PETROGRAPHY AND STRATIGRAPHY OF THE LATE PALEOZOIC ROCKS IN THE WILDHAY RIVER - ROCK LAKE AREA, ALBERTA

by

Robin Humphrey Dawson

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ABSTRACT

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Robin H. Dawson

(M.Sc. thesis, 1966, The University of British Columbia)
(156 pages, 37 plates, 12 figures and 5 tables)

This paper describes the Mississippian. Exshaw, Banff and Rundle units, a remnant of ? Pennsylvanian strata and cherty sandstones of the Permian Ishbel Group; paleontological details include information on the megafossils, foraminifers and algae.

The Exshaw Formation includes a sanidine bearing tuffaceous sandstone. The Banff was subdivided into four rock units - Basal Shale, Cherty Unit, Crinoidal Unit and Upper Unit. The Rundle Group was divided into the Pekisko, Shunda, Turner Valley and Mount Head Formations. The term Jasper Lake Formation is applied to a sequence of crinoidal biosparites and dolomites at the South Berland River section which are bank-marginal lateral equivalents of eastern Shunda micrites.

The Mississippian rocks of the three stratigraphic sections upon which this study is based are assigned to eight main petrographic facies and six petrographic subfacies.

Facies A - calcisiltite: argillaceous crinoidal biomicrite and associated calcareous shales

Facies B - an interbedded sequence of facies A and B

Facies C - calcarenite: argillaceous crinoidal biomicrite

Facies D - calcarenites: crinoidal biosparite

Subfacies Da - calcarenite: 'mature' crinoidal intrasparite

Subfacies Db - calcarenite: intraclast bearing crinoidal biosparite

Facies E - oolitic and/or grapestone bearing calcarenites

Subfacies Ea - fossiliferous intraclast bearing oosparite

Subfacies Eb - intrasparites and sparry intramicrites; four lithotypes are recognized

(1) oolitic micritic crinoidal intrasparite

(2) grapestone bearing intrasparite

(3) oolite bearing partially merged intrasparite

(4) grapestone and oolite bearing, sparry intramicrite

Facies F - pure limestone micrites

Subfacies Fa - crinoidal micrite

Subfacies Fb - micrites, pelsparites, pelmicrites and dismicrites

Facies G - unfossiliferous micrograined dolomite, commonly with microbedding

Facies H - dolomite breccias

The progression through the facies and subfacies from A to H reflects a change in depositional environment from that of normal marine deep quiet waters to lagoonal and evaporitic conditions; modern sedimentation of the Bahama Banks is used as a partial model.

The facies distribution pattern for the Rundle carbonates of the

area shows a tendency toward lagoonal facies in the east (Mumm Creek section), bank-marginal facies in the west (South Berland River section) and intermediate facies at the Eagles Nest Pass section.

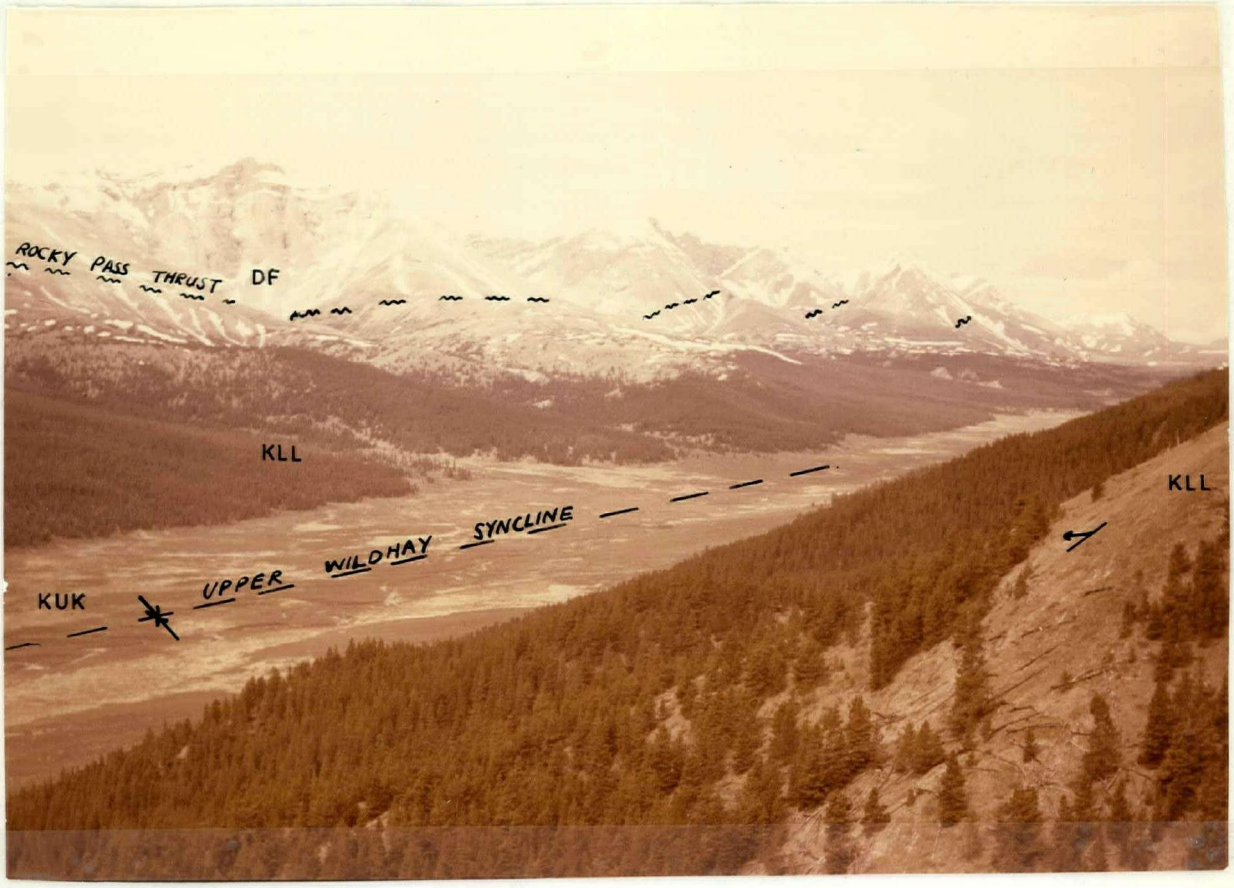

PLATE 1

Upper Wildhay River Valley and Persimmon Range

View looking west-northwest from the hills north of Eagles Nest Pass. The approximate traces of the Rocky Pass Thrust and the axis of the Upper Wildhay Syncline are shown. The rocks in the hanging wall of the thrust consist of Upper Devonian Fairholme Group reef carbonates (DF); those in the hanging wall consist of Jurassic and Lower Cretaceous sandstones. The valley floor is underlain by Upper Cretaceous Kaskapau shales (KUK) in the core of the syncline. The grassy slope in the foreground is underlain by sandstones of the Lower Cretaceous Luscar Formation (KLL) forming part of the northeast limb of the syncline.

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CHAPTER I

INTRODUCTION

General statement. The main purpose of this thesis is to describe in detail the Mississippian rocks of the Rocky Mountain Front Ranges and Western Foothills in the Wildhay River - Rock Lake area of Alberta and to correlate these rocks with stratigraphic units and major cycles of sedimentation which have been described in areas to the south. The Mississippian is capped by younger Paleozoic strata in the western part of the area and a brief discussion of these Permian and, possibly, Pennsylvanian rocks is included.

Location. The Wildhay River - Rock Lake area (Figures 1 and 2) is located in the Rocky Mountains and Foothills, 190 miles due west of Edmonton and about 20 miles east of the British Columbia - Alberta border; it straddles the northern border of Jasper National Park.

The total area is about 400 square miles and it includes all or most of the following townships:

Township 51 in Ranges 2-4, west of the sixth meridian, and
Townships 52 and 53 in Ranges 2-5, west of the sixth meridian.

The area is covered by portions of the following National Topographic Series maps (1:50,000) - Rock Lake, Moberly Creek, Blue Creek and Adams Lookout. The big bend of the Snake Indian River marks the position of the southern border of the area.

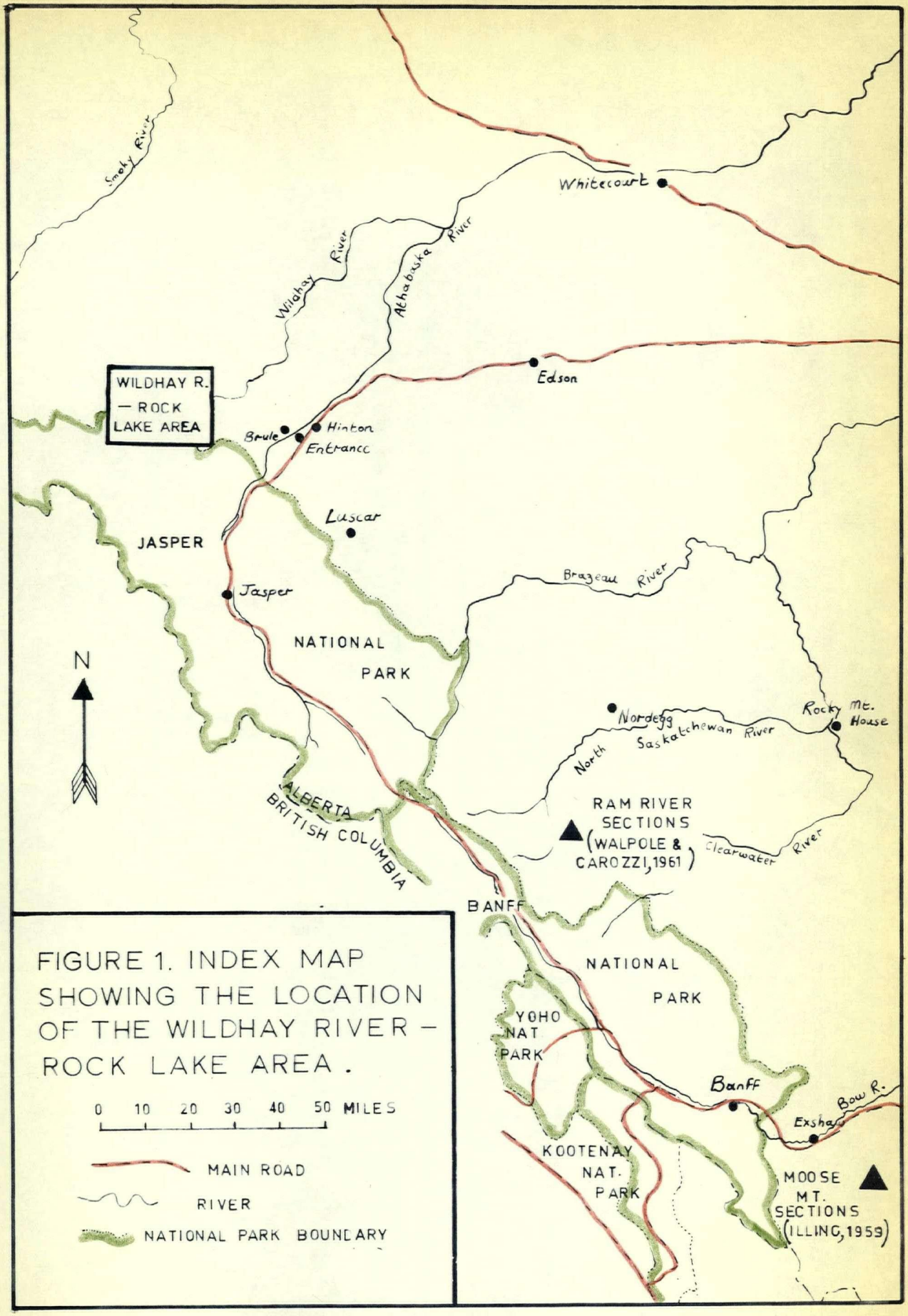


FIGURE 1. INDEX MAP SHOWING THE LOCATION OF THE WILDHAY RIVER – ROCK LAKE AREA.

Accessibility. A gravel motor road from Rock Lake connects with the Edmonton - Jasper highway at a point 4 miles west of Hinton, the distance from Rock Lake to the main highway being 40 miles. A network of good pack-horse trails, maintained by the Alberta Forest Service, extends across the area and connects with similar trails maintained by the National Parks Service in Jasper National Park.

Previous Stratigraphical Studies in the Area. Three late Paleozoic stratigraphic sections have been measured in the area by the Geological Survey of Canada: one at Eagles Nest Pass (Mountjoy, 1962, Table I) and two by Irish (1947) at the location shown in Figure 2. McGugan et al (1964) and McGugan and Rapson (1961b) and (1963a) described the Permo-Carboniferous rocks exposed in the southwestern parts of the area as part of their extensive and continuing studies of these rocks in the Rocky Mountains.

Field Work. During the summer of 1957 the writer geologically mapped part of the area for Pan American Petroleum Corporation and carried out some detailed stratigraphic work in the field. This stratigraphic work included the measurement, sampling and description of the three, well exposed, Late Paleozoic surface sections used in this thesis embracing the entire sequences of Carboniferous and Permian strata present at each location (Figure 2). The two western sections South Berland River (Plate 3 A-B) and Eagles Nest Pass (Plate 4) are in the Rocky Pass Thrust Sheet while that at Mumm Creek (Plate 5) is in the Hoff Thrust Sheet (Figure 6).

Thickness measurements were usually carried out directly using a five-foot pogo stick. At suitable times a method employing a hundred-foot tape and two Brunton compasses was used in which case footages were adjusted

later. Rock samples were generally taken at five foot intervals and at every noticeable change in lithology, but sampling points were more widely spaced where the rocks had a uniform appearance over a considerable thickness of the section.

Fossil collections were made wherever good representative specimens could be obtained.

Laboratory Work.

1. Study of the hand specimens in the laboratory. Over seven hundred hand specimens were collected in the field from the 4,000 feet of Upper Paleozoic strata dealt with in this report. The step by step routine described below was found to be the most efficient method of obtaining the maximum amount of pertinent information available from the hand specimens.

a. Flat surfaces were ground or cut on over half of the total number of field samples.

b. Each specimen was etched by bathing in dilute hydrochloric acid for about a minute. Porous samples were studied, prior to etching, to determine the amount and type of the natural porosity.

c. Each dry etched sample was examined under a binocular microscope to determine the content and distribution of dolomite, clay, silt, pyrite and authigenic silica.

d. Each sample was liberally painted with oil and examined under a binocular microscope. Under oil the textural features and composition of the rock usually showed up quite clearly.

e. Chips of a few representative specimens were dissolved in acid and the residues were examined.

The information obtained during the above steps was recorded in note form.

2. Thin Sections. A polarizing microscope was used during the examination of the two hundred and sixty-five thin sections made from carefully selected hand specimens. (The Rundle Group was examined, using this method, in far greater detail than the Banff Formation.)

Over 110 photomicrographs were taken during and after the routine examination of the thin sections; the main purpose being to record photographically any especially interesting and/or typical textures and grains so that they could later be edited for inclusion in the thesis. A by-product of this process was the formation of rough pictorial logs of the three sections which were most useful for reference.

Logs of Sections. The pertinent information furnished by the laboratory and field studies was interpreted and is presented diagrammatically in Figures 3, 4 and 5. The key to the symbols used in these figures, together with an explanation of the system, is grouped in Table 2.

Acknowledgments. The writer is indebted to the Pan American Petroleum Corporation for providing the opportunity for the study of the Upper Paleozoic sections in the Wildhay River - Rock Lake area, and for permission to use the results of this study in this thesis.

Dr. W. R. Danner, of the Department of Geology, University of British Columbia, as thesis advisor, gave guidance and valuable criticism during the preparation of this thesis.

Dr. J. W. Murray, of the Department of Geology, University of British Columbia, offered encouragement and guidance during discussions and read a preliminary draft of the thesis.

The writer wishes to express his appreciation to Dr. Wayne Bamber of

the Geological Survey of Canada for identifying the megafossils, to Dr. Robert Green of the Research Council of Alberta for identifying the foraminifers, and to Professor Emeritus J. Harlan Johnson for identifying the algal material found in the thin sections.

Thanks are due to Triad Oil Company for furnishing information of the Wildhay well and to Canadian Stratigraphic Service Limited for a copy of their log of the Triad well. Texaco Exploration Company permitted the writer use of their laboratory facilities and Brad Geisler, of that Company, helped in taking photomicrographs. K. Bottoms and L. Howes rendered stalwart assistance in the field. Messrs. L. Bello and J. Kostynuck, outfitters of Nordegg and Rocky Mountain House, Alberta, rendered faultless service in the field with constant good humour.

Thanks are also due to the writer's sister, Pepita, for typing services and to technicians J. A. Donnan and E. Montgomery of the Department of Geology, University of British Columbia, for preparation of some of the thin sections.

CHAPTER II

GENERAL GEOLOGY OF THE WILDHAY RIVER - ROCK LAKE AREA

This chapter is only intended as a brief and general discussion of the stratigraphy and structure of the area. The Geological Survey of Canada has carried out a large amount of work in the region and the entire Wildhay River - Rock Lake area is now covered by published maps. The south half of the area (Mountjoy, 1962) has been mapped on a scale of 1" = 2 miles, while the north half has been mapped (Irish, 1947, 1949 and 1955), Lang (1949) and (Eccles, 1957) on a scale of 1" = 1 mile.

Stratigraphy

The rock units, which crop out in the area, are shown in Table I together with notes concerning lithology and thickness. The local distribution of these units is dealt with later in this chapter during the discussion of the various structural divisions of the area.

The oldest exposed rocks in the area belong to the marine Upper Devonian Fairholme Group, present both as an on-reef carbonate sequence (Cairn and Southesk Formations) and as a three unit, off-reef sequence consisting of the Flume carbonates at the base, Perdrix shales in the middle and Mount Hawk carbonates at the top. The Fairholme Group is in places overlain by the Sassenach Formation, a somewhat recessive unit bearing terrigenous clastics but in much of the area this unit is either poorly developed or absent so that it becomes difficult to recognize a division between the Upper Fairholme carbonates and those of the overlying late Devonian Palliser Formation, a thick sequence of fairly pure marine limestones which directly underlie Mississippian strata in the area. The

Mississippian rocks are assigned to the Exshaw Formation, the Banff Formation and the Rundle Group. In parts of the area Pennsylvanian rocks of the Spray Lakes Group and Permian rocks of the Ishbel Group cap the Paleozoic section. Details of the Carboniferous and Permian rocks of the area are given in Chapter IV.

The Triassic is divided into two marine Formations, a lower predominantly siltstone unit (Sulphur Mountain Formation), and an upper unit (Whitehorse Formation) made up of carbonates, sandstones, breccias and gypsum which is disconformally overlain by the Jurassic Fernie Formation.

The Jurassic is divided between a marine shale unit, the Fernie Formation at the base and a marine sandstone unit, the Lower Nikanassin at the top. The upper part of the Nikanassin consists of sandstones, shales and coaly beds and is thought to represent Lower Cretaceous continental to brackish water deposition. The Nikanassin is capped by the resistant Cadomin conglomerates, Lower Cretaceous, which form a most useful marker horizon in this part of the section.

The Lower Cretaceous Luscar Formation, which overlies the Cadomin conglomerate, consists of a series of sandstone and siltstone beds interbedded with minor proportions of shale, conglomerate and coal.

The Shaftesbury Formation consisting of several hundred feet of dark grey shale spans the Early Cretaceous - Late Cretaceous border and is overlain by the Upper Cretaceous Dunvegan Formation. The Dunvegan is represented by a thin sandstone - shale, mainly marine, sequence that separates the dark grey shales of the underlying Shaftesbury from the thick sequence of similar shales of the Kaskapau Formation which overlies the Dunvegan Formation.

The Bighorn Formation consisting of resistant marine sandstones with some marine shale separates the underlying soft Kaskapau shales from the overlying Wapiabi Formation. The Wapiabi is mainly composed of dark grey marine shales. Interbedded sandstones and shales at the top of the Wapiabi form a transition zone between the marine Wapiabi and the continental beds of the Upper Cretaceous Brazeau Formation, the youngest rock unit in the area.

Disconformities. Several notable disconformities are present in the stratigraphic succession preserved in the Wildhay River - Rock Lake area (Table 1). Angular bedding discordances associated with the disconformities are not observable in the field, but regional studies show that such discordances are present between the rock units involved so that in fact these features are angular unconformities with slight angular discordances.

Devonian Facies Changes. A major facies change from reef carbonates in the northwest to an off-reef argillaceous facies in the southeast is present within the Upper Devonian between Eagles Nest Pass and the headwaters of the South Berland River (Figure 2). This facies change is interpreted to be an easterly facing reef front which before faulting was continuous with the similarly facing edge of the Ancient Wall carbonate complex (Mountjoy, 1962, Fig. 4). The latter edge is now located twenty-three miles to the southeast from Eagles Nest Pass. The northwest edge of the Ancient Wall carbonate complex is plainly visible near Glacier Pass (Mountjoy, 1962) four miles southwest from the north end of the Starlight Range. This westerly facing edge of the carbonate complex is not known to be exposed in the Persimmon Range, and probably passes west of Persimmon Creek in the subsurface.

TABLE I

TABLE OF FORMATIONS

Period	Rock Unit		Lithology	Thickness in Feet
Late Cretaceous	Brazeau Fm.		Sandstone and conglomerate with some siltstone, shales and thin coal seams	4,800
	Wapiabi Fm.		Shale and some sandstone	1,600
	Bighorn Fm.		Sandstone and shale	240
	Kaskapau Fm.		Shale	1500-1800
	Dunvegan Fm.		Sandstone and shale	100
Early Cretaceous	Shaftesbury Fm.		Shale	400
	Luscar Fm.		Sandstone, siltstone and coal seams	2,000
	Cadomin Fm.		Conglomerates	30-100
	Nikanassin Fm.	Upper Unit	Sandstone, shale and coaly beds	200
		Lower Unit	Sandstone	800
Jurassic	Fernie Fm.		Shale	900
		Disconformity		
Triassic	Whitehorse Fm.		Carbonates, sandstone, breccia and gypsum	130-800
		Disconformity		
	Sulphur Mt. Fm.		Siltstone	935
		Disconformity		

TABLE I (cont.)

Period	Rock Unit		Lithology	Thickness in Feet
Permian	Ishbel Group	Mowitch Formation	Sandstone	0-100
		Ranger Canyon Formation	Chert with conglomerate at base	0-20
			Disconformity	
Penn-sylvanian	Spray Lks. Gp.		Dolomite, limestone, breccia and conglomerate	0-30
		Possible Disconformity		
Mississippian	Rundle Group	Mt. Head Fm.	Dolomite (biosparites and dolomicrites)	230-440
		Turner Valley Formation	Dolomites with limestone and traces of tuffaceous siltstone in lower portion of Formation	260-305
		Shunda Fm.	Limestone (micrite)	320-45
		Jasper Lake Fm.	Dolomites and limestones	0-380
		Pekisko Fm.	Limestone (biosparite)	24-112
	Banff Formation	Upper Unit	Argillaceous limestone	174-198
		Crinoidal Unit	Argillaceous biomicrite limestone	40-62
		Lower Unit	Argillaceous limestone and shale	250-290
		Basal Shale	Calcareous shale and minor limestone	5-64
		Exshaw Fm.	Shale, siltstone and tuffaceous sandstone	0-8
	Possible slight disconformity			

TABLE I (cont.)

Period	Rock Unit	Lithology	Thickness in Feet
Upper Devonian	Palliser Fm.	Limestone	800
	Possible disconformity		
	Sassench Fm.	Calcareous shales, mudstones and argillaceous limestones	0-50
	Fairholme Group: Mount Hawk Fm. (Off-reef limestones)	Southesk Fm. (Reef Carbonates)	1,500
		Cairn Fm. (Reef carbonates)	
	Perdrix Fm. (Off-reef shales)		
	Flume Fm. (Carbonates)		
	Sub-Devonian disconformity		

Changes in the Mesozoic. The Wildhay River - Rock Lake area is located in or near a portion of the mountains where stratigraphic changes first became evident, which tend to make the Mesozoic succession more like that found to the north (Mathews, 1946; Stott, 1963) than the typical central Alberta succession. The Nikanassin Formation thickens rapidly northwest of the area to 4,000 feet five miles north of the Smoky River and attains a thickness of 6,400 feet twenty-five miles further to the northwest at the Kakwa River (Zeigler and Pocock, 1960). The latter thickness is more akin to that recorded by Mathews in the Carbon River area.

Structure

General. The Wildhay River - Rock Lake area contains portions of the Eastern Foothills, Western Foothills and Eastern Front Range belts of the Rocky Mountains (Figure 6).

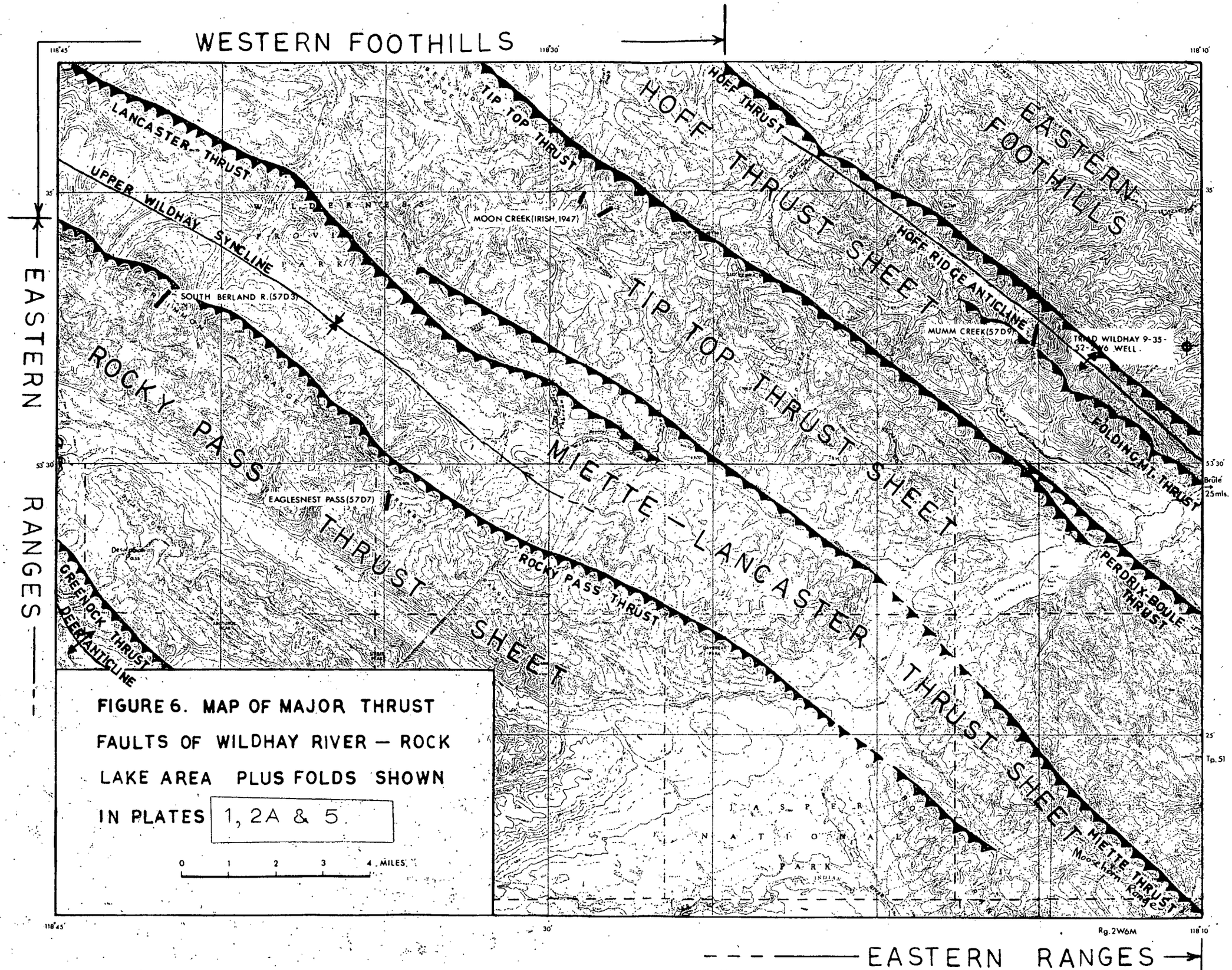


FIGURE 6. MAP OF MAJOR THRUST FAULTS OF WILDHAY RIVER — ROCK LAKE AREA PLUS FOLDS SHOWN IN PLATES 1, 2A & 5

PLATE 2

A **Deer Anticline**

View looking to the west from Desolation Pass. Mountjoy (1962) maps the Greenock Thrust trace passing through the Fernie shales in this area.

CMR - Rundle Group
ꝗW - Whitehorse Formation
JF - Fernie Shales
ꝗS - Sulphur Mountain Formation

B **Banff Formation at Daybreak Peak**

View looking to the south down the Snake Indian River Valley, the upper portion of the Banff is seen here folded into an anticline.

CMBc - Banff Crinoidal Unit
CMB - Top of Banff Formation

Age - Kinderhookian


CMR
TS
TW
JF


CMBc
CMB

PLATE 3

A Sulphur Mountain Formation (Triassic) at the South Berland River Section

This view shows the typical appearance of the Formation which mainly consists of brown weathering siltstones.

B South Berland River Section

View looking southeast from alpine meadows at the headwaters of Persimmon Creek.

DP - Top of Palliser Formation
CMBc - Top of Banff Crinoidal Unit
CMB - Top of Banff Formation
XX - Approximate base Turner Valley Fm.
CMR - Top Rundle Group
PR - Rocky Mountain Group
ŦS - Sulphur Mountain Formation


DP
CMBc
CMB
XX
CMR
TS
PR

PLATE 4

A Persimmon Range

View looking to the west along strike from the Eagles Nest Pass section.

CMBc - Top of Banff Crinoidal Unit
CMB - Top of Banff Formation
CMR - Top of Rundle Group (Rocky Mt. Group covered)
TR S - Sulphur Mountain Formation

B Eagles Nest Pass Section

View looking to the northwest.

DP - Palliser Formation
CMB - Top Banff Formation
CMBc - Top Banff Crinoidal Unit

TPS
CMR
CMB
CMBc

DP
CMBc

PLATE 5

Hoff Ridge Anticline

View looking to the north from the Mumm Creek Section showing the Mississippian succession exposed in the eastern limb of the Hoff Ridge Anticline. All but the lower twenty feet of the massive light grey weathering cliff belong to subfacies Fb.

DP - Palliser Formation
CMB - Top of Banff Formation
X - Approx. base of member 'B' of Turner Valley Fm.
XX - Approx. base of Turner Valley Fm. member 'A'
CMBc - Top of Banff Crinoidal Unit


XX
CMB
CMBc
DP

The Eastern Foothills consists of moderately deformed younger Mesozoic rocks, while the Western Foothills is a more strongly deformed belt in which older Mesozoic and Upper Paleozoic strata are present. In the Eastern Front Range Belt, the proportion of older rocks forming the surface is higher than in the Western Foothills belt. The area is situated in a special position relative to the Eastern Front Ranges. The easternmost Front Range, referred to here as the First Range, forms a more or less single distinct and continuous feature to the south for two hundred and fifty miles along strike from Rock Lake. Along this two hundred and fifty mile stretch the First Range is bordered on the east by the southwest dipping McConnell thrust or, in the Jasper area, its close relative, the Miette Thrust (Mountjoy, 1960).

The position relative to regional strike of the typical "First Range" changes in the Wildhay River - Rock Lake area. The northwest plunge of the Paleozoic rocks in the hanging wall of the Miette Thrust in the Moosehorn Range make it necessary to define the Persimmon Range as the First Range. Northwest of the area, the Paleozoic rocks of the Rocky Pass and Greenock Thrust sheets also plunge below the surface and the "First Range" has to be picked still further to the southwest across strike. The northwest plunge of the Paleozoic rocks results in a considerable widening of the Foothills belt at the expense of the Front Ranges. The dominant structures of the area are southwest dipping thrust faults whose traces tend to follow the strike of the strata. The more important of these thrust faults form borders for the six structural units listed below, (Figure 6). This subdivision is a modification of that established

by Mountjoy (1962). Each thrust sheet is named by using the name of the major thrust which acts as the sole fault for the sheet.

1. Eastern Foothills
2. Hoff Thrust Sheet — Western Foothills
3. Tip Top Thrust Sheet
4. Miette - Lancaster Thrust Sheet — Eastern Front Ranges
5. Rocky Pass Thrust Sheet
6. Mount Greenock Thrust Sheet

The Hoff Thrust Sheet. The Hoff Thrust may have originated as a fore limb thrust which broke the eastern limb of the Hoff Ridge Anticline. The Palliser Formation exposed in the core of this anticline (Plate 5) is the oldest rock unit cropping out in the sheet. Numerous faults, commonly of low angle, slice the back limb of the anticline. One of these faults, the Folding Mountain Thrust, becomes of major importance southeast of the area.

Between the crest of the Hoff Ridge Anticline and the Tip Top Thrust, in a general way, progressively younger rocks appear at the surface as the Hoff Thrust Sheet is traversed from northeast to southwest; Paleozoic rocks are present in the core of the Hoff Ridge Anticline and Upper Cretaceous shales are exposed below the Tip Top Thrust on the southwestern exposed edge of the Hoff Thrust Sheet. Thus the outcrop pattern of the Hoff Thrust Sheet west of the axis of the Hoff Ridge Anticline suggests a southwesterly dipping homocline complicated by minor faults and folds.

Tip Top Thrust Sheet. The Tip Top Thrust Sheet is similar in some respects to the Hoff Thrust Sheet and the preservation of the eastern limb of an anticline at many points along the eastern edge of the thrust suggests that the Tip Top Thrust originally formed as a fore limb thrust of this anticline in the same way as the Hoff Thrust.

The Devonian Rocks, forming the hanging wall of the Tip Top Thrust for many miles along strike are the oldest rocks exposed in this sheet. The Tip Top Thrust dies out to the south end and the displacement is picked up by the Perdrix - Boule Thrust. The Tip Top Thrust Sheet contains many minor faults and folds but the distribution of formations across the sheet again suggests a southwest dipping homocline and Upper Cretaceous shales are again found exposed in the footwall of the next main thrust to the southwest (Lancaster Thrust).

Miette - Lancaster Thrust Sheet. Paleozoic rocks of this sheet are only exposed in the southeast part of the area in the hanging wall of the Miette Thrust. The Upper Wildhay River syncline clearly dominates the structure of the northern half of the sheet. The core of this syncline contains Upper Cretaceous shales and the Nikanassin formation is exposed for long distances along each limb. This syncline has been thrust over the Tip Top Sheet to the east and has in turn been overthrust by the Rocky Pass Sheet in the west. In the southern half of the area, minor faults and folds have affected the Miette-Lancaster Thrust Sheet, but the outcrop pattern suggests that the structure is dominated by the northwest plunging portion of the Upper Wildhay Syncline.

Rocky Pass Thrust Sheet. The thick Devonian sequences, which are well exposed in the hanging wall of the Rocky Pass Thrust, are the oldest rocks

exposed in the area. The youngest rocks exposed in the Rocky Pass Thrust Sheet belong to the Nikanassin Formation and only occur where the Rocky Pass Thrust appears to die out in the southern part of the area. Triassic rocks form the surface over large areas of the sheet and form most of the surface of the Starlight Range. The broad Rock Creek valley east of this range is directly underlain by the soft Fernie shales. The sheet contains many broad folds but few faults, and altogether the sheet, both structurally and stratigraphically, is quite different from the Foothills sheets.

