GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF MINES
AND TECHNICAL SURVEYS

MEMOIR 336

FLATHEAD MAP-AREA, BRITISH COLUMBIA AND ALBERTA

R. A. Price

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FLATHEAD MAP-AREA,
BRITISH COLUMBIA AND ALBERTA

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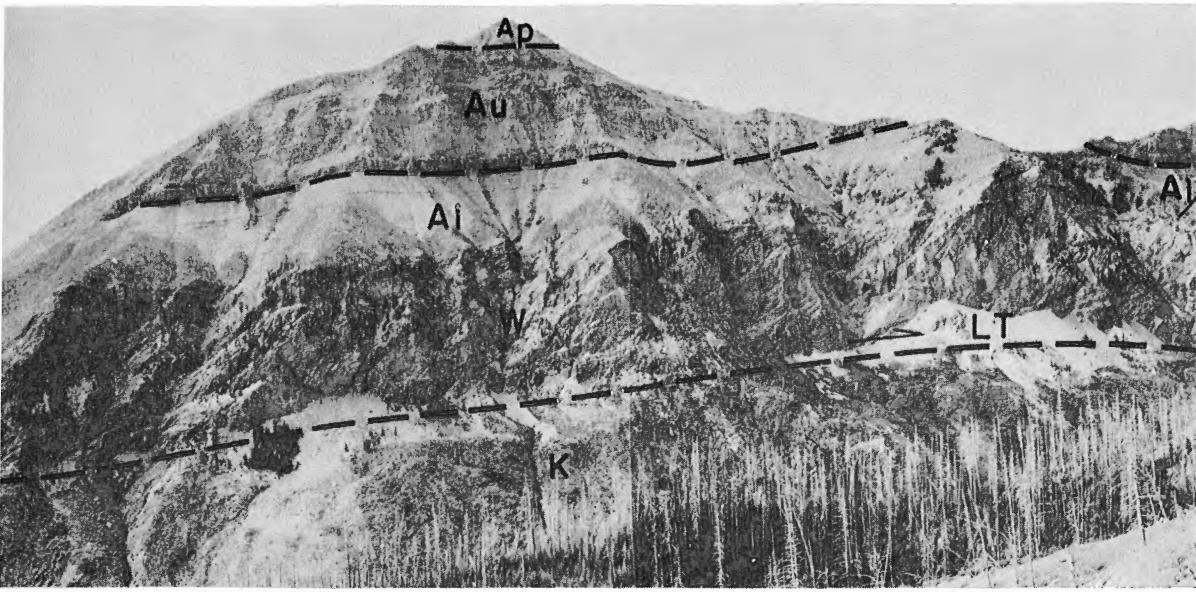

R.A.P., 111174

PLATE I. Panoramic view looking northwest across the Cate Creek window in the Lewis thrust sheet toward Packhorse Peak. Stratigraphic units identified as follows: Ap—Appekunny Formation; Au—upper part of Altyn Formation; Al—lower part of Altyn Formation; W—Waterton Formation in series of imbricate fault slices lying above Lewis Thrust Fault (LT); K—Belly River Formation and Alberta Group.

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PREFACE

The complex structures in the southern Rocky Mountains have long puzzled geologists and yet on their correct solution depends the understanding of the geology of this important region.

The author describes his studies in an area containing the tremendous Lewis Thrust Fault and innumerable less important faults, all associated with intensely folded strata. He considers each structural unit in turn and offers for each a carefully considered solution. From these emerges a clearer understanding of the geology of the whole region and its economic possibilities.

J. M. HARRISON,
Director, Geological Survey of Canada

OTTAWA, March 18, 1964

Memoir 336—Flathead-Kartenblatt, Britisch-Kolumbien und Alberta. Von R. A. Price

Der Bericht beschreibt eine vom Spät-Präkambrium bis zum Tertiär reichende, Sedimentfolge im Kanadischen Felsenbirge, die stark gefaltet und von vielen grossen Überschiebungen und Verwerfungen durchzogen ist. Hauptsächlich auf theoretischen Überlegungen gegründete Lösungen für viele der komplexen Struckturen werden vorgeschlagen.

МЕМУАР 336. Р. А. Прайс. Лист геологической карты Флэтхед Британской Колумбии и Альберты

В этом отчете дается описание последовательности осадочных пород Скалистых гор Канады от позднедокембрийского до третичного времени, которые были подвержены интенсивному складкообразованию и разбиты многочисленными надвигами и обыкновенными сбросами. Предлагается решение многих сложных структур, основанное главным образом на теоретических рассуждениях.

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FLATHEAD MAP-AREA,

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Abstract

Flathead map-area, about 200 square miles in the south-central part of the Canadian Rocky Mountains, is underlain by a sequence of unmetamorphosed sediments with minor intercalated volcanic rocks. These include the Purcell (Precambrian) to Lower Cretaceous succession of the Lewis thrust sheet, the Jurassic to Upper Cretaceous sequence of the Foothills, and an unknown thickness of mid-Tertiary fanglomerates and associated sediments along the downthrown side of the Flathead fault. A regional unconformity separates Purcell strata from Cambrian rocks. Devonian strata of the Fairholme Group unconformably overlie the probably Middle Cambrian Elko Formation. Both the clastic and carbonate facies of the Fairholme Group are present. The Peechee Member of the Southesk Formation occurs as several discrete dolomitized segments of a reef front. The lithofacies in the lower part of the Fairholme Group differ from those in the region to the north and new names are proposed. The Mississippian sequence is like that to the north and is overlain by sandstones of reported Pennsylvanian age assigned to the Rocky Mountain Formation. The Mesozoic sequence is like that of adjacent areas. Lower Cretaceous or younger trachyte and syenite dykes and stocks occur in the Lewis thrust sheet. Their emplacement appears to coincide with the deposition of the alkalic detrital material of the Blairmore Group and Crowsnest Formation.

Two distinct groups of structures occur. The older group, dominated by the Lewis thrust, is characterized by thrust faults, generally subparallel with bedding, along which pre-Cenozoic strata have undergone eastward and northeastward displacement relative to beds beneath. A transverse northwest-facing monocline in the Lewis thrust sheet marks the locus of an abrupt transverse 'step' in the path of the Lewis thrust from one glide surface to another. Structures produced by easterly thrusting have been superimposed discordantly on structures formed by northeasterly thrusting. In the area, the horizontal displacement along the Lewis thrust appears to be more than 32 miles.

The younger group of structures is dominated by the Flathead fault, a west- and south-dipping gravity fault with a maximum stratigraphic separation of more than 20,000 feet. The downthrown block is cut by faults that outline the west side of an asymmetric graben. Mid-Tertiary fanglomerates deposited in this structural trough were tilted by later movement along the Flathead fault.

These structures developed within an anisotropic layered medium inherently susceptible to interstratal slip. The anisotropy is reflected in the habit of the thrust faults and the shape of the folds. The folds are typically flexural-slip folds; flexural slip thrust faults, which commonly follow the bedding, are genetically related to the folding.

Résumé

La région de Flathead, d'une superficie d'environ 200 milles carrés, dans le centre Sud des Rocheuses canadiennes, recouvre une succession de roches sédimentaires non métamorphisés où s'intercalent un peu de roches volcaniques. Ces roches comprennent la succession Purcell (Précambrien) jusqu'à celle du Crétacé inférieur de la nappe de charriage Lewis, la succession du Jurassique jusqu'à celle du Crétacé supérieur des avant-monts et une épaisseur inconnue de brèche boueuse et de roches sédimentaires associées au Tertiaire moyen le long de la lèvre abaissée de la faille Flathead. Une discordance régionale sépare les strates Purcell des roches cambriennes. Les strates dévoniennes du groupe Fairholme recouvrent en discordance la formation Elke qui est probablement du Cambrien moyen. Les deux facies, clastique et à carbonate du groupe Fairholme sont présents. Le membre Peechee de la formation Southesk se présente sous forme de plusieurs segments discontinus à dolomie provenant d'un front de récif. Les facies lithologiques de la partie inférieure du groupe Fairholme diffèrent de ceux de la région du Nord et on leur a proposé de nouveaux noms. La succession de roches mississippiennes est comparable à celle du Nord et elle est sous-jacente à des grès qui remonteraient au Pennsylvanien, c'est-à-dire du même âge que la formation des Rocheuses. La succession mésozoïque est comparable à celle des régions adjacentes. Le Crétacé inférieur ou des dykes à trachyte et à syénite plus jeunes et des massifs se trouvent dans la nappe de charriage Lewis. Leur mise en place semble avoir coïncidé avec celle des dépôts de débris alcalins du groupe Blairmore et de la formation Crowsnest.

On distingue deux groupes de structures. Le groupe le plus ancien dominé par la nappe Lewis est caractérisé par trois failles de poussée généralement sous-parallèles à la stratification, le long desquelles les strates précénozoïques ont été soumises à des déplacements vers l'Est et le Nord-Est par rapport aux couches inférieures. Un monoclinal transverse qui fait face au Nord-Ouest dans la nappe de charriage Lewis marque l'emplacement d'un «gradin» transverse abrupt à travers la nappe de poussée Lewis, d'une surface de glissement à l'autre. Dans la région, le déplacement horizontal le long de la poussée Lewis semble être supérieur à 32 milles.

