et al
1962

* AFTER FOLK, 1959

GEOLOGICAL MAP OF MEDICINE AND MALIGNE LAKES

LEGEND

<p>sh Jurassic</p> <p>si Triassic</p> <p>l M Mississippian and Pennsylvanian-Permian</p> <p>l / / / / / Devonian: Palliser Formation</p> <p>l \ \ \ \ \ Devonian: Fairholme Group</p> <p>l O_s Ordovician: Sarbach Formation</p>	<p>l O_c Ordovician: Chushina Formation</p> <p>l ε_L Cambrian: Lynx Formation</p> <p>l o o o Cambrian: Arctomys and Pika Formations</p> <p>l ε_T Cambrian: Titkana Formation</p> <p>sh ε_s Cambrian: shale unit</p>	<p>Fault..... ———</p> <p>Geological boundary definite, uncertain. ———</p> <p>Synclinal axis..... ———</p> <p>Anticlinal axis..... ———</p>
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Sources of Information:
 A.S.P.G. 1955 Guidebook;
 E.W. Mountjoy, 1961 and unpublished;
 field checks and unpublished data



CORRECTION
 SAMSON PEAK IS PALLISER