Greenock Thrust Sheet. The Deer Creek Anticline is the dominant structure of the Greenock Thrust Sheet (Plate 2A). This anticline is a large asymmetical fold with a steeply dipping or overturned eastern limb with the Palliser Formation exposed in the core.

The stratigraphic throw of the thrust is not great, the Whitehorse Formation and Fernie shales for the hanging wall of the thrust, while the footwall consists of Fernie shales. Near the edge of the area the Greenock Thrust seems to die out in contorted Fernie shales (Plate 2A).

CHAPTER III

LATE PALEOZOIC STRATIGRAPHIC NOMENCLATURE

The history of the nomenclature used for the Late Paleozoic rocks of Alberta has been plagued with many miscorrelations largely due to unrecognized facies changes and lack of paleotological control; an excellent historical review of the subject prior to 1955 is given by Moore (1958) and largely clarified by him. The subject is discussed further by Penner (1959), Nelson (1960), (L961), and (1962), Green (1962), McGugan and Rapson (1962), McKay and Green (1963) and Green (1963). In many of these papers special emphasis is placed on the problem of the definition of the Banff-Rundle contact. The development of the nomenclature which is currently standard and applicable over wide areas is traced below. Reference to publications which have not resulted in the definition of new units applicable in the study area are omitted where possible or mentioned briefly. Table 3 shows the correlation of the Late Paleozoic rock units currently used in Alberta with units of similar age in Western North America and the Arctic.

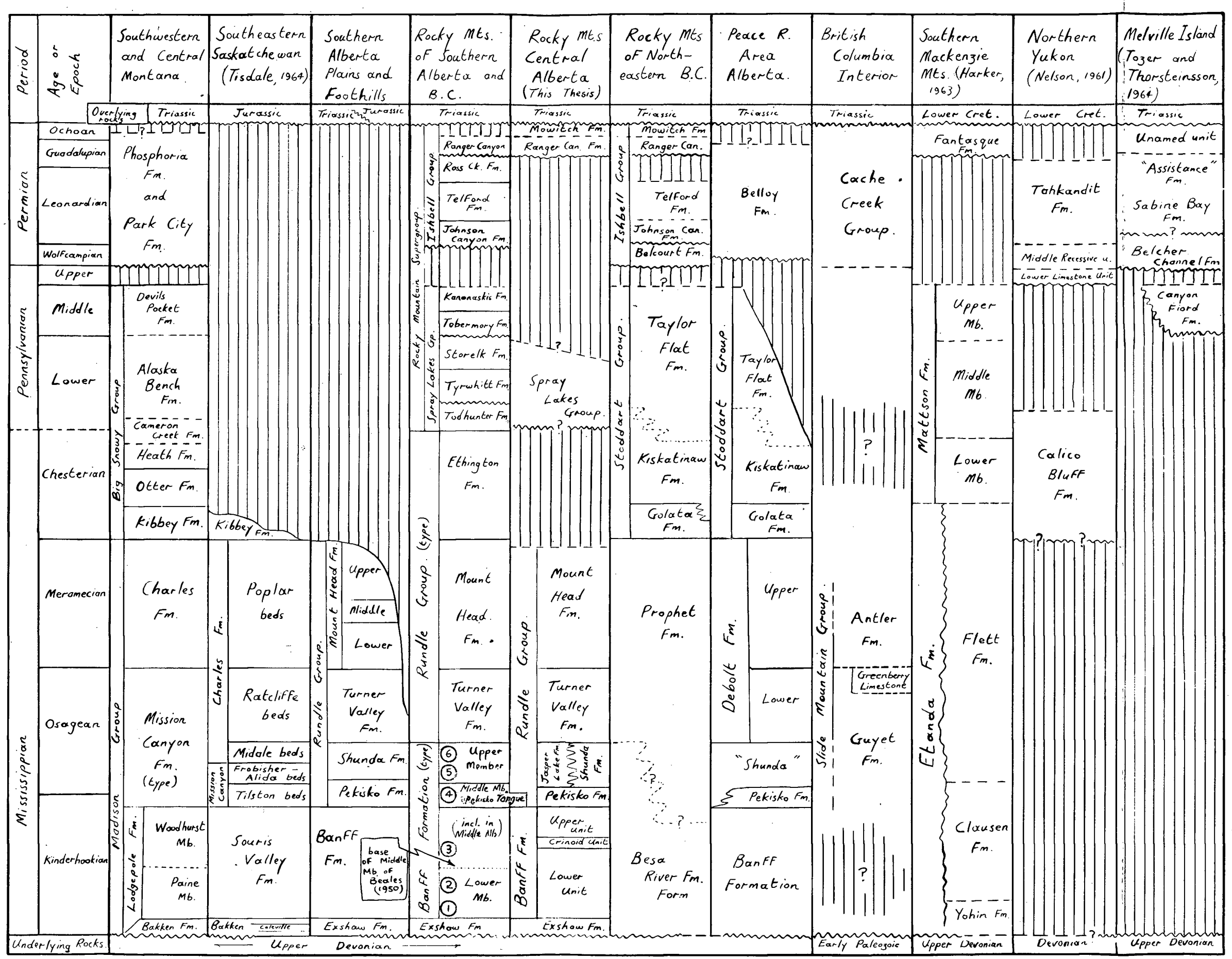


Table 3. - Correlation of Late Paleozoic Rock Units.

The circled numbers at the Banff type section refer to the units of Green (1963)

Southern Alberta. (Lower and Middle parts of the Carboniferous)

The first descriptionsof the Late Paleozoic of the Bow Valley area were published by McConnell (1887) who used the term 'Banff' for Devonian, Carboniferous and Permian rocks of the area. Type sections for the Mississippian units "Banff Shales" and "Rundle Limestone" were established by Kindle (1924) on the north end of Mount Rundle at Banff and a detailed description was published by Warren (1927). Warren split the Banff into Lower, Middle and Upper Members and these were later proven to be very important divisions. Warren (1937) described the Exshaw Formation, proposing a Devonian age. The Exshaw, in spite of its thinness, is on an extremely widespread unit; in some areas a Late Devonian age is suggested while in other areas an early Mississippian age is evident.

The next additions to the nomenclature which have survived were given orally by Beach in 1947. Beach called his three divisions Tunnel Mountain, "Shunda" and "Dyson Creek" but only the first name is now retained in the sense supposedly intended by Beach. Scott (1964, p. 131) suggests that the name Tunnel Mountain be either dropped or raised to group status to indicate a sandstone sequence. Beach referred to the unit below the Tunnel Mountain Formation as "Shunda", miscorrelating these beds to similar beds on Shunda Creek near Nordegg.

Douglas (1950) proposed a fourfold division of the Rundle, lettered A-D, and later (1953) gave these divisions geographical names with the middle two units split between six members as shown below. The Loomis Member is the only one of these six which is traceable over a wide area (Middleton, 1963).

Rundle Group	(D) Etherington Formation		
	Mount Head Formation	(C) Upper	Carnarvon Member
			Marston Member
		(B) Lower	Loomis (Cummings) Member
			Salter Member
			Baril Member
			Wileman Member
	(A) Livingstone Formation		

The type section of the Livingstone Formation was established by Douglas (1953) and (1958) along the ridge north of Flat Creek in the Mount Head map area and was described there by Beales (1950). Douglas (1958) and Douglas and Harker (1958) correlated the type section of the Livingstone with a subsurface section in the Turner Valley Oil Field suggesting that the same seven equivalent subdivisions could be recognized at both localities. The Anglo-Canadian et al Devonian Test well Lsd. 2-25-19-3W5th Meridian was specified as the type section for the Pekisko and Turner Valley Members and their subdivisions (Douglas, 1958, pp. 38-39). The subdivisions of this well section are shown below; many of the names are drillers'terms. The present day usage is shown on the right.

Mount Head Fm.			
Livingstone Formation	Turner Valley Member	Upper Porous beds	Turner Valley Formation
		Middle Hard beds	
		Lower Porous beds	
		Dark Limestone beds	Shunda Formation
		Banner beds	
	Pekisko Member	Upper	Pekisko Formation
		Lower	
Banff Formation			

In the Exshaw area Clark (1949) measured the Banff Formation and divided it into three distinct members as shown below.

Banff Formation	Upper Shale Member	200' - 250'
	Middle Limestone Member	175' - 200'
	Lower Shale Member	575' - 600'

Clark pointed out that the Middle Limestone Member "... is easily confused with the basal beds of the Rundle ...". Moore (1958) included a section near Exshaw in a cross section showing that the Middle Limestone Member of Clark, often referred to as "Clark's Member", is the lateral equivalent of the Pekisko as defined in the Turner Valley area.

Moore (1958, Figure 3, pp. 150-152) considered that the Pekisko and Shunda Formations, as Douglas' lower four subdivisions were to become, were

homotaxial with the Middle and Upper Banff Members of the Banff Formation at the type section on Mount Rundle, and he further suggested that the Pekisko is coeval with the Middle Member of the (type) Banff Formation. Moore's conclusions were supported by Middleton (1963) following a study of the facies variations in thirty six sections in the Elbow Valley region.

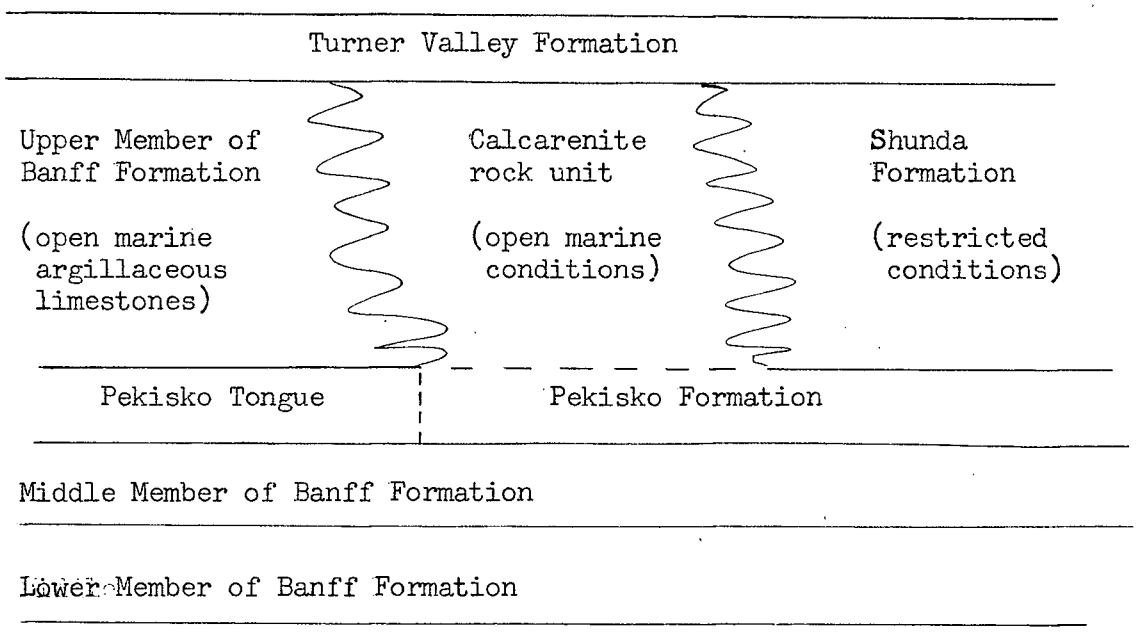
> "... the Pekisko and Shunda Formations pass westward into the Middle and Upper Banff (approximately). The Turner Valley thickens markedly and passes westward into the Livingstone Formation." (ibid., p. 1814)

Nelson (1959c) found that the base of the Rundle in the Crowsnest Pass area was almost the same age as the base of the type Rundle. Nelson and Rudy (1959) consequently urged that caution should be used in correlation of the units referred to as "Pekisko" and "Shunda" in the Highwood River area since the Pekisko and Shunda north of Banff may be considerably older than the units in the Highwood River area to which the same names had been applied (Douglas, 1958). The observations of Oswald (1963) confirm the doubts of Nelson and Rudy concerning the "Pekisko" and "Shunda" of the Highwood River area, for Oswald, with eighty sections available for step by step correlation, observed that the top of the Banff Formation at Mount Rundle and the Flat Creek type section of the Livingstone Formation are very close to being coeval. The interpretation of Green (1962, Fig. 7, p. 304) differs from that of Nelson and Rudy, Oswald and Middleton. Green considers that the base of the Livingstone at Mount Head is about the same age as the base of the Pekisko at Moose Mountain and slightly younger than the Pekisko base at Pine Creek #1 well in the Turner Valley area.
The ASPG - AAPG Carboniferous Committee (1955) adopted the name Pekisko as used by Douglas (1958) in the Turner Valley field and for the overlying

"Banner" and "Dark Limestone beds" the Committee adopted the term Shunda, used in the sense of Gallop (1951) and gave the Turner Valley, Shunda and Pekisko formational ranks. The type section of the Shunda Formation on Shunda Creek near Nordeggg, previously undescribed but extensively used and often miscorrelated, was finally described in detail by Stearn (1956). The Committee made a minor revision of Stearn's type section by placing the top thirty three feet higher (Penner, 1958, pp. 65-66). If the Livingstone is used in the sense shown by Douglas and Harker (1958, Table III), then this unit has to be given group status. The best procedure may be to abandon the term Livingstone altogether, as suggested by Moore (1958, p. 171) and use the term Turner Valley Formation in its place; both type Livingstone and type Turner Valley have approximately the same age and lithology.

A Nomenclature System for Upper Banff,
Pekisko and Shunda Equivalents

The nomenclature system sketched below embodies the concepts of Moore (1958, p. 153) with an added refinement, the recognition where possible and separate naming of a dominantly calcarenite succession, presumably deposited under open marine conditions, which is a lateral equivalent of a sequence of Shunda strata of a restricted environmental type. In the Mount Greenock and Wildhay River - Rock Lake areas the name Jasper Lake is applied to a calcarenite succession which is the lateral equivalent of Shunda rocks.



Where the Pekisko calcarenites are overlain by open marine argillaceous limestones, Banff type, the unit should be called Pekisko Tongue. In the case where the Pekisko is overlain by a unit such as the Jasper Lake, a predominantly calcarenite sequence, the separation of the formations may become difficult and the term Pekisko may have to be applied to the entire lime-sand series. The term Shunda should be applied where, and only where, greater than 50% of the interval in question consists of restricted Shunda facies - micrites, dismicrites, cryptocrystalline dolomites, breccias and anhydrite.

Jasper and Peace River areas

The early stratigraphic studies in the Jasper area included studies by McEvoy (1900) and Kindle (1929). Allan et al. (1932) demonstrated that the stratigraphic succession in the Athabaska Valley was, in general, quite similar to the succession in the Bow Valley. Irish (1947) and Lang (1947) published brief descriptions of measured surface sections together with a

description of the section in the Jasper #1 bore hole. The Rundle was divided into three parts by Irish, the lower division being recognizable as the combined Shunda and Pekisko and the overlying two divisions being approximately equal to the Turner Valley and Mount Head Formations.

The work of Brown (1952) constituted the first published detailed study of the Permo-Carboniferous in the Jasper area; emphasis was placed on the faunal succession. Brown divided the Permo-Carboniferous into three formations as shown below with the Greenock divided into three members and the Banff into two members.

Triassic		
Permo-carboniferous	Greenock Formation	Upper Member
		Middle Member
		Lower Member
	Rundle Formation	
	Banff Formation	Upper Member
		Lower Member
Devonian		

Nelson (1962) refers to Brown's lower and upper members of the Banff as member A and member B respectively.

Drummond (1961) subdivided the Mount Greenock section of Brown and applied the Southern Alberta nomenclature; the Greenock Formation was discarded with the lower member placed with the Mount Head Formation and the upper two members placed in the Rocky Mountain Group. The Upper Member (sanstone) was later assigned to a new unit named the Mowitch Formation and the Middle Member (chert) to the new Ranger Canyon Formation

of the Ishbel Group (McGugan and Rapson, 1963b and McGugan, Roessingh and Danner, 1964). The upper part of the lower member of the Greenock Formation carries a Morrowan fauna and evidently belongs to the Spray Lakes Group (McGugan and Rapson, 1963b).

Mountjoy (1962) recognized that in the Jasper area the Banff Formation could be divided into three parts with the middle part consisting of crinoidal limestone. The Rundle Group was divided by Mountjoy into four formations lettered A, B, C, and D in ascending order, tentatively correlated with the Pekisko, Shunda, Turner Valley, and Mount Head Formations.

The recent paper by Hawryszko and Hamilton (1964) introduces the term Jasper Lake Member which is applied to a thick sequence of dolomitized crinoidal biosparites at Mount Greenock, designated as the type section, thought to be lateral equivalents of typical Shunda strata in the vicinity and representing the local encroachment of more basinal conditions.

The term Debolt Formation is applied by Hawryszko and Hamilton to the upper half of the section at Mount Greenock. The Debolt Formation was proposed by Macauley (1958, pp. 298-301) for strata in the Peace River area of Alberta coeval with the type Turner Valley and the Mount Head formations; the name is now widely used in the subsurface. The type section for the Debolt is the well Amerada Crown 'G' F 23-11 located near the village of Debolt 30 miles east of Grande Prairie, Alberta. The Debolt was divided into upper and lower units, the lower unit consisting mainly of cherty bioclastic limestone separated by minor widespread shaly zones and the upper unit consisting of dolomites and anhydrites. The base of the Upper Debolt is marked by a thin zone with terrigenous clastics.

Only thin sequences of Late Mississippian (Chesterian), Pennsylvanian and Permian rocks are present in Central Alberta but thick sequences are present both to the north, in the subsurface and mountains of the Peace River and Fort St. John areas (Irish, 1963) and to the south in Southern Alberta (refer to isopach maps, Macauley et al (1964) and McGugan, et al, 1964). The lithology of these sequences throughout Alberta and in Northwestern B.C. is broadly similar in that terrigenous clastics, sandy dolomites and chert predominate. The nomenclature used in the northern sequences is not discussed in this thesis.

CHAPTER IV

LATE PALEOZOIC ROCK UNITS IN THE WILDHAY RIVER-ROCK LAKE AREA

The Mississippian succession in the area is in many respects quite similar to the succession in the Foothills and Plains of Southern Alberta and the same rock unit nomenclature can, in most cases, be readily applied (Table 4).

In the unit by unit discussion which follows, general features are described, and the fossils, important in a stratigraphic sense, are listed.

The petrographic details of the rock units at each section are shown in Figures 3-5 together with facies subdivisions and other data. The facies relationships between sections are shown in Figures 10 and 12.

The subdivisions of the Mississippian used by Mountjoy (1962) are broadly similar to those used in this thesis but Mountjoy appears to place the Mount Head base lower in the section than the writer as shown by measurements at Eagles Nest Pass.

	Mountjoy (1962)	This thesis
Rundle Group at the Eagles Nest Pass vicinity	Formation D (Mount Head?) 303 ft.	Mount Head 233 ft.
	Formation C (Turner Valley?) 202 ft.	Turner Valley 305 ft.
	Formation B (Shunda?) 338 ft.	Shunda 320 ft.
	Formation A (Pekisko?) 116 ft.	Pekisko 112 ft.

Other differences between Mountjoy's subdivisions and those of the writer are noted below:

a - Mountjoy does not treat the Jasper Lake type of succession separately.

b - Mountjoy includes some Mount Head crinoidal calcarenites in Formation C (Ibid., p. 33).

c - The Banff subdivisions noted by Mountjoy are treated more formally in this thesis and in addition the Basal Shale is split off from Mountjoy's lower unit.

TABLE 4

LATE PALEOZOIC STRATIGRAPHIC UNITS IN WILDHAY RIVER - ROCK LAKE AREA

System	Stage	Rock Unit			
Permian	Oachoan? to Guadolupian	Rocky Mountain Supergroup	Ishbel Group	Mowitch and Ranger Canyon Formations (undivided)	
				Unconformity	
Penn-sylvan-ian	? Morrowan		Spray Lakes Group		
				Possible Unconformity	
Mississippian	Meramecian	Rundle Group		Mount Head Formation	
	Osagean			Turner Valley Formation	
				Shunda Formation / Jasper Lake Formation	
	Late Kinderhookian to Early Osagean			Pekisko Formation	
	Kinderhookian	Banff Form.			Upper Unit
					Crinoidal Unit
					Cherty Unit
					Basal Shale
	Early Kinderhookian	Exshaw Formation			

EXSHAW FORMATION

(Plates 35A and 36A-B) The Exshaw is present at the Wildhay well and at Mumm Creek. The Formation is usually poorly exposed due to its soft nature but the following complete section was observed at the Mumm Creek locality.

Overlying rocks - Banff Formation

Transitional zone from black Exshaw shales to argillaceous calcilutites and limy shales of the Banff Form.	3 ft.
Shale; black, bituminous, non-calcareous, soft and fissile.	3 ft.
Siltstone; dark grey, pyritic with traces of brachiopods and crinoid fragments.	2 ft.
Sandstone; light brownish grey, composed of very fine to coarse angular grains of quartz and minor sanidine in a microgranular clay mineral matrix. The sandstone contains conodonts and fibrous material (? fish bones)	3 ft.

Underlying rocks - Palliser Formation

The black bituminous shales are absent at the Wildhay well but the fossiliferous siltstone and arkosic sandstone are both present and are underlain by some waxy shales which are missing from the Mumm Creek section. The Exshaw at the well has four times the radioactivity of the overlying Banff Formation.

Contacts. The lower contact is very distinct and may represent a slight disconformity. The upper contact is gradational over a few feet and may be placed at the point where calcareous shales or limestones first appear in the sequence.

Regional Distribution. The Exshaw and formations of closely similar age and lithology are widespread and appear to be more or less continuous from the Mid-Continent to Northeastern British Columbia.

Fossils and Age. The brachiopods collected from the Exshaw siltstone at Mumm Creek were identified by E. W. Bamber of the Geological Survey of Canada as follows:

Rhipidomella sp. orthotetinid brachiopod unidentified rhychonellid brachiopod	GSC Loc. 59683

At Jasper, sandstones similar to those occurring at Mumm Creek contain a conodont fauna dated as earliest Mississippian (Green, 1963, p. 69) and it is thought that the same age can be assumed for the Exshaw at Mumm Creek. An absolute age of 267 x 10^6 years was obtained for the Exshaw at Nordegg by Folinsbee and Baadsgaard (1958) using sanidine separated from a bentonite bed. It is probable that the Mumm Creek sanidine was derived during the same volcanic phase as the ash at Nordegg.

BANFF FORMATION

The Banff Formation is almost identical at each of three surface sections and if it were so desired the Formation could be subdivided into seven correlatable members using the facies variations. In this thesis the Banff has been split into four members.

The argillaceous and recessive nature of the Banff Formation make it readily distinguishable from the Palliser and Rundle units. The thickness of the Formation ranges from about 510 feet to about 580 feet; the thickest sections occur to the west.

Fossils and Age. Identifiable fossils were only collected in the upper half of the Banff Formation in the area and these all seem to belong to the *Spirifer missouriensis* Zone (Harker and Raasch, 1958) of late Kinderhookian age. E. W. Bamber of the Geological Survey of Canada states that the fauna occurs in the Middle Member of the Banff Formation at its type section, evidently referring to the lower part of the middle member of Beales (1950). The fauna also occurs at Morro Creek (Brown, 1952, Figure 13) and Green (1963, pp. 7 and 10) has tied this section to the Banff type section using the well defined ostracode assemblages. These relationships show that the upper half of the Banff Formation in the subject area is the same age as the lower part of the Middle Member of the Banff Formation in its type section as described by Beales (1950) and is coeval with Green's 'unit 3' at the type section and it is therefore assumed that the unfossiliferous lower half of the Formation is coeval with Green's 'units 1 and 2'.

BASAL SHALE

There is a distinct tendency for the lower portion of the Banff Formation of the area to have a high proportion of shale. The shale is typically dark grey, calcareous, shaly to fissile with planar surfaces and it is somewhat pyritic and silty; the Unit is 60 feet thick at Eagles Nest Pass but only a few feet thick at the other two surface sections.

Contacts. The lower contact of the Basal Shale is gradational where the Exshaw is present and sharp where it directly overlies the Palliser Formation; the latter contact may represent a slight disconformity.

The upper contact is placed below the zone where the proportion of limestone in the overlying Cherty Unity becomes less than fifty percent.

Regional Distribution. The occurrence of a basal shale is a common feature of the Banff Formation in Jasper Park.

Fossils and Age. The Basal Shale was barren of fossils at the sections examined but the dating of the conodont fauna at Jasper and the correlation of the Basal Shale to that area, suggest that the unit is coeval with the lower portion of the Lower Member of the Banff in its type section.

CHERTY UNIT

This unit, distinguished by its cherty nature and by its well developed rhythmic banding, consists of interbedded argillaceous limestones and shaly limestones with recognizable crinoid content increasing toward the top. The unit is 275 $\pm$ 10 feet thick at all three sections.

Contacts. Both upper and lower contacts are gradational.

Fossils and Age. The only fossils collected from the Cherty Unit came from the upper part and were identified by E. W. Bamber of the Geological Survey of Canada as follows:

fenestellid bryozoa *Spirifer esplanadensis* Brown	GSC loc. 59682

The brachiopod occurs in the Middle Banff at the type section and indicates the Kinderhookian age of the unit.

CRINOIDAL UNIT.

The Crinoidal Unit, seen in outcrop as a more resistive unit near the Middle part of the Banff Formation of the area, mainly consists of argillaceous crinoidal biomicrites with shaly partings and ranges from 40 feet to 60 feet in thickness.

Contacts. Both the upper and lower contacts of the unit are gradational.

Regional Distribution. The unit seems to extend from the subject area at least as far as the Athabaska River and it is suspected that the unit may prove to be widespread.

Fossils and Age. The fossils collected from the unit were identified by E. W. Bamber of the Geological Survey of Canada as follows:

Spirifer esplanadensis? Brown - young specimen *Punctospirifer* sp. "*Platyrachella*" *rutherfordi* (Warren) *Composita* sp. *Camarotoechia* sp. Ostracodes indet. *Paraconularia* aff. *alternistriata* (Shimer)	GSC loc. 59681
Spirifer esplanadensis Brown *Punctospirifer* sp. *Spirifer* sp.	GSC loc. 59698

Dr. Bamber gives the age of this fauna as Kinderhookian and points out that the same fauna occurs in the Middle Member of the Banff at its type section.

UPPER UNIT.

This argillaceous recessive unit consists of biomicrites and micrites with the middle part having a lower proportion of large organic fragments than adjoining parts. The upper portion of the Unit contains silty, pyritic dolomites and quartzose sediments. The thickness ranges from 195

to 175 feet.

Contacts. The lower contact is gradational. The upper contact with the Rundle is very sharp as shown by Plate 6A-B. Both contacts are conformable.

Regional Distribution. There seems to be a basin-wide tendency toward the occurrence of the Upper Unit; the homotaxial Woodhurst Member of Montana and Southern Alberta for example may reflect similar conditions. However the clear definition of the Upper Unit depends to a large extent on the presence of the underlying Crinoidal Unit.

Fossils and Age. The following fossils, listed in order of their stratigraphic occurrence in the Upper Unit at Mumm Creek, were identified by E. W. Bamber of the Geological Survey of Canada.

?*Composita athabaskensis* Warren	GSC Loc. 59676
?*Camarotoechia allani* Warren	
?*Composita* sp. - immature specimen	GSC Loc. 59677
?*Ekvasophyllum* sp. - incomplete specimen	GSC Loc. 59678
Syringopora sp.	GSC Loc. 59679
?*Rhipidomella* sp. - young specimen	
*"*Platyrachella*" *rutherfordi* (Warren)	GSC Loc. 59680
* *Composita athabaskensis* Warren	

The fossils shown with a star* occur toward the base of the unit and have been dated by Dr. Bamber as Kinderhookian and related to the similar fauna which occurs in the Middle Member of the Banff at the type section. He considers that the upper two brachiopods are probably Kinderhookian.

PLATE 6

A Banff - Rundle Contact at Mumm Creek Section

This view shows the contact between thin bedded argillaceous limestones belonging to the Upper Unit of the Banff Formation and the overlying crinoidal calcarenites of the Pekisko Formation, the lowest unit of the Rundle Group.

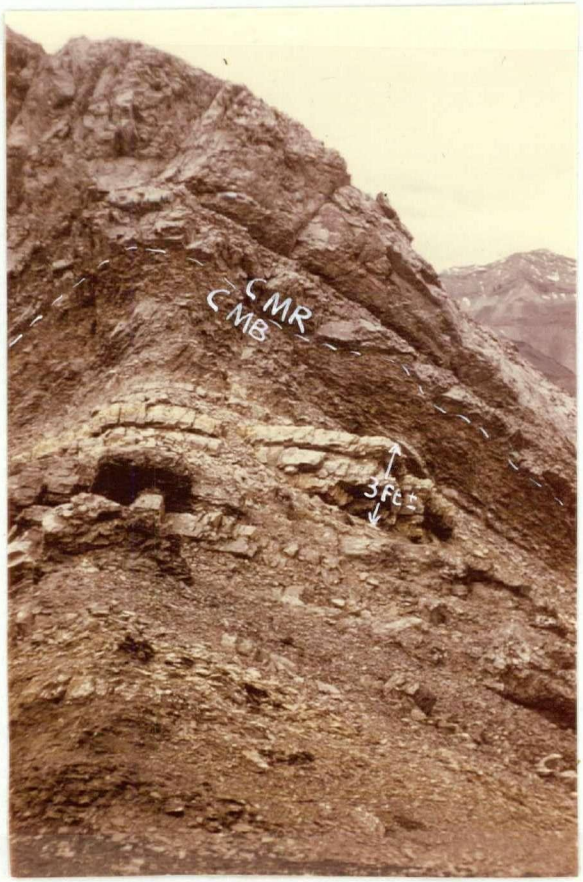
CMR - Base of Rundle Group
CMB - Top of Banff Formation

B Banff - Rundle Contact at Eagles Nest Pass Section

Note the contrast between the thin to medium bedded, brownish weathering argillaceous limestones of the Banff Formation and the thick bedded, light grey weathering crinoidal calcarenites of the Pekisko Formation, the lowest unit of the Rundle Group.

CMR - Base of Rundle Group
CMB - Top of Banff Formation


CMR
CMB


CMR
CMB
3 ft ±

RUNDLE GROUP

The Rundle outcrops are resistive and have a light grey weathering colour contrasting strongly with the adjacent recessive brownish weathering Banff and Spray River Formations. Considerable facies variations occur in the group (Figures 10 and 12). The group thickens toward the west but irregular pre-Upper Permian erosion has resulted in an anomalously thin section at Eagles Nest Pass and pre-Triassic (or early Triassic) erosion has resulted in a thin section at Moon Creek.

	South Berland River	Eagles Nest Pass	Moon Creek	Mumm Creek
Rundle Group thickness	1250 ± ft.	969 ft.	665 ft.	940 ft.

In this thesis the Rundle has been split into the Pekisko, Shunda, Turner Valley and Mount Head Formations. In the westernmost section, lateral equivalents of the Shunda are assigned to the Jasper Lake Formation. The units have been so named in the Rock Lake area because they are homotaxial, approximately coeval and have lithologies similar to the units to which these names have been applied in Southern Alberta and in the Jasper area.

PEKISKO FORMATION

The Pekisko Formation forms resistive light grey weathering cliffs composed of sparry calcarenites which change in character vertically within the Formation in a manner suggesting a general pattern; the stratigraphic order is as follows, basal beds at the bottom.

4. Either oosparites or grapestone bearing intrasparites with grains which were comparatively resistant to plastic deformation during consolidation.

3. Intraclast bearing biosparites with moderately sorted and rounded grains.

2. Crinoidal biosparites with poorly sorted angular grains.

1. Crinoidal intrasparites with well sorted rounded grains.

The thicknesses attained by the Pekisko in the area are tabulated below:

	South Berland River	Eagles Nest Pass	Moon Creek	Mumm Creek
Pekisko Formation thickness	70 ft. or > 70 ft.	112 ft.	?15 ± 10 ft.	25 ft.

Contacts. Both the upper and lower contacts of the Pekisko are sharp. At the South Berland River Section the Pekisko top has to be picked arbitrarily owing to dolomitization. By interpreting the zone marked "Shunda-Pekisko Transition" on Figure 5 as part of the Pekisko, the Pekisko at the South Berland River section becomes about 450 feet thick. In this thesis this extra thickness is assigned to the Jasper Lake which is thought to warrant formational status and is so treated.

Regional Distribution. The Pekisko is a very widespread and persistent unit from the Peace River area to Southern Alberta. In the Rocky Mountains, the Pekisko has the habit of persisting basinward for many miles beyond the point where overlying restricted Shunda facies has been replaced by open marine argillaceous limestones (Speng 1953, p. 686, "cliff. 1").

Fossils and Age. The following megafossils collected from the Pekisko of the area have been identified by E. W. Bamber of the Geological Survey of Canada.

Vesiculophyllum sp. *Lithostrotionella microstylum* (White) (= L. *jasperensis* Kelly)	GSC loc. 59690
Camarotoechia sp. *Rhynchotetra usheri* Brown *Spirifer* cf. *albertensis* Warren	GSC loc. 59696
Cleiothyridina sp. horn coral indet.	GSC loc. 59700
Vesiculophyllum sp. ?*Syringopora* sp.	GSC loc 59675
gastropod indet.	GSC loc. 59692

Dr. Bamber states that the brachiopods of this fauna occur in the Middle Member of the Banff at its type section indicating a Kinderhookian age. The *Lithostrotionella microstylum* suggests a late Kinderhookian or early Osagean age and Dr. Bamber's comments concerning the occurrence of this fossil are quoted in the section dealing with the fossils of the Jasper Lake Formation.

The Pekisko of the area was found to contain numerous foraminifers and these have been identified by R. Green of the Research Council of Alberta as listed below:

From the Eagles Nest Pass section:

Spiroplectammina sp. Granuliferelloides jasperensis Granuliferella granulosa Endothyra tumula ?Endothyra spinosa Endothyra sp. indet. E. sp. cf. E. spinosa E. sp. ?sp. B. Tournayella nonconstricta	Assemblage A
Endothyra tumula Granuliferella sp. Granuliferelloides jasperensis	Assemblage B

Dr. Green considers that assemblage A represents the Endothyra tumula - Endothyra spinosa Concurrent - range zone and thus correlates the enclosing strata to the Shunda at the Morro Creek section. Assemblage B is considered to represent the Endothyra tumula Range Zone and correlates with the Pekisko equivalent at Morrow Creek. (McKay and Green, 1963)

From the South Berland River section:

Granuliferella sp. Endothyra sp.	Assemblage C
Endothyra tumula E. ?morroensis Granuliferella granulosa	Assemblage D

Dr. Green considers that assemblage D probably belong to Pekisko - equivalent strata, referring to the section at Morro Creek.

From the Mumm Creek section:

Granuliferelloides jasperensis McKay and Green Spiroplectammina sp.	Assemblage E

Not much can be said about assemblage E beyond pointing out that these foraminifers occur together in the upper few feet of the Banff Formation and

lower few feet of the Pekisko at Morro Creek (McKay and Green, 1963, Figure 4).