Le groupe de structures plus jeunes est dominé par la faille Flathead, faille de gravité à pendage Ouest et Sud qui présente une séparation stratigraphique maximum de plus de 20,000 pieds. Le bloc abaissé est coupé par des failles qui délimitent le côté Ouest d'un ravin asymétrique. Des brèches boueuses du Tertiaire moyen déposées dans cette fosse structurale ont été remaniées par un mouvement ultérieur le long de la faille Flathead.

Ces structures se sont développées dans un milieu stratifié anisotropique où il semble avoir eu glissement entre les strates. On reconnaît l'anisotropie à la nature des failles de poussée et à la forme des plis. Ce sont de vrais plis de flexure due au glissement. Les failles de poussée à flexure par glissement qui suivent habituellement la stratification s'apparentent aux plis.

Chapter I

INTRODUCTION

Location

Flathead map-area, which lies within the central part of the Canadian Rocky Mountains less than 20 miles north of the International Boundary (*see* Fig. 1, in pocket), covers about 200 square miles of mountainous terrain bounded by longitudes 114°30′ and 114°45′ and latitudes 49°15′ and 49°30′. Its northeast quarter lies north and east of the Continental Divide and is within the province of Alberta, the remainder lies within the province of British Columbia. Parts of Flathead, Clark, and Macdonald Ranges lie within the map-area as do parts of the Foothills and Flathead Valley.

Access

A road maintained by the British Columbia Forest Service, which follows the valleys of Michel and Squaw Creeks in the northern half and continues down the Flathead Valley beyond the southern boundary, provides access to the greater part of the map-area from Crowsnest Pass to the north and from localities along Flathead River in Montana to the south. It is passable to most motor vehicles during the summer and autumn. Logging roads in the northeastern part of the map-area along the valleys of Carbondale River and both branches of Lost Creek provide road connection with Hillcrest, Alberta. One from Blairmore, Alberta, follows the upper part of the valley of Lynx Creek, passing immediately northeast of the map-area. Throughout much of the remainder of the map-area pack-horse trails follow most of the principal streams. Generally these trails are not maintained and require some work before they are passable. A pack-trail through North Kootenay Pass connects the roads on either side of the Continental Divide.

Field Work

Reconnaissance investigations of the geology of parts of the map-area have been carried out by Dawson (1886)[1], McEvoy (1902), Rose (1918), Hume (1933), Olsson and Caster (1935), Béthune (1936), and Newmarch (1953). The central part near 'Flathead Townsite', has been examined in relative detail by Béthune (1936). Clow and Crockford (1951) prepared an account of the

[1] Dates in parentheses refer to publications listed in the *Bibliography*.

geology of the Carbondale River area, the northwest corner of which lies within Flathead map-area, and Norris (1959a) compiled a preliminary geological map of adjacent Carbondale River map-area. MacKay (1931) and Norris (1957a) compiled detailed maps of the structurally complex coal-bearing strata on Coal Mountain in the north-central part of the map-area, and most of the structural features illustrated by Norris are reproduced on the accompanying geological map.

Field work was commenced in the summer of 1956 by the writer and completed in 1957. Geological observations were plotted directly on vertical aerial photographs and were compiled on topographic maps at a scale of 1:20,000.

Acknowledgments

This report is based on a doctoral dissertation presented to the Graduate School of Princeton University, and prepared under the supervision of Professors J. C. Maxwell and A. G. Fischer who provided helpful suggestions and assistance. R. J. W. Douglas of the Geological Survey of Canada furnished unpublished data on the structural geology and stratigraphy of the region and gave much helpful advice on all phases of the geological interpretation.

Able assistance was rendered in the field by R. G. Lawrence and J. S. Thomlinson in 1956, and by D. C. Fonteyne and D. R. Pyke in 1957. The writer is indebted to D. U. Wise for his assistance in the field work in 1957 and for much critical discussion in the course of the preparation of this report.

Many courtesies were extended to the field party by residents of the district, and helpful information was supplied by J. J. Crabb, geologist for the Crowsnest Pass Coal Company at Fernie, British Columbia.

PHYSICAL FEATURES

Physiography

Flathead map-area embraces parts of two major physiographic subdivisions within the Rocky Mountain system: the Foothills and the Front Ranges. These meet along the prominent east- and north-facing scarps of Flathead and Clark Ranges respectively.

The Foothills subdivision is characterized by a series of narrow subparallel ridges composed of the resistant rocks of the Crowsnest Formation and the lower parts of the Blairmore Group and Belly River Formation. Intervening valleys have been eroded by subsequent streams which follow the less resistant rocks of the Alberta Group and the upper parts of the Blairmore Group and Belly River Formation. Local relief is about 1,500 feet. The principal streams are tributary to Carbondale River and drain eastward into the Interior Plains. They are transverse to the ridges and presumably acquired this relationship through superposition. As in adjacent regions, slopes in the Foothills are relatively smooth and exposures of bedrock are commonly found in ridge tops and stream beds. Most of the Foothills subdivision is characterized by mature stands of pine, spruce, and fir, with dense underbrush, and is thereby distinguished from much of the Foothills in adjacent regions where trees and shrubs are less prolific and tracts of open grassland are common.

The Front Ranges of the Rocky Mountains in this region comprise the smaller physiographic units of Flathead Range, Taylor Range, the region west of McLatchie and McEvoy Creeks, Macdonald Range, Clark Range, and Flathead Valley.

Flathead Range, a prominent strike ridge formed by the resistant carbonate strata of the Palaeozoic, is characterized by jagged peaks and rugged serrate spurs, and culminates in the 9,036-foot summit of Mount Darrah. Local relief along the range is about 4,000 feet. The prominent scarp marking its east slope is drained by short, intermittent, transverse streams. Timber-line is poorly defined along the steep rugged slopes. A mantle of high altitude species of conifers on the lower slopes is cut by numerous avalanche scars that terminate in cirques along the base of the scarp. The western slope is less precipitous and is drained by transverse streams that flow into the subsequent valleys of Squaw and Michel Creeks along the western border of the range. Forest fires within the past few decades destroyed a thick stand of evergreens that mantled the lower parts of the western slope.

Taylor Range lies west of Squaw and Michel Creeks, north of Flathead River, and east of McEvoy and Leach Creeks. It is "*la crête orientale de la chaine Flathead*" of Béthune (1936). The southern part of the range comprises a group of interlocked strike ridges culminating in Mount Corrigan and Limestone Ridge. Locally these exhibit rugged slopes and jagged peaks. In the northern part the topography is more subdued and the summits tend to be rounded or flat-topped. Only a few isolated patches of evergreens have survived the forest fires.

West of McLatchie and McEvoy Creeks the topography is even more subdued. Flathead River and Foisey Creek and their tributaries form a dendritic drainage pattern within a group of relatively low rounded hills. Exposures of bedrock are rare and prior to the extensive forest fires the slopes were mantled with a thick growth of evergreens. The southern and eastern boundaries of this region are marked by the subsequent valleys of Lodgepole and McLatchie Creeks which have been carved in the less resistant shaly strata of the Fernie Group. Moderate scarps along the perimeter of the region, adjacent to these valleys, are supported by resistant sandstones and conglomerates of the Kootenay Formation and Blairmore Group. Flathead Valley, which breaches these resistant beds, presumably acquired this relationship through superposition.

The northeastern part of Macdonald Range is a broad massif with dendritic drainage carved in nearly flat lying carbonate rocks. It lies southeast of Lodgepole and McLatchie Creeks and south and west of Flathead Valley. The summits are between 7,500 and 8,000 feet and are generally rounded or nearly flat. They are stripped surfaces. The valley walls are more rugged and the relief reaches 3,000 feet. Isolated patches of green timber that survived the forest fires suggest that the timber-line was at an elevation of about 7,500 feet.

Clark Range, a second broad massif with dendritic drainage, has a relief of 3,300 feet, and within the map-area culminates in the 7,910-foot summit of Packhorse Peak. Its western boundary is a fault-line scarp along the east side of Flathead Valley. To the northwest it terminates at North Kootenay Pass which separates it from the *en échelon* Flathead Range. Peaks within the range are steep and rugged and the lower slopes and valley bottoms are covered with dead and fallen trees as a consequence of widespread forest fires.

Flathead Valley extends across the central and southern parts of the map-area and is occupied by the east- and south-flowing Flathead River. The valley follows an asymmetric graben. The northeast slope is a relatively prominent fault-line scarp whereas the southeast slope is typically much more subdued. That part of Flathead Valley within the map-area marks the northern end of a prominent northwest-trending linear physiographic depression more than 70 miles long. It is similar in form to and parallel with the southern part of the Rocky Mountain Trench which lies about 25 miles to the southwest. A thick growth of evergreens which formerly covered the valley floor has been virtually destroyed by forest fires. The resulting tangle of fallen trees makes travel slow and difficult.

Glacial Geology

The topographic detail in the Flathead map-area dates from a period of alpine glaciation. Most glacial phenomena appear to be the result of the last cycle of glaciation, and data relating to earlier phases are fragmentary and suggestive at best. With the possible exception of small firn patches at high elevations, deglaciation is complete.