Assemblage A is the youngest assemblage of foraminifers collected from the Pekisko of the area. At the Morro Creek section (McKay and Green, 1963, Figure 4) most of the elements of this assemblage are abundant in strata associated with 'fossil location 92' of Brown (1952) from which fossils of the Camarotoechia cobblestonensis Zone were collected. This fauna is typical of Warren's "Middle Banff Member" (Harker and Raasch, 1958, p. 226) which is coeval with the Pekisko. The evidence of the foraminifers and the megafossils seems to indicate that most of the Pekisko of the area is coeval with the Middle Banff Member of Warren and thus with the Pekisko of the Front Ranges and Foothills from Jasper to Moose Mt. (ibid p. 226) and strata correlated with the Pekisko of the Turner Valley region in the Southern Plains of Alberta (Penner, 1958, Figure 4, p. 276).

SHUNDA FORMATION

The rocks of this Formation in the area appear as a thick-bedded, light grey weathering limestone sequence occupying most of the lower half of the Rundle Group of the area except in the west, where the Jasper Lake nomenclature has been applied.

The rocks consist of micrites and dismicrites (birdseye limestones) and minor amounts of intramicrites, intrasparites, pelmicrites, pelsparites and biomicrites with traces of dolomite and shale.

The thicknesses of the Shunda in the area are tabulated below:

	South Berland River	Eagles Nest Pass	Moon Creek	Mumm Creek
Shunda Fm. thickness	45 ft.	320 ft.	235 ± ft.	240 ft.

The thickening of the Shunda from east to west may be a normal depositional thickening although at one time the possibility of an important disconformity within the Shunda of the area was considered by the writer and discussed with Dr. S. J. Nelson who had previously considered such possibilities (Nelson, 1962, Figure 5). Nelson (unpublished manuscript) points out that Laudon (1948) diagnosed a hiatus in the Wapiti Lake area. The relationship, however, between Laudon's "hiatus" and the thrust fault which other workers later found to cut some of his sections is unknown.

The thin Shunda section at the South Berland River is due to the lateral facies changes and application of the Jasper Lake nomenclature; the term Shunda at the latter section is arbitrarily restricted to a few tens of feet at the top of the section.

Contacts. Both the upper and lower contacts of the Shunda of the area are sharp and simple to define at Eagles Nest Pass and Mumm Creek. The lower contact is drawn at the border between the underlying sparry calcarenites of the Pekisko and the overlying Shunda micrites, dismicrites or biomicrites.

The upper contact is drawn at the base of a series of oolitic, grapestone bearing, intramicrites and oolitic, micritic, intrasparites which are thought to be recognizable as an important marker in the general Mount Greenock - Wildhay River - Rock Lake district.

Regional Distribution. The Shunda appears to be a widespread unit from the subject area southeast to the Turner Valley area. The name has probably been frequently misapplied by other workers to normal open marine limestones.

Fossils and Age. The only megafossil collected from the Shunda was identified by E. W. Bamber of the Geological Survey of Canada as follows:

?*Cleiothyridina* sp. - poorly preserved GSC loc. 59674

Dr. J. Harlan Johnson identified the codiacean alga *Hedstromia* Rothpletz 1913 from the lower part of the Formation.

The material did not permit an age determination. The fossils found in the adjoining units suggest that the Shunda of the area represents a large part of an Osagean Series.

JASPER LAKE FORMATION

In this thesis, the Jasper Lake is raised to formational status; there are two reasons for this change of status. The first and main reason being that it is felt strongly that the term Shunda should only be used for facies deposited in a restricted environment and since crinoidal biosparites are held to be 'normal' marine facies a thick sequence of such rocks should not be considered as belonging to the Shunda Formation.

The second reason is that it is felt that banks of crinoidal biosparites provided the partial barrier between the open sea and the restricted Shunda lagoons and that this barrier was laid down as a continuous feature and should therefore be preserved as a mappable unit.

At the South Berland River a unit consisting of calcareous dolomites, dolomitic limestones, limestones and some shale is homotaxial with local micritic Shunda rocks and seems to represent a thick sequence in which crinoidal biosparites were interbedded with a minor proportion of micritic rocks. This sequence is thought to be part of the above crinoidal barrier and is therefore termed the Jasper Lake Formation.

A shale unit, possibly 25 feet thick is present near the middle of the Formation. It is difficult to say whether this shale was laid down under lagoonal or basinal conditions.

At the South Berland River, the Jasper Lake Formation is 380 feet thick.

Contacts. Owing to dolmitization the contacts of the Jasper Lake Formation are difficult to define at the South Berland section; the top of the Pekisko is drawn at the base of the first lagoonal type bed and the top of the Jasper Lake Formation is drawn at the base of a rather thick (45 feet) series of beds suggestive of the Shunda.

Regional Distribution. The Jasper Lake Formation is thought to loop around the restricted Shunda Lagoon. For example, in the Bow Valley a crinoidal sequence similar to the Jasper Lake Formation should occur between the Roxana #1 and Exshaw sections shown in Figure 3 of Moore (1958).

Fossils and Age. The megafossils obtained from the Jasper Lake Formation were identified as follows by E. W. Bamber of the Geological Survey of Canada:

Spirifer sp.	GSC loc. 59688
Lithostrotionella microstylum (White) (= L. jasperensis Kelly)	GSC loc. 59689

The *Lithostrotionella* was collected a few feet above the base of the Formation and Dr. Bamber considers that this fossil indicates a late Kinderhookian or early Osagean age and points out that

> "...*L. microstylum* occurs in the upper part of the middle member of the Banff Fm., at its type locality. It is found in the upper part of the Banff Fm., and the lower part of Mountjoy's Formation A in the Jasper area. (See Mountjoy, 1962, GSC Paper 61-31.)"

The foraminifers collected from a bed about 100 feet from the base of the Formation were identified by Dr. Robert Green of the Research Council of Alberta as follows:

Septatournayella? sp.
Endothyra sp.

Dasycladacean algae from the Jasper Lake Formation were named by Dr. J. Harlan Johnson as follows:

Orthriosiphon Johnson and Konishi 1956
Albertaporella involutus n.gen., n.sp. Johnson

The age of the Jasper Lake Formation appears to range from late Kinderhookian or early Osagean to rather late in the Osagean.

TURNER VALLEY FORMATION

The Turner Valley Formation in the area can be divided into two parts. The lower part, referred to here as member 'A' is thin bedded and light brown to yellowish grey weathering. The upper part referred to here as member 'B' is thick bedded, in places massive, and has a greyish brown weathering colour of generally darker appearance than Member A. The colour and bedding contrasts present at Mumm Creek can be distinguished in Plate 5.

Member A is vertically a more variable unit than Member B but laterally both members are remarkably consistent in lithology although some facies changes occur between sections.

Member A is composed of interbedded micritic and oolitic, intraclast bearing rocks and includes some silty shales and very thin orange weathering siltstone beds which may be tuffaceous. Numerous angular fragments of quartz and/or feldspar observed in thin sections of the siltstones may represent a shower of volcanic dust.

The oolitic rocks (micritic intrasparites and grapestone bearing intramicrites) (Plates 24A-B, 26B, and 27A-B) present at the base of the lower member of the Turner Valley are traceable in all three sections. In the Eagles Nest Pass and Mumm Creek sections the carbonates of member A are split about half and half between dolomite and limestone but at the South Berland River most of the member is dolomite.

Member 'B' of the Turner Valley is almost entirely dolomite at all three sections and consequently some difficulty is encountered in determining the exact facies; the distribution or crinoid ghosts (Plates 31A-B and 32) however, does suggest that crinoidal biosparites predominated in the west and that to the east increasing amounts of non-crinoidal deposits, presumably micritic lagoonal rocks, are interbedded in the sequence. The rocks of Member B differ from the earlier Mississippian rocks of the area in having a greater number of large sized single and colonial corals. These corals, and some of the brachiopods, found in member 'B' are commonly replaced by silica. Although sparse, the corals make a prominent feature of the outcrops of member B.

The thicknesses of the Turner Valley and its members in the area are tabulated below:

	South Berland River	Eagles Nest Pass	Mumm Creek
Member 'B'	175 ft.	165 ft.	175 ft.
Member 'A'	145 ft.	140 ft.	130 ft.
Total Turner Valley	320 ft.	305 ft.	305 ft.

Contacts. The lower contact of the Turner Valley is placed at the base of the muddy oolitic subfacies Eb illustrated in the plates noted above; other workers would place this contact considerably higher in the section,

as pointed out below.

It is of particular interest to note that the muddy oolitic bed occurs 500 feet above the Banff-Rundle contact at the South Berland River and that at Morro Creek in the Mount Greenock area an oolitic bed is present 520 feet above the same contact. Since the Morro Creek section was probably depositionally further west, it is quite possible that these two beds occur at the same stratigraphic horizon and this seems to be borne out by the respective foraminifers. The contact between member A and member B of the Turner Valley is transitional and is placed where silty or argillaceous dolomites of the upper part of member A give way to the crinoidal dolomites of member B. In the Jasper area, some workers place the base of the Turner Valley at, or close to, the base of member B and include the siltstones and shales and underlying strata of member A with the Shunda (Campbell and Lerbekmo, 1965, Fig. 1).

The upper contact of the Turner Valley is transitional and occurs in a crossbedded zone where the fossiliferous dolomites of the Turner Valley give way to the finely laminated, microcrystalline, unfossiliferous, terrigenous clastic bearing dolomites of the lower portion of the Mount Head Formation.

Regional Distribution. The Turner Valley Formation can be traced from the area to Southern Alberta and eastward to its erosional truncation in the subsurface of the Plains west of Edmonton. Northward the same strata appear to form the Lower Debolt of the Peace River Area.

Fossils and Age. Megafossils collected from the Turner Valley Formation of the area were identified by E. W. Bamber of the Geological Survey of Canada as follows:

From Member A:

South Berland River section:	Vesiculophyllum sp. Ekvasophyllum cf. proteus Sutherland	GSC loc. 59687
From Mumm Creek section:	Syringopora sp. Lithostrotion (Siphonodendron) cf. mutabile (Kelly) Vesiculophyllum sp. ?Zaphriphyllum sp.	GSC loc. 59673

Dr. Bamber assigns an Osagean age to the above South Berland fossils and points out that Ekvasophyllum proteus occurs in the upper part of Mountjoy's Formation B.

In referring to the form listed above, Dr. Bamber states that

> "...L. (S.) cf. mutabile appears to be intermediate between L. (S.) mutabile (Kelly), which occurs in rocks equivalent to upper type Banff Fm. and lower type Rundle, and L. (S.) whitneyi Meek, a middle Mount Head form."

and assigns a Late? Osagean age to the collection from Mumm Creek on that basis.

From the lower part of Member B:

(a) South Berland River	Zaphriphyllum cf. disseptum Sutherland Vesiculophyllum sp.	GSC loc. 59685
	Caninia sp. Lithostrotion (Siphonodendron) oculinum Sando	GSC loc. 59686
(b) Eagles Nest Pass	Lithostrotion (Siphonodendron) warreni Nelson Vesiculophyllum sp.	GSC loc. 59695

From the upper part of Member B
at the Eagles Nest Pass section:

Syringopora sp. Amplexizaphrentis sp. Vesiculophyllum sp. Zaphriphyllum sp.	GSC loc. 59694

The first two corals listed are dated as "probably Osagean" by Dr. Bamber; the other fossils from member 'B' at the South Berland River section are dated Late Osagean or early Meramecian.

With reference to Lithostrotion (Siphonodendron) oculinum Sando, Dr. S. J. Nelson (personal communication) points out that this is a transitional form between L. mutabile and L. n. sp. warreni and that the beds are therefore coeval with Livingstone strata (presumably at Banff).

The collection from the lower part of member 'B' at Eagles Nest Pass is dated as Early Meramecian and Dr. Bamber points our that "...L. (S.) warreni occurs in the Lower Mount Head Formation. The collection from the upper part of member 'B' at Eagles Nest Pass is dated as probably Osagean." Dr. Bamber states that the form Zaphriphyllum resembles a form found in Mountjoy's Formation C.

The muddy oolitic Eb subfacies at the base of the Turner Valley at the South Berland section yielded some foraminifers and these were identified by Dr. Robert Green of the Alberta Research Council as follows:

Endothyra spinosa
? E. tuberculata
Endothyra sp. (pl. 4, fig. 15, RCA Bull. 10)
E. sp. (pl. 4, Fig. 13, RCA Bull. 10)

The presence of E. tuberculata and E. spinosa is considered by Green to suggest a late Tournaisian age.

Dasycladacean and red algae from member A are described by Dr. J. Harlan Johnson as follows:

Albertaporella involutus n.gen., n. sp. Johnson
A thin red alga n.gen., n. sp. Johnson

In summary, the fossil evidence shows that the Turner Valley Formation of the area ranges in age from Late Osagean into Early Meramecian.

MOUNT HEAD FORMATION

The Mount Head of the area consists of a rather regularly bedded resistive sequence of sub-lithographic, light brownish grey to yellowish grey weathering cherty dolomites with traces of green, grey and brown shales, quartzose sandstone and siltstone. In the west, greyish brown and brown weathering somewhat thicker bedded crinoidal dolomites occur in the lower half of the Mount Head, a duplication of the Shunda - Jasper Lake depositional pattern.

Thicknesses of the Mount Head Formation are tabulated below; the variations are mainly due to pre-Triassic (Sulphur Mt.) erosional periods.

	South Berland River	Eagles Nest Pass	Mumm Creek
Mount Head Fm. thickness	395 ft.	233 ft.	374 ft.

Contacts. The lower contact is transitional and it is thought probable that the terrigenous clastics which occur in the lower portion of the Mount Head represent the clastic unit characteristic of basal Upper Debolt strata of the Peace River area (Macauley, 1958, p. 301).

The upper contact of the Mount Head in the area occurs at one of three different erosion surfaces (Figure 12). The three erosion surfaces converge in space so that the position of the section controls the nature of the upper contact. This contact is at the pre-Triassic erosion surface in the east (Mumm Creek), at the widespread pre-Upper Permian erosion

surface at Eagles Nest Pass and at a pre-Middle Pennsylvanian erosion surface in the west and southwest, as suggested by sections in the Mowitch Creek - Deer Creek area (McGugan and Rapson, 1961b) and, possibly by the South Berland River section.

Regional Distribution. The Mount Head Formation extends from the subject area to Southern Alberta but does not extend very far east of the Foothills due to erosional truncation.

The Mount Head is homotaxial with the Upper Debolt of the Peace River area.

Fossils and Age. Megafossils collected from talus at the base of the Formation at Eagles Nest Pass were identified by E. W. Bamber of the Geological Survey of Canada as follows:

Syringopora sp. *Syringopora bassoi* Nelson *Vesiculophyllum* sp. cf. *Dorlodotia inconstans* (Easton and Gutschick)	GSC loc. 59693

Dr. Bamber assigns a Late Osagean or early Meramecian age to the fauna and points out that

> "...*Syringopora bassoi* ranges from the upper Livingstone Fm., through the basal 150 ft. of the Mount Head Fm., and is most common in the Mt. Head Fm."

Foraminifers found in the middle of the Mount Head at the South Berland River section were identified by R. Green of the Research Council as *Tournayella ?nonconstricta* which is a common species in the Mount Head in Southern Alberta (McKay and Green, 1963, p. 27).

The Formation is thought to be Meramecian.

?SPRAY LAKES GROUP

A twenty to thirty foot thick zone capping the Late Paleozoic carbonate section at the South Berland River locality possibly represents the Pennsylvanian Spray Lakes Group. The occurrence of Pennsylvanian beds in the area west of the Starlight Range (Figure 2) has been reported by McGugan and Rapson (1961b, p. 77).

Lithological Description and Contacts. The ?Pennsylvanian interval is described below and general features are shown in Figure 5. The silicified fossils are thought to be lag deposits, residues of erosional processes; similar deposits have been observed by the writer in the Devonian to Silurian succession near Summit Lake on the Alaska Highway. The brecciated dolomite is thought to be an ancient weathered zone.

Overlying rocks - Permian basal conglomerate

-Unconformity _____

	Thickness (Feet)
?Dolomite finely crystalline	5
Zone of silicified brachiopods, corals and bryozoans cemented with coarsly crystalline calcite and containing limy chert in the lower part.	7.5
Dolomite, yellow grey, micrograined, brecciated with banded chert between fragments.	2
Dolomite, light grey micrograined, cherty.	10
Dolomite, light brownish grey, siliceous, micrograined with rounded and angular chert pebbles and very coarse sand grains.	0.5

-Possible Disconformity _____

Underlying rocks - grey, cryptograined cherty dolomites of the Mount Head Formation

Regional Distribution. Thick sequences of Pennsylvanian strata are present in Southern Alberta and in the Peace River country but only thin erosional remnants are present in the Jasper-Berland River area (McGugan and Rapson, 1961b Figure 2).

Fossils and Age. Fossils collected from the bed below the pre-Upper Permian unconformity were identified by Dr. E. W. Bamber of the Geological Survey of Canada as shown below, but the material was insufficient for age determination.

Caninia sp. GSC loc. 59684
fenestellid bryozoa

Caninia is a common Pennsylvanian coral but also occurs in the Devonian, Mississippian and Permian. At Deer Creek, McGugan and Rapson (1961, p. 77) report foraminiferal cherts of approximately Morrowan age and the rocks in question at the South Berland River section may be of the same age.

ISHBEL GROUP

The Ishbel Group is a massive to flaggy resistant unit which caps the Paleozoic in the western part of the area (plate 3B). The outcrops of the Group have a dark appearance due to a cover of black, green and red lichens.

Thicknesses of the Group in the area are tabulated below:

Ishbel Group thickness:

	Headwaters of Deer Creek (#60, McGugan and Rapson 1961b)	Starlight Range - East side (#61, McGugan and Rapson, 1961b)
In the Southwest —	120 ± ft.	25 ± ft.

	Eagles Nest Pass (Eccles, 1957)	Eagles Nest Pass (57D7)	South Berland R. (57D3a)	Moon Ck. (Irish 1947)
In the Persimmon Range —	102 ft.	65 ft.	60 ft.	0 ft.

At southwest sections, the Group can be divided into a lower chert unit (Ranger Canyon Fm.) and an upper, sandstone unit (Mowitch Fm.) but in the Persimmon Range no such subdivision is possible.

McGugan and Rapson (1963, pp. 152-3) consider that the Ishbel chert has resulted from "...complex diagenetic changes in which original siltstone, sandstone and occasionally carbonates were silicified and recrystallized to various degrees."

The sandy nature of the chert bands and nodules present in the sandstone sequences of the Persimmon Range suggests that this chert may indeed be altered sandstone. It follows that the Range Canyon chert present in the southwest part of the area, could be alteration produce of original sandstones.

Lithological Description. (Figs. 4 and 5) (Plate 37A-B) The Persimmon Range rocks of the Group consist of silica cemented quartz sandstones with minor amounts of chert in bands and nodules. The sandstones are well sorted very fine, fine or medium grained and carry coarser grains toward the base of the Group. The grains are mainly quartz with detrital chert making up between 2 and 20% of the grains. The chert nodules and bands commonly contain thin walled tubes and sand grains. A characteristic conglomerate occurs at the base of the Group and at the South Berland River this conglomerate consists of dolomite, chert and phosphatic pebbles in a sandy matrix.

Contacts. Both upper and lower contacts of the Ishbel Group in the area are unconformable although beds above and below these unconformities appear to be parallel.

The unconformity at the base of the Group truncates strata of ?Morrowan

and Meramecian ages; the unconformity at the top of the Group truncates the Group itself and a large part of the Mount Head Formation.

Regional Distribution. The chert unit of the Permian is very widespread in the Rocky and Mackenzie Mountains; the sandstone unit is less widespread and is present from Jasper northwards and may correlate with a portion of the Bellow Fm. of the Peace River Area and with sandstones north of the Liard River at Mount Merrill, Yukon Territory (Sutherland, 1958, pp. 33-34). Actually, as previously implied, the chert and sandstone unit may be partly equivalent.

Age. McGugan et al (1964) assign an Ochoan? Age to the Mowitch Formation and an Guadalupian to Ochoan age to the Range Canyon Formation.

CHAPTER V

PETROGRAPHY OF MISSISSIPPIAN ROCKS

General. In this paper the writer has followed the carbonate rock classification of Folk (1959, 1961 and 1962); a graphical form of Folk's limestone classification is reproduced below for the convenience of the reader (Figure 7).

It will be noted that Folk uses the terms allochemical and orthochemical in his system. Allochemical constituents, or allochems, are defined by Folk (1959, p. 4) to

> "...include all materials that have been formed by chemical or biochemical precipitation within the basin of deposition but which are organized into discrete aggregated bodies and for the most part have suffered some transportation...".

Oolites, fossils, intraclasts and pellets are allochems. On the other hand, orthochemical constituents, or orthochems (Folk, 1959, p.7) include all

> "...normal precipitates, formed within the basin of deposition or within the rock itself and showing little evidence of significant transportation."

Thus the term orthochem, in addition to embracing microcrystalline carbonate oozes, evaporites and calcite cement, includes secondary orthochemical constituents formed by replacement recrystallization and precipitation. In some cases it has been found desirable to refer to carbonates without further qualification by using the general terms dolomite, limestone, calcarenite, calcilutite, and calcisiltite. The simple grain size scale adopted by Leighton and Pendexter (1962, p. 52) is employed in this thesis.

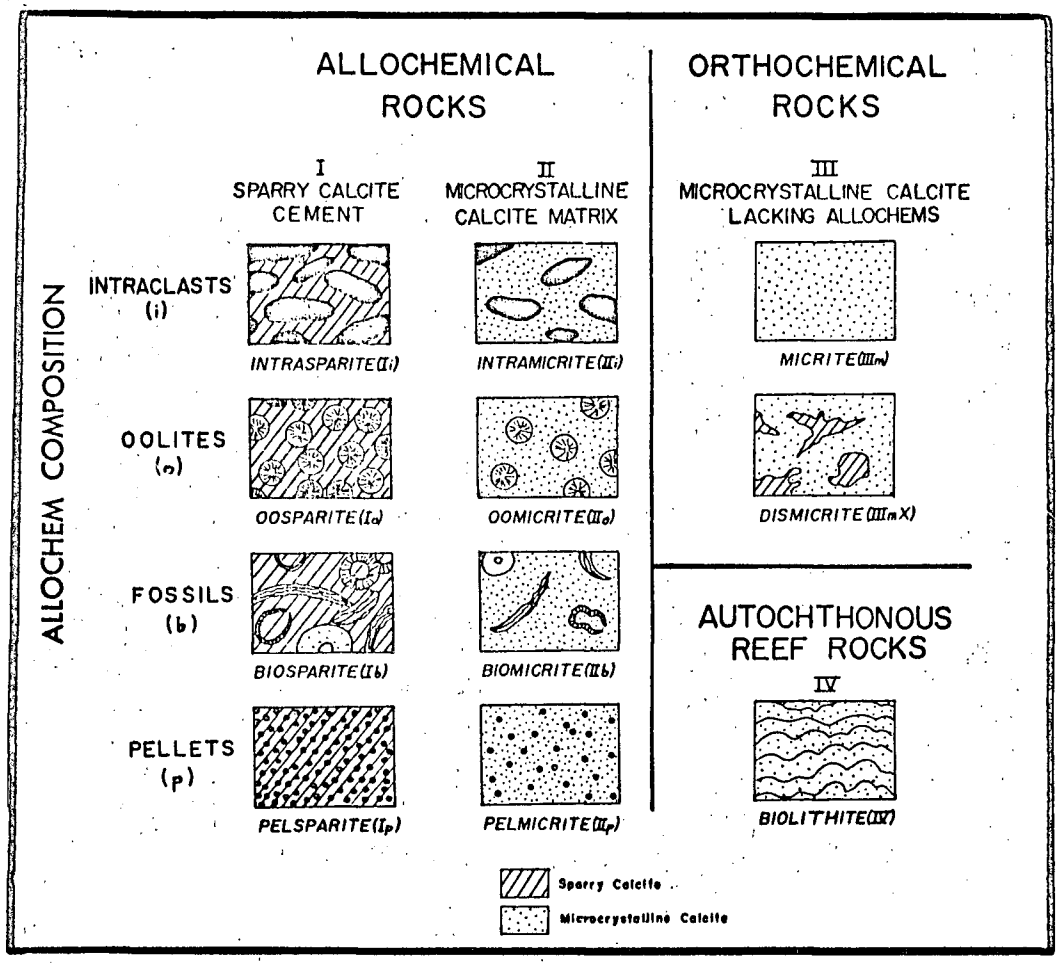


Fig. 7. Graphic Classification Table of Limestones (after Folk, 1962)

ORGANIC ALLOCHEMS

The inferred life distributions of organisms shown in Figure 11A correspond in part to the distribution of the various organic grains within the rock. The crinoids appear to be the only organism which contributed significant volumes of detritus to the Mississippian of the area. The bryozoans and algae, however, may have played important roles as sediment binders in some environments.

Crinoids. The unicrystalline elements recorded as crinoid may include some cystoid fragments. The remains range from a few indigenous large-jointed stems, occasionally found with cup attached, to transported silt-sized grains, which have been considerably abraded and corroded.

In thin sections, the crinoid grains frequently show a pale amber colour when examined with unpolarized light, thus offering a marked contrast with the colourless calcite spar cement which habitually is in optical continuity with the crinoid elements (Plate 35A). At the time of death, the crinoidal material, like the modern crinoids probably consisted of a unicrystalline calcite skeleton enclosed by dermal tissue and permeated by fleshy matter and at some later time, intraskeletal precipitation of calcite took place, giving the solid unicrystalline grains observed in thin sections. The sedimentation of crinoidal grains is not simple, since the mesh skeleton probably gave the grains considerable buoyancy and they may have been able to float. Volumetrically the crinoidal remains may have composed about a quarter of the Mississippian sediment of the area.

Bryozoans. (Plate 7) Fragments of fenestellid bryozoans are fairly common in the crinoidal sediments of the Rundle and Banff, but only make up a small volume of the rock.

PLATE 7

Biosparite

Fenestrate bryozoan (b), crinoid (c), foraminifer (f) and echinoid spine (e) fragments cemented with sparry calcite:

Subfacies Db.
Pekisko Formation (Late Kinderhookian - early Osagean)

(57D7. 983-88)

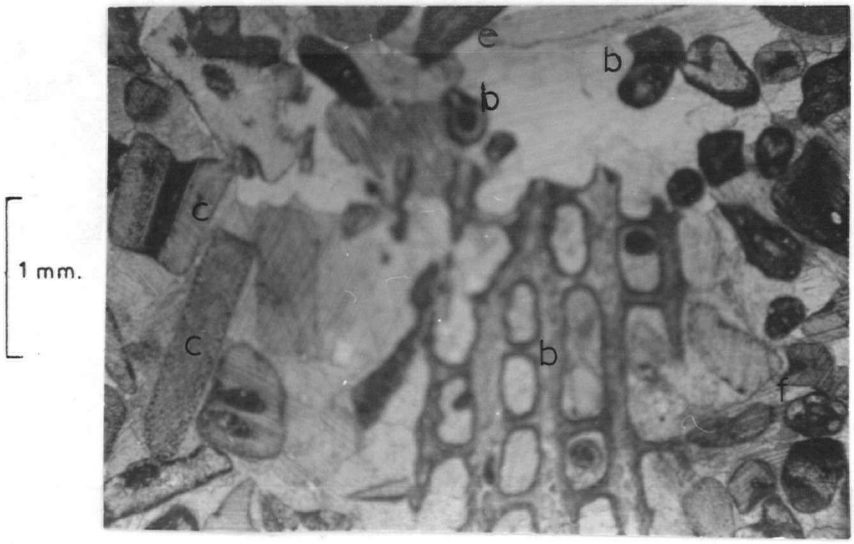

e
b
b
c
c
b
f
1 mm.

PLATE 8

A

Pellets and Calcispheres

This photograph shows numerous calcispheres and faintly distinguishable pellets in a birdseye micrite of subfacies Fb, the elongated sparry calcite birdseyes are roughly parallel to bedding.

Shunda Formation (Late Kinderhookian - early Osagean)

(57D9. 655)

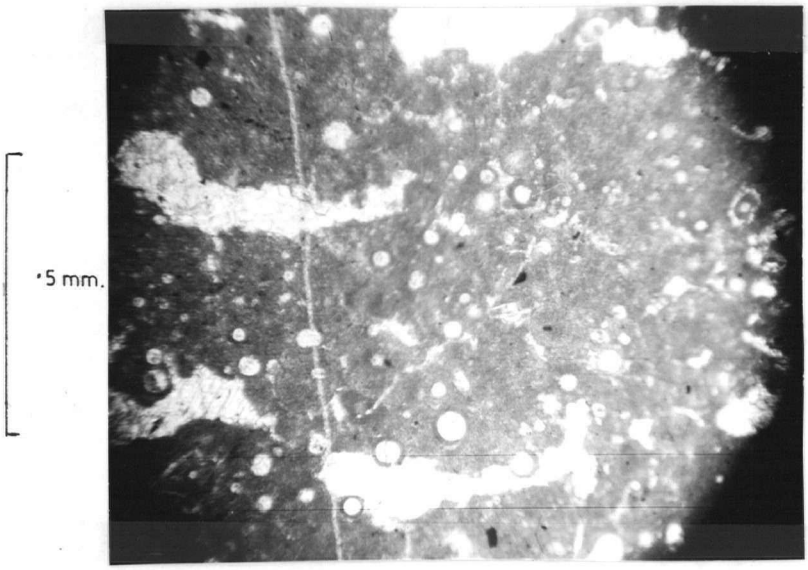
B

Groups of Spheres

Possible calcispheres within (? original) multiwalled capsule. The rock has been extensively dolomitized.

Basal Turner Valley beds (Osagean)

(57D9. 782)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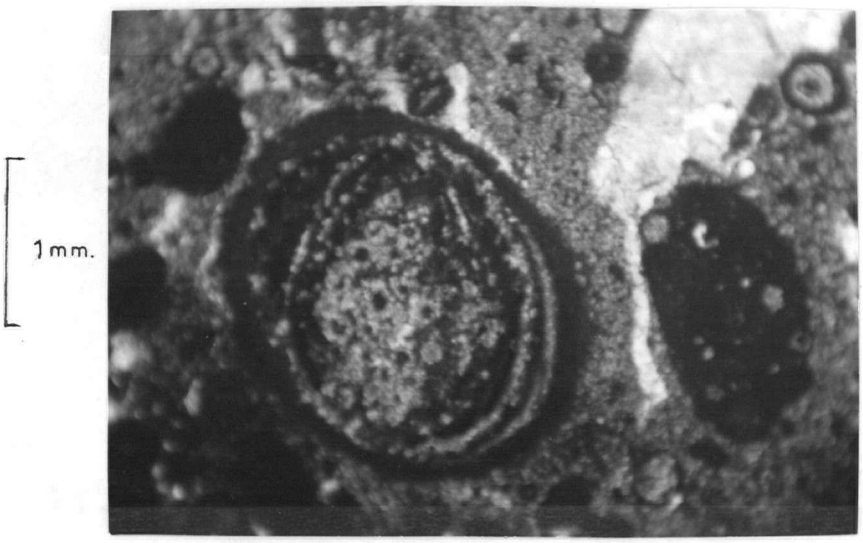
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Calcispheres. Minute calcite spheres generally ranging from 40-100 microns, with a few being 200 microns in diameter, are commonly scattered in the micrites and closely associated pellet and intraclast bearing rocks of the Shunda Formation in the area. These calcispheres are a typical consituent of the above limestones, but usually only amount to a very small percentage of the rock. In a few parts of the Shunda, however, the calcisphere content attains 10% of the rock volume.

The calcispheres consist of the following types in order of abundance.

(a) Solid calcite spheres - Plate 8A

(b) Spheres with thin walls, preserved - Plate 8A

(c) Spheres as above but with short spines or nodes on the outer surface

(d) Groups of spheres apparently enclosed in a container - Plate 8B.

Calcispheres have been reported by various authors from Ordovician, Devonian and Carboniferous strata. Kloven (1964) and Stanton (1963) both report calcispheres from Upper Devonian shallow water back reef facies, a facies similar in some respects to the Shunda Formation of the area. Baxter (1960) describes some Mississippian calcispheres, including one with a diameter of 86 microns containing smaller spheres 18-20 microns in diameter within the central cavity, and suggests that this specimen preserves some sort of reproductive capsule. Several authors consider the calcispheres are most probably reproductive bodies of calcareous algae. It has been reported recently that a small dasycladacean algae, found in Florida, annually disintegrates releasing thousands of calcareous spheres (J. W. Murray, verbal communication). A similar mode of origin may be possible for the Mississippian calcispheres.

Algae. Codiacean and dasycladacean algal fragments were found in the Pekisko, Jasper Lake and Turner Valley Formations.

PLATE 9

A Dasycladacean Algae

This alga probably belongs to an undescribed species of the genus Orthriosiphon, Johnson and Konishi 1956 (J. H. Johnson written communication).

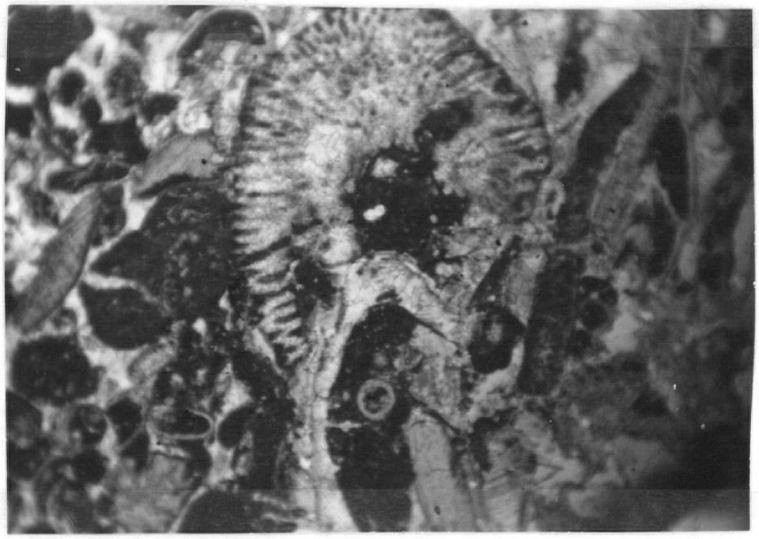
Jasper Lake Formation (Osagean)

(57D3b. 865-70)

B Albertaporella involutus n. gen., n. sp. (J.H.Johnson, written communication) Brachiopod-rich, laminated subfacies Da

Jasper Lake Formation (Osagean)

(57D3b. 865-70)



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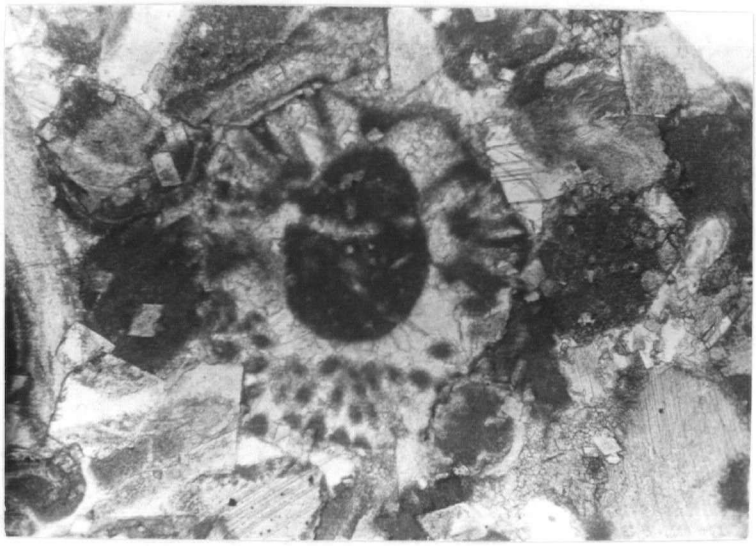

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PLATE 10

Dasycladacean Algae

A *Albertaporella involutus* n. gen., n. sp., (J.H.Johnson, written communication) Brachiopod - rich laminated subfacies Da

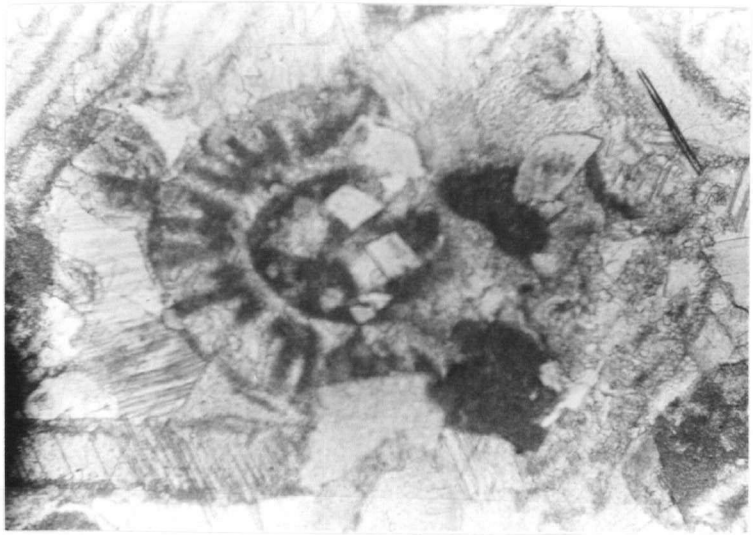
Jasper Lake Formation (Osagean)

(57D3b. 865-70)

B *Albertaporella involutus* n. gen., n. sp., (J.H.Johnson, written communication) Dolomitized subfacies Fb.

Turner Valley - member A (Osagean)

(57D9. 870)



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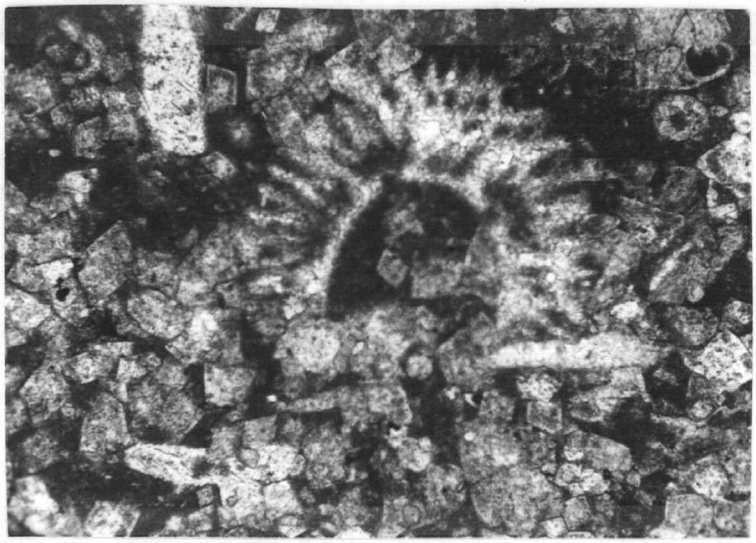


·5 mm.

PLATE 11

A Codiacean Algae

Hedstromia Rothpletz 1913 (J.H.Johnson, written communication). In this specimen, the micritic matrix has been strongly dolomitized, the algal grains have been moderately affected but the unicrystalline crinoid grains have remained almost unaffected by dolomitization.

Subfacies Fa of basal Shunda beds (?early Osagean)

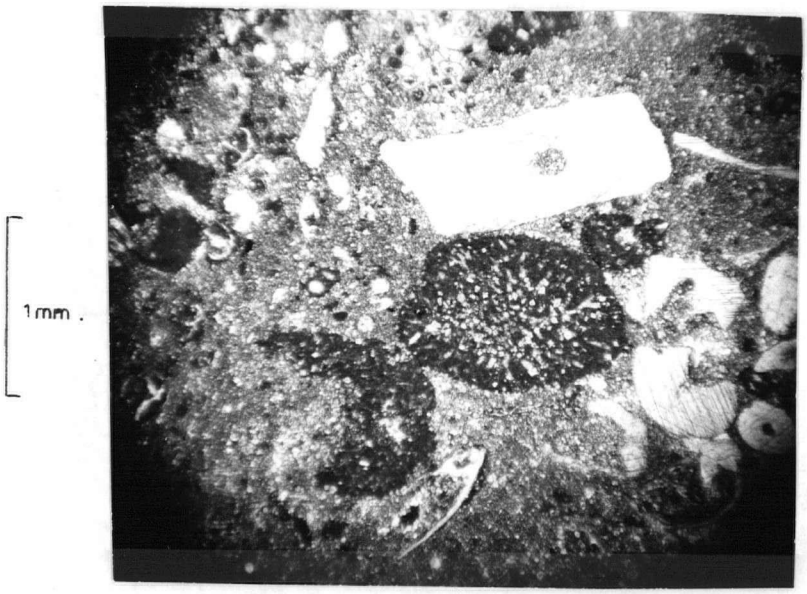
(57D7. 918)

B Red Alga

A new genera and species of thin red alga (J.H.Johnson, written communication)

Turner Valley - member A (Osagean)

(57D9. 870)


1 mm.


1 mm.

Dr. J. Harland Johnson (written communication) reports that "with the exception of a few small threads of Ortonella, Garwoodia and Hedstomia they all represent new undescribed material" (Plates 9A-B, 10A-B and 11A). A new thin red alga, found in the Turner Valley, member A is shown in Plate 11B. A paper describing the algae is being prepared by Dr. Johnson for publication in the Journal of Paleontology.

Algae do not appear to have contributed much skeletal material to the sediments; many algae do not have hard parts which show up as fossils and some sparry calcite bodies such as the laminated birdseyes of the Shunda may represent lithified algal mat. Algae may have been intrumental in effecting the direct precipitation of dolomite and calcite from seawater in the manner described by Alderman and Skinner (1957). At the locality described by these authors dolomite precipitation is due to a rise in pH. caused by the extraction of CO_2 from water by plants during photosynthesis in strong sunlight.

Brachiopods and Corals. Brachiopods and corals form a very minor rock-building constituent in the Mississippian of the area. The more complete forms have been identified by Dr. Wayne Bamber of the Geological Survey of Canada.

Foraminifers. (Plates 12A-B and 17A) In the rocks studied it was found that foraminifers mainly occur in cleanly washed calcarenites (Plates 15A, 17A, 21A-B, 22A-B, 31A and 35A). A few foraminiferal whorls were found in muddy lagoonal rocks occurring there with a relatively large number of forms which resemble the rectilinear portion of endothyroid tests. The foramineral tests commonly make up less than 1% of the rock volume but in places they are especially numerous and may account for 10% of the volume. Many of the foraminifers have been identified by Dr. Robert Green of the Research

Council of Alberta; the details are given under the various rock unit headings in Chapter IV. Most of the foraminifers found belong to the family Endothyridae but the families Textulariidae and Tournayellidae are also represented. The paper by McKay and Green (1963) was a most useful reference.

Echinoid Spines. Fragments of echinoid spines were found in small amounts in the Banff, Pekisko and Jasper Lake Formations.

Ostracodes and Small Bivalved Fossils. These fossils make up an insignificant portion of the sediments and were only found in undolomitized portions of the sections. They show up readily in the Banff where other identifiable forms occur sparsely. Where the two valves are together, the interior may be found filled with either mud or sparry calcite. A combination of these two fillings gives a geopetal texture (Plate 13A).

Sponges. Thin walled tubes are especially noticeable, preserved in Rocky Mountain Group cherts, and occur sparsely in the Mississippian, they may be sponge spicules. Other material, thought to be of sponge origin, is shown in Plate 14.

Mollusks. Gastropods were only found by the writer in the Rundle Group and do not make significant contributions to the rock volume. The basal few feet of the Pekisko at the South Berland River Section includes an unusually large number of gastropods.

It is suspected that pelecypods were an important element of the Mississippian Fauna of the area but due to the aragonite composition of the shell, diagentic processes resulted in destruction of identifiable structures;

PLATE 12

Foraminifers

A Specimen is *Granuliferelloides jasperensis* McKay and Green in subfacies Db.

Pekisko Formation (Late Kinderhookian - early Osagean)

(57D9. 519)

B (1) *Spiroplectammina* sp. and
(2) indet. sp. in subfacies Db.

Pekisko Formation (Late Kinderhookian - early Osagean)

(57D9. 519)


·5 mm.

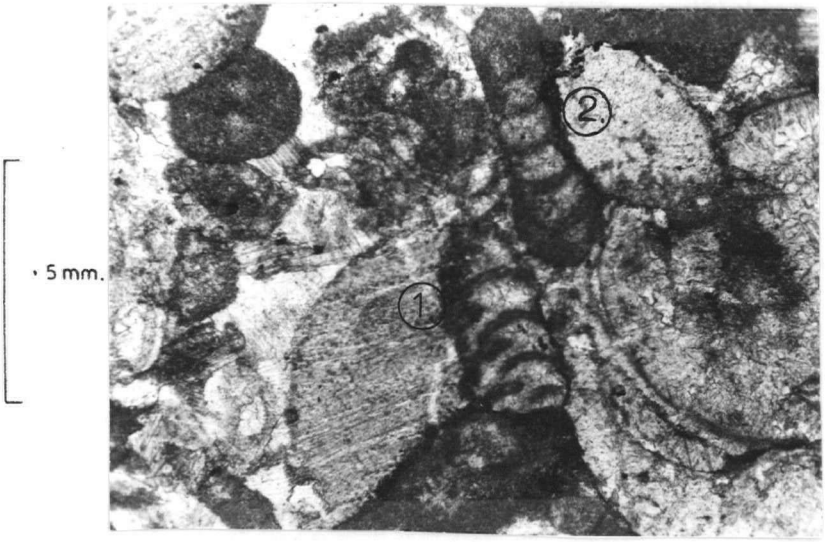

·5 mm.
1
2

PLATE 13

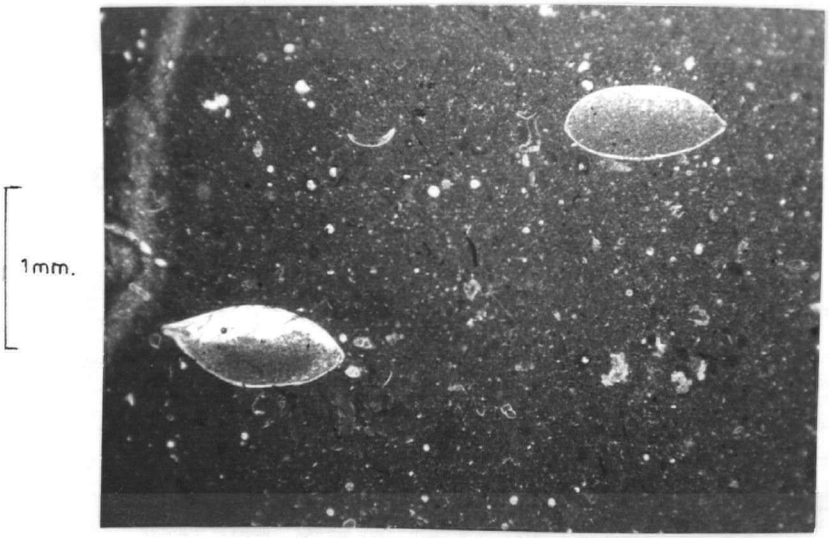
A and B

Geopetal Texture

Fluffy lime mud partly fills the ostracode shells and ? burrows; precipitated sparry calcite fills the upper parts of cavities. The groundmoss is micrite carrying calcispheres and traces of indeterminate organic material. Subfacies Fb.

Shunda Formation (Osagean)

(57D9. 774)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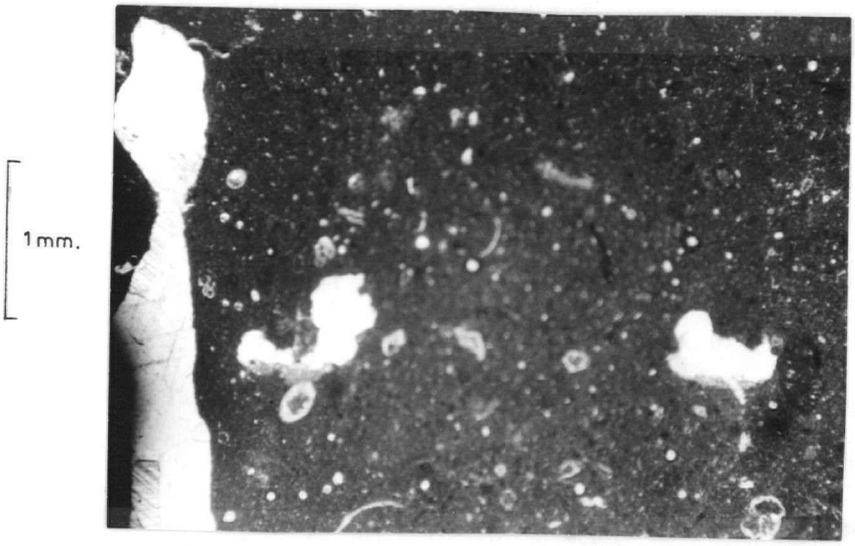
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PLATE 14

Possible sponge spicules

The slide is of a sparry portion of facies C, crinoid grains (C) and possible sponge spicules (ss) are cemented by sparry calcite.

Banff Formation - Crinoidal Unit (Kinderhookian)

(57D3b, 1403-1413)

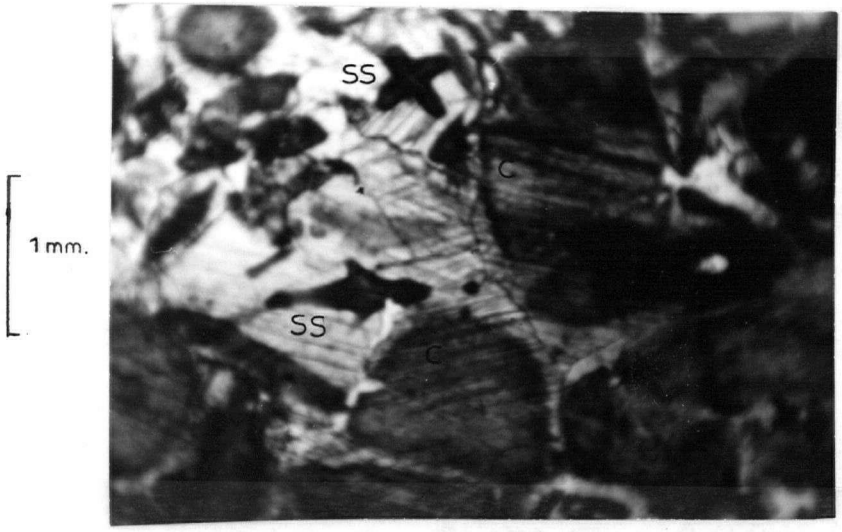

SS
C
1 mm.
SS
C

PLATE 15

Composite Intraclast

A This rounded intraclast grain, itself, contains crinoid and composite intraclast grains. The original sparry cement within the composite intraclast has been recrystallized to micro-grained calcite. Other grains visible include crinoid fragments, foraminifers (f) and ? bryozoans (b). Three generations (1, 2 and 3) of crinoidal sediment may be inferred. The original sparry cement of the intermediate generation must have been well formed by the time the last stage intraclast was born. Final cement is sparry calcite: subfacies Db.

Pekisko Formation (late Kinderhookian - early Osagean).

(57D7. 983-988)

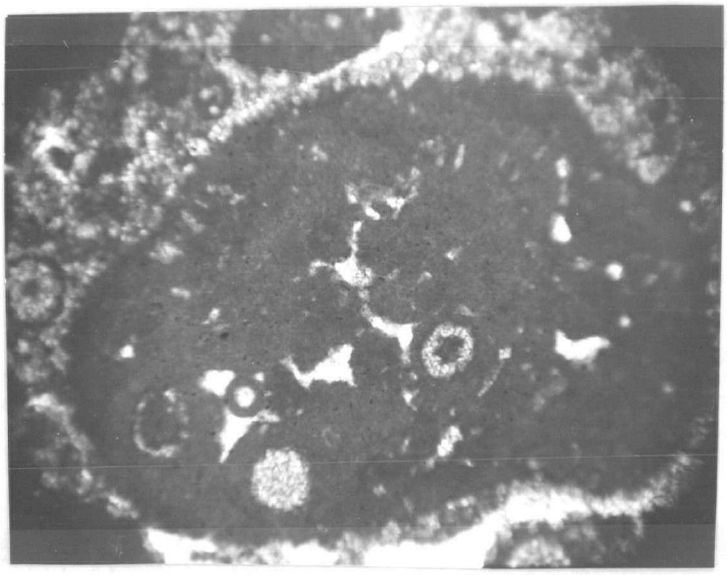
Grapestone - like Intraclast

B Note that this composite grain has a crypto-grained homogenous outer zone and an inner zone within which individual grains are distinguishable, partly outlined by clear calcium carbonate cement. Compare this grain and similar grains in Plates 25A, 26A and 27A to the modern Bahaman grapestone grains illustrated by Illing (1954, Plate 3) and Purdy (1963, Plates 2 and 4).

Basal Turner Balley Beds (Osagean).

(57D9. 782)

1 mm.



·5mm.

PLATE 16

Oolite Grains

A Nuclei are formed by crinoid fragments and cryptograined intraclasts, the cement is sparry calcite.

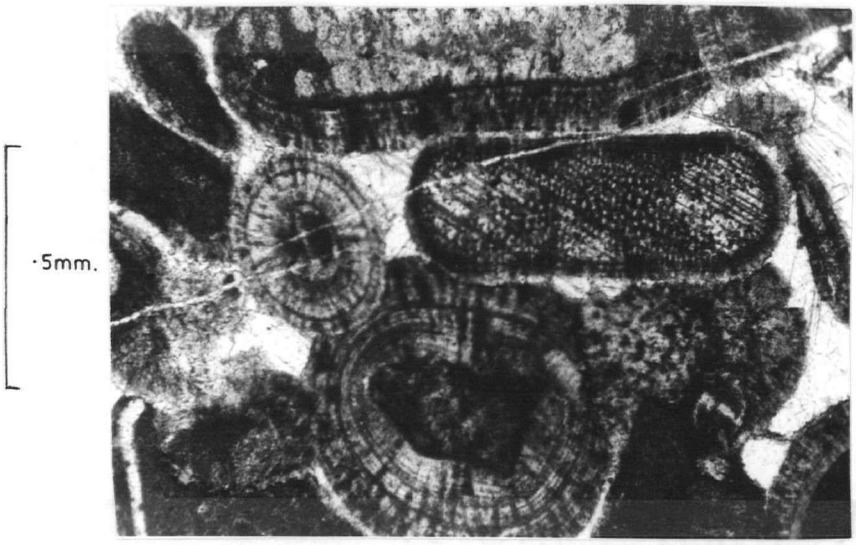
Top of Pekisko Formation (Late Kinderhookian - early Osagean).

(57D7. 923-933)

B Nuclei are formed by cryptograined intraclasts, crinoid fragments and a foraminifer, the cement is sparry calcite.

Top of Pekisko Formation (Late Kinderhookian - early Osagean).

(57D7. 923-933)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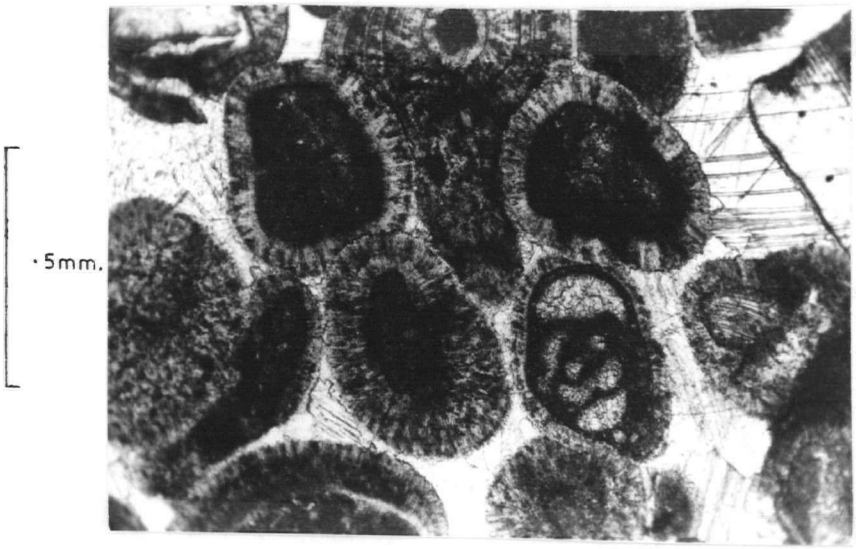

·5mm.

some of the grains classified as unidentified organic fragments may be altered pelecypod fragments.

Conodonts. These fossils are typical of the Exshaw Formation in Alberta and are found in this formation at the Mumm Creek exposures - Plate 36A.

INORGANIC ALLOCHEM GRAIN TYPES

Intraclasts. This term was introduced by Folk (1959) to describe sedimentary grains resulting from penecontemporaneous erosion of partly lithified sediments from nearby parts of the sea bottom. Folk (1962, p. 64) intends the term to cover a wide range of particles that originate in many different ways and specifically includes the "grapestone aggregates" of Illing (1954). It follows that Folk would include the grains originating as accretionary "friable aggregates" and "grains of aragonite matrix" described by Illing, provided that these grains were greater than 150 microns in diameter. Grains in these last three categories have been called "Bahamite grains" (Beales, 1958). Grains originating from the reworking of barely cohesive lime mud, if of the required size, are also classified as intraclasts. Although most of the intraclast grains found in the Mississippian of the area are rounded, the sorting in intraclast-rich rocks varies from very well sorted to very poorly sorted; this apparently anomalous relationship may in part reflect the rapidity with which fragments of soft, partly lithified material were rounded during transportation for short distances. Some of the intraclasts may have been formed faecally.

The pasticity of some intraclast grains at the time they were deposited is suggested by the manner in which these grains pack together (Plate 25B) or by the shapes they take when packed with firmer grains such as oolites

or skeletal grains. In this thesis, the term 'intraclast' is applied to composite grains showing internal structure and to homogeneous rounded grains composed either of finely micrograined or cryptograined calcite. The term is restricted to grains of greater than 150 microns in diameter and the intraclasts of the Mississippian rocks of the area range in size from this arbitrary figure to pebbles 2 cm. in diameter. The composite intraclast grains may contain pellets, oolites, intraclasts, calcispheres and other organic grains - Plate 23; a few of the grains have the internal structure characteristic of grapestone lumps (Plates 15B, 25A, 26A-B and 27A-B). The latter grains have a dark crytocrystalline outer zone within which the original constituent grain boundries are indistinguishable. The composite nature of these grains is evident inside the outer zone where individual grains can be distinguished in some cases outlined by sparry calcite bodies. These composite grains have a strong resemblance to the "grapestone lumps" described by Illing (1954, pp. 30-31, Plate 3) and later by Purdy (1963, pp. 343-345 Plates 2 and 4) from the modern sediments of the Bahamas.

Many of the homogenous intraclast grains are the end product of a recrystallization process and may have originally been crinoid fragments, algal balls, oolites, grapestone grains, faecal pellets or mud aggregates. Recrystallization is discussed at the end of this chapter. Sedimentary grains, in which bodies of cryptograined calcite are enclosed by an unidentifiable organic sheath, are classed with intraclasts; where the sheath is identifiable, the grain is classified with the particular fossil form. In some cases these sheathed grains are difficult to distinguish from "superficial oolite grains" (see below). About 3% of the total Mississippian strata of the area contain numerous intraclasts.

Pellets. (Plate 8A) In this paper the term pellet is applied to rounded grains consisting of aggregates of micritic carbonate with an upper size limit of 150 microns forming the arbitrary border between intraclasts and pellets. Folk (1962, pp. 64-5) considers that particles of this type are probably invertebrate faecal pellets. The writer, however, has considerable reservations as to the faecal origin of many of the pellets encountered in the Mississippian rocks of the area because there usually seems to be a gradation in size from pellets to large intraclasts, suggesting that the pellets are minute intraclasts or vice versa. A certain proportion of the pellets probably represent recrystallized grains; the association of pellets with calcispheres and elongate birdseyes, both of which have a postulated algal origin, suggests that these pellets are also formed by algae.

The saturated to supersaturated conditions which existed during Shunda deposition would favour the formation of the accretionary particles described by Illing (1954). The latter origin is suggested by Beales (1958) for rock building particles of pellet and intraclast type found in many Paleozoic formations. Rocks built by these particles, as previously mentioned, are called Bahamites by Beales. Recognizable pellet-bearing rocks make up 1% of the Mississippian strata studied in the area.

Oolites. Oolite grains are formed under modern conditions where tidal current action is particularly strong in warm, shallow waters supersaturated with calcium carbonate (Illing, 1954). In the Mississippian rocks studied, the oolitic sheaths commonly have a radial structure (Plates 16A-B and 17A) suggestive of the acicular form of aragonite. These sheaths were formed by the physico-chemical precipitation of calcium carbonate around nuclei

mainly consisting of intraclasts and crinoid fragments with occasional pellets, foraminifers, bryozoan and other organic fragments. Dark patches, which interrupt laminae of many oolitic grains, are possibly due to the action of blue-green and green algae. Newell et al (1960, p. 490, Plates 1C, 1F and 2A) shows the presence of such algae in Bahamian oolitic deposits; Purdy (1963, pp. 346-7) reports that dark blebs, similar to those observed in the Mississippian samples, are due to boring algae. The oolite grains are typically well sorted and rounded. The beds containing recognizable oolites are confined to the Rundle Group and comprise 1% of this Group.

Superficial Oölites. The term superficial oolite is used in a sense similar to that used by Illing 1954 (pp. 35-36) for grains only having a thin external oolitic layer. These grains may have originated in an environment approaching that of the oolites, but with current action much weaker. The grains usually consist of micrite with a faint thin outer rim either lighter or darker than the nucleus. The grains are usually rounded and well sorted.

CRYPTOGRAINED OOZES (ORTHOCHEMICAL)

Micrite. This term was proposed by Folk (1959) for cryptograined calcite ooze with grains 1-4 microns in diameter. He considers that this material forms mainly by biochemical or physico-chemical precipitation in sea water with only a negligible amount being produced by abrasion of organic debris (Folk, 1959, p. 8 and 1962, p. 66). Other workers feel that most modern lime muds form from the abrasion and break down of skeletal debris.

Most of the Shunda Formation and possibly part of the Mount Head Formation of the area was laid down as micrite. The Shunda of the Mumm

Creek section is an excellent sample of a thick sequence of relatively unaltered micrite interbedded with typically associated beds. It is difficult to determine how much of the unfossiliferous finely micrograined Mount Head dolomites were laid down as micrites and how much as dolomicrites.

Dolomicrite. This term was proposed by Folk (1959) for primary dolomite ooze analgous to the micrites. Much of the Mount Head Formation may have been laid down as a primary dolomite ooze - the evidence which suggests this origin is the presence in these dolomites of microbedding, discussed later in this chapter in connection with Facies G.

TERRIGENOUS PARTICLES

Grains presumably derived from exposed land surfaces volumetrically make up a very small fraction of the Rundle Group. However, clay may account for perhaps 30% of the Banff Formation.

Clay. The argillaceous material abundant in the Banff, and especially in the lower part of this formation, has a brown colour when separated from the limestones and small amounts of similar material are also present in the Rundle Group. Green shale beds occurring in the Mount Head Formation are similar to the bentonitic beds referred to by Nelson (1961, p. 21).

Quartz Silt and Sand. Only a trace of these terrigenous grains is present but they tend to be localized to certain horizons resulting in the production of useful stratigraphic markers.

Volcanic Ash. Beds interpreted as being largely derived from volcanic ash showers occur at two horizons. The first horizon is in the Exshaw and contains angular fragments of quartz and sanidine set in an amorphous

ground mass. The second horizon, in the lower part of the Turner Valley Formation, contains scattered angular silt-sized mineral fragments set in a weakly birefringent matrix.

CEMENT (PRIMARY PRECIPITATED CEMENT)

Sparry Calcite Cement. The washed calcarenites are cemented with clear calcite spar which frequently forms overgrowths on crinoid fragments in optical continuity with the organic crystal. Some of the calcite cement may have originally been precipitated as aragonite and later inverted to calcite. In a few thin sections the cement has a fibrous radiating habit similar to the aragonite prism cement illustrated by Illing (1954, Plates 3 - 8).

Dolomite Cement. Primary dolomites, per se, probably had a dolomite cement but in the rocks which may be primary dolomites, some of the facies G rocks, this cement is indistinguishable from the grains owing to development of a grain growth mosaic.

ALTERATION

A large proportion of the Mississippian rocks of the area have suffered some degree of alteration and in some cases it is rather difficult to determine the original rock type. The types of alteration observed, or suspected, in these rocks are listed below:

(1) Dolomitization

(2) Inversion of aragonite to calcite

(3) Cementation by sparry calcite

(4) Solution

(5) Silification

(6) Recrystallization

(7) Fracturing

(8) Vug filling

Dolomitization. Dolomitization is by far the most important type of alteration found in the Mississippian rocks of the area. Some grains were more resistent to dolomitization than others, and Plates 11A, 19A and 27A-B illustrate some of the evidence for the order, shown below.

Apparent ease of dolomitization:

Micrite $>$ Micritic intraclasts, algal balls $>$ Organic fragments $\geq$ sparry calcite cement

The argillaceous limestones of the Banff Formation were not subject to much dolomitization. Most of the porous rocks found in the sections are dolomites; ghost textures and the presence of fossils strongly suggest that most of these porous rocks are secondary dolomites derived from the replacement of original bioclastic limestones. Dolomitization was probably partly controlled by the degree of original porosity; in many cases, porosity was increased as a result of the replacement process. In some cases dolomitization proceeded in such a fashion that much of the original texture was preserved (Plate 31A-B and 34A); in other cases preservation is less perfect and it is more difficult to determine the original rock type (Plates 32, 33 and 34B).

Inversion of Aragonite to Calcite. A large proportion of modern carbonate deposits are composed of aragonite, a metastable form of calcium carbonate. Aragonite is an important constituent of mollusk, coral and algal skeletons, and it is also the common form assumed by calcium carbonate in modern so-called "inorganic" deposits.

The Mississippian deposits of the area have many similarities to the deposits of the Bahama banks, which are largely aragonitic, so that a proportion of the Mississippian rocks may have undergone inversion from aragonite to calcite at some period in their history. The following rock types of the Rundle are especially similar to the modern aragonitic deposits of the Bahamas.

(a) Pure carbonate micrites and dismicrites (subfacies Fb)

(b) Oosparites (subfacies Ea)

(c) Oolitic, grapestone bearing intramicrites (subfacies Eb -lithotype 4)

(d) Grapestone bearing intrasparites (subfacies Eb -lithotype 2)

(e) Oolitic merged-intrasparites (subfacies Eb-lithotype 3)

(f) Pure carbonate biomicrites (subfacies Fa)

In addition, some of the gastropod shells and unidentified carbonate, possibly pelecypod, grains which are found in the rocks studied have probably suffered inversion since both ancient and modern gastropod and pelecypod shells are largely composed of aragonite.

Cementation by Sparry Calcite. The cementation by sparry calcite is thought to have occurred at an early stage, following deposition of the grains, and may have been penecontemporaneous with deposition. Evidence for early cementation is provided by Plate 15A. As mentioned previously, the sparry calcite cement frequently crystallized, externally as well as internally, in optical continuity with the crinoid grains (Plate 35A). In some of the thin sections the earliest cement deposited had a fibrous radiating habit suggestive of the aragonite prism cement found in recent sediments of the Bahamas (Illing, 1954, Plates 3-8).

Solution. Solution has resulted in the appearance of the following features in the rocks studied:

(1) Stylolites

(2) Vugs

(3) Dolomite breccias

(4) Welded ossicle contacts.

The stylolites were found to be much more common in the Rundle limestones than in the more argillaceous Banff limestones. Many of the vugs found in the Rundle are probably solution features and in places, were observed to have the shape of crinoid ossicles. Facies H, as mentioned previously, is thought to be due to the solution of evaporites similar to those found further to the southeast in the Jasper #1 (Lang, 1947a) and Solomon Creek Wells. The observed interlocking contacts between crinoid ossicles is believed to have been produced by solution under pressure. The pressure welding reduces the size of interstitial spaces which are usually filled with sparry calcite, partly derived from the pressure solution process.

Silicification. Some of the cherts may have originated as primary precipitates from seawater but much of the silicification is thought to be early-diagenetic. Cherts were observed which had textures similar to those found in unaltered carbonates, including fine laminations, pelletal structures and calispheres. The latter cherts are clearly silica replacements of the carbonates.

In parts of the sections and especially in the Turner Valley equivalent, most of the fossils are silicified. The silicification of fossils may have a relationship to the conditions which produced dolomitization, since the silicified fossils were only found in the dolomites. Emery and Rittenberg

(1952) suggested that the early diagenetic formation of chert is due to the changes in pH which occur in the upper few feet of sediment. These workers found that the upper few inches of recent marine sediments were acidic, but below these few inches alkaline conditions prevailed. Siliceous material tends to go into solution under alkaline conditions. During compaction, the silcia-rich solutions formed are squeezed out and silica is precipitated into the upper acidic environment with replacement of fossils and lime muds. In a few thin sections, silicification takes the form of randomly oriented minute quartz prisms which show a preference for microcrystalline hosts such as micritic matrix and intraclasts.

RECRYSTALLIZATION (penecontemporaneously with deposition?)

Great quantities of cryptocrystalline grains, similar to the grains embraced by the terms intraclast and pellet in this thesis, are present in the deposits of the Great Bahama Bank. Purdy (1963, p. 348) in referring to these grains states:

> "There can be no doubt that cryptocrystalline grains are a recrystallization produce, for all stages were observed in the transition of various non-skeletal and skeletal constituents to cryptocrystalline carbonate. In each instance, the alteration process tends to produce a homogenous texture throughout the affected grain."

The presence of recrystallized grains in the modern Bahamian sediments suggests that such recrystallization is penecontemporaneous with deposition but in this respect these sediments may be atypical due to recent changes in sea level.