The most conspicuous results of glaciation are the numerous deeply incised cirques and the typical glacial-trough character of all larger valleys. Throughout most of the map-area cirques dominate the topography above an elevation of about 6,000 feet but are not evident in that part lying within the Foothills or west of McLatchie Creek. Most cirque floors occur between elevations of 6,000 and 6,500 feet. Nearly all cirques are on north- and northeast-facing slopes. Flathead Range shows evidence of especially marked modification. Cirque incision along both the east and west slopes has reduced the range to a series of sharp *arêtes* and horns, and these, together with steep cirque headwalls, make it essentially impassable. In Macdonald Range deeply incised cirques are commonly separated by flat-topped or gently rounded ridges. These are stripped surfaces developed on shallow-dipping beds, and are generally covered with felsenmeer.

A glacier occupying Flathead Valley in the central part of the map-area (present elevation of valley floor is 5,000 feet) attained an elevation of at least 6,400 feet and possibly more than 6,800 feet. Lower Cretaceous erratics originating in the west occur at an elevation of 6,400 feet on the ridge between Pollock Creek and Flathead River (vicinity of British Columbia Forest Service "Pollock

Lookout"), others have been carried over the ridge into the valley of Pollock Creek. On the west slope of that valley channeled kame terrace remnants reach an elevation of 6,100 feet. Several deeply cut cols along the Continental Divide in the north end of Clark Range (North Kootenay Pass, elevation 6,800 feet; pass immediately to the south, 6,700 feet; pass at the head of Pollock Creek, 6,200 feet; pass at the head of St. Eloi Brook, 6,500 feet) may have been eroded by ice that drained across the present Continental Divide. Glacial erratics derived from Flathead Range are common on nearby ridge crests in the Foothills. The distribution of these erratics indicates that the ice must have attained an elevation of at least 6,500 feet in this western area of the Foothills.

Throughout most of the map-area ice drainage followed the present stream pattern. The cols mentioned above are the main exceptions. In addition a change in drainage pattern is evident near Flathead Pass where ice from the west slope of Flathead Range, in part, by-passed the valleys of Squaw and Michel Creeks and flowed westward via a glacial trough through 'Taylor Range' and thence southward into Flathead Valley. The floor of the trough is covered with channeled outwash deposits.

Glacial drift covers the floors and the lower slopes of most valleys. Locally, remnants of kame terraces occur at relatively high elevations on valley walls (6,600 feet on the east slope of the pass between McEvoy Creek and Leach Creek). These generally have been dissected by meltwater channels. Well-defined moraines have not been seen within the map-area. Deposits of till with knob-and-kettle topography occur in re-entrants to Flathead Valley at the mouths of McLatchie and Squaw Creeks. At both localities the till is essentially restricted to the west slopes of the tributary valleys, in the lee of bedrock ridges. Till also occurs at an elevation of 6,500 feet along the headwaters of Carbondale River, immediately east of North Kootenay Pass.

Most drift occurs as glacio-fluvial gravel on valley floors. The gravels are characterized by a high proportion of admixed sand, silt, and clay and, in general, by imbrication and crude stratification. In the Flathead River Valley these outwash gravels accumulated to an unknown depth, forming a flat floor that has since been dissected to produce a complex of alluvial terraces.

In Flathead Valley south of the mouth of Pollock Creek, alluvial terraces are especially well developed. The highest and most prominent is marked by a well-defined set of paired terrace remnants that can be traced without difficulty to beyond the south boundary of the map-area. The gradient along the paired terrace remnants and the present Flathead River between Pollock Creek and Harvey Creek is about 35 feet per mile. Numerous smaller, local, non-paired terrace remnants occur below the highest terrace level. Shepp Creek and Harvey Creek, the principal tributaries to Flathead River from the Macdonald Range in the southern part of the map-area, have built large alluvial fans that are graded to the main terrace level. Subsequent stream entrenchment in the fans has produced narrow valleys with terraced walls. Alluvial fans are less evident on tributaries entering the Flathead Valley from the Clark Range.

Chapter II

STRATIGRAPHY

Most of the rocks exposed in Flathead map-area comprise a sequence of essentially unmetamorphosed sediments ranging in age from Purcell (Precambrian) to late Cretaceous. Minor thicknesses of Purcell and Cretaceous extrusive rocks are intercalated in this sequence. The stratigraphic succession is characterized by abundant carbonate rocks and by texturally and mineralogically mature, non-carbonate sediments. This concordant sequence is overlain with angular unconformity by synorogenic Tertiary sediments of local provenance. Concordant intrusive rocks of Precambrian age and discordant bodies of Cretaceous or Tertiary age occur also but are not common.

The stratigraphy differs significantly between the two major structural units represented within the map-area: the Lewis thrust sheet and the Foothills. The Lewis thrust sheet originated in the west and is allochthonous within the map-area. Strata within the thrust sheet range in age from Purcell to Lower Cretaceous and attain an aggregate thickness of 20,000 feet. Within the map-area, strata exposed below the Lewis thrust sheet range in age from Upper Jurassic to Upper Cretaceous and attain an aggregate thickness of 7,500 feet. Individual stratigraphic units in both the Lewis thrust sheet and the Foothills are thicker and contain more coarse clastic material within the thrust sheet than beneath it.

The Palaeozoic strata of the Lewis thrust sheet are especially well exposed and have been examined with special care in an attempt to elucidate aspects of their depositional history of importance in exploiting their established economic potential.

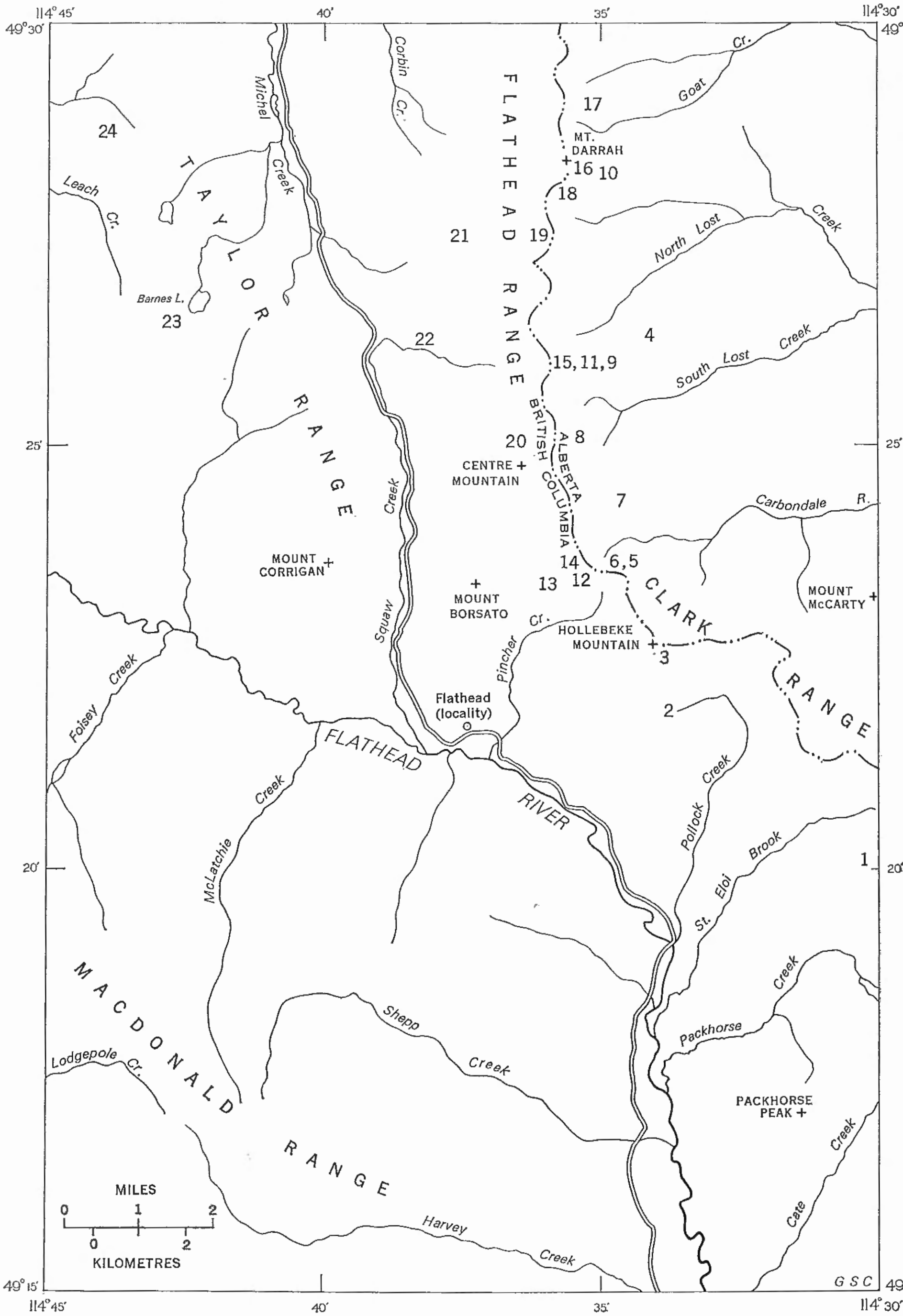

FIGURE 2. Locations of described stratigraphic sections, Flathead map-area.