In the Mississippian rocks of the subject area, transitions were observed from grains with clearly recognizable internal structure, including crinoid fragments, oolitic grains and grapestone grains, to homogenous

micrograined or cryptograined bodies, termed intraclasts. Since transitional grains were rather difficult to find in the thin sections where homogenous intraclasts are mixed with crinoid, oolite or grapestone grains, recrystallization may have played only a minor role in the alteration of the grains. The rocks which show the transitional types were mostly assigned to subfacies Da and Eb. Plate 22A shows partly altered crinoid grains, Plates 26A-B and 27A-B show grapestone grains in various stages of recrystallization and in Plates 24B and 26A-B the faint oolitic structure of some grains suggests that a portion of the homogenous grains present could be altered oolites.

Fracturing and Recrystallization. Most of the fracturing of the Mississippian rocks of the area is probably related to the Laramide Orogeny. Fractures were mostly found to be filled with sparry calcite.

Some of the recrystallization of crinoid ossicles seems to be related to the same period as the fracturing; the recrystallization of crinoid ossicles with the development of polysynthetic twinning is especially intense where the rocks are strongly deformed.

Vug Filling. Material found in vugs includes bitumen, sparry dolomite, quartz and sparry calcite. From the few vugs examined, where relationships could be seen, the following sequence is suggested for a vug formed in dolomite:

(1) Early periferal development of space-grown dolomite

(2) Migration of oil into vugs

(3) Development of quartz crystals in vugs

(4) Sparry calcite deposition in vugs

(5) Fracturing - calcite veins cut all preceding vug deposits.

SEQUENCE OF ALTERATION

The sequence of alteration shown below is suggested by a variety of evidence. Vug formation took place at various times during diagenesis; the most important period may have followed partial dolomitization (Plate 32). In any particular case, one or more steps may be missing and reversals may occur.

(1) Sediment deposition and penecontemporaneous recrystallization

(2) Cementation and pressure welding of crinoid grains

(3) Dolomitization, silicification

(4) Oil migration into vugs

(5) Quartz crystals developed in vugs

(6) Sparry calcite deposition in vugs

(7) Fracturing and recrystallization

(8) Solution of evaporites

(9) Present weathering

TEXTURES

Primary textures observed in the Mississippian rocks of the area may be fitted into a textural spectrum similar in a general way to that shown in Figure 8.

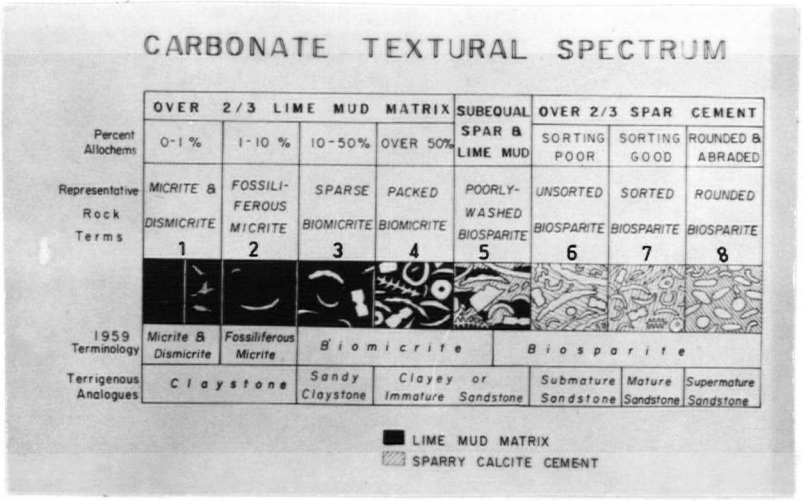


Fig. 8 (after Folk Fig. 4, 1962)
In this figure lower energy sediments have textures to the left, while those of higher energy occur to the right. Note that from left to right the percentage of allochems increases to a maximum beyond which higher energy levels are represented firstly, by washing out of the interallochem lime mud, the most distinct break on the scale, and secondly, by sorting and rounding of the allochems.

The above figure depicts the carbonate textural spectrum with fossil fragment allochems and a micrite matrix, but rocks with variations in the type of matrix and allochem are analogous, other things being equal, and may be fitted into this type of spectrum with an energy level interpretation a consequence of the position in the spectrum. The textural spectrum, however, cannot be used as an absolute energy level scale, for rates of supply of material and other factors have to be considered. For example, rounding of grains must be interpreted, recalling that some grains may be soft and easily rounded, while other grains such as oolites, may be fundamentally round. Crinoidal rounded biosparites were not found among

the Mississippian rocks of the area, although rocks with crinoid allochems have the most complete representation in the spectrum (1 - 7): the "super mature" end member (8) is represented by oosparites and these rocks, in fact, may have originated in the highest energy environment which existed in the Mississippian.

The matrix of the Banff and Rundle rocks are markedly different from each other. The Rundle matrix for the most part consists either of pure calcium carbonate micrite (Plate 28A) or calcite spar cement. In contrast, the matrix of the Banff rocks typically consists of a pasty mixture of argillaceous and micritic material with large amounts of silt-sized, unicrystalline calcite grains present through much of the section, the largest percentage of which probably represent broken-up crinoid fragments (Plates 17B and 18A-B). Sparry calcite cement is present in varying amounts in the matrix of the Banff crinoidal calcarenites. The argillaceous nature of the Banff as a whole results in the characteristic brownish weathering appearance of the formation which contrasts strongly with the grey of the underlying Palliser and overlying Rundle rocks.

FACIES

In 1838 Gressly recognized that a particular stratigraphic unit changed in the horizontal dimension in its petrographic nature and fossil content and he called the resulting assemblages of modifications facies or aspects of the unit (Dunbar and Rodgers, 1957). Since this original definition of the term facies by Gressly, geologists have widened its definition and usage extensively; basically, there are two main areas of usage today, petrographic and stratigraphic. In this thesis 'facies' is used primarily in a descriptive petrographic sense. This descriptive petrographic usage leads

to discrimination of more subtle stratigraphic relationships than would normally be discernible under the classical usage of the term.

Illing (1959 a and b) found that the Mississippian rocks at Moose Dome (Figure 9, this thesis) could be assigned to eight "phases" each typified by the preponderance of certain petrographic types - for example, phase D by bioclastic limestones with sparry cement. The eight main facies which are used in this thesis are basically similar to Illing's "phases" and the same lettering system is applied, however, refinements have been added by the splitting, where possible, of facies D, E and F into subfacies Da, Db, Ea, Eb, Fa and Fb. The defined facies boundaries are arbitrary as the types grade into one another. In the field, however, the transition from one facies to another was found in some cases to be quite sharp.

DESCRIPTION OF FACIES

Facies A. (Plates 17B and 18A-B) Facies A was only found in the Banff Formation and in outcrop is seen to consist of dark grey, pyritic, argillaceous calcilutites, cherty in part and containing a few traces of clearly recognizable crinoid fragments. These limestones are associated with calcareous shales which are lumped with Facies A. The facies commonly occurs as a thin bedded sequence of argillaceous calcilutites rhythmically interbedded with somewhat thinner calcilutite beds which have a higher argillaceous content than the other beds and grade to grey limy shales. The sequence has a brownish weathering colour. Microscopically, the facies was found to have numerous 20-40 micron, silt-sized, unicrystalline calcite grains with traces of recognizable crinoid grains together with a few ostracode valves. The crinoid grains range from the silt-size to 1.2 mm. in diameter. These grains are set in an argillaceous cryptograined lime matrix, the whole forming a pasty mixture. Assuming that the silt-sized grains are

PLATE 17

A

Oolite Grains

Nuclei include a bryozoan fragment, crinoid fragments and intraclasts. The uncoated foraminifer is Endothyra sp. indet. The dark patches interrupting oolite laminae are possibly due to the action of blue green and green algae.

Top of Pekisko Formation (late Kinderhookian - early Osagean).

(57D7. 923-933)

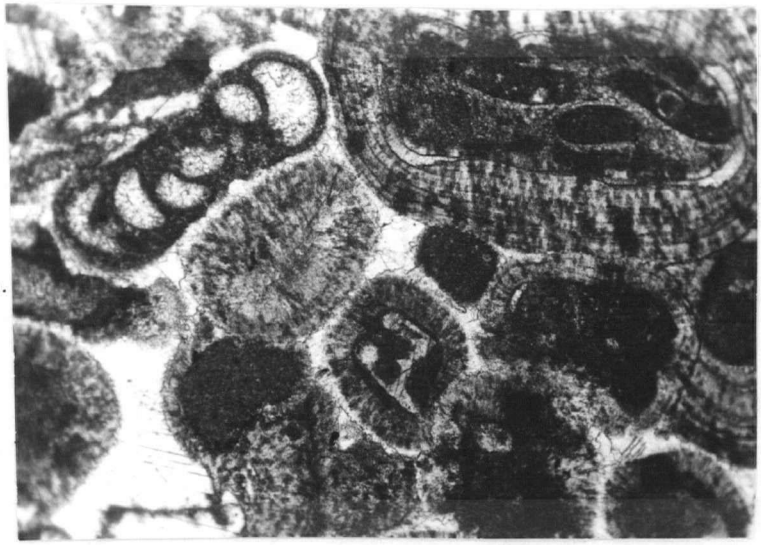
B

Facies A

Argillaceous calcisiltite with numerous fine sand-silt sized (? crinoid) fragments and some quartz silt grains mixed in a pasty matrix, with probable ostracode valves.

Banff - Cherty Unit (Kinderhookian)

(57D9. 147)



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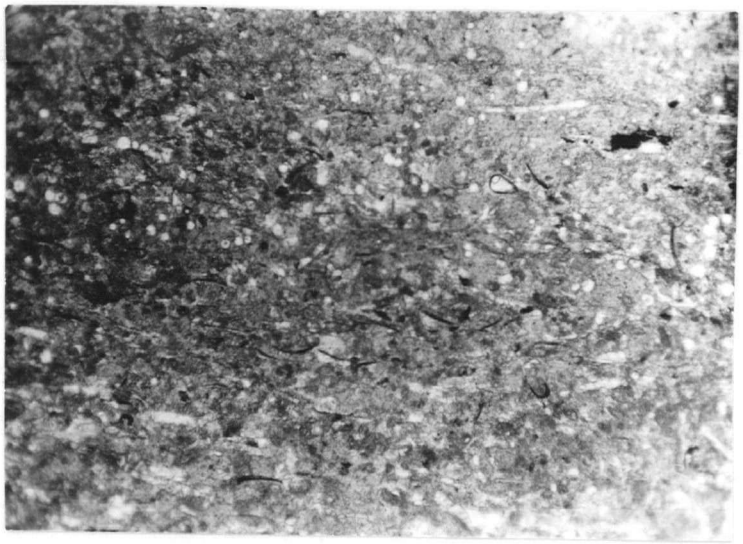

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PLATE 18

Facies A

A Argillaceous calcisiltite. The silt sized grains have unit extinction and probably are crinoidal.

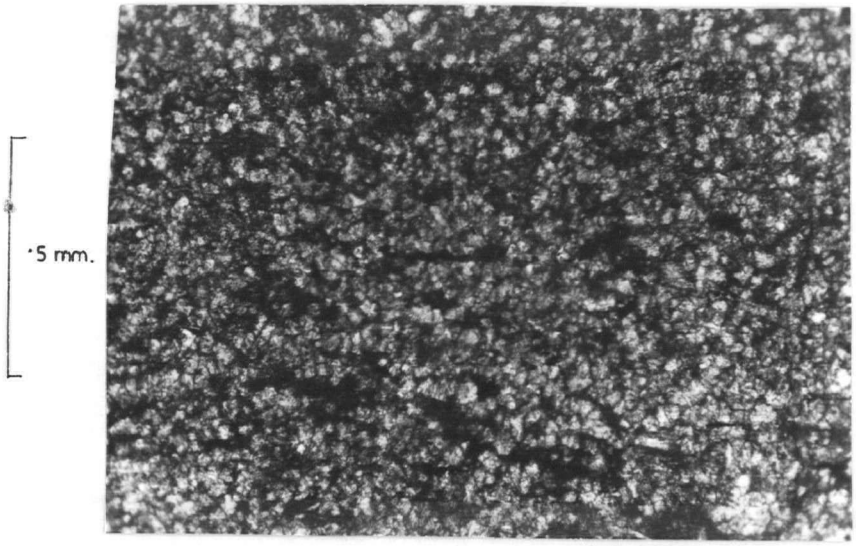
Banff - Cherty Unit (Kinderhookian)

(57D3b. 1662-69)

B Argillaceous calcisiltite with poorly sorted crinoid fragments mixed in the pasty matrix with traces of quartz silt.

Banff - Cherty Unit (Kinderhookian)

(57D3b. 1507-1516)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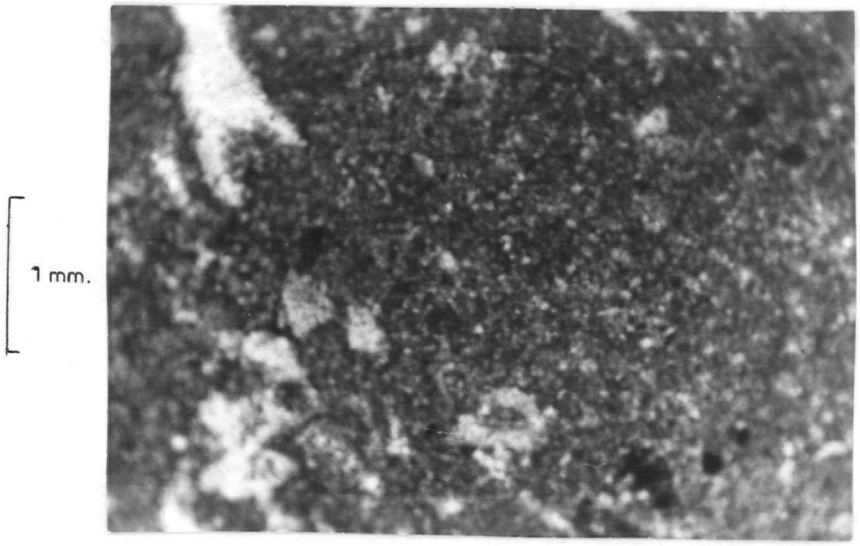

1 mm.

crinoidal, the rock, could be called 'calcisiltite: argillaceous crinoid biomicrite', using Folks classification.

Facies B. (Plate 19A-B) In parts of the Banff Formation continuous sequences of beds were found, making up an appreciable thickness of strata, in which the rock types alternate between those of facies A and the crinoidal biomicrites of facies C type. In this interbedded zone, defined as facies B, the crinoidal beds range from 2 inches to 3 feet in thickness, but are mostly between 4 inches and 9 inches in thickness. Dolomites and siltstones, present in the top zone of the Banff and lumped with facies B will be discussed later.

Facies C. (Plates 14 and 20) Facies C was found to be restricted to the Banff Formation. In outcrop this facies appears as a relatively resistive series of light brown-grey, fine to coarse grained crinoidal biomicrites. The facies forms a good marker bed which is easily picked out in the general views of the sections (Plates 3 to 8). These biomicrites occur as ash-grey weathering beds, ranging from 3 inches to 3 feet in thickness, commonly separated by argillaceous partings; ripple marks were observed at one locality. Microscopically the rock of facies C is seen to be composed of crinoid fragment allochems which, together with a small percentage of bryozoan fragments and traces of brachiopod and coral fragments, make up between 65% and 75% of the rock volume. The remaining percentage consists of dark argillaceous cryptograined micritic material and sparry calcite. The amount of these last two constituents varies so that in some specimens (Plate 20) only a trace of sparry calcite cement is present, and the spaces between the fossil fragments are filled with the micritic material. In other specimens only a trace of micritic material is observed and the

PLATE 19

Facies B (Crinoidal Bed)

A Poorly sorted, angular crinoid fragments with a small mud-filled bivalve fossil and a possible echinoid spine (e) in a pasty, argillaceous, micritic, and slightly dolomitized (preferentially) matrix. Traces of sparry calcite cement adjoin some of the crinoid fragments.

Banff - Upper unit (Kinderhookian)

(57D9. 363-368)

B Crinoid, echinoid spine (e), shell and bryozoan grains, the bryozoans may be of an encrusting sort. The matrix is a slightly dolomitized, argillaceous lime mud. Note the prevalence of sparry overgrowths on echinoderm grains.

Banff - Upper unit (Kinderhookian)

(57D9. 496)


1 mm.


1 mm.
e
e
e
e
e

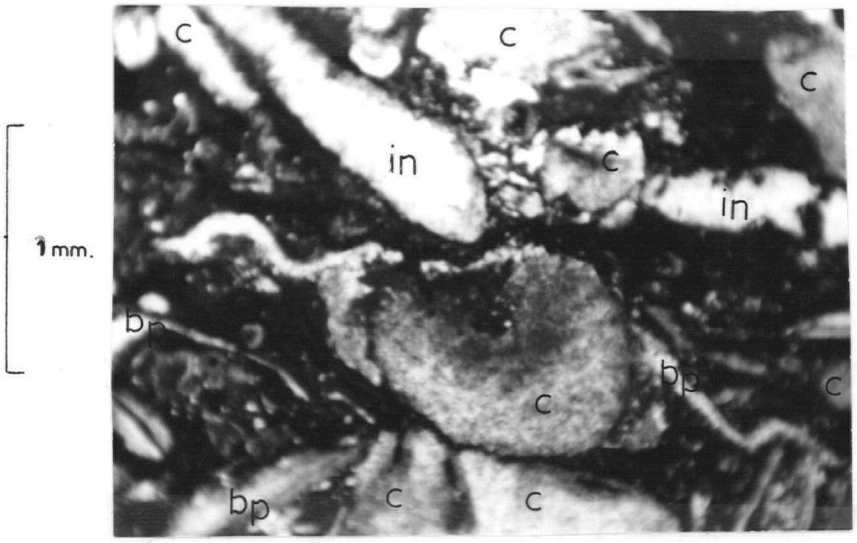
PLATE 20

Facies C

Argillaceous, crinoidal biomicrite with crinoid (c), brachiopod (bp) and indeterminate grains (in) in an argillaceous, pasty, partly dolomitized matrix.

Banff - Upper unit (Kinderhookian)

(57D3b. 1252)


c
c
c
in
c
in
1 mm.
bp
bp
c
c
bp
c
c

texture approaches that of facies D (Plate 14).

Facies D. This facies is found in the Pekisko, Jasper Lake, Turner Valley and Mount Head Formations, and to a limited extent in the Banff Crinoidal Unit. In outcrop, facies D is seen to consist of a resistive sequence of ash-grey weathering sucrosic crinoidal calcarenites, the colour of which ranges from light grey to dark grey owing to a variation in the bitumen content. Few bedding planes are visible and the sequence tends to be massive. Crossbedding was observed at several places in the outcrops of facies D. Grain size ranges from very fine to very coarse. The unaltered calcarenites have traces of intergranular and small vug porosity. Microscopically, facies D can be split into subfacies Da and Db, although where the rock has been altered this becomes more difficult. The Db subfacies tends to consist of coarse-grained angular crinoid fragments with a minor proportion of homogenous intraclasts; in the Da subfacies, crinoid grains are a minor constituent and the rock contains a large number of medium-grained, rounded homogenous intraclasts.

Subfacies Da. (Plate 21A-C) Subfacies Da was only identified in the Jasper Lake and Pekisko Formations. Microscopically, this subfacies is typified by the preponderance of homogenous cryptograined intraclasts with recognizable crinoid grains occupying an important but subsidiary part of the volume; sparry calcite forms the cement.

Minor components include foraminifers (locally important volumetrically) and fragments of brachiopods, fenestellid bryozoans and echinoid spines. The presence of relatively unabraded single and colonial corals, brachiopods and gastropods suggests that these represent a portion of an indigenous fauna which also included crinoids, foraminifers, echinoids and ostracodes.

PLATE 21

A and B — Subfacies Da

Well-sorted, crinoidal intrasparites containing a few foraminiferal, bryozoan, echinoid spine and shell fragments. The intraclasts consist of cryptocrystalline calcite and may in part represent recrystallized crinoid grains. The rock is cemented with sparry calcite.

Pekisko Formation (late Kinderhookian - early Osagean)

A (57D3b. 1165-75)

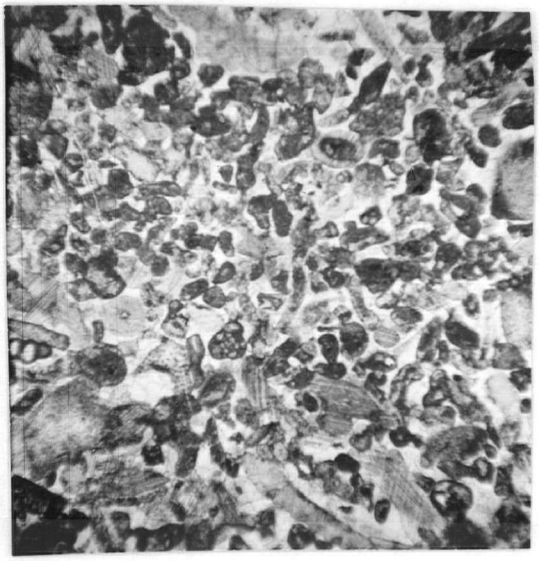
B (57D3b. 1160-65)

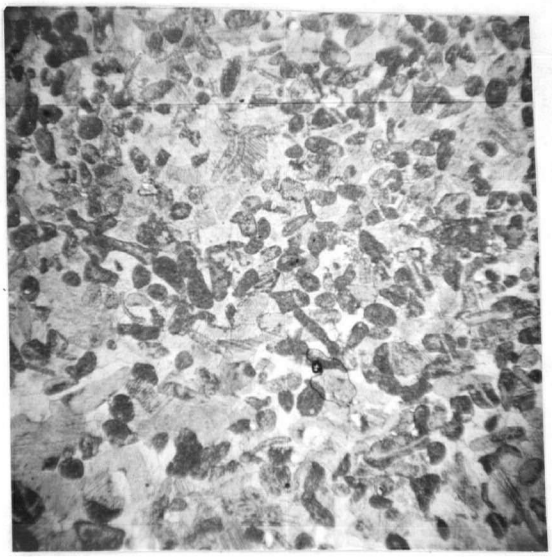
C — Subfacies Da - Laminated Brachiopod-rich Phase

Grains include crinoid (c), crinoid plate (p), intraclasts (i), brachiopod (dp), echinoid spine (e), dasycladacean algae (d) and fossil-cast intraclasts or ? superficial colites (fi). The cement is sparry calcite.

Jasper Lake Formation (Osagean)

(57D3b. 820-825)





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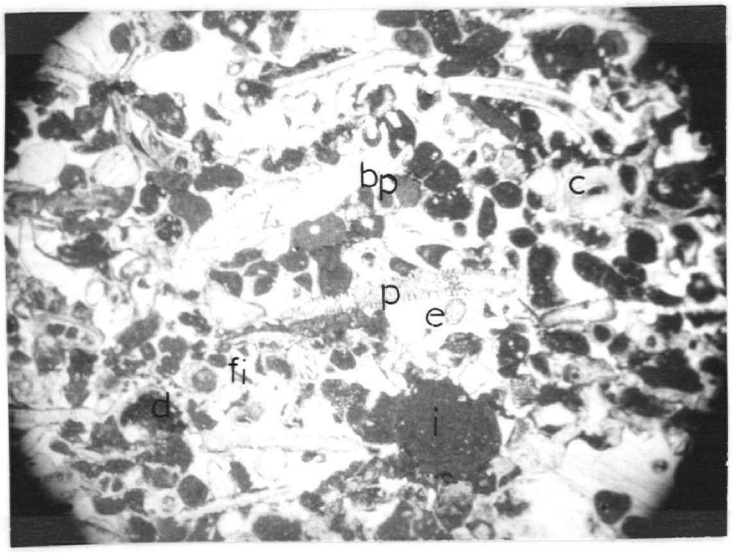


PLATE 22

Subfacies Db

A Poorly sorted, intraclast bearing, crinoidal biosparite. The intraclast grains are dark homogenous grains, many of which are probably altered crinoid fragments, witness the partly altered grain indicated by an arrow. In addition to crinoid and intraclast grains the rock has foraminifers and ? brachiopod fragments. The cement is sparry calcite.

Pekisko Formation (late Kinderhookian - early Osagean).

(57D9. 519)

B Poorly - moderately sorted, intraclast bearing biosparite. Grains consist of crinoid (c), bryozoan (b), foraminifer (f), echinoid spine (e), ostracode (o), composite intraclasts (ic) and fossil sheathed intraclasts (is). Note the micrite filling the internal canals of crinoid grains.

Pekisko Formation (late Kinderhookian - early Osagean).

(57D7. 988-998)


1mm.


1mm.
c
b
c
ic
e
ic
b
f
is
c

The grains are rounded to very well rounded and moderately to very well sorted, with sizes ranging from very fine to coarse sand. Many of the intraclast grains are thought to represent recrystallized crinoidal material. The rock may be described as a mature, fossiliferous crinoidal intrasparite.

A minor phase of subfacies Da is marked by an abundance of brachiopod and crinoid plate fragments which give this phase a laminated texture. Dasycladacean algae are more abundant and complete in this phase of subfacies Da than in other Mississippian rocks of the area and probably, with red algae, brachiopods and foraminifers, represent part of an indigenous biota; the rock could be termed a brachiopod-bearing, crinoidal, intrasparite which contains algal remains.

Subfacies Db. (Plate 22A-B) Recognizable in the Pekisko, Jasper Lake, and Mount Head Formations and the Banff Crinoidal unit, in thin section, this subfacies is seen to be mainly composed of crinoid fragments with intraclasts forming a minor constituent of the rock; in places all the grains are crinoidal. As in subfacies Da, sparry calcite forms the cement but in the less mature parts of the subfacies a small amount of micritic lime mud occurs between the grains.

Minor components include superficial oolites, oolites and foraminifers, echinoid spines, bryozoans, corals, gastropods, ostracodes and dasycladacean algae. Crinoid debris, foraminifers, brachiopods, bryozoans, echinoids, and single and colonial corals probably represent part of an indigenous fauna. The crinoid grains range from angular to rounded and from very poorly sorted to moderately sorted with sizes grading from around 2.0 to 0.1 mm. in diameter.

The intraclast grains tend to be more rounded and better sorted than the crinoid grains and, as in subfacies Da, many of the intraclast grains

may be recrystallized crinoidal material. The rock could be described as a fossiliferous, intraclast-bearing, biosparite.

Subfacies Ea. (Plates 16A-B, 17A and 23A-B) This subfacies was only found in its unaltered state at the top of the Pekisko but it is suspected that portions of member B of the Turner Valley and the Mount Head Formation originated as this rock type. Outcrops of subfacies Ea have a similar appearance to those of facies D but microscopically Ea is seen to be mainly composed of very well-sorted oolite allochems with an average grain size of 600 microns, very well packed and cemented with sparry calcite. Oolite grains comprise about two-thirds of the allochems of the typical Ea subfacies, the remaining allochems consist of intraclasts, a minor proportion of crinoid fragments plus traces of other fossil fragments. The crinoid grains are larger and much more angular than the intraclast grains, which are mostly well rounded. The fragments which form the nuclei of the oolite grains consist of intraclasts, crinoid grains and other fossils (foraminifers, bryozoans, echinoid spines, gastropods, brachiopods and algae). The nuclei types occur in about the same proportions as the uncoated allochems in the same rock. The rock may be described as a fossiliferous, intraclast-bearing, oosparite.

The oolitic subfacies Ea is rather rare in the stratigraphic sections measured. Subfacies Ea and Eb are closely related.

Subfacies Eb. In outcrop subfacies Eb has few distinguishing features; beds found to belong to the subfacies include both thin bedded and massive types with weathering colour varying from ash-grey to buff. In some cases, the sparry calcite birdseyes are stained and give the outcrops an orange-speckled appearance.

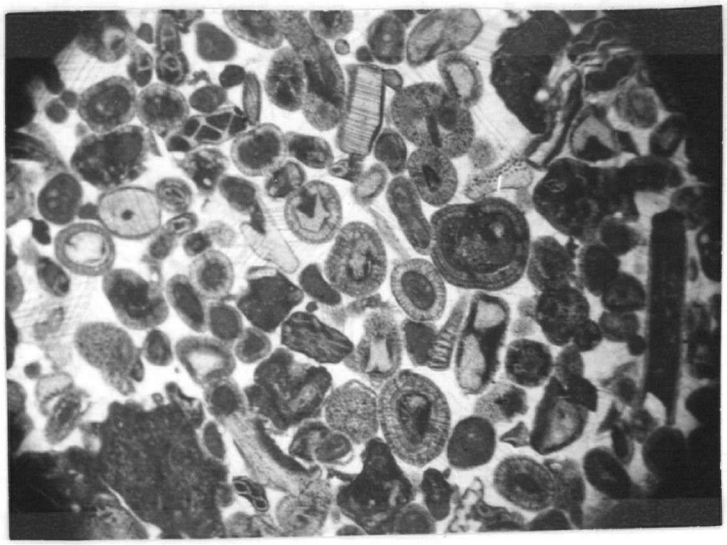
PLATE 23 A and B

Subfacies Ea

Oosparite. (See also Plates 25-27) Nuclei are mainly formed by crinoid grains and intraclasts. The crinoid grains are both angular and rounded, in part inherently round. The cement is sparry calcite,

Top of Pekisko Formation (late Kinderhookian - early Osagean)

(57D7. 923-933)



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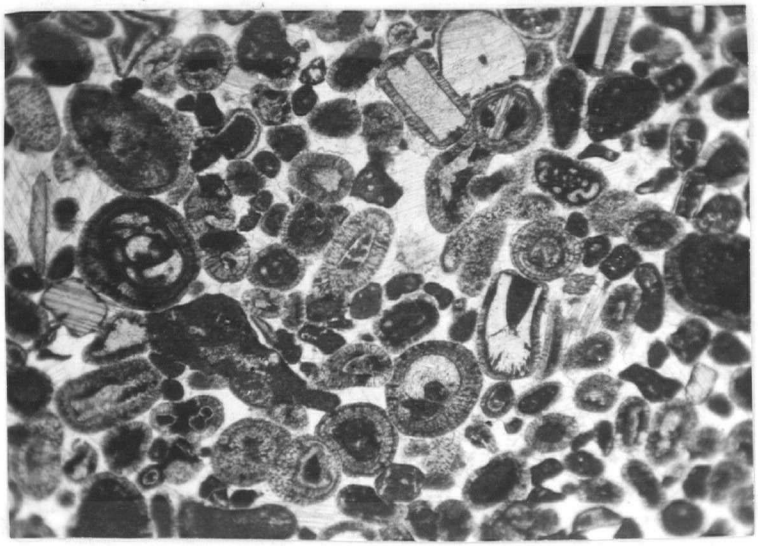

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When examined in thin section, rocks of this subfacies are observed to contain a high proportion of intraclasts and most of them contain oolite grains. The subfacies can be further subdivided into four lithotypes, which partly grade into one another.

Eb Lithotype 1. (Plates 24A and B) A large variety of grains are mixed together in this type (see description attending the above plates). The grains are very poorly sorted and tend to be angular. The largest grains are angular fragments of reworked sediment classed as intraclasts and these have an approximate size range of from 0.9 mm to 5.0 mm.

The intergranular spaces are mainly filled with sparry calcite but, in places, most of this space is filled by mud. Type 1 was only found in one thin section of a basal Turner Valley specimen and may be described as an oolitic, micritic, crinoidal, intrasparite.

Eb Lithotype 2. (Plate 25A) This lithotype is entirely composed of intraclasts, some of which can be readily recognizable as grapestone, but they mainly consist of homogenous cryptograined calcite. The intraclasts tend to be poorly sorted, angular, and cemented with sparry calcite. Evidently the grains were firm enough at the time of deposition to resist compressive distortion.

This rock type was only found in one thin section but it is similar in many respects to the "pseudo-oolite" of Illing (1959b, Plate II-6). Eb lithotype 2 is best described as a grapestone-bearing intrasparite.

Eb Lithotype 3. (Plates 25B and 34A) The intraclasts of this rock type may have been somewhat plastic at the time of deposition so that the grains tended to merge with one another or to be separated by narrow spaces which

gave form to a fine sparry calcite tracery. Larger bodies of calcite, 'birdseyes', also appear in the rock. The grains are very well sorted and range in size from fine to medium sand. The lithotype was found in the Shunda and Mount Head Formations and it could be referred to as a partially merged intrasparite. If the grains were more completely merged it would be difficult to distinguish Eb lithotype 3 from birdseye micrite of subfacies Eb.

Eb Lithotype 4. (Plates 26A-B and 27A-B) This type is distinguished by having a micritic matrix with a minor amount of sparry calcite cement. The grains consist of intraclasts, mostly of the homogenous sort, but also including recognizable grapestone lumps, oolites and calcispheres. The grains are usually rounded and very poorly sorted, with a size range from very fine to very coarse sand. Lithotype 4 was found in Pekisko, Shunda and basal Turner Valley beds and its presence is also suspected in parts of the Mount Head Formation. The rock is an oolitic, grapestone bearing, sparry, intramicrite,

Subfacies Fa. (Plate 11A) This subfacies is less widespread than most of the others and appears to be a transitional type between the micrites of facies F and the crinoidal biosparites of facies D. Facies Fa is typified by a pure limestone biomicrite containing floating crinoidal material. The crinoidal remains in facies Fa tend to be more complete than those found in facies D. It is thought that this crinoid debris was washed into the muddy environment from closely adjacent facies D crinoid banks.

Codiacean algal balls were found in this subfacies along with other skeletal material.

PLATE 24 A and B

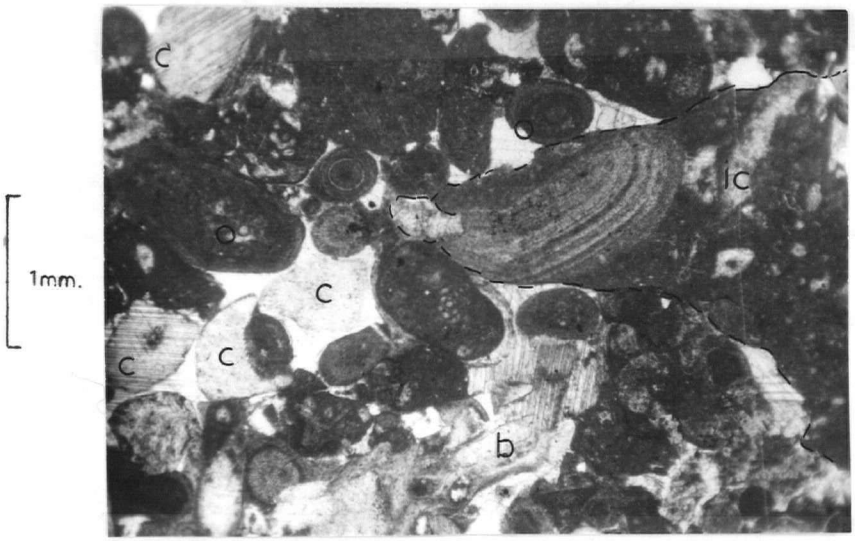
Subfacies Eb - Lithotype 1

Micritic intrasparite

The main components are large composite (partly oolitic) intraclasts (ic) plus crinoid (c) and oolite (o) grains. Other grain types present in the thin section, some of which are visible in the plates, include fragments of foraminifers (f), algae, bryozoans (b), gastropods, echinoid spines, ? corals and indeterminate organic fragments. The intergranular spaces are filled with sparry calcite plus traces of mud (m). Less obvious composite intraclast grain boundaries are shown dashed.