Table of Formations

Era	Period or Epoch	Group Formation	Lithology	Thickness (feet)
Cenozoic	Pleistocene and Recent		Till, gravel, sand, silt	
	Unconformity			
	Eocene and Oligocene	Kishenehn Formation	Conglomerate	
Unconformity				
Mesozoic	Upper Cretaceous	Belly River Formation	Green and grey sandstone; mudstone and shale	1,500
		Alberta Group		
		Wapiabi Formation	Dark grey shale, silty shale, sandstone	1,800
		Cardium Formation	Dark grey sandstone, siltstone, silty shale	125
		Blackstone Formation	Dark grey shale, silty shale, siltstone	300
	Disconformity			
	Lower Cretaceous	Crowsnest Formation	Trachyte agglomerate, tuff, volcanic-rich sandstone, mudstone, conglomerate	500
	Lower Cretaceous, may be younger		Trachyte, syenite, volcanic breccia	
	Lower Cretaceous	Blairmore Group	Grey and greenish grey sandstone, arkosic sandstone, green and red mudstone; minor brown limestone	1,800–3,750
	Disconformity?			
	Jurassic and (?) Cretaceous	Kootenay Formation	Dark grey, carbonaceous sandstone and conglomeratic sandstone, siltstone, shale; coal	500–1,700
	Jurassic	Fernie Group	Grey calcareous shale, shaly limestone, silty limestone; dark grey shale, limestone; sandstone	1,250
	Disconformity			
	Triassic	Spray River Formation	Grey dolomitic siltstone and sandstone; brown siltstone and silty shale	300?

Era	Period or Epoch	Group Formation	Lithology	Thickness (feet)
			Disconformity	
Palaeozoic	Pennsylvanian and (?) Permian	Rocky Mountain Formation	Sandstone, quartzite, dolomite, dolomitic sandstone	660
	Mississippian	Rundle Group		
		Etherington Formation	Light grey crinoidal limestone; grey sandy, and silty limestone; cherty dolomite; green shale	435
		Mount Head Formation	Grey, silty and sandy dolomite; light grey crinoidal limestone; dark grey and black fine-crystalline and cryptocrystalline limestone; black shale	860
		Livingstone Formation	Light grey crinoidal limestone, fine-crystalline limestone, dolomite	1,370
		Banff Formation	Medium and dark grey, cherty and argillaceous limestone; black shale and banded chert	655
		Exshaw Formation	Black shale	35?
			Disconformity?	
	Devonian	Palliser Formation	Dark grey, fine-crystalline limestone mottled with brown dolomite; brown dolomite	660
			Disconformity?	
	Devonian	Alexo Formation	Silty dolomite and limestone; sandstone; limestone and dolomite breccia	25 100
			Disconformity?	
	Devonian	Fairholme Group Mount Hawk, Southesk, Borsato, Perdrix (?), and Hollebeke Formations	Dark grey, fine-crystalline limestone and argillaceous limestone; black shale; brown, medium-crystalline dolomite; light grey coarse-crystalline dolomite; silty dolomite; limestone and dolomite breccia	1,000– 1,500

Table of Formations (*Conc.*)

Era	Period or Epoch	Group Formation	Lithology	Thickness (feet)
	Unconformity			
Palaeozoic	Cambrian	Elko Formation	Light grey dolomite, mottled dolomitic limestone	280–350
			Green shale: dark grey limestone and glauconitic limestone	215
		Flathead Formation	Light grey and yellowish brown quartzite and conglomeratic quartzite	140
Unconformity				
Precambrian	Purcell?	Moyie Intrusions	Diorite sills	
	Purcell	Kintla Formation	Red quartzite, sandstone, siltstone, argillite; green argillite, dolomitic argillite	600–1,600
		Sheppard Formation	Dolomite, quartzite, siltstone, argillite	150
		Purcell lava	Chloritized, amygdaloidal andesite; pillow andesite	320
		Siyeh Formation	Grey, fine-crystalline dolomite; green, red, and black argillite	1,130
		Grinnell Formation	Red argillite; white, green, and red quartzite; red siltstone	350
		Appekunny Formation	Green argillite; white, grey and green quartzite; sandy argillaceous dolomite and dolomitic argillite	1,700
		Altyn Formation	Grey, argillaceous limestone and dolomite; black argillite; sandy dolomite	1,250
		Waterton Formation	Banded and streaked limestone and dolomite; green argillite; red, argillaceous dolomite; white limestone	450

DESCRIPTION OF FORMATIONS

Precambrian

Purcell

The oldest rocks exposed in the map-area are typical of the conformable lithological sequence that underlies most of the Lewis and Clark Ranges of the Rocky Mountains. This sequence, originally described in some detail by Willis (1902), was named the 'Lewis series' by Daly, who correlated it with his 'Purcell series' of the Purcell Mountains. The 'Purcell series' was subsequently redefined by Schofield (1914, p. 8), who again suggested a correlation with the 'Lewis series'. Data from the Flathead map-area are in agreement with this correlation, which is adopted in the discussion that follows. Rapid changes in lithofacies within the established sequences and between the structural units in which they occur preclude precise lithological correlation of individual formations within the framework of available data, nevertheless certain tentative correlations are indicated.

In recent discussions of the Precambrian stratigraphy of parts of southeastern British Columbia and southwestern Alberta, the name 'Purcell' has come into general use as a time and time-stratigraphic term presumably equivalent to a period and system respectively. A precise definition of the 'Purcell system' is lacking and it is not within the scope of this discussion to provide one. The term 'Purcell' is, however, used here as a provincial time and time-stratigraphic name of systemic value. As such it is meant to imply that the Precambrian strata exposed in the Clark Range are essentially of the same age as the Purcell sequence and comprise an older sequence than the Windermere system of the Purcell and Selkirk Mountains and of the Hughes Range of the western Rocky Mountains (Little, 1950; Leech, 1954; Reesor, 1957).

Waterton Formation

Rocks assigned to the Waterton Formation (Daly, 1912, pp. 50-56; amended by Douglas, 1952) are the oldest known in Flathead map-area. They occur immediately above the Lewis Thrust Fault within the Clark Range, where they are exposed in the floors and walls of some of the larger valleys (*see* Pl. I). There, together with some younger beds, they have been imbricated and closely folded. Complex structural relations and sparse exposures obscure the stratigraphic relationships both within the Waterton Formation and between it and the overlying Altyn Formation. It is estimated that the aggregate thickness of Waterton beds exposed in the valley of St. Eloi Brook is about 450 feet.

Four principal rock types have been recognized:

1. medium grey and medium brownish grey, very fine crystalline limestone and dolomite, which weather to a banded and streaked light grey and orange-yellow;
2. medium to dark green argillite and argillaceous dolomite;

3. brownish red, argillaceous dolomite commonly laminated with light green;
4. white, very fine crystalline and cryptocrystalline limestone.

These rock types are characteristic of the Waterton Formation in the type sections in Waterton map-area (Douglas, 1952).

In Flathead map-area the Waterton Formation forms relatively prominent topographic features beneath the recessive-weathering lower part of the Altyn Formation (*see* Pl. I). Banded and streaked grey limestone and dolomite occur in the upper part of the formation interbedded with black argillite, and apparently mark a transition from the Waterton to the Altyn Formation.

Altyn Formation

The type locality of the Altyn Formation, as defined by Willis (1902, p. 321), is on the lower cliffs of Appekunny Mountain north of Altyn, Montana. Daly (1912, p. 56), on the basis of exposures on Oil Creek (Cameron Brook) in Waterton Lakes National Park, Alberta, expanded the definition of the Altyn Formation to include older beds not observed by Willis. Douglas (1952) provided a supplementary description of the Altyn Formation at this locality and divided the formation into three parts. 'Altyn Formation' is used here in the sense of Douglas, and comprises the dominantly argillaceous carbonate sequence occurring below the non-carbonate Appekunny Formation and above the varicoloured, and banded and streaked carbonate rocks of the Waterton Formation.

Within Flathead map-area, Altyn strata are known to occur only in Clark Range where they comprise a sequence about 1,400 feet thick. There the formation has been divided into two informal units, mapped separately, which are litho-stratigraphic equivalents of the two units mapped by Douglas in Waterton map-area. A summary description of the Altyn Formation as exposed along the eastern border of the map-area immediately south of St. Eloi Brook, is given in Section I of Appendix A.

The lower Altyn is about 565 feet thick and comprises dark grey and black, fine-crystalline, platy, argillaceous limestone and dolomite, and black fissile shale or platy argillite. It is recessive-weathering and forms dark, relatively gentle slopes in contrast to the units above and below (*see* Pl. I). Limestone and dolomite beds become more abundant within the lower 150 feet of the unit marking a gradation into the underlying Waterton Formation.