Basal Turner Valley beds (Osagean)

(57D3b. 685-695)



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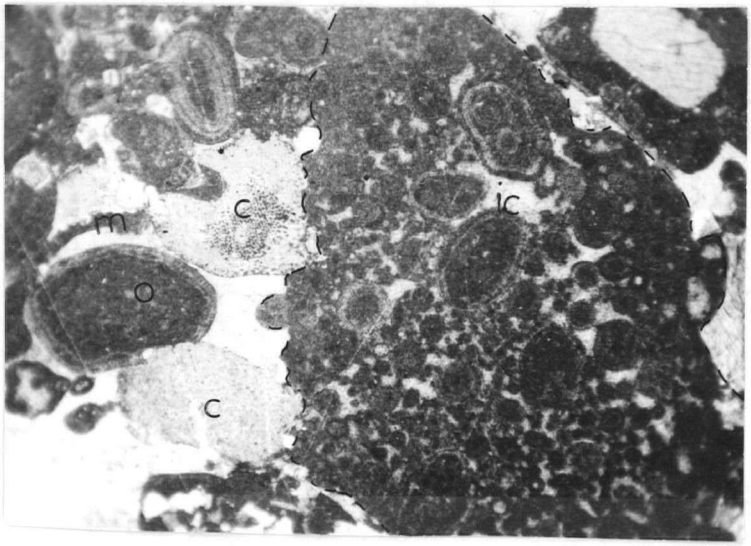

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PLATE 25

A Subfacies Eb - Lithotype 2

Grapestone bearing intrasparite

The poorly sorted, subangular intraclast grains include homogenous cryptocrystalline grains and grains with grapestone structure. The cement is sparry calcite.

Top of Pekisko Formation (late Kinderhookian - early Osagean).

(57D9. 534½)

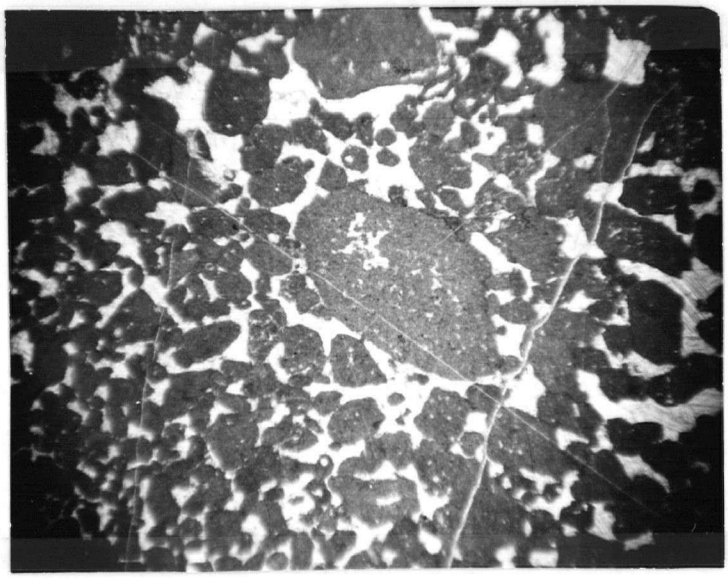
B Subfacies Eb - Lithotype 3

Partially merged intrasparite

Original and possibly moderately well sorted soft cryptocrystalline grains may have been pressed together making their borders indistinct. The origin of the sparry calcite 'birdseyes' is unknown. In places recrystallization of the cryptocrystalline material to sparry calcite seems to have taken place around the borders of birdseyes leaving the sparry calcite clouded with impurities, giving the orange-stained birdseyes seen in the field. Scattered oolites and superficial-oolites are observable in the thin section.

Shunda Formation (Osagean)

(57D7. 655)



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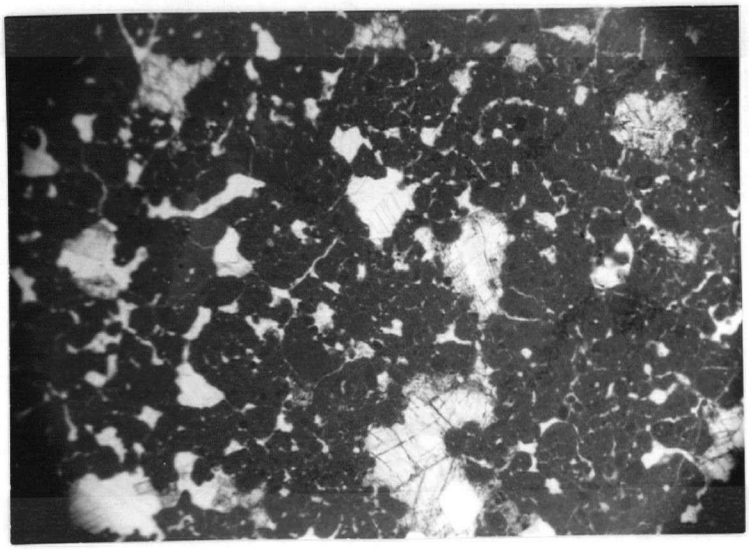

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PLATE 26

Subfacies Eb - Lithotype 4

Oolitic grapestone bearing intramicrites

A Intramicrite, slightly silty, in which grapestone (ig), homogenous intraclast (i) and oolitic (o) grains are contained in a micritic matrix bearing pellets and calcispheres. The grains are partly cemented with sparry calcite. This particular sample grades to lithotype 2 by an increase in the amount of sparry cement.

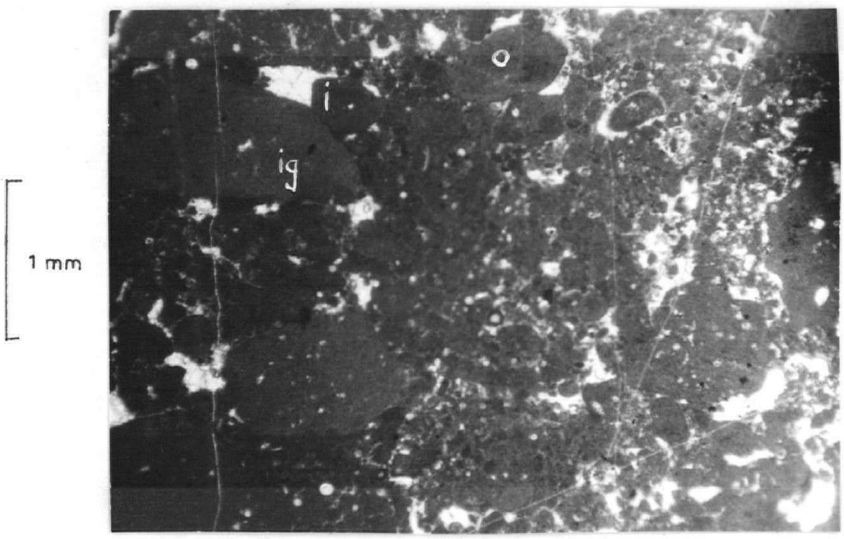
Top of Pekisko Formation (late Kinderhookian - early Osagean)

(57D9. 534½)

B This rock is closely similar to that of Plate 26A but here the grapestone grains (ig) have an almost homogenous nature.

Basal Turner Valley beds (Osagean)

(57D7. 593)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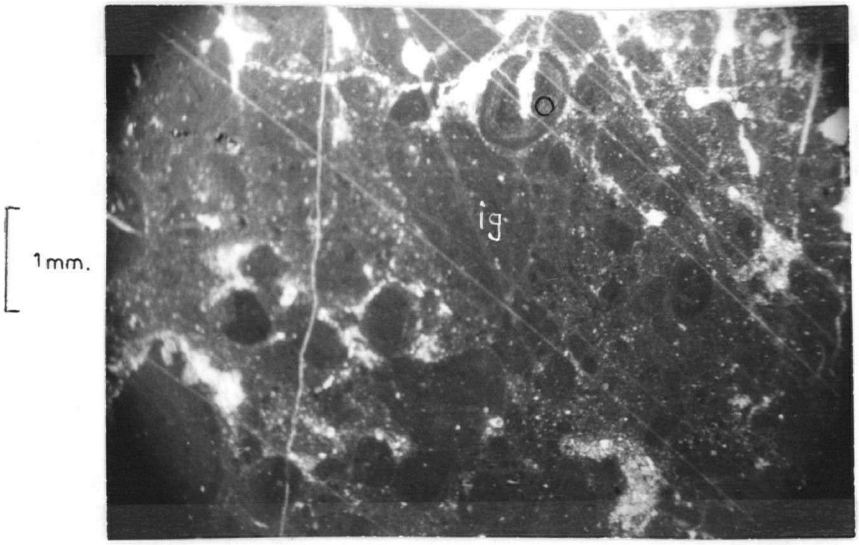
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PLATE 27

Subfacies Eb - Lithotype 4

Oolitic, grapestone bearing intramicrites

A Oolitic intramicrite - as Plate 26A - but dolomitized. The micritic matrix was more susceptable to dolomitization than the allochems; the matrix has been largely replaced by dolomite.

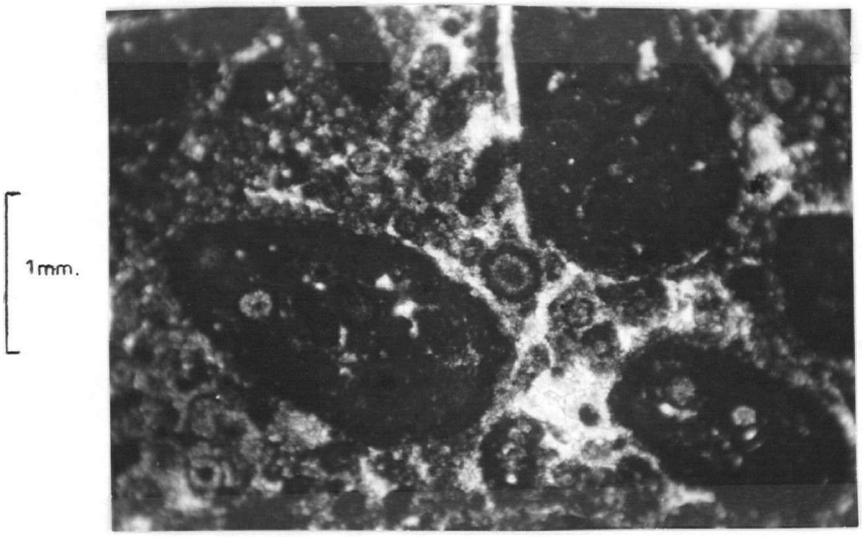
Basal Turner Valley beds (Osagean).

(57D9. 782)

B Oolitic intramicrite - as Plate 27A (dolomitized matrix) - showing the ? calcisphere-bearing multiwalled capsule of Plate 12B.

Basal Turner Valley beds (Osagean)

(57D9. 782)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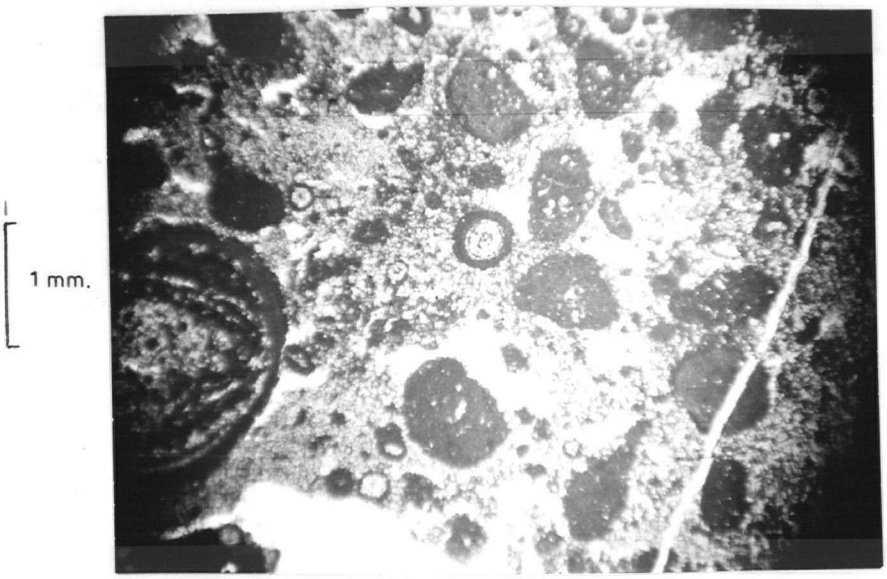
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Subfacies Fb. (Plates 8A, 11B, 13A-B, 28A-B and 29) This subfacies is the typical Shunda rock of the area but parts of the Jasper Lake and Turner Valley also contain limestones similar to subfacies Db. Outcrops consist of thin to thick bedded sequences of light grey weathering lithographic limestones (Micrite) which, in places, tends to have a massive appearance (Plate 5). On close examination the rock is often found to have numerous small sparry calcite birdseyes and stringers elongate parallel to bedding. These limestones are brown to dark grey when dry, light brown-grey when wet and are translucent in thin chips. Isoluble residue studies of representative samples show that subfacies Fb rocks are particularly pure limestones. Minor amounts of siltstone and shale are lumped with subfacies Fb.

Microscopically, the rock is found to be mainly composed of cryptograined calcite with grains less than 4 microns in diameter. The rock commonly contains numerous calcispheres which, in a few places, make up close to 10% of the rock volume. Apart from the calcispheres, a few ostracodes and traces of foraminifers and dasycladacean algae (Plate 10B) subfacies Fb contains very few recognizable fossils.

A large proportion of the birdseye texture may be due to the binding action of blue-green algae - Folk (1959), Ginsberg and Lowenstam (1958) and Hamm (1954), and some of the structures in Plate 29 may also be of algal origin. The micrites of subfacies Fb are commonly found to be intimately associated with pelleted micrites (Plate 8A). The birdseye micrites are termed dismicrites by Folk.

In summary, subfacies Fb typically consists of an intimate association of micrites, pelsparites, pelmicrites and dismicrites.

PLATE 28

Facies Fb

A Micrite with traces of dolomite rhombs, calcispheres and indeterminate fossil fragments.

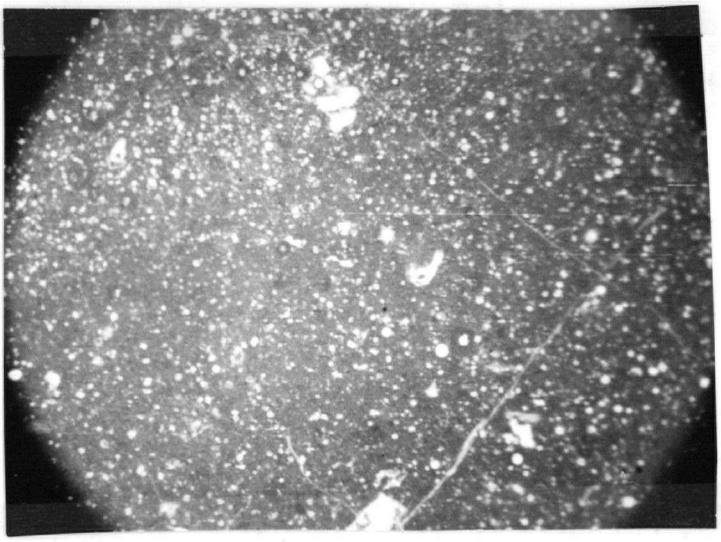
Shunda Formation (Osagean).

(57D7. 853-863)

B Pelleted dismicrite (birdseye limestone) with pellets (possibly faecal) and calcispheres. The sparry calcite birdseyes are elongate parallel to bedding. (See also Plate 8A).

Shunda Formation (late Kinderhookian - early Osagean).

(57D9. 655)



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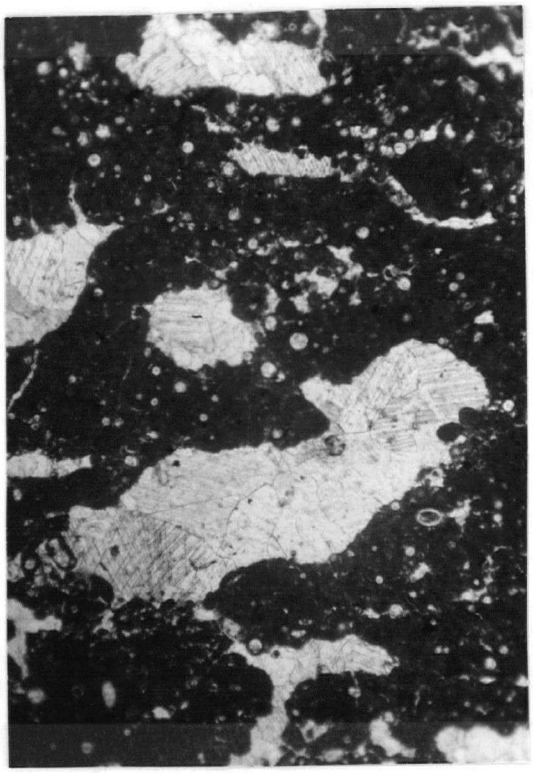

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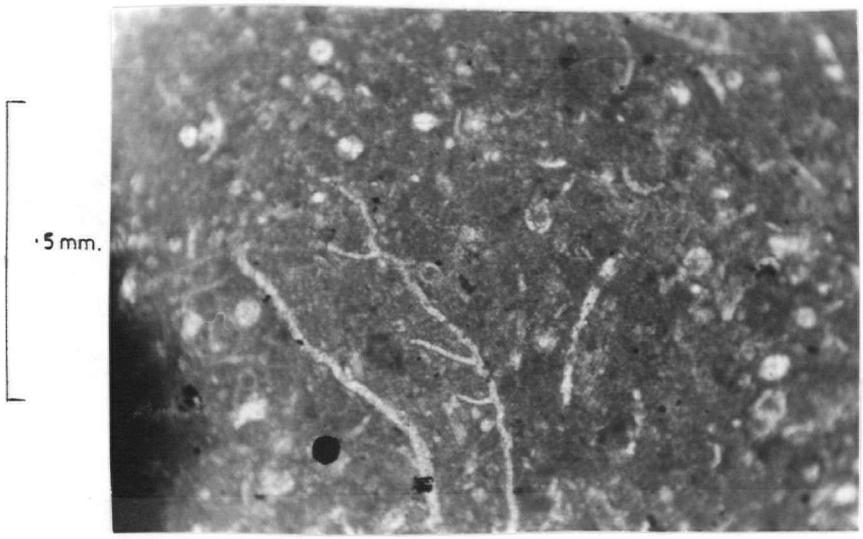
PLATE 29

Facies Fb

Micrite with calcispheres and indeterminate organic material.

Shunda Formation (late Kinderhookian - early Osagean).

(57D9. 585)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Facies G. (Plates 30A-B) Considerable thicknesses of facies G were found in the upper parts of the stratigraphic sections of the area where it forms monotonous sequences with very little change in lithology from bed to bed and section to section. In outcrop the facies is seen as a series of grey, cryptogranular, dense, cherty dolomites with a light brown-grey to yellowish-grey weathering colour. The beds range from 6 inches to 3 feet in thickness. The chert content is usually less than 10% and occurs as thin beds and bands of nodules. A very minor amount of siltstone, green, black and grey shale, and sandstone is associated with the facies.

At the Wildhay well, breccias believed to be of a type different from those of facies H, are closely associated with green shale and it is thought that they are of intraformational shallow water type and are included with Facies G.

Traces of crossbedding and ripple marks were observed in the dolomites of facies G and the dolomites were often found to have fine laminations of the order of 1 mm. spacing (cf. Illing, 1959, Plate III). This microbedding feature is taken by many workers, including Illing (1959b), to be a characteristic of primary dolomites and it is felt that a large proportion of these dolomites are indeed primary dolomite precipitates although it is noted that Fairbridge (1957) considers that microbedding structure and lateral persistence (Facies G is laterally persistent) is not sufficient proof of a primary origin.

Pelletal texture and calcisphere-like forms, which are so frequently found in subfacies Fb, are seen preserved in the cherts of facies G, suggesting a relationship to subfacies Fb. The rare occurrence, however, of birdseye texture suggests that the dolomites of facies G are not in the main dolomitized versions of subfacies Fb, and that an origin as a dolomite

precipitate seems more likely. Examination of thin sections shows that the dolomites tended to be equigranular with a crystalline mosaic texture. The dolomites taken as a whole were found to range in crystal size from 2 microns to 250 microns, with most specimens falling within the 8 - 62 micron range, (see Figures 3-5) and may be termed unfossiliferous micro-grained dolomite.

Facies H. This facies consists of dolomite breccias, the dolomite itself being of facies G type. The facies is only present in the most easterly section (Mumm Creek) and it is thought that these breccias are the result of collapse following leaching of underlying evaporites.

PLATE 30

Facies G

A Micrograined dolomite. The mosaic texture is formed by interlocking grains about 7 microns in diameter with a few being around 40 microns in diameter. Fine bedding laminations (several per millimeter) are present in the thin section but are not visible in the Plate. These laminations are formed by an alternation of the above grain sizes.

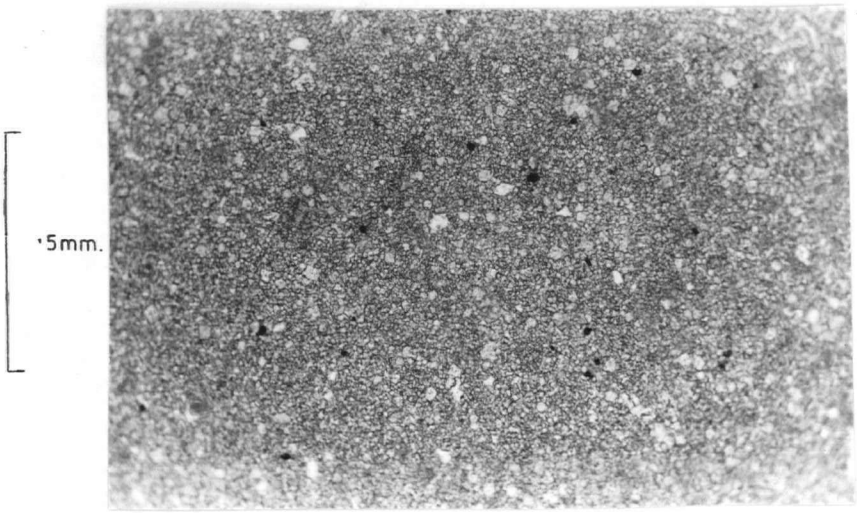
Mount Head Formation (Meramecian)

(57D3b. 40)

B Micrograined dolomite. Mosaic texture given by grains averaging 45 microns, in diameter.

Mount Head Formation (Meramecian)

(57D9. 1280)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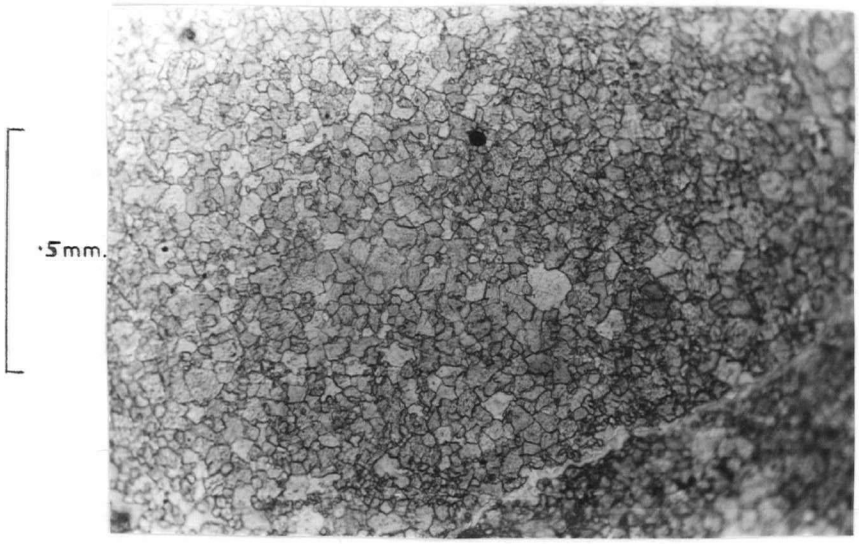
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PLATE 31

Dolomitization

A Dolomite with a ghost texture of a crinoidal limestone bearing an *Endothyra* sp.; possible subfacies Db.

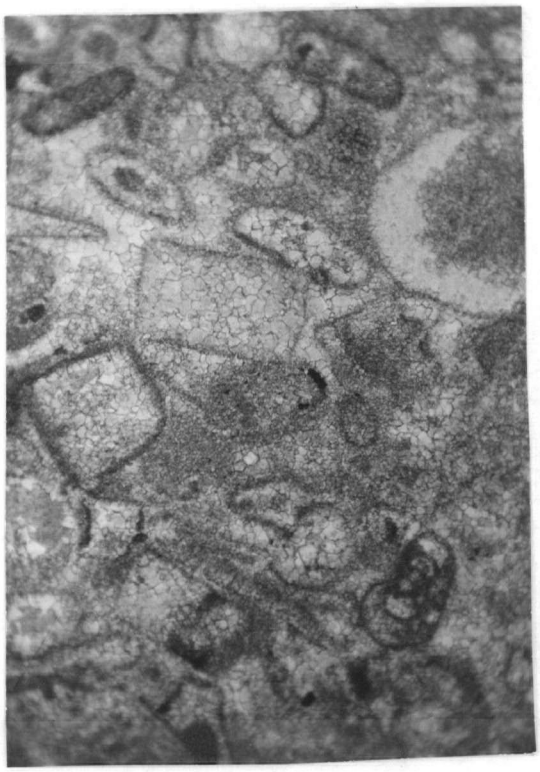
Turner Valley Formation - member 'B' (late Osagean or early Meramecian)

(57D3b. 415)

B Dolomite with a ghost texture of a crinoidal limestone suggestive of subfacies Da.

Turner Valley Formation - member 'B' (late Osagean or early Meramecian)

(57D3b. 415)



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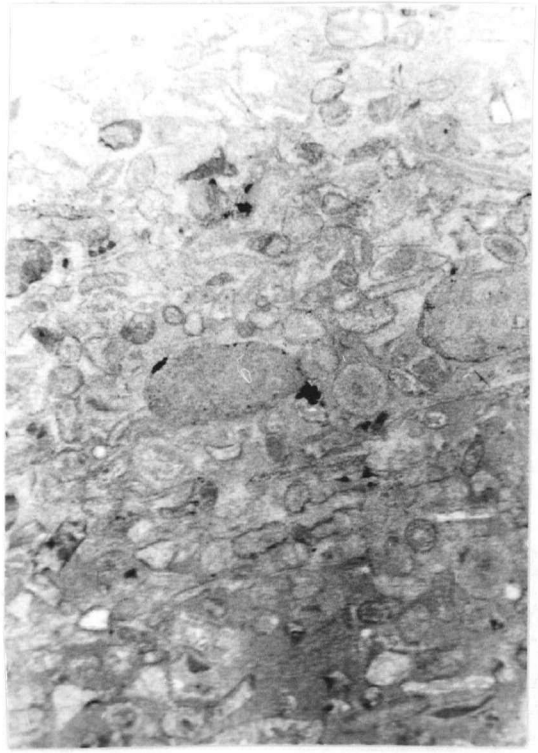

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PLATE 32

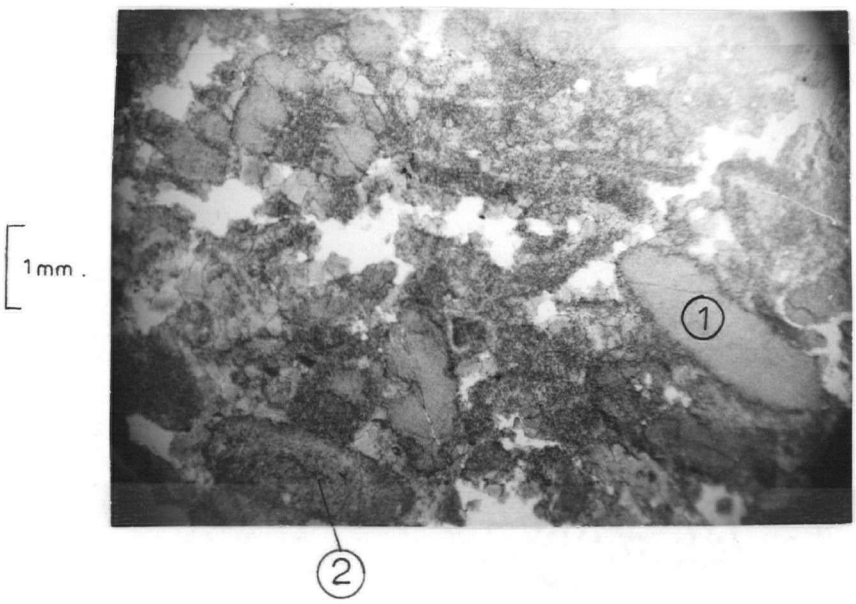
Dolomitization

The original coarse-grained crinoidal limestone has been entirely dolomitized. The large unicrystalline dolomite grains are pseudomorphs after crinoid ossicles; they enclose minute, scattered, randomly oriented dolomite crystals; some grains (2) contain more of these small crystals than others (1) and the replaced ossicles tend to lose their distinctive appearance. The axial canal of a rectangular ossicle in the upper left is filled with dolomite crystals, 60-100 microns in diameter; background dolomite ranges from 25-100 microns in diameter. Traces of clear dolomite in optical continuity with brown ossicles suggest the original presence of some sparry calcite cement. White areas represent pore spaces. Hand specimens are brown, crumbly, porous, coarse-grained rocks in which at least part of the porosity is due to the leaching of ossicles; small vugs have the form of ossicles with projecting sticks of dolomite which evidently once replaced the micritic material of axial canals.

Two generations of dolomite and an intermediate period of calcite leaching are suggested. The specimen resembles Plate III-6 of Illing (1959a).

Turner Valley Formation - member 'B' (late Osagean or early Meramecian).

(57D3b. 485-90)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2

PLATE 33

Dolomitization

Dolomite with a grain growth mosaic; crystals range from 60-150 microns in diameter. The specimen has pin-point and small vug porosity. Faint lighter-appearing outlines may represent crinoid ghosts.

Mount Head Formation (Meramecian)

(57D3b. 308)

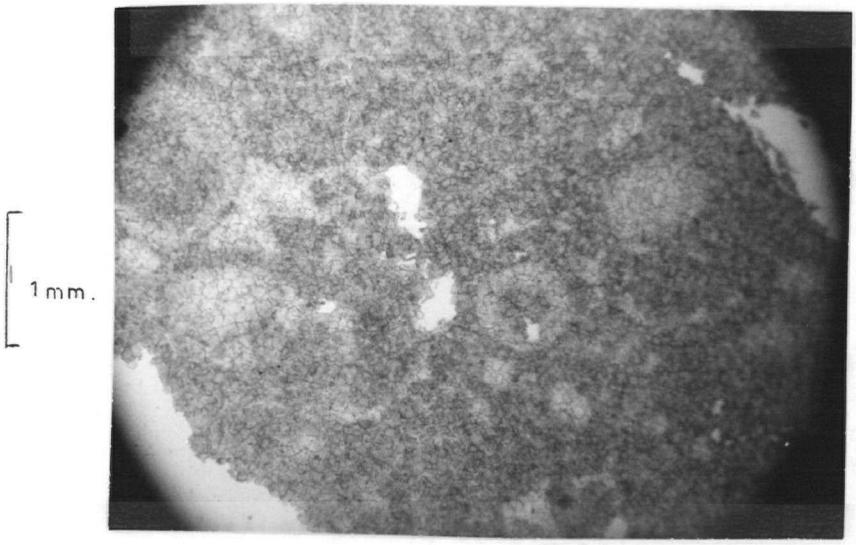
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PLATE 34

Dolomitization

A Dolomite with the same texture as the limestone of subfacies Eb - Lithotype 3 (Plate 25B). The internal structure of the birdseyes suggest that original drusy vugs were later filled by a coarse-grained sparry carbonate.

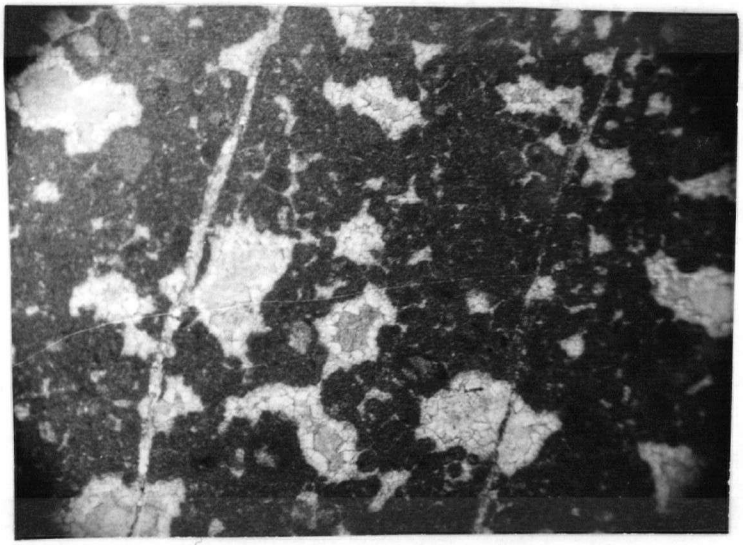
Mount Head Formation (Meramecian)

(57D3b. 210)

B A partially dolomitized limestone with a texture suggestive of a subfacies Eb - lithotype 4 rock in which the micritic matrix has been preferentially dolomitized leaving the rounded cryptocrystalline grains only slightly affected. Many of the grains have feint traces of an oolitic structure. The dolomite consists mainly of rhombs ranging from 75 to 150 microns in diameter.

Turner Valley Formation - member A (Osagean)

(57D7. 550)



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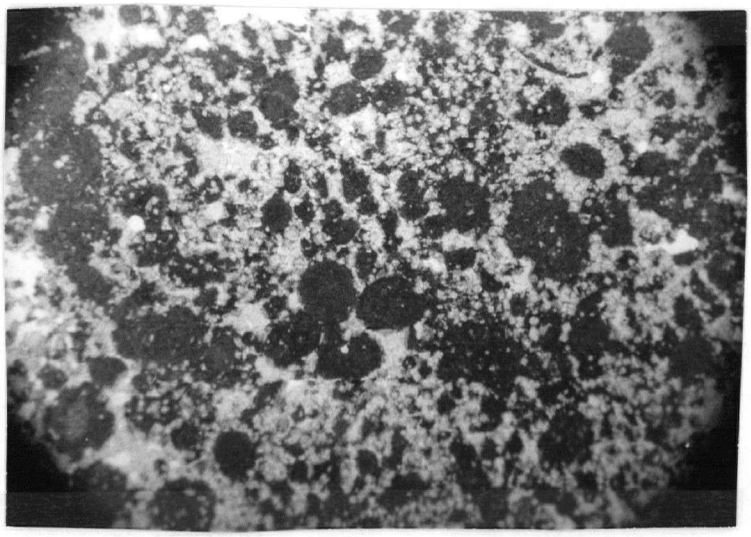

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PLATE 35

A

Sparry Cementation

Crinoidal biosparite of subfacies Db showing sparry cement in optical continuity with a crinoid ossicle. Grains include crinoid (c), foraminifers (f), intraclast (? ex-crinoid) (i), ostracode (o) and possible dasycladacean algae (a) cf. Plate 67, Fig. 3 of Johnson 1961). Nicols crossed.