In the upper Altyn, which is about 825 feet thick, five units can be recognized as follows:

5. Upper transition beds; gradational into the overlying Appekunny Formation; about 340 feet thick.
4. Upper 'concretionary' beds; about 300 feet thick.
3. Black argillite; 50 feet thick.
2. Lower 'concretionary' beds; about 60 feet thick.
1. Sandy limestone; about 70 feet thick.

The sandy limestone embraces a sequence of quartzose calcarenites and silty limestones that are gradational into the overlying lower 'concretionary' beds and the underlying lower Altyn. In thin sections both carbonate and silicate grains are discernible in the clastic fraction. The carbonate grains include single crystals and rounded aggregates of very fine crystalline calcite, both of fine sand grade. Quartz constitutes the bulk of the non-carbonate clastic grains and is accompanied by minor amounts of feldspar, metamorphic quartzite, and mica. 'Concretions' occur sporadically in the lower part of the sequence where non-carbonate clastics are less abundant.

The upper and lower 'concretionary' beds comprise light and medium grey, fine-crystalline limestone and dolomite with faint, fine textural lamination and few to abundant calcareous 'concretions'. The concretions are ellipsoidal in cross-section, 1 inch to 6 inches long and less than 2 inches thick. They are oriented with their long dimension in the plane of the bedding. The fine textural lamination passes through them, with individual laminae more widely spaced within the concretions than in the surrounding rock. The structures show at least a superficial resemblance to stromatolites of the genus *Newlandia* as described by Rezak (1957) from the Belt Series in Glacier National Park, Montana. Because of the uncertainty as to their origin, the structures in the Altyn Formation are tentatively referred to as concretions.

The black argillite forms a conspicuous dark recessive-weathering band in cliff exposures, separating the adjacent cliff-forming sequences, and is easily recognized. The basal contact is sharp but the upper contact is gradational.

The upper transition beds consist mainly of light grey and greenish grey, fine-crystalline, argillaceous dolomite with lesser amount of red and brownish red argillaceous dolomite, and minor dolomitic siltstone or mudstone. The interbeds of red and brownish red dolomite are characteristic of the unit and distinguish it from the lower beds as well as from the basal beds of the overlying Appekunny Formation. The Altyn Formation is gradational into the Appekunny and the base of the lowest green argillite bed is arbitrarily chosen as the base of the Appekunny Formation. Argillaceous dolomites lying above this bed are included in the Appekunny Formation. Near the headwaters of Pollock Creek, sandy green dolomites occur in the upper 100 feet of the Altyn Formation and in the lower 100 feet of the Appekunny.

Appekunny Formation

The Appekunny Formation was defined by Willis (1902, p. 322) as: ". . . a mass of highly siliceous argillaceous sediment approximately 2,000 feet in thickness. Being in general of a dark-grey color, it is very distinct between the yellow limestone below and the red argillites above." The type locality was given as the northeastern spur of Appekunny Mountain in Glacier National Park, Montana. In Flathead map-area, strata in the Appekunny Formation comprise green argillites; white, grey, and green quartzose sandstone and quartzite; and minor sandy argillaceous dolomite and dolomitic argillite. These lie between the brownish yellow weathering dolomites and limestones of the Altyn Formation and the red argillites of the Grinnell Formation. No completely exposed section of the Appekunny Formation was observed within the map-area, but on the basis of graphic calculations the formation is assumed to be about 1,700 feet thick in the vicinity of Pollock Creek.

No persistent stratigraphic subdivisions were recognized within the formation. Sandstone and quartzite zones, about 100 feet thick, occur throughout the sequence and consist of coalescing lenticular beds. Individual sandstone beds commonly consist of pure, coarse-grained quartz arenite and contrast sharply with the adjacent argillite beds. A light green and white quartzite zone, with thin interbeds of green and red argillite-pebble conglomerate, about 50 feet thick, marks the top of the formation immediately west of Pollock Creek. Red argillites of the basal part of the Grinnell Formation are sharply defined above the formation. The base of the Appekunny Formation is transitional through dolomitic argillite into the argillaceous dolomites of the underlying upper Altyn.

Grinnell Formation

At its type locality on Mount Grinnell, at the head of Swift Current Valley in Lewis Range, Montana, the Grinnell Formation comprises "argillite, dark red, shaly, sometimes arenaceous, ripple-marked, and sun-cracked." (Willis, 1902, pp. 316, 322). In Flathead map-area, strata assigned to this formation are red argillite, white and light green quartzite with zones of red argillite-pebble conglomerate, and red siltstone and quartzite, lying between the green argillites and white quartzites of the Appekunny Formation and the dolomite, dolomitic argillite, and argillite of the Siyeh Formation. A detailed description of the Grinnell Formation along the headwaters of Pollock Creek about 2½ miles east of Flathead, where the formation is 350 feet thick, is given in Appendix A, Section 2. The formation thickens eastward to 760 feet (Hage, 1943) in Beaver Mines map-area, and southeastward to 1,000 feet (Douglas, 1952) in Waterton map-area. Within the Flathead map-area, exposures are limited to the northwest corner of Clark Range.

The Grinnell Formation consists mainly of bright red argillites and coarse-grained white quartzites. The quartzites are sharply defined against the argillites, commonly lying on a scoured, channeled surface of argillite. They consist of coalescing lenticular beds that do not appear to be laterally persistent. Thin, red argillite partings are common and these occasionally grade into zones of intraformational conglomerate characterized by flat pebbles of red argillite in a coarse-grained white quartzite matrix. Ripple-marked surfaces occur on the quartzites and mud-cracked surfaces characterize some of the argillite beds. The quartzites are relatively pure quartz arenites.

The Grinnell Formation is sharply defined between the Appekunny and Siyeh Formations, forming a conspicuous red band between the green beds below and the brownish yellow beds above, and appears to be gradational into both these formations.

Siyeh Formation

The Siyeh Formation, whose type locality is Mount Siyeh in the Lewis Range, Montana, was defined by Willis as:

> . . . in general an exceedingly massive limestone, heavily bedded in courses 2 to 6 feet thick like masonry. Occasionally it assumes slabby forms and contains argillaceous layers. It is dark blue or greyish, weathering buff . . . (1902, pp. 316, 323).

At the type locality it is sharply defined over red Grinnell argillites and is overlain by an "extrusive igneous sheet".

Within Flathead map-area, grey, fine-crystalline dolomite and sandy dolomite, and green, red and black argillite, lying between the red argillite of the Grinnell Formation and the Purcell lava, have been assigned to the Siyeh Formation. The formation is exposed along the northwest side of Clark Range and the southeast slope of Flathead Range. Along the Continental Divide at the headwaters of Carbondale River and Pollock Creek it is 1,130 feet thick. A detailed lithologic description of the unit at this locality is given in Section 3, Appendix A.

Three lithostratigraphic units are recognizable, which are equivalent to those described by Douglas (1952) from Waterton map-area, and those described by Daly (1912) from Galton Range. The lower unit, about 30 feet thick, consists of green and black argillite with interbeds of green and grey argillaceous and arenaceous dolomite. Its basal contact is sharply defined above the white quartzite and sandstone and the red argillite of the underlying Grinnell Formation, but the sequence appears to be gradational, with no significant stratigraphic break.

The middle unit, 1,000 feet thick, consists primarily of fine-crystalline, thin-bedded, grey dolomite. Thin interbeds of grey and black argillite and of dolomitic sandstone and quartzite occur locally. The dolomite is slightly argillaceous and contains a small amount of fine quartz silt. It almost invariably exhibits a very fine or microscopic textural lamination. Intraformational conglomerates, consisting of flat pebbles of laminated dolomite embedded in a matrix of dolomitic sandstone, are associated with some of the sandstone and quartzite interbeds. Sandstone beds are more common in the lower part of the unit and many of them are feldspathic, containing up to 15 per cent of fresh microcline and plagioclase. *Cryptozoon*-type stromatolites (Rezak, 1957) were observed in the middle subdivision north of Carbondale River.

The upper unit, 100 feet thick, comprises light green argillite and dolomitic argillite, commonly ripple-marked, with a zone of red, mud-cracked argillite at the top. Locally the argillites grade into silty mudstone. A pillowed andesite at the base of the Purcell lava lies with sharp contact on the red argillite zone.

Table I

Thickness (feet) of Lithostratigraphic Units in the Siyeh Formation

Unit	North Kootenay Pass	Waterton Map-area (Douglas, 1952)	Southern Galton Range (Daly, 1912)
upper	100	600+	1,200
middle	1,000	900+	2,000
lower	30	500+	800
Total	1,130	2,000 to 3,000	4,000

Purcell Lava

Daly (1912, p. 207) applied the name Purcell lava to a sequence of chloritized basic lavas that he described as occupying the same stratigraphic position in Lewis, Clark, and Galton Ranges of the Rocky Mountains and in McGillivray Range of Purcell Mountains. He stated (1912, p. 213) that in Clark Range "It rigidly preserves its conformable position between the Siyeh and Sheppard Formations and steadily holds a thickness of about 260 feet."

Within Flathead map-area, chloritic andesitic lava with subordinate chloritic pillowed andesite in a matrix of 'tuff breccia' comprise the Purcell lava as defined by Daly. Between North and South Lost Creeks, on the east slope of Flathead Range, the lava is 321 feet thick and consists of one thick, complex flow unit of andesite, underlain by several thin andesite flows with a pillowed zone at the base. A summary description at this locality follows (Section 4):

	Thickness (feet)	Height above base (feet)
OVERLYING BEDS—SHEPPARD FORMATION		
Quartzite, dolomitic, light grey-green, fine grained; beds 6 to 8 inches thick; weathers brownish yellow, blocky; sharp basal contact; surface of lava shows local relief of up to 6 inches and over an exposed length of 30 feet it is undulatory with relief of several feet	4.0	

	Thickness (feet)	Height above base (feet)
PURCELL LAVA		
Andesite lava; no well-defined or persistent flow layering, irregular distribution of textural varieties with discontinuous parallel zonation locally; dominant textural variety— dark purple-green, equigranular, fine-grained, chloritic andesite, amygdaloidal (chlorite-quartz-calcite) in part; pipe amygdales are apparent locally but do not define persistent zones; porphyritic in part with tabular, thin (3-inch by ¼-inch) plagioclase phenocrysts; equigranular, medium-grained, in part; lenses and discontinuous bands (less than 4 inches thick) of dark red chert occur locally without apparent consistent orientation; unit appears to be a composite flow unit	241.0	323.0
Andesite lava; poorly defined but persistent flows from 5 to 15 feet thick; pipe amygdales (chlorite-quartz-calcite) along sharply defined bottoms of flows; equigranular, fine- to medium-grained interiors, commonly with one porphyritic zone characterized by tabular (3-inch by ¼-inch) plagioclase phenocrysts and irregular chlorite amygdales up to ½-inch in diameter; vesicular and amygdaloidal flow tops	50.0	82.0
Andesite pillowed lava; pillows—ellipsoidal, 'bun-shaped', and irregular with smooth curved outlines, up to 4 feet in diameter; aphanitic, dark red andesite with occasional tabular (3-inch by ¼-inch) plagioclase phenocrysts occurs in interior, gradational toward the periphery to aphanitic dense, waxy, green, chloritic andesite; matrix is a breccia with shard-like fragments of waxy, green chloritic andesite up to 2 inches long in a dense black chloritized tachylyte (?) matrix	30.0	32.0
Ellipsoidal masses of andesite, similar to that forming the pillows, enclosed in platy, laminated, green argillite	2.0	2.0
Underlying beds—Siyeh Formation, red and green argillite.		

Most of the Purcell lava consists of dark green and reddish or purplish green, equigranular, medium- and fine-grained, amygdaloidal andesite. Porphyritic andesite, equigranular non-amygdaloidal andesite, and chloritized tachylyte (?) or chloritic devitrified andesitic glass are less common. The amygdales consist of chlorite and less commonly of calcite or of mixtures of chlorite and calcite, calcite and quartz, and chlorite and quartz. The rock generally has a relict hyalopilitic texture in which chlorite and magnetite-ilmenite occupy angular interspaces between plagioclase laths. The plagioclase is andesine and is generally clouded and partly replaced by sericite (?), clinozoisite, chlorite, and magnetite-ilmenite. In the porphyritic phase tabular phenocrysts of calcic andesine a quarter inch or less thick and up to 3 inches in diameter occur in a fine-grained matrix. The estimated average mode of the lava is:

	Per cent
Andesine	50
Chlorite	40
Magnetite-ilmenite and other accessories	10

Pillow structure was observed only in the basal part. The pillows average about 18 inches in diameter but occasionally are as much as 4 feet. Their dark red interiors consist of plagioclase microlites set in a matrix of chlorite that is clouded with hematite and magnetite-ilmenite. Amygdales of chlorite and chlorite-quartz are relatively common. Large tabular phenocrysts of plagioclase occur but are rare. Towards the periphery, the pillows become light green and in the peripheral zone they consist of plagioclase microlites set in a matrix of chlorite that is clouded with leucoxene globulites, magnetite-ilmenite, and minor hematite. The interstices between the pillows are filled with breccia consisting of light green shard-like fragments from 1 to 10 mm long set in a black matrix. The fragments have the same mineralogical composition and texture as the peripheral zone of the pillows and are assumed to represent material that has spalled off their surface. The fragments are generally rimmed with thin concentric layers of microcrystalline quartz and fine-crystalline calcite. The matrix of the breccia consists of spherulitic chlorite (penninite) with minor amounts of hematite, microcrystalline quartz, and fine-crystalline carbonate.

Sheppard Formation

Willis (1902, p. 324) introduced the name Sheppard quartzite for the sequence of beds occurring above the "extrusive igneous sheet" (Purcell lava) and below the red argillaceous quartzite and shale of the Kintla Formation in the vicinity of Mount Cleveland, Montana. Daly (1912, pp. 77-78) described the Sheppard Formation as consisting of "siliceous dolomite" with subordinate amounts of dolomitic quartzite on the Continental Divide immediately north of the International Boundary, where he reported it to be 600 feet thick. And in Beaver Mines map-area, Hage (1943) assigned 470 feet of "brown weathering argillite, arenaceous limestone, feldspathic sandstone" to the Sheppard Formation.

Within Flathead map-area, strata lying between the Purcell lava and the red siltstone and argillite of the Kintla Formation have been referred to the Sheppard Formation. These consist of dolomite, quartzite, feldspathic sandstone, and minor argillite and stromatolitic dolomite. The formation varies in thickness from 120 to 160 feet along the east slope of Flathead Range. There appears to be significant lateral variation in the relative amounts of carbonate and clastic non-carbonate rock within the formation, and either may be dominant locally. A detailed description of the formation along the provincial boundary east of North Kootenay Pass, is given in Section 5 of Appendix A.

The 'quartzites' of the Sheppard Formation contain up to 15 per cent feldspar and up to 25 per cent argillaceous and micaceous matrix. They are gradational from relatively pure quartz arenites to feldspathic quartz arenites and feldspathic quartz wackes. The feldspar is clear and relatively 'fresh', and includes microcline, microperthite, orthoclase, and plagioclase. *Collenia*-type stromatolitic dolomites occur within the formation and are locally gradational into stromatolite-fragment conglomerates. Other dolomites within the sequence are characteristically very fine crystalline and exhibit delicate textural lamination.

The Sheppard Formation lies with sharp contact above the lava. Locally detritus derived from the lava is incorporated in the lower part of the basal quartzite of the formation, but nowhere does a deeply eroded surface appear to have been developed on the lava. The formation is in gradational contact over an interval of a few feet with the overlying red argillites and siltstones of Member A of the Kintla Formation.

Kintla Formation

At the type locality on the International Boundary northeast of Upper Kintla Lake (Willis, 1902, p. 324), this formation consists of ". . . deep red argillaceous quartzites and siliceous shales, with marked white quartzites and occasional calcareous beds." To the north in Clark Range, Hume (1933, p. 6B) recognized four lithostratigraphic subdivisions, which in Beaver Mines map-area, Hage (1943) designated as Members A, B, C, and D. Members A, B, and C have been recognized and mapped separately in Flathead map-area. Member D has been recognized and mapped separately south of the map-area in Macdonald Range near Twentynine Mile Creek (*see* Fig. 3) but has been removed by pre-Palaeozoic erosion within the map-area.

The Kintla Formation, which is exposed along the east and southeast slopes of Flathead Range, consists of red siltstone and argillite, green argillite and dolomitic argillite, and red quartzite and sandstone. Pre-Palaeozoic erosion has resulted in the thickness varying from 1,600 feet near North Kootenay Pass to about 600 feet near Goat Creek. The thickest section known in the map-area is described in Section 6 of Appendix A, measured along the provincial boundary immediately south of North Kootenay Pass.

Member A consists primarily of dark red, argillaceous, hematitic siltstone and quartzitic siltstone with minor green dolomitic argillite and argillaceous dolomite. It forms a conspicuous red band between the underlying yellowish weathering Sheppard Formation and the overlying green beds of Member B. The member is about 650 feet thick except in the northern part of the Flathead Range, where more than 100 feet have been removed by pre-Palaeozoic erosion.

Member B consists of green argillite and argillaceous siltstone with minor argillaceous and silty or sandy, light green, fine-crystalline dolomite. It is gradational at the base with Member A, the two units being distinguished solely by their colour differences. Member B is also gradational with Member C, but that boundary is characterized by a change from argillite to sandstone as well as by a distinctive colour change from green to red. Near North Kootenay Pass Member B is about 500 feet thick.

Member C consists mainly of red, hematitic, fine- and medium-grained quartzite and sandstone. Ripple-marked bedding surfaces occur locally. Occasional thin zones of intraformational conglomerate, consisting of flat pebbles of red argillite and mudstone in a quartzite or sandstone matrix, appear to grade laterally into thin argillite or mudstone partings and interbeds. Within the map-area,

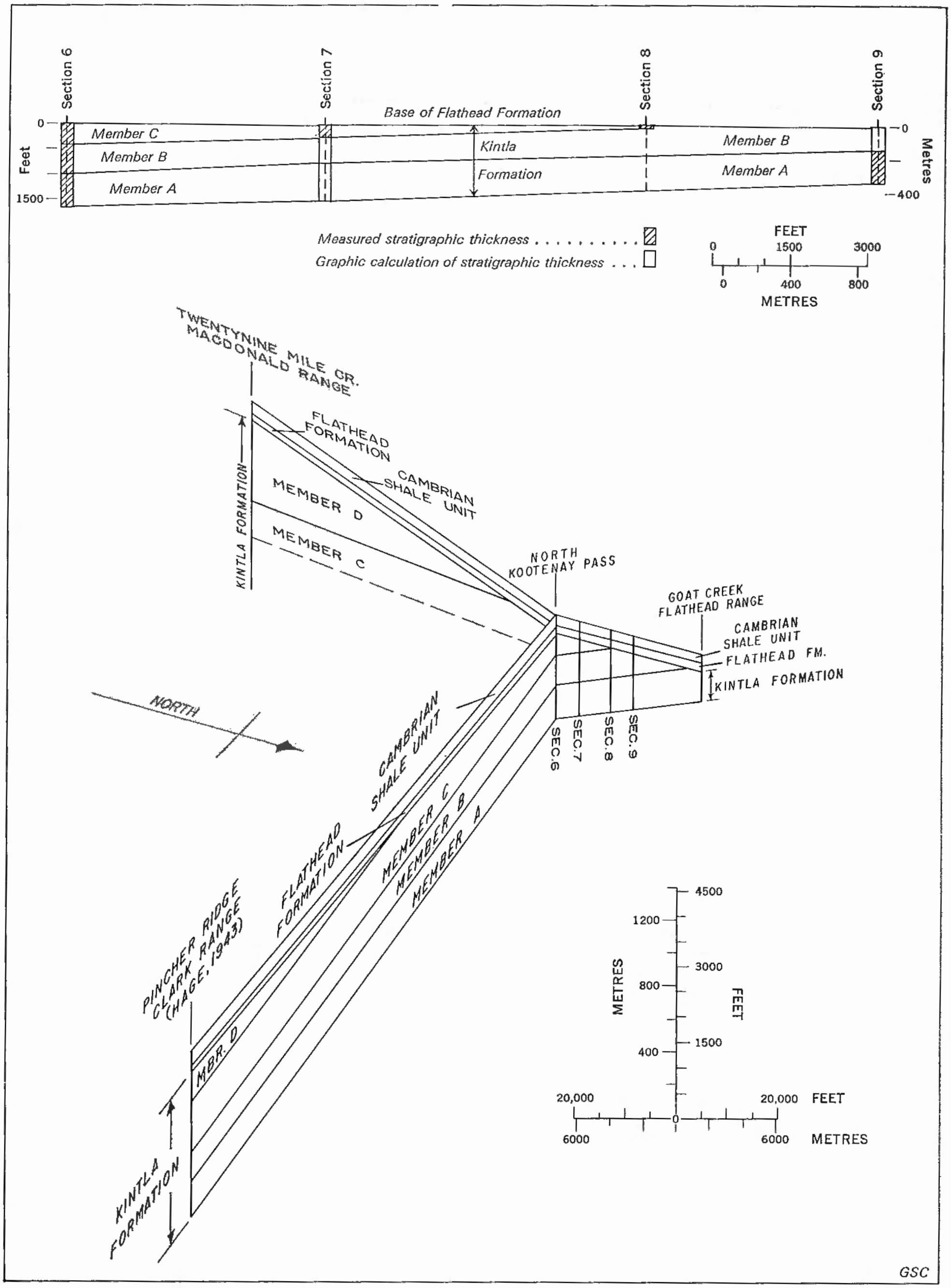

FIGURE 3. ***Stratigraphic relationships between the Flathead and Kintla Formations (for locations of sections, see Fig. 2).***

Member C is unconformably overlain by the basal unit of the Palaeozoic sequence —the quartzites of the Flathead Formation. Within Flathead map-area Member C attains a maximum thickness at North Kootenay Pass, where the Flathead Formation lies above 400 feet of Kintla C beds. South of the map-area where overlain by Member D, Member C is about 800 feet thick. The quartzites contain up to 15 per cent feldspar (microcline, microperthite, plagioclase, and orthoclase), and are gradational from pure quartz arenites to feldspathic quartz arenites. Locally the quartz cement is replaced by hematite and the quartzites are gradational to hematitic sandstones.

Correlation of Lithostratigraphic Units

Distinctive and persistent units such as the Purcell lava and Member C of the Kintla Formation, and gross lithologic similarities in the stratigraphic succession from area to area, provide the only bases, at present, for correlating the

Table II

Lithostratigraphic Correlations in the Purcell System

SOUTHERN ROCKY MOUNTAINS				SOUTHERN PURCELL MOUNTAINS
CLARK RANGE		GALTON RANGE		
Hume, 1933; Hage, 1943; Douglas, 1952; this report		Daly, 1912		Schofield, 1915; Rice, 1937 and 1941; Leech, 1952; Reesor, 1957
Kintla Fm.	Member D	Roosville Fm.		Mount Nelson Fm.
	Member C	Phillips Fm.		
	Member B	Gateway Fm.	Upper m.	?
	Member A			
	Sheppard Fm.		Lower m.	Dutch Creek Fm.
Purcell lava		Purcell lava		Purcell lava
Siyeh Fm.	Upper m.	Siyeh Fm.	Upper m.	Siyeh Fm.
	Middle m.		Middle m.	Kitchener Fm.
	Lower m.		Lower m.	
Grinnell Fm.		Wigwam Fm.		Creston Fm.
Appekunny Fm.		*		
Altyn Fm.				Aldridge Fm.
Waterton Fm.				

*Recent mapping in Macdonald Range by the writer has shown that Daly's MacDonald and Hefty Formations do not occupy this position but are synonymous with the Kintla Formation.

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rocks of the Purcell System. Table II summarizes the writer's interpretation of the available data pertaining to lithostratigraphic correlations in the Purcell System of the southern Rocky Mountains and the southern Purcell Mountains in Canada.

Age of the Purcell System

Within the map-area, along the east slope of Flathead Range, pre-Palaeozoic erosion has resulted in the truncation of the Kintla Formation along a surface with a minimum stratigraphic relief of 1,000 feet (*see* Fig. 3). The pre-Palaeozoic erosion surface shows no significant relief on a local scale. Where observed in individual exposures the contact between the Cambrian and the Purcell strata is sharply defined and parallels the stratification above and below. Locally, a weathered zone is apparent at the top of the Kintla Formation (*see* Section 6 of Appendix A). Northward erosional truncation of the Kintla Formation is also evident in Beaver Mines map-area (Hage, 1943). Figure 3 illustrates the north-south relationships between the Purcell and Palaeozoic sequences across Flathead map-area and the east-west relationships between Flathead and Beaver Mines map-areas.

The oldest diagnostic faunas collected within Flathead map-area lie about 250 feet above the base of the Palaeozoic sequence and belong to the *Albertella* zone of the Middle Cambrian. On the basis of the stratigraphic evidence available, within the map-area the Purcell strata can only be dated as pre-Middle Cambrian and probably Precambrian. As indicated previously, they have been correlated with the Purcell sequence of the Purcell Mountains and constitute a Precambrian sequence older than the Windermere System. The precise temporal position of the Purcell System within the Precambrian is unknown. It has been suggested that on the basis of the low grade metamorphism and gross-lithologic similarity to some of the overlying Palaeozoic strata, the Purcell System be considered as very Late Precambrian. Recent radioisotope age determinations on veins cutting lateral equivalents of the Purcell System in the Coeur d'Alene district of Idaho have, however, indicated an age greater than 1,200 million years (Eckelmann and Kulp, 1957), i.e., middle Proterozoic.

Moyie Intrusions

Purcell strata within the map-area are cut by a series of diorite sills from less than 5 feet thick to at least 35 feet. These sills are petrographically similar to the Moyie Intrusions of the Purcell Mountains and show the same structural relationships (Reesor, 1957, p. 30). Sills have been observed in the upper part of the Altyn Formation, the Appekunny Formation, the Siyeh Formation, the Sheppard Formation, and the three lower members of the Kintla Formation. They are more common in the upper part than the lower part of the Purcell sequence and are especially abundant in the Kintla Formation. Igneous rocks of this type are not known from the Palaeozoic or Mesozoic sequences. At North Kootenay Pass below the Middle Cambrian Flathead quartzites a weathered zone 2 feet thick has been developed on a diorite sill that cuts the Kintla Formation. The Moyie Intrusions are considered to be post-Kintla Formation and of Precambrian age.