Pekisko Formation (late Kinderhookian - early Osagean).

(57D7. 983-988)

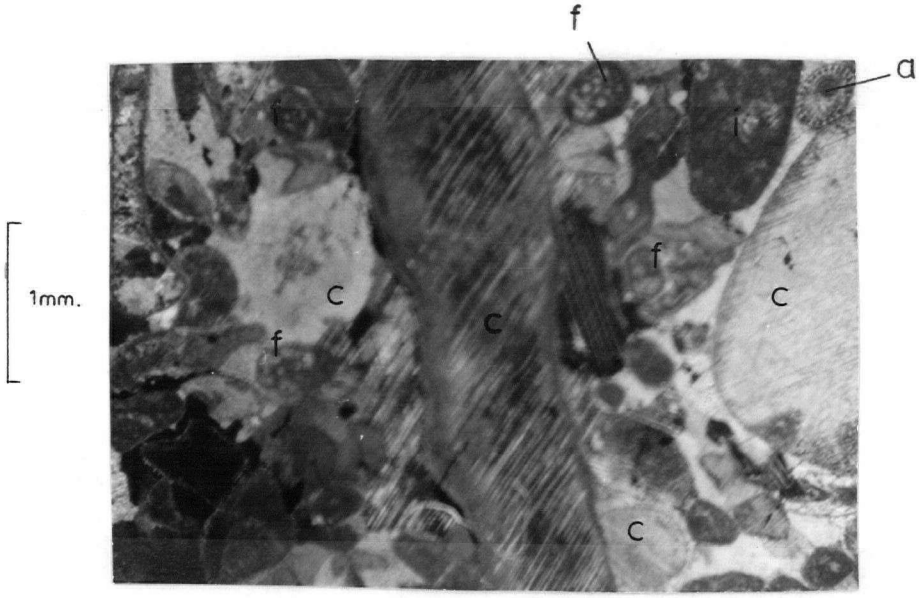
B

Exshaw Sandstone

Fresh angular sanidine and minor quartz grains floating in a silty clay matrix.

Exshaw Formation (? early Kinderhookian)

(57D9. O (II))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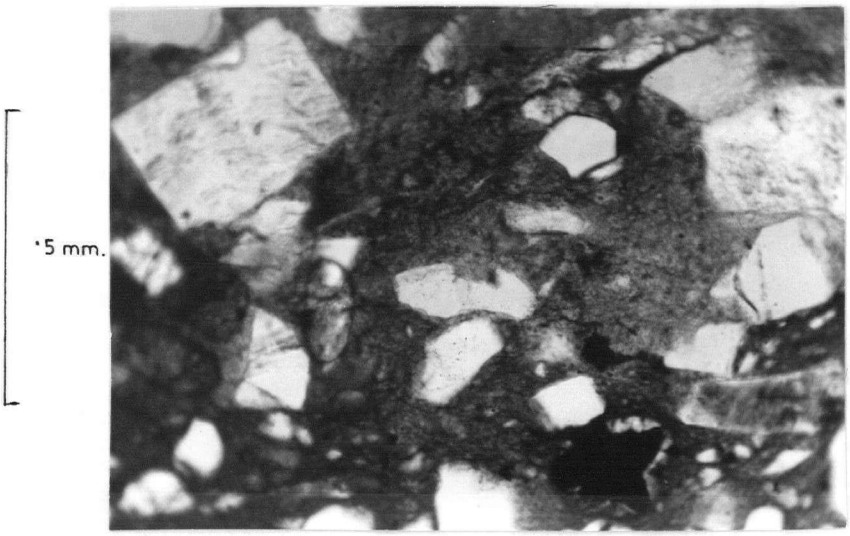
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PLATE 36

Exshaw Sandstone

A Conodonts in a quartz-sanidine sandstone with a matrix consisting of microcrystalline quartz, iron oxides and clay minerals. The specimen also contains the ? bone fibres shown in Plate 36B.

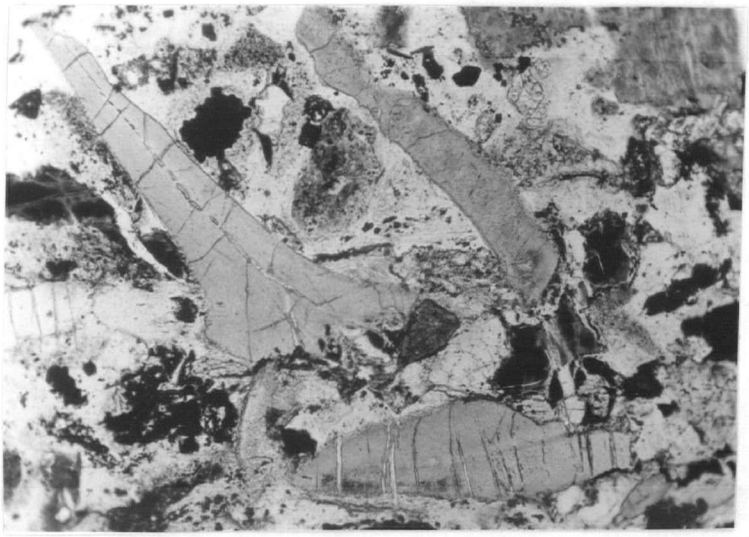
Exshaw Formation (? early Kinderhookian)

(57D9. O III)

B Possible bone fibres in Exshaw sandstone. Nicols crossed.

Exshaw Formation (? early Kinderhookian)

(57D9. O III)



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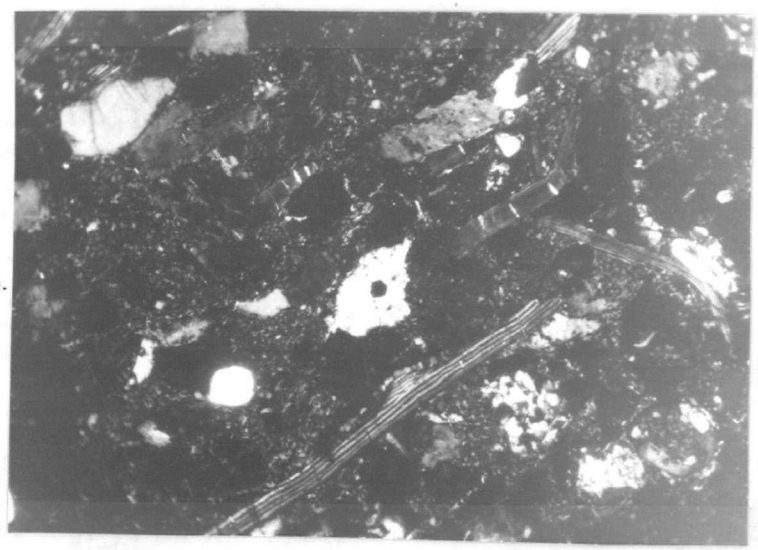

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PLATE 37

Permian Sandstone

A Orthoquartzite with quartz grains forming a grain growth mosaic; microcrystalline quartz and chert grains tend to retain their rounded form.
Nicols crossed.

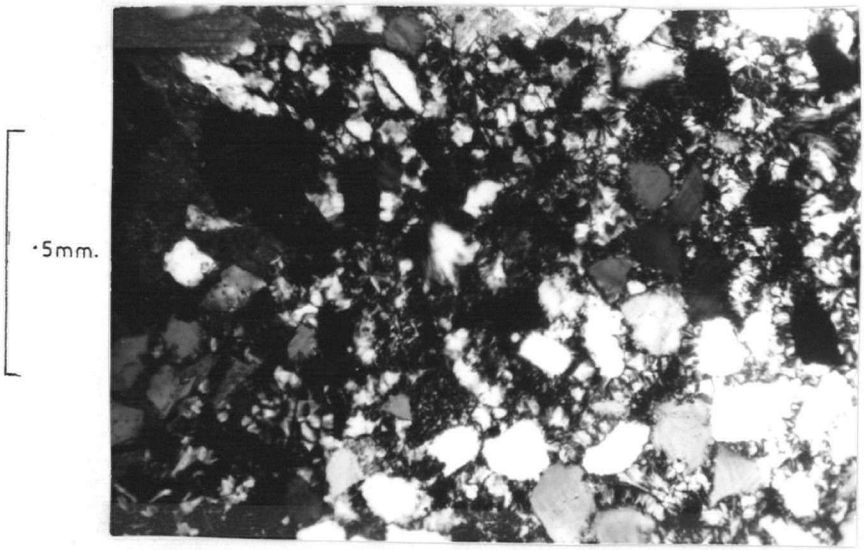
Mowitch - Ranger Canyon Formation (Permian)

(57D3a. 39)

B Sandstone with well-sorted quartz and minor chert grains; the cement is microcrystalline and chalcedonic quartz with sparry calcite patches.
Nicols crossed.

Mowitch - Ranger Canyon Formations (Permian)

(57D3a. 25)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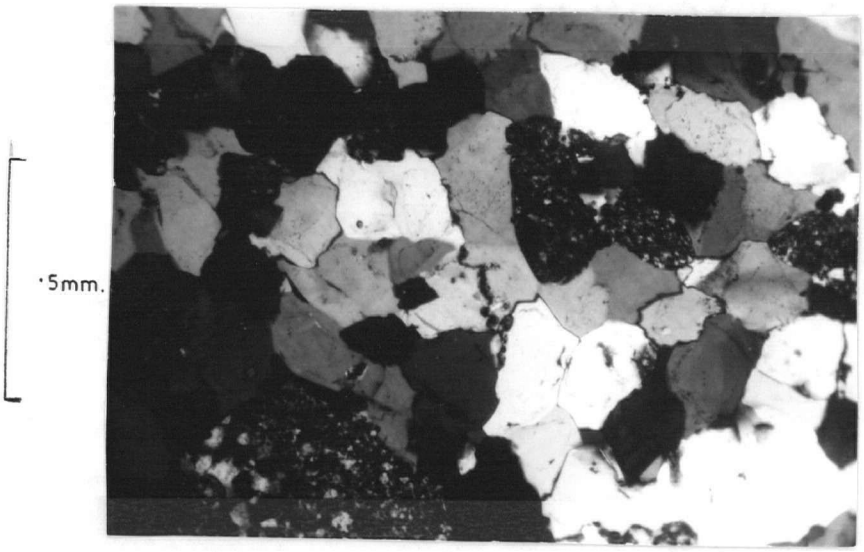
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CHAPTER VI

DISCUSSION OF FACIES

REGIONAL DISTRIBUTION OF FACIES

The Mississippian rocks exposed in the Rocky Mountain belt extending from Wapiti Lake, British Columbia to the Bow Valley in Southern Alberta have the same general facies as those in the Wildhay River - Rock Lake area. Facies changes are much more gradual along this belt than they are across it in the east-west direction.

The best documented east to west changes occur between the type sections at Banff and sections in the Foothills and Plains areas thirty to forty miles to the east, as exemplified by the Moose Mountain sections (Illing, 1959). The late Kinderhookian - early Osage beds have facies in the D - H range in the above eastern area, and facies in the A - C range at Banff. Another illustration of the profound east-west facies changes is given by comparing the rocks of the subject area with the Mississippian rocks just one hundred miles west of the Rock Lake area in the Cariboo Mountains (Sutherland Brown, 1963). The Mississippian rocks in the latter area are more akin to the greenstone-chert-greywacke assemblage of Gabrielse and Wheeler (1960). The facies distribution in the Rock Lake - Jasper area and the Moose Mountain - Banff area both indicate a tendency for western facies to be of a normal open marine type contrasting strongly with eastern facies of a shallow-water, restricted circulation, evaporitic type.

It follows from the foregoing that facies A - H may have been laid down in rough belts, approximately parallel to each other, with the eastern belts approaching evaporitic conditions and the western belts approaching normal marine conditions.

DEPOSITION ENVIRONMENTS OF FACIES AND PARTICLE DERIVATION

General. Facies D to Fb of the Mississippian in the subject area, are so similar to the facies found in the modern sediments of the Bahama Banks that one can suppose that closely similar conditions of deposition prevailed and the facies belts are thought of as being laid down roughly parallel to the edge of a Bahaman type bank.

The facies and subfacies found in the Mississippian are shown in Figure 11 related to physical and chemical environments and depositional sites.

The argillaceous facies A - C are not so well documented in modern sediments as D - Fb and consequently the assumptions made in regard to them are less firmly grounded. The argillaceous material found in facies A - C was probably borne into the area as a suspension in normal marine waters from a source to the west in the greenstone-chert-greywacke province.

Facies A. This facies may be classed with the "normal marine limestone" of Krumbein and Sloss (1953, p. 137) and is thought to have been deposited on the shelf seaward from the other facies from deep quiet waters below wave base.

Facies B. This facies, an interbedded sequence in which the rock type alternates between facies types A and C, is thought to have been deposited on the same flat or gently westerly sloping surface as facies A. However, the water depth over the site of facies B appears to have shoaled from time to time resulting in the deposition of sediment containing a higher proportion of skeletal grains than facies A.

The higher proportion of allochems in the alternate beds is a manifestation of the periodic occurrence of slightly higher energy environments.

The energy during deposition of the latter beds was insufficient to wash out enough of the argillaceous mud matrix to give a texture having mutual grain support.

The fossil content, chiefly crinoids with some bryozoans, brachiopods and other fossils, may have been derived either from within facies B or from adjacent banks of facies C or D type.

Facies C. This facies is thought to have developed on a portion of the sea bottom over which the waters were more turbulent than those associated with the deposition of facies A and B. Crinoids flourished in this environment, the energy of which was sufficient to distribute crinoid debris over wide areas of the bottom, giving deposits with a high degree of grain-supported texture.

Subfacies Da. The sediments of this subfacies are thought to have been deposited from shallow water on a current-swept bottom. The dasycladacean algae found in the brachiopod-rich laminated phase of this subfacies are probably indigenous, thus indicating a water depth of not more than a few tens of feet. The rounded, well sorted grains of the subfacies and the lack of interstitial micritic material indicate fairly strong currents.

This subfacies is thought to have been deposited at sites of the following three different types:

(1) On the open seaward side of a Bahaman-type platform downslope from subfacies Db

(2) Immediately bankward from the Db subfacies in shallow water

(3) On isolated sand shoals within the lagoon.

The possibility of the three different sites is suggested by the cyclic occurrence of the subfacies and the slight reversal of general tendency in the Pekisko mentioned in connection with subfacies Db.

The intraclasts of this subfacies consist of cryptograined calcite without identifiable internal structure. These grains are thought to have had three different modes of origin. Some of the grains may have originated as faecal pellets, as suggested by the association of ostracodes with similar microcrystalline grains in thin beds at the base of the Pekisko (Figure 4). Many of the grains may have been formed by agglutination to aggregates as described by Illing (1954, pp. 26-7). A certain proportion of the grains, however, may be recrystallized skeletal grains, notably crinoidal, as mentioned previously. Intraclast grains of the latter genesis seem to be more common in the open seaward sites than in the shallower, more lagoonal sites. The brachiopod-rich laminated phase of subfacies Da seems to belong to depositional sites of the second and third types, the shallow bank-marginal and lagoonal sites, with some bias in favour of the lagoonal sand shoals.

If a higher proportion of the intraclasts of subfacies Da are recrystallized organic fragments, then the basis for the differentiation of facies D into subfacies Da and Db changes to that based on the degree of recrystallization of the crinoid fragments as well as the roundness, sorting and size factors previously mentioned.

All these factors seem to indicate that the grains of subfacies Da were involved in transportation for longer periods of time than subfacies Db. The crinoid material of subfacies Da may, in fact, have been transported from the sites of subfacies Db deposition positioned some distance from those of subfacies Da.

Subfacies Db. The depositional sites of subfacies Db had associated water depths somewhat less than those of Da and the currents were probably stronger. The Pekisko shows general trends within subfacies and it can be seen that

passing upward from subfacies Da, sorting becomes poorer and grains become more angular and of larger size. This trend reaches a peak in the upper third quarter of the Pekisko, after which there is a slight reversal of the tendency. The peak of the above trend possibly occurs at the site of crinoid gardens which gave some protection from the washing action of bottom currents. This explains the occurence of interstitial mud at the peak giving a rock like portions of facies C, although less argillaceous. It seems likely that most of the crinoid material of the Pekisko was transported from crinoid gardens existing bankward during the earlier phase and seaward during the late phase of the Pekisko.

Subfacies Ea. This cleanly washed oolitic subfacies was probably formed under similar conditions to the oolitic deposits of the Bahama Banks, that is, in very shallow warm waters supersaturated with respect to calcium carbonate under strong current conditions. The presence of numerous angular crinoid grains, both free and acting as nucleii for oolitic layers, suggests that the Ea oolitic subfacies was deposited bankward from and immediately adjacent to subfacies Db. In the upper part of the Pekisko at Eagles Nest Pass, an oolitic phase of Db subfacies is present adjacent to, and probably transitional with, subfacies Ea, again suggesting the contiguous depositional relationship of subfacies Ea and Db.

Subfacies Eb. By content this subfacies is transitional between the oolitic subfacies Ea and the lime mud subfacies Fb, but it also includes both muddy and sparry intraclast rock (intramicrite and intrasparite) the grains of which may have originated by several different processes. Some of the intraclasts may have arisen from the breaking up of partly lithified lime mud, while others could have been formed as faecal pellets, friable aggregates

or grapestone grains (Plates 15B, 25A, 26A-B and 27A-B) as described by Illing (1954, pp. 24-35). In addition, many of the grains may have originated as oolite, skeletal or algal grains but suffered later recrystallization with destruction of the original structure, as discussed previously.

The Eb subfacies was probably deposited in relatively quiet waters of either the Db or Ea subfacies under similar conditions to those existing in the Andros shelf lagoon, Bahamas.

Subfacies Eb lithotypes 2 and 4 are probably equivalent to the grapestone facies of Purdy, while lithotype 3 may correspond to the pellet-mud facies (Purdy, 1963, pp. 479-492).

The high oolite content in portions of the Eb subfacies suggests a depositional site immediately bankward of Ea subfacies sites. The pellet-mud facies west of the northern end of Andros Island and perhaps the contiguous grapestone facies (Purdy, 1963, pp. 473 and 483) may be modern counterparts, for in the latter area the pellet-mud facies contains a high percentage of oolite grains which were probably transported from the nearby areas of the oolitic facies during occasional storms.

Subfacies Fa. This subfacies probably existed at the borders of the lagoon in places protected in some fashion from the strong currents. The well preserved crinoidal material may represent either the remains of a sparse indigenous fauna or material washed in from a closely adjacent Db subfacies. The presence of algal balls in the subfacies indicates deposition in fairly shallow water.

Subfacies Fb. The close resemblance of this subfacies to the mud facies of the Andros Lagoon (Purdy, 1963, pp. 492-3) suggests that these sediments were deposited under similar conditions. It is evident that the Andros

muds have several modes of origin and the same must be assumed for the mud of subfacies Fb. The more important processes which may be involved at Andros Island are listed below:

(a) Physico-chemical precipitation

(b) Precipitation due to benthonic algae

(c) Precipitation due to phytoplankton (whitings)

(d) Breakdown of calcareous algae

(e) The abrasion of animal skeletal material giving fine material

Physico-chemical precipitation is probably the most important source of the fine material in the sediments west of Andros Island and a similar origin for a large part of subfacies Fb of the Shunda is indicated by its lateral equivalance to anhydrite and gypsum beds found in wells to the southeast. The possible algal origin of the calcite birdseyes common in subfacies Fb has been referred to previously as well as the presence in the subfacies of dasycladacean algae and other possible algal skeletal material. In addition, faint traces of fine filementous bodies of calcite, which are more transparent than most of the enclosing micrite are present in subfacies Fb. These calcite filaments resemble those illustrated by Illing (1959, Plate II-4) and are thought to be due to the former presence of algae. Algae, by the extraction of carbon dioxide, cause the local precipitation of microcrystalline calcium carbonate and some of the mud of subfacies Fb could have been formed in this manner.

In the Bahamas, isolated patches of milky water, known as whitings, frequently occur in waters underlain by the mud facies and have been investigated by Cloud (1962, pp. 19-22) without a definite conclusion as to their origin. Wells and Illing (1964) found that similar whitings in the Persian Gulf were accompanied by a shower of aragonite needles and

concluded that this precipitation was due to a sudden increase in the numbers of phytoplankton resulting in a sharp increase in the consumption of carbon dioxide. A quarter of the fine silt and mud-sized grades of sediment west of Andros Island is composed of aragonite needles. Lowenstam and Epstein (1957) considered that these needles could be derived from the breakdown of certain algal skeletons, but Cloud (1962) disputes the proportion from this source. It seems likely that the phytoplankton have played a role in the production of the needles.

It is probable that part of the mud of subfacies Fb was produced by the abrasion of skeletal debris and the contribution from this source was probably quite important near the bank edge.

The possible origins of the pellets and intraclasts found in subfacies Fb have been discussed previously and are summarized below:

(a) By the reworking of partly consolidated mud

(b) A faecal origin

(c) By accretion, perhaps with agglutination

(d) By recrystallization of grains which had recognizable structures.

It is not known which mode of origin is the most important. Purdy (1963, p. 495, Fig. 4 and p. 496) concluded that for an idealized Bahaman platform the pellet-mud facies should lie bankward from the mud facies, although the reverse could be interpreted from his map of facies distribution (ibid., 473, Fig. 1). In the Rock Lake area, the distribution appears to be reversed from the above ideal since subfacies Fb, which is akin to the mud facies of Purdy, seems to have been deposited bankward from subfacies Eb which resembles the pellet mud facies of Purdy. The presence of oolite grains in subfacies Eb gives this idea special force.

Facies G. The dolomites of this facies may be dolomite precipitates produced in a similar fashion to the primary dolomites described by Alderman and Skinner (1957) in a South Australian lagoon. Alternatively the dolomites could have been laid down as lime mud similar to subfacies Fb with penecontemporaneous dolomitization. Occurrences of recent dolomite have been reported by Deffeyes et al (1963), Curtis et al (1963), Illing and Wells (1964) and by Shinn and Ginsberg (1964) from the Lesser Antilles, the Trucial Coast, Qatar and from Andros Island. These occurrences have in common the dolomitization of lime muds by hypersaline brines in shallow water or subaerially in a hot climate.

In the Rock Lake area, facies G mainly occurs in easternmost Mount Head sections; to the southeast, homotaxial facies G type dolomites are associated with anhydrites, strongly suggesting the prevalence of hypersaline conditions for the deposition of facies G.

Facies H. The anhydrites of this facies were probably precipitated directly from shallow, warm hypersaline waters, possible in an intertidal zone.

FACIES COMPARISON

The eleven facies and subfacies into which the Mississippian rocks of the Rock Lake area have been subdivided are shown in Table 4 correlated, not only with the subdivisions of Illing (Figure 9 below) and those of Walpole and Carozzi (1961) for Mississippian rocks in other areas of Alberta but also with the facies of Purdy (1963) for the modern sediments of the great Bahama Bank.

TABLE 5

FACIES CORRELATION CHART

Mississippian Wildhay River - Rock Lake area, Alberta. Dawson (this paper) "facies and sub-facies"	Modern Bahama Banks. Purdy (1963) "facies"	Mississippian Ram River, Alberta. Walpole and Carozzi (1961) "microfacies"	Mississippian Moose Mountain, Alberta. Illing (1959) "phases"
H			H
G			G
Fb	Mud	5a	F
Fa		5b	
Eb	Pellet-Mud	5a	
	Grapestone		
Ea	Oolitic	3	E
Db		4	
Da	Coral-Algal	3	D
C		2	C
B		1	B
A			A

FACIES VARIATIONS THROUGH TIME

In Figure 10 the facies variations through Mississippian time for each section are plotted so that the curves shift toward the right as more lagoonal facies occur and to the left as the facies approaches a normal open marine type. The vertical occurrence of facies as revealed in this figure has a cyclic nature. For example, in the Banff complete cycles are present commencing with facies A in the Cherty Unit, peaking with facies C or subfacies Db in the Crinoidal Unit and returning to facies A in the Upper Unit. In the lower part of the Rundle Group there is a tendency for the occurrence of a half cycle, commencing with facies D in the Pekisko progressing through facies E to facies F in the Shunda.

The similarity of the Mississippian cycles of sedimentation in the subject area to those in the Moose Dome area is indicated by the general agreement of the curves of Figure 10 with that of Figure 9; a smoothed-out Figure 10-type curve of the Eagles Nest Pass sequence, if plotted on the same scale as Figure 9b, would approach a mirror image of the Figure 9b curve.

LATERAL FACIES VARIATIONS

At Mumm Creek the Shunda consists almost entirely of facies Fb but to the west the proportion of facies Eb increases and farther westward at South Berland River, strata coeval with the Shunda of Mumm Creek largely consist of facies D. These changes are similar to those encountered moving up the section through the Pekisko to Shunda half cycle as summarized above and thus the vertical order of facies gives an indication of the lateral facies changes to be expected passing either bankward or basinward from a particular depositional site.

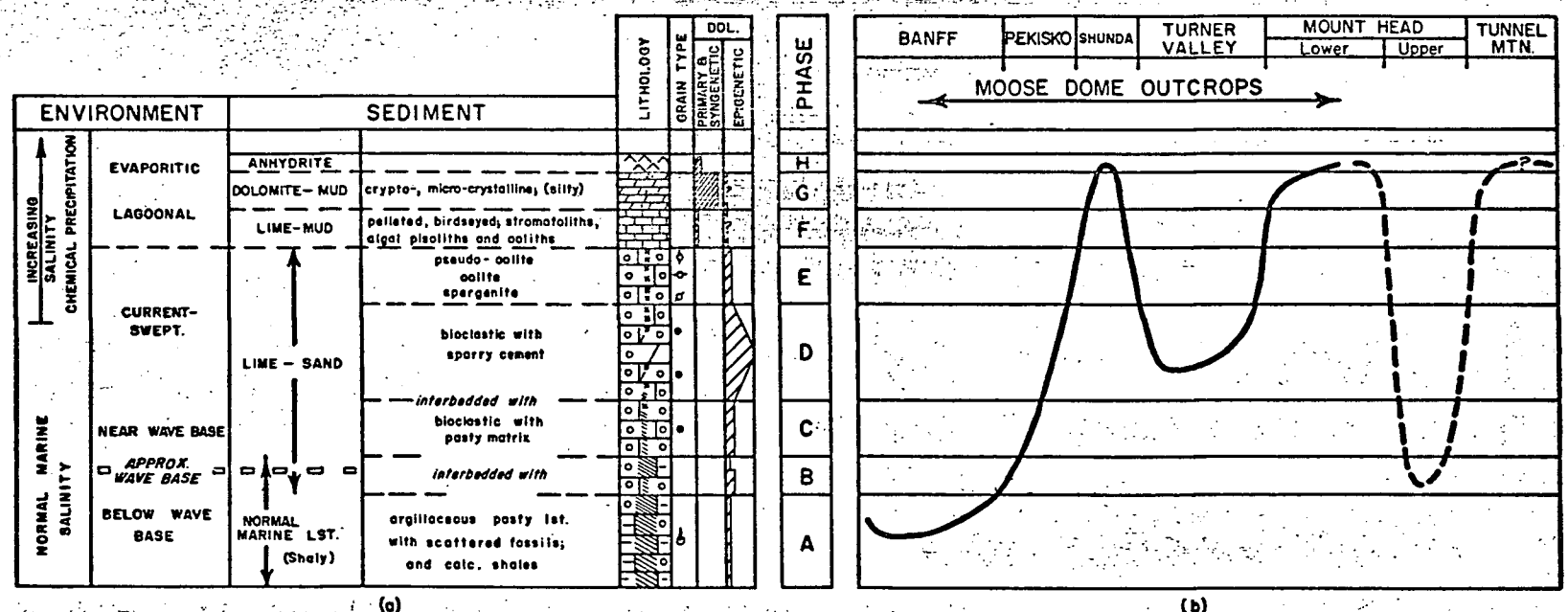

FIG. 9—Carbonate Sedimentation cycle: (a) General, (b) Applied to the Mississippian of Moose Dome.

THIS FIGURE SUMMARIZES AND INTERPRETS THE FACIES FOUND AT MOOSE DOME (b) IN TERMS OF THE IDEALIZED CYCLE (a)

AFTER ILLING (1959 a & b)

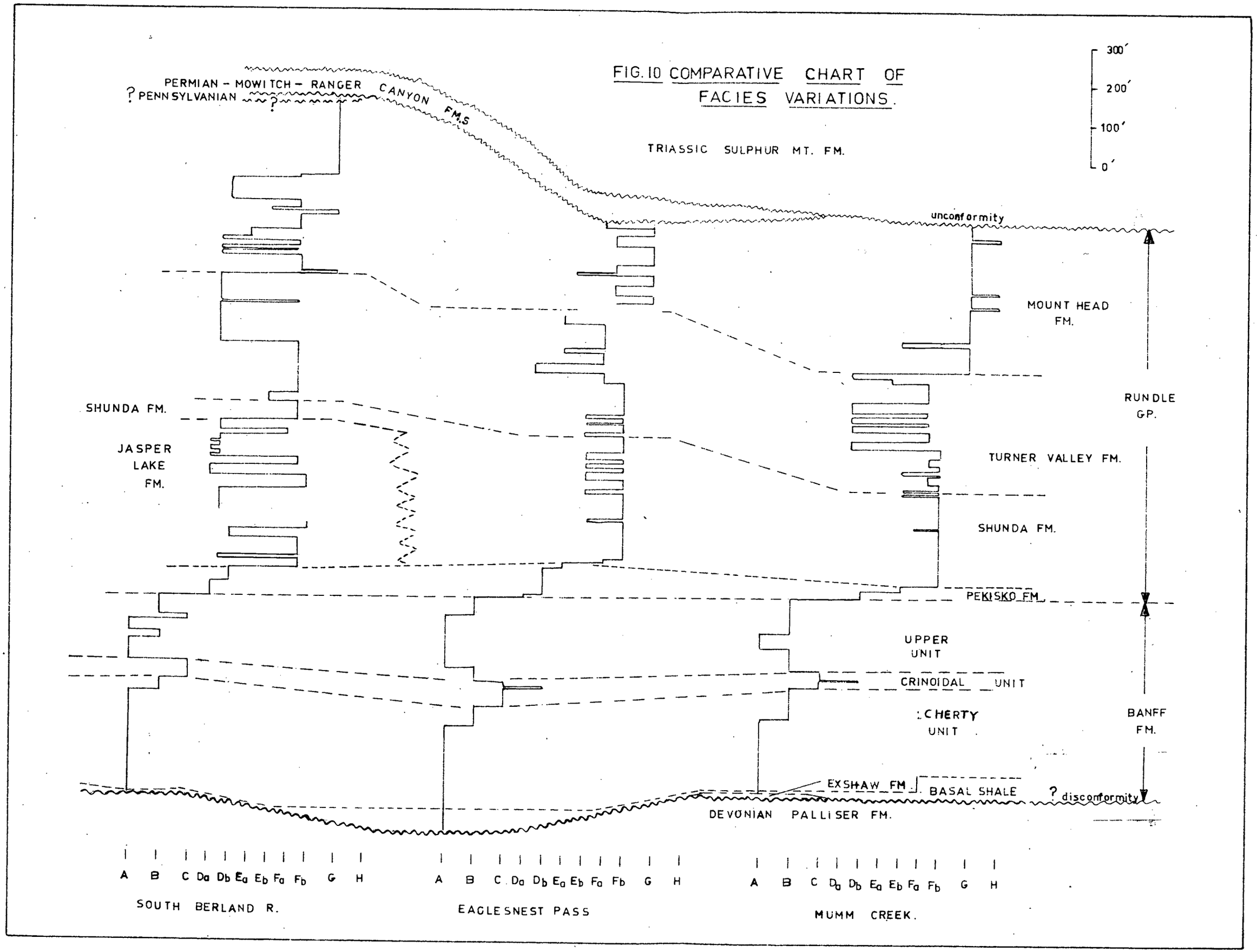
FIG. 10 COMPARATIVE CHART OF FACIES VARIATIONS.
300'
200'
100'
0'
PERMIAN - MOWITCH - RANGER CANYON FMS
? PENNSYLVANIAN ?
TRIASSIC SULPHUR MT. FM.
unconformity
MOUNT HEAD FM.
RUNDLE GP.
SHUNDA FM.
JASPER LAKE FM.
TURNER VALLEY FM.
SHUNDA FM.
PEKISKO FM.
UPPER UNIT
CRINOIDAL UNIT
CHERTY UNIT
BANFF FM.
EXSHAW FM.
BASAL SHALE
? disconformity
DEVONIAN PALLISER FM.
A B C Da Db Ea Eb Fa Fb G H
SOUTH BERLAND R.
A B C Da Db Ea Eb Fa Fb G H
EAGLESNEST PASS
A B C Da Db Ea Eb Fa Fb G H
MUMM CREEK.

IDEAL CYCLE

The progression from facies A to facies H is considered to be an ideal half-cycle reflecting the progression from an environment in quiet, relatively deep water of normal salinity through a current-swept environment into a lagoonal environment where salinity increases beyond the normal. Along the inner margins of the current-swept environment and in the lagoon the waters were probably relatively warm, shallow and saturated to supersaturated with respect to calcium carbonate (Figure 11A).

Some disagreement is present between the ideal half cycle which seems to be evident in the Mississippian of the Rock Lake area and the orders postulated by Purdy and by Walpole and Carozzi. The four interpretations of the sediments or rocks resulting from the ideal progression from open sea to lagoonal evaporitic conditions may be compared by reference to Figure 11B coupled with Table 5.

The apparent reversal of the pellet-mud and mud facies of Purdy has been discussed previously. The pellets of the pellet-mud facies of Purdy are supposedly of faecal origin so that a change of the type and number of pellet-making organisms associated with otherwise similar ancient or modern facies could result in a markedly different faecal pellet content.

The other disagreement is the relationship of facies D and E with microfacies 3 and 4 of Walpole and Carozzi. The latter workers recognized the occurrence of the oosparites and intramicrites but did not consider these of sufficient importance to separate them from microfacies 3 and 4. In the Rock Lake area, although the above textural types were not common, their occurrence is thought to be quite critical in the cycle as evidenced by their stratigraphic position at the Pekisko top marking the change from the biosparite to micritic lagoonal facies, which is the same position as that mapped by Purdy (1963) and Illing (1954) in the Bahamas.