Most of the sills have been altered. Alteration is especially pronounced in the thinner sills where the rock is a felted, patchy aggregate of chlorite, clinozoisite, 'sericite', and carbonate, with a reticulating network of blade-like magnetite-ilmenite. The detail of texture and mineralogy in the sediments appears to be unchanged near the sills. In a few of the thicker sills, the primary mineralogy and texture are clearly discernible. These are dark green rocks with a grain size varying from 0.5 mm or less in a marginal chill zone to about 2.0 mm in the interior of the sill. The approximate modal composition is as follows:

Plagioclase	50%
Augite	15%
Chlorite	10%
Magnetite and/or ilmenite	10%
'Micropegmatite'	10%
Quartz	3%
Other accessories	2%

Plagioclase forms a mesh of euhedral to subhedral laths. Its composition varies from andesine to calcic oligoclase, and it is generally clouded with fine granular clinozoisite and feathery 'sericite'. Augite occurs as small anhedral grains that are locally zoned. It is partly mottled with, and enclosed in, chlorite and epidote. In addition to its association with augite, chlorite occurs as blade-like crystals and as irregular interstitial patches between plagioclase crystals. Magnetite-ilmenite forms blade-like crystals as well as irregular or equidimensional grains that are generally interstitial. 'Micropegmatite', consisting of a micrographic intergrowth of orthoclase and quartz, occurs together with quartz as interstitial material within the plagioclase mesh. Pyrite, chalcopyrite, and pyrrhotite (?) are present in small amounts locally. Small amounts of sulphides impregnate the wall-rocks adjacent to a few of the sills. The distribution of sulphides is erratic in both the diorite and the wall-rocks and only very small quantities of sulphides were seen. On the basis of mineralogy, fabric, and structural relations, the diorites are considered to be of magmatic origin, probably genetically related to the Purcell lava. The alteration is probably deuteric and a result of reaction between the diorite magma and the water-saturated sediments it intruded.

Palaeozoic

Exposures of Palaeozoic strata within the map-area are restricted to the Lewis thrust sheet, where the Palaeozoic sequence differs significantly in stratigraphic detail from the well-known sequence of the western Interior Plains and the Foothills. These differences can be attributed to lateral variations in depositional environment in the Palaeozoic sedimentary basin, accentuated by tectonic shortening of the original basin along northwest-trending thrust faults and associated folds.

As in the western Plains and the Foothills, the Palaeozoic sequence consists predominantly of carbonate rocks[1]. At several stratigraphic horizons in the region to the east and northeast porous carbonate strata within this sequence form important petroleum reservoirs. The well-exposed Palaeozoic strata of Flathead Range have therefore been examined in somewhat greater detail than other parts of the stratigraphic sequence within the map-area.

Most of the data assembled in this study consist of field descriptions of rocks comprising the various stratigraphic sections examined. To facilitate a relatively clear distinction between petrographic data and interpretations of petrogenesis two basic textural classes have been utilized: those rocks possessing a megascopically distinguishable clastic fabric are termed calcarenites, calcisiltites, etc., and their texture is designated in the terminology used for other clastic rocks; those rocks possessing a crystalline mosaic fabric which may or may not mask a primary clastic fabric of comparable grain size are termed crystalline limestones, crystalline dolomites, etc., and their texture is designated as follows:

very coarse-crystalline	more than 1 mm
coarse-crystalline	1.0-0.5 mm
medium-crystalline	0.5-0.1 mm
fine-crystalline	0.1-0.01 mm
very fine-crystalline	0.01-0.001 mm
cryptocrystalline	less than 0.001 mm

Where more detailed data on the fabric of the carbonate rocks have been obtained through microscopic examination of selected rock specimens and thin-sections, these have been incorporated in the general descriptions of the rock-units but not in the field descriptions of measured stratigraphic sections.

The term bedding, as used in this report, refers to primary parallel or sub-parallel surfaces of physical discontinuity in the sedimentary fabric along which the rock separates during weathering and mechanical disintegration. Lamination or banding as distinct from bedding is described separately.

Cambrian

Exposures of Cambrian strata occur along the east and south slopes of Flathead Range and at the headwaters of Howell and Harvey Creeks in Macdonald Range. The Cambrian sequence is divisible into at least three distinctive litho-stratigraphic units, which have been mapped separately. The lower unit, which is lithologically like the Flathead sandstone of northwestern Montana and occupies the same stratigraphic position, is named the Flathead Formation. The middle unit is lithologically similar to the Gordon shale of northwestern Montana and occupies a comparable stratigraphic position, but as its upper contact cannot be correlated unequivocally with that of the Gordon shale on the basis of available data, no formal name is applied here. The upper unit differs significantly from

[1] 'carbonate rocks' is used to denote sedimentary rocks composed primarily of calcite and/or dolomite.

strata in the corresponding part of the Cambrian succession in northwestern Montana but is lithologically similar to the Elko Formation of southeastern British Columbia, and occupies the same stratigraphic position. It is so named in this report.

Flathead Formation

Weed's original definition (1899, p. 285) of the Flathead sandstone in the Little Belt Mountains has been emended by Deiss (1936, p. 1328), whose description of its lithology and stratigraphic relations applies directly to the strata assigned to the Flathead Formation in Flathead map-area.

The Flathead Formation is about 140 feet thick and consists predominantly of light grey and light yellowish brown, coarse-grained quartzitic sandstone (relatively pure quartz arenite), in beds from 0.5 foot to 3 feet thick. Pebble and granule conglomerate zones occur locally and are most common near the base of the formation. The unit weathers to light rust-brown, light grey, and white, and forms blocky scree slopes and relatively prominent topographic forms. No fossils have been found. The sandstones are unconformable on the Purcell sequence below, but are gradational through a relatively thin interval into the overlying shales. The formation is the lithostratigraphic equivalent of the basal quartzite unit of the Palaeozoic sequence on Windsor Mountain in Beaver Mines map-area (Hage, 1943). It is similar to the Cranbrook Formation of the southwestern part of the Rocky Mountains in British Columbia (Rice, 1937, pp. 18-21; Leech, 1954, p. 7), but grades upward into Middle rather than Lower Cambrian shales. As suggested by North (1953, p. 115), the Cranbrook and Flathead Formations are markedly diachronic and probably represent littoral sands deposited during the Lower and Middle Cambrian marine transgression within this part of the Canadian Cordillera.

Shale Unit

Green and greenish grey, waxy, platy, and fissile shales with sparse thin interbeds and lenses of fine-crystalline limestone and glauconitic limestone occupy the interval between the Flathead and Elko Formations in Flathead, Macdonald, and Clark Ranges. Section 11, on the east slope of Flathead Range on the ridge between North Lost Creek and South Lost Creek, is typical of this unit. There the unit is 219 feet thick and consists mainly of greenish grey shale. Grey and yellowish grey limestone occurs as interbeds from a few inches to 4 feet thick. The lower 12 feet of the unit is not exposed, but observations made within other parts of Flathead Range indicate that the shales are gradational into the sandstone of the underlying Flathead Formation. At the top, the shale unit grades through interbedded limestone and shale into the dolomite-mottled limestone of the lower part of the Elko Formation. The contact is designated as the top of the highest shale interbed. The shales are easily eroded and typically form gentle scree slopes between the more resistant Flathead and Elko Formations.

Along Flathead Range, the thickness of the shale unit is relatively constant, generally between 200 and 220 feet, but southward it increases, and at Windsor Mountain (Hage, 1943; Norris, 1959a), in Beaver Mines map-area, is 288 feet. There the unit consists of grey and greyish green shale, variegated green, brown, and maroon shale, thin grey sandstone, and grey nodular limestone. Thickness variations and their relations to thickness variations in the Flathead Formation are shown in Figure 3.

The shales locally contain abundant trilobite fragments and inarticulate brachiopods. Most of the limestone interbeds consist of a very fine-crystalline crystalloblastic calcite mosaic enclosing disseminated skeletal fragments (including trilobite carapaces and brachiopods) and locally spherical and ellipitical pellets of fine- and very fine-crystalline calcite. Many of the limestones are mottled with medium-crystalline calcite or dolomite patches. Dolomitic mottling is most common toward the top of the formation whereas medium-crystalline calcite mottling is more common toward the base. Pellets of glauconite up to 2 mm long occur within the limestones in the lower part of the formation.

Fossil collections have been made from the upper 110 feet of the shale unit at Sections 11 and 12 (*see* Appendix A for precise stratigraphic positions of collections), and have been identified by A. W. Norris of the Geological Survey of Canada (*see* Appendix B for faunal lists and comments on individual collections). The fauna includes *Albertella, Zacanthoides, Kochina, Ptarmigania, Vanuxemella, Glossopleura*?, *Hyolithes, Iphidella,* and *Micromitra.* Norris states that the presence of specimens of the trilobite genus *Albertella* in all collections dates the enclosing beds as early Middle Cambrian. They are correlated with the Ross Lake shale member of the Cathedral Formation in the Kicking Horse Pass region and with the Gordon Formation of Montana.

Elko Formation

At the type section near Elko, British Columbia (Schofield, 1914, p. 83; Leech, 1958, p. 11), the formation comprises about 200 feet of carbonate strata, underlain by shales that have yielded a Middle Cambrian trilobite fauna, and overlain by about 200 feet of dolomite, dolomitic sandstone, and shale that marks the base of a sequence of strata characteristic of the Fairholme Group (Leech, 1958, p. 23). A 30-foot dolomite-mottled limestone zone at the base is gradational upward into thickly bedded dolomite.

Strata assigned to the Elko Formation in Flathead map-area comprise a cliff-forming, medium-crystalline dolomite unit, 275 to 350 feet thick, with a zone of dolomite-mottled limestone at the base. They are underlain by Middle Cambrian shales and overlain