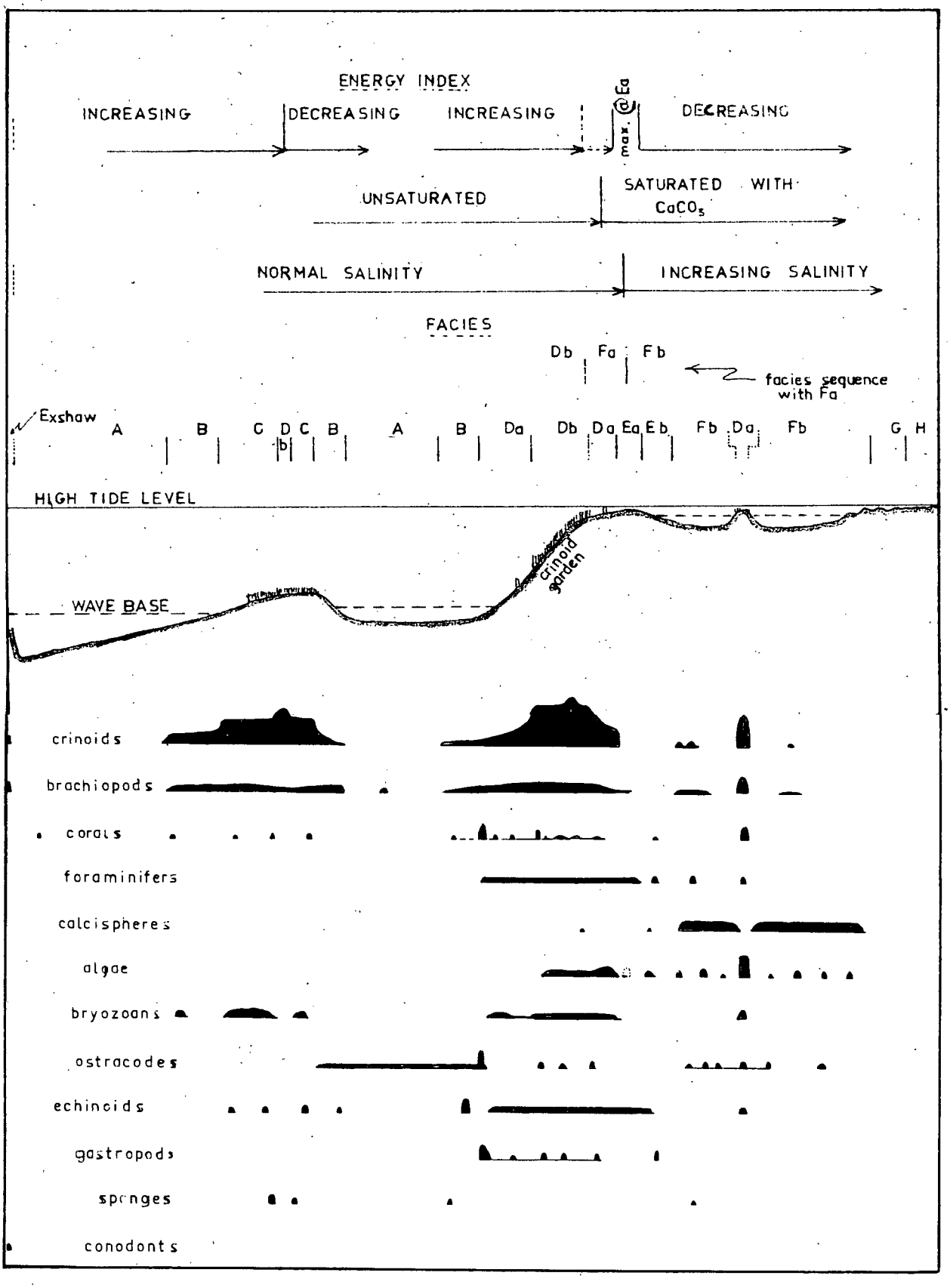

FIGURE 11A. HYPOTHETICAL CROSS SECTION SHOWING DEPOSITIONAL SITES OF FACIES, ENVIRONMENTAL TRENDS AND INFERRED LIFE DISTRIBUTIONS OF ORGANISMS IN THE MISSISSIPPIAN OF THE WILDHAY RIVER - ROCK LAKE AREA.

DEPOSITIONAL SITE AND CONDITIONS	SEAWARD OF BANK DEEP OPEN WATER NORMAL MARINE CONDITIONS			BANK EDGE AND FLANK NORMAL MARINE CONDITIONS			OUTER MARGIN OF LAGOON WARM TURBULENT WATERS	LAGOON WARM PROTECTED QUIET WATERS			LAGOON INTERIOR EVAPORITIC CONDITIONS	
GREAT BAHAMA BANK-PURDY (1963)				CORALGAL FACIES			OÖLITIC FACIES	GRAPESTONE FACIES	MUD FACIES	PELLET-MUD FACIES		
MISSISSIPPIAN FACIES AND SUBFACIES OF WILDHAY R.-ROCK LAKE AREA, ALTA (THIS THESIS)	A	B	C	Da	Db	Da	Ea	Eb Fa	Fb		G	H
MISSISSIPPIAN PHASES AT MOOSE DOME, ALTA ILLING (1959)	A	B	C	D			E	F			G	H
MISSISSIPPIAN MICROFACIES RAM RIVER, ALTA WALPOLE AND CAROZZI (1961)	1		2	3	4			5b	5a			

FIGURE 11B. DIAGRAM SHOWING AN INTERPRETATION OF MISSISSIPPIAN ROCKS OF ALBERTA IN THE LIGHT OF STUDIES OF THE MODERN LIMESTONE FACIES OF THE BAHAMAS.

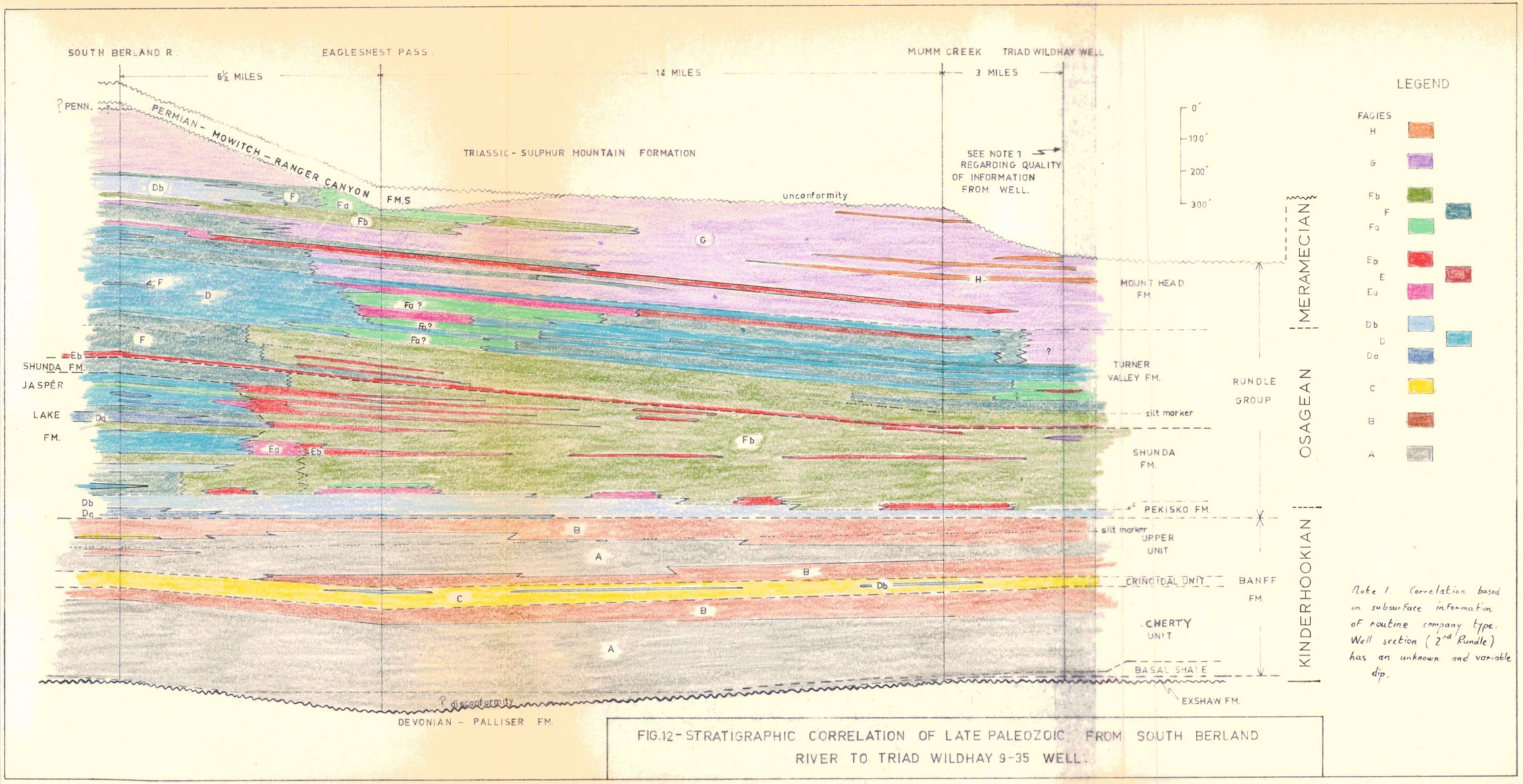

FIG.12 - STRATIGRAPHIC CORRELATION OF LATE PALEOZOIC FROM SOUTH BERLAND RIVER TO TRIAD WILDHAY 9-35 WELL.

CHAPTER VII

LATE PALEOZOIC DEPOSITION IN THE WILDHAY RIVER - ROCK LAKE AREA

General Pattern. The Mississippian facies sequences recorded in the Rock Lake area are shown correlated in Figures 10 and 12; the cyclic nature of the deposition, is especially clear in Figure 10. It can be seen that minor fluctuations are superimposed on, but do not hide, large cycles which are thought to reflect major marine transgressions and regressions. Furthermore, if the transgressive phases in the Turner Valley and Mount Head are ignored the Banff and Rundle can be seen as the rock record of one half cycle, a period (Mississippian) of regression. The figures show that the Banff has a fairly constant facies sequence and thickness throughout the area and can be readily subdivided into several time equivalent units of identical composition. Important differences exist between the westernmost Rundle section, South Berland and the eastern Rundle section, Mumm Creek; the western section tends to have a sandy bank-marginal character while the eastern section has more of a muddy lagoonal nature. The Eagles Nest sectionis distinctly of a transitional or intermediate nature between the eastern and western extremes.

The tendency for the Mississippian section to thicken toward the west, toward the probable geosynclinal axis, is shown by the increase in the thickness of the Pekisko-Shunda-Turner Valley interval from about 570 feet in the east to over 800 feet in the west.

Depositional History. During the late Devonian time, the shallow Wabamun -Palliser sea covered the area and at the end of the Devonian slight

structural changes resulted, firstly, in the production of restricted, possibly shallow, basins in which the Exshaw sediments were laid down and, secondly, in a regional subsidence. Following this subsidence, the turbid early Kinderhookian sea covered the region. The first Banff sediments, consisting of calcareous shales, filled in bottom depressions and were succeeded by a remarkable rhythmically bedded, thick sequence of facies A which appears to have been with the main type of deposition during the early Kinderhookian stage. Later during this stage the seas shallowed periodically and facies B succeeded facies A. During the mid-Kinderhookian the seas shallowed still further and a great number of crinoids inhabited the current-washed bottom, and lime sands of facies C were spread throughout the area. These lime sands were mainly composed of crinoidal debris but also contained significant amounts of fenestrate bryozoan fragments. Late in this sandy phase, partly due to the sand buildup itself, current and wave action was such that washed sands of facies Db type were laid down; this phase represented the peak of a cycle, for shortly afterward a reversal occurred and gradually deepening water lead to the return of deposition of facies C type, which was in turn succeeded, during the late Kinderhookian, by deposition of facies B and by facies A. There was some difference however in the character of these later facies A and B for these beds are somewhat less argillaceous than the facies A and B deposited during the early Kinderhookian and, furthermore, traces of elements such as calcispheres and foraminifers appeared for the first time in notable amounts in the Mississippian sediments of the area. The higher percentage of calcium carbonate reached in these late phases of facies A and B seems mainly due to the influx of micritic mud. Could it be that this lime mud, together with the few calcispheres and foraminifers, represents

bank derived material transported into the deeper water environments of facies A and B deposition from a Bahaman type bank which existed to the east of the area? Late in the Kinderhookian a gradual regression of the sea brought about a great change in the character of sedimentation in the area. This change was heralded by the return to the deposition of facies B and by an influx of quartz sands and silts. The advent of quartz silt and sand seems to be a characteristic feature of the last phase of Banffian sedimentation, in the lithologic sense, not only in the general Jasper - Rock Lake region (Mountjoy, 1962, p. 29) but also throughout a large area of Alberta extending from the Peace River area (Macauley, 1958, p. 296) to Southern Alberta (Penner, 1958, p. 273); (Douglas and Harker, 1958, p. 180) and (Green, 1963, Fig. 12).

Microgranular dolomites of an anomalous nature are associated with the above siliceous sediments and have been grouped with facies B. These dolomites are silty, argillaceous and pyritic; quite unlike the microgranular dolomites of facies G. One explanation for these anomalous Banff rocks is that dolomite sedimentary grains were derived during erosion of soft dolomite muds of facies C type and subsequently transported into relatively deep normal marine waters to be deposited in the environment associated with facies B. The possible erosion of these dolomite muds and the influx of quartz silts and sands may be related to the early stages of the above regressive phase. A second explanation is that these dolomites were formed in situ as supratidal deposits. A third and perhaps more reasonable explanation is that these dolomites are the result of dolomitization of fine grained sediments by relatively dense magnesium-rich ground waters which perculated through the still porous crinoidal sands of the Pekisko from a neighbouring lagoonal source.

Deposition of the microgranular dolomites and fine-grained argillaceous limestones was succeeded abruptly, in the late Kinderhookian - early Osagean, throughout the area, by sparry calcarenites of the Pekisko. In the western part of the area the basal Pekisko sands were of facies Da type but in the east, sands of this type may have been absent. In the east and in the north at Moon Creek, deposition of Pekisko calcarenites soon gave way to lagoonal lime muds, but lime sand deposition persisted later in the west and southwest (Berland River and Eagles Nest Pass sections) ending with the deposition of the lagoonal muds; transitional oolitic and skeletal mud stages occur at the Eagles Nest Pass section - Figure 12. In the east and north, deposition of lagoonal lime muds continued during the late Kinderhookian - early Osagean and early Osagean with very minor interruptions in the east (Figure 12). In the north at Moon Creek (Irish, 1947, p. 11) these interruptions were possibly of somewhat greater frequency and duration. During the breaks in the lime mud deposition, the deposits had a more bank-marginal character. In the western part of the area, as typified by the sequence at South Berland River, early Osagean deposition of thick sequences of crinoidal biosparites, facies D, alternated with lagoonal sediments, facies F; six complete couplets seem to be present. A few miles to the southwest these strong pulsations resulted in synchronous developments of subfacies Eb in the predominantly Shunda lagoonal lime mud sequence at Eagles Nest Pass. The second transgressive peak appears less strong than the later transgressions of the early Osagean sea and the only possibly related effect at the Eagles Nest Pass section was the deposition of fossiliferous micrites 880-890 feet below the top of the section. To the east only the third and possibly sixth transgressive peaks appear to have affected lagoonal Shunda deposition. The lateral facies changes from

crinoidal sands of facies D in the west to muddy lagoonal facies in the east, which characterized the deposition during local Shunda time, were also characteristic of Turner Valley and Mount Head deposition in the area. Towards the close of the early Osagean muddy lagoonal facies were deposited throughout the area. These sediments were succeeded by an oolitic Eb subfacies which seems correlatable in all four sections shown in Figure 12. Foraminifers from this Eb subfacies suggest a probable correlation with the Turner Valley Formation and the base of this Formation, in this thesis, is placed at the base of this Eb subfacies.

Following the above oolitic phase, during the late Osagean, facies F lagoonal muds associated with minor amounts of silt and clay were deposited resulting in member A of the Turner Valley.

During the remainder of the Osagean a major transgression occurred and Turner Valley - member B crinoidal sands were spread periodically throughout the area. A somewhat higher proportion of lagoonal muds seems to have been laid down in the east than in the west and there is also some suggestion of the deposition of a muddy crinoidal facies at Eagles Nest Pass.

Owing to dolomitization precise assignment of subfacies is difficult in the upper part of the Turner Valley and much of the Mount Head but there is no doubt that the transgression which occurred in the Turner Valley was widespread and of long duration. During the early Meramecian a recessive phase occurred which resulted in the deposition of early Mount Head lagoonal muds throughout the area. Following this recessive phase, several transgressive - regressive cycles occurred and in the west deposition of Mount Head sediments alternated between facies D and G types.

Only two of these pulsations had any notable effect at Eagles Nest Pass; one of the early pulsations was reflected by the deposition there of subfacies

Eb and the final one by the deposition of subfacies Fa. In the east, only the first of these two pulsations had a notable effect - a thin sequence of subfacies Eb was laid down, the remainder of the eastern Mount Head sediments being of facies G and H types. Thus the characteristics depositional pattern, so evident in the early Osagean (Jasper Lake - Shunda), was repeated during the Meramecian with lagoonal facies in the east, bank marginal facies in the west and intermediate facies at Eagles Nest Pass.

Later on in the Meramecian, dolomites of facies G, were deposited throughout the area perhaps with some anhydrites in the east.

The Mount Head deposition differed from that of the Shunda in that lagoonal sediments were predominantly of facies G with some facies H in the east. In contract, the typical lagoonal Shunda of the area is of subfacies Fb. Facies G is very widespread in Mount Head strata of the Rocky Mountains of Central Alberta, from the Big Horn Range near Nordegg to the Rock Lake area, and is very similar to the Upper Debolt at its type section near Grande Prairie, 120 miles north of the Rock Lake area (Macauley, 1958, p. 300).

The record of further Mississippian deposition following the final recorded facies G has been lost due to post-Mississippian erosion in the area but it does not seem likely that another transgressive phase of the previous type took place since, where the record exists, the general tendency during the late Mississippian seems to have been toward the deposition of sandy dolomites and terrigenous clastics like the Chesterian Etherington, Stoddart and Big Snowy units. Fossils diagnostic of Chesterian strata have not been reported to date in the Jasper-Berland River vicinity of the Rockies (Brown, 1952, p. 63), (McGugan and Rapson, 1961b, p. 77) and (Mountjoy, 1962, p. 34) and strata of this age may be

absent from the vicinity, due either to erosion or to non-deposition.

It is suspected that a period of erosion followed the completion of the Mississippian cycle of deposition and that Pennsylvanian sediments were laid down on the eroded surface of the Mississippian. Cherty marine dolomites of Pennsylvanian Morrowan age are known to be present in the Deer Creek vicinity in the southwest corner of the map area (McGugan and Rapson, 1961b) and it is felt by the writer that a thin Pennsylvanian interval, showing strong weathering effects, may be present at the top of the carbonates of the South Berland River section sandwiched between a post-Mississippian unconformity and the widespread pre-Upper Permian unconformity (McGugan et al 1964). An extensive period of erosion followed deposition of Pennsylvanian and possible Lower Permian beds during which most of the Permian and Pennsylvanian and some of the Mount Head strata were removed. During later Permian time, widespread deposition of quartzitic sands and sandy cherts, with a basal conglomerate, occurred. These sediments blanketed the erosion surface which truncated Pennsylvanian and some Mount Head strata.

Deep erosion, prior to the deposition of the Triassic Sulphur Mountain silts and sands, appears to have produced at least 600 feet of relief on the Paleozoic surface for, at South Berland River the Permo-Carboniferous is 1,717 feet thick while at Moon Creek, where Permian, Pennsylvanian and much of the Mount Head strata are missing, the same interval is only 1,150 feet thick.

Permian strata, not present at the Wildhay well and Mumm Creek locations, are typically missing from Late Paleozoic Sections cropping out in the eastern side of the Rocky Mountain folded belt in Central Alberta. It is

thought that pre-Sulphur Mountain erosion was more severe to the eastern side of the belt removing the entire Permian sequence from this area.

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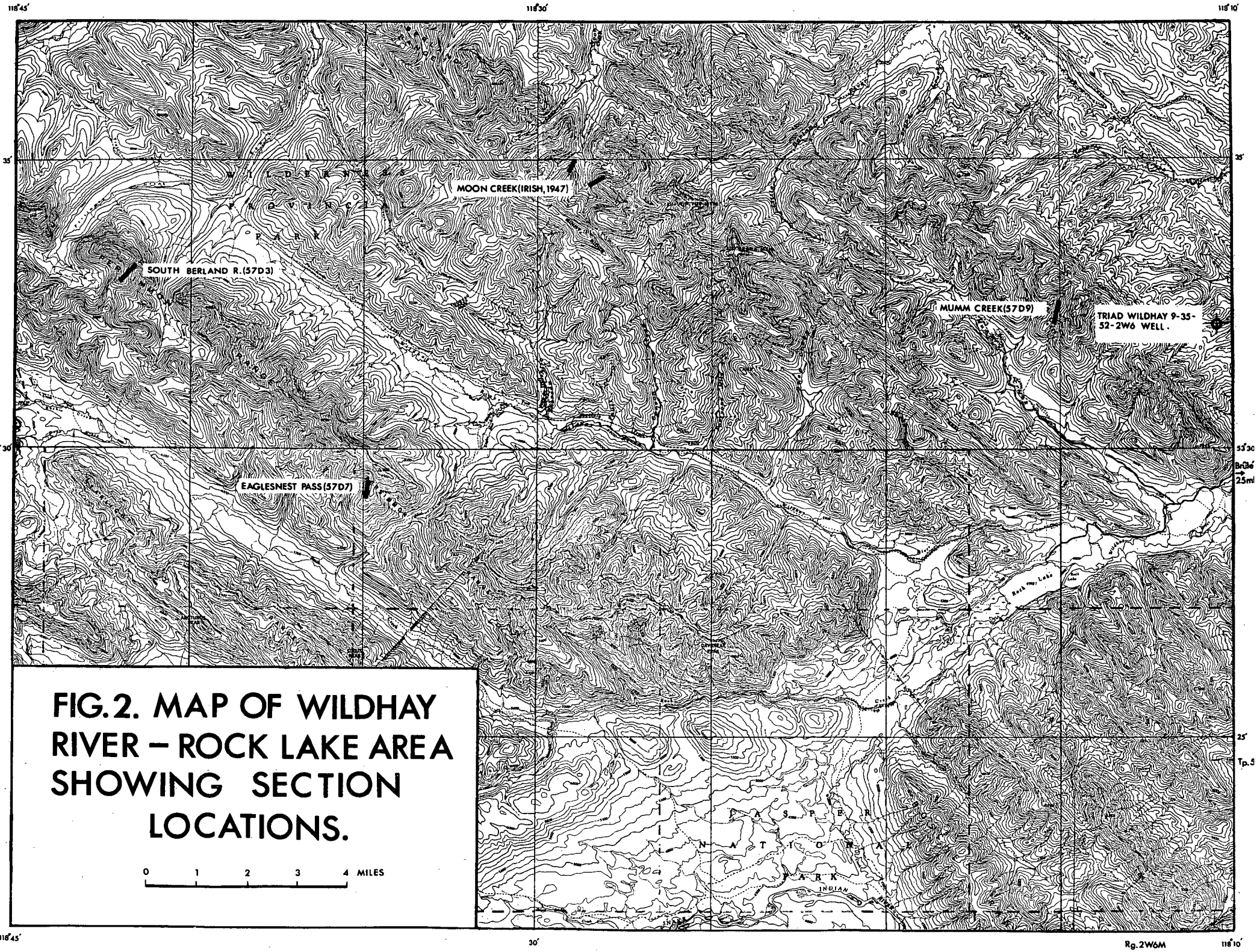

FIG. 2. MAP OF WILDHAY RIVER – ROCK LAKE AREA SHOWING SECTION LOCATIONS.

0 1 2 3 4 MILES

FIG.3 – MUMM CREEK (57D/9) SECTION.

Lsd. 15 Sec. 32 Tp. 52 Rg. 2 W6th M.

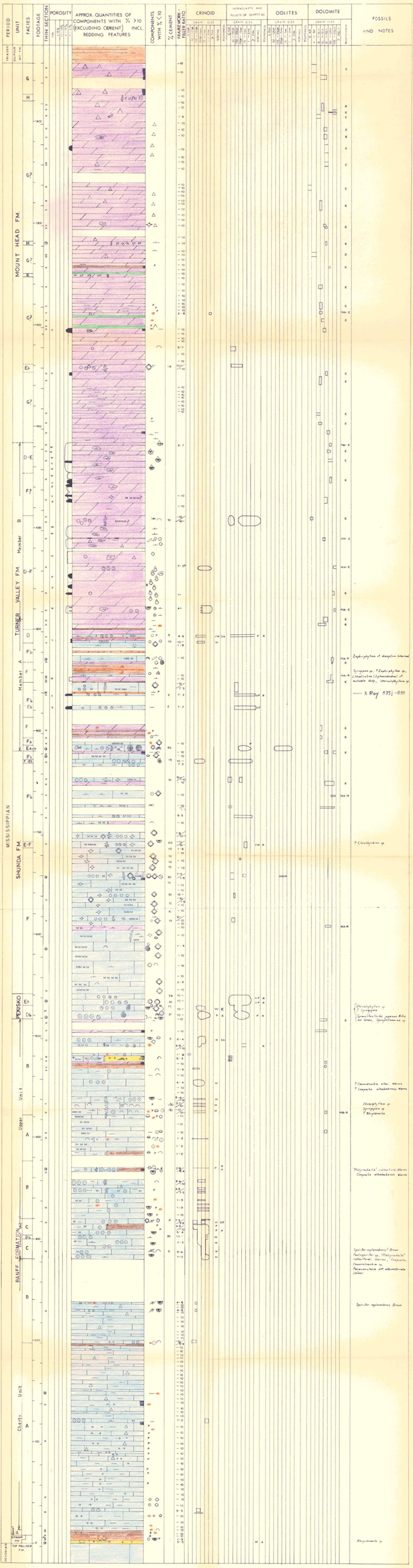

FIG 4. EAGLESNEST PASS (57D7) SECTION.

Sec.18 Tp.52 Rg.4 W5th M.

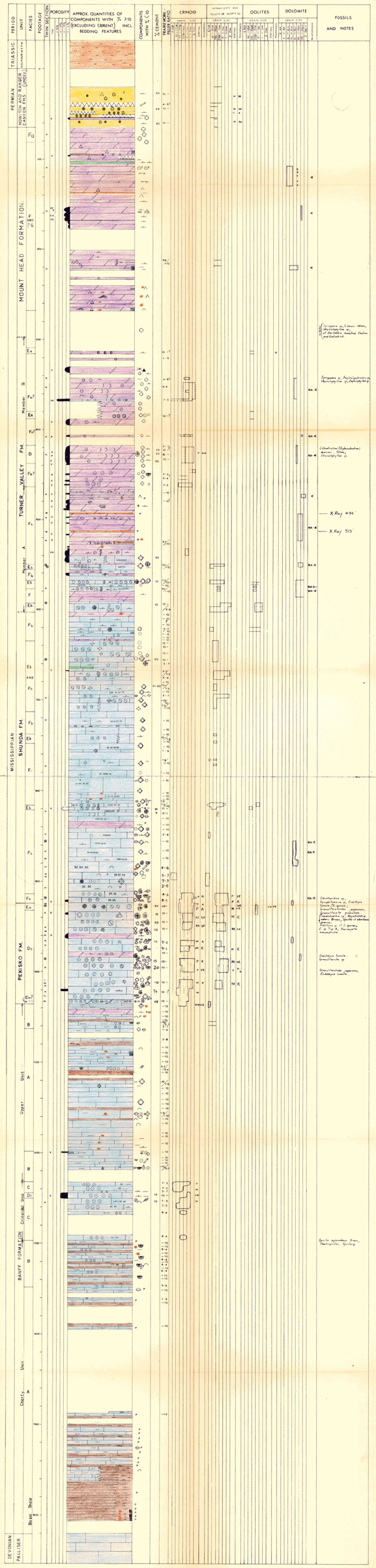

FIG. 5 SOUTH BERLAND RIVER (57D3a and b) SECTION.

Sec. 5 Tp. 53 Rg. 3 W6th M.

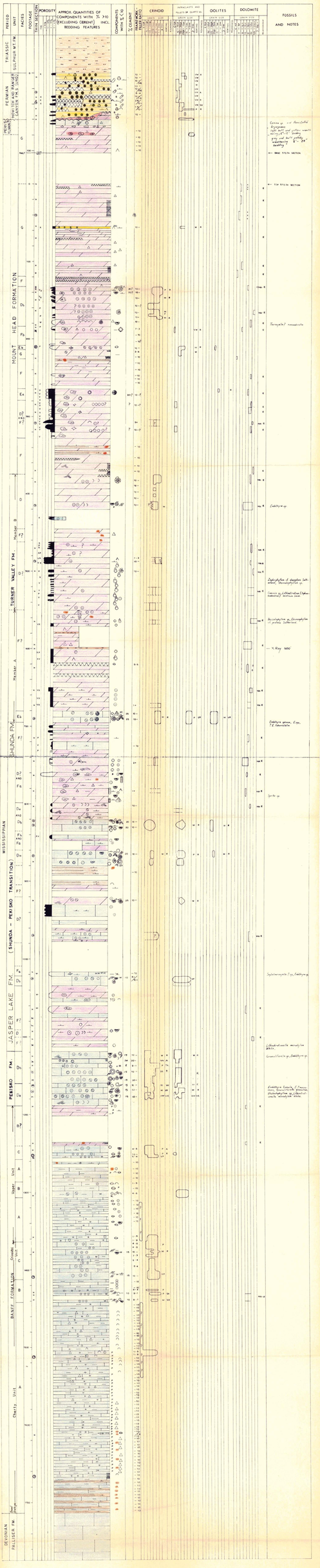

TABLE 2.

KEY TO STRIP LOGS OF SECTIONS WITH EXPLANATORY NOTES

PERIOD	1.
UNIT	2.
FACIES	3.
FOOTAGE	4.
THIN SECTION	5.
POROSITY (TYPE; > 18 %; 12 - 18 %; 6 - 18 %; 0 - 6 %)	6.

1. 2. 3. Refer to Chapter 4.

4. South Berland Section measured in two parts - numbered and measured top - base.

Eaglesnest Pass Section measured continuously - numbered and measured top - base.

Murrin Creek Section measured continuously - numbered and measured base - top.

5. Thin section

Thin section photographed.

6. X Inter-granular

V Vugular

Vugular but plugged with carbonate

P Pin point

F Open fractures

Portion of graph right of curve indicates visually estimated percentage of original porosity excluding sparry cement and calcite birdseyes. Shaded portion of curve shows percentage of present porosity.

Limestone — Dolomite

Chert — Breccia

Quartz Sandstone — Quartz & Chert Sandstone

Shale — Shale (green)

Siltstone — Tuff

Covered interval. — Conglomerate

Symbols are displayed in Column 7 to show quantities present.

< 10%	none shown	
10-25%	one symbol	
25-50%	two symbols	
50-70%	three symbols	
> 70%	four symbols	
e.g.	45% Crinoid fragments	
	20% Intraclasts	
	30% Micrite	

APPROX. QUANTITIES OF COMPONENTS WITH % > 10 INCL. (EXCLUDING CEMENT) BEDDING FEATURES — 7

COMPONENTS WITH % < 10 — 8.

7 and 8. Transported organic and inorganic and indigenous fossils.

- Crinoid
- Pellet (diameter < 150)
- Intraclast (diameter > 150)
- Algal
- Oolite
- Brachiopod
- Superficial oolite
- Coral
- Bryozoa
- Calcisphere
- Silt sized clastic carbonate grain
- Unidentified carbonate grain
- Unidentified organic grain
- Gastropod
- Echinoid Spine
- Crinoid multiple columnal } probably indigenous
- Crinoid complete cup } probably indigenous
- Foraminifera
- Micrite
- Ostracode
- Silt grain
- Argillaceous material
- Quartz sand grain
- Chert sand grain
- Feldspar detrital grain
- Conodont or scolecodont
- Thin walled tube of unknown affinity.

Authigenic constituents, replacement features and vugs.

- Pyrite
- Light coloured chert
- Dark coloured chert
- Calcite birdseye
- Dolomite
- $CaCO_3$ content
- Authigenic quartz
- Calcite filled vug
- Dolomite filled vug
- Calcite & quartz filled vugs
- Dolomite & quartz filled vug.
- Calcite blebs elongated parallel to bedding
- Devitrified tuff
- Bitumen
- Silicification
- Silicified crinoid fragment
- Silicified coral
- Silicified brachiopod.

Bedding features:

- Cross bedding
- Fine laminations e.g. several per mm.

8. Symbols shown in Column 8 are used in a purely qualitative manner.

% CEMENT — 9.

FRAMEWORK-FILLER RATIO — 10.

9. The figure shown is the percentage of sparry calcite cement of carbonate rocks or the silica cement of quartz and chert sandstone.

10. Ratio shown is the ratio of sedimentary grains > 62 μ diameter to sedimentary grains (silt and mud) < 62 μ

-	0 - 5%	4	40 ± 5%	8	80 ± 5%
1	10 ± 5%	5	50 ± 5%	9	90 ± 5%
2	20 ± 5%	6	60 ± 5%	10	95 - 100%
3	30 ± 5%	7	70 ± 5%		

Shaded areas of the log show observable grain size distribution. Unshaded and dotted areas show possible original grain size distribution where record is poor due to alteration of rock.

CRINOID — 11.

< 62 μ	GRAIN SIZE
62 - 125 μ	GRAIN SIZE
125 - 250 μ	GRAIN SIZE
250 μ - .5 mm	GRAIN SIZE
.5 - 1 mm	GRAIN SIZE
1 - 2 mm	GRAIN SIZE
> 2 mm	GRAIN SIZE
SORTING	
ROUNDNESS	

INTRACLASTS AND PELLETS OR QUARTZ SDS. — 12

< 62 μ	GRAIN SIZE
62 - 150 μ	GRAIN SIZE
150 - 250 μ	GRAIN SIZE
250 μ - .5 mm	GRAIN SIZE
.5 - 1 mm	GRAIN SIZE
1 - 2 mm	GRAIN SIZE
> 2 mm	GRAIN SIZE
SORTING	
ROUNDNESS	

OOLITES — 13.

< 62 μ	GRAIN SIZE
62 - 125 μ	GRAIN SIZE
125 - 250 μ	GRAIN SIZE
250 μ - .5 mm	GRAIN SIZE
.5 - 1 mm	GRAIN SIZE
1 - 2 mm	GRAIN SIZE
> 2 mm	GRAIN SIZE
SORTING	
ROUNDNESS	

DOLOMITE — 14.

< 4 μ	GRAIN SIZE
4 - 8 μ	GRAIN SIZE
8 - 16 μ	GRAIN SIZE
16 - 31 μ	GRAIN SIZE
31 - 62 μ	GRAIN SIZE
62 - 125 μ	GRAIN SIZE
125 - 250 μ	GRAIN SIZE
> 250 μ	GRAIN SIZE
RELATIONSHIP	

11, 12 and 13. Sorting

		Graphic Standard Deviation.
VW	very well sorted	< .35 Ø
W	well sorted	.5 - .35 Ø
M	moderately sorted	.5 - 1.0 Ø
P	poorly sorted	1.0 - 2.0 Ø
VP	very poorly sorted	> 2.0 Ø

Roundness

VR	very round
R	round
SR	sub round
SA	sub angular
A	angular

14. ∈ Dolomite with mosaic texture

MA-R Matrix partly dolomitized with floating rhombs

MA-∈ Matrix completely dolomitized to dolomite mosaic.

FOSSILS AND NOTES — 15.

15. Megafossil identifications by Geological Survey of Canada. Microfossil identifications by the Alberta Research Council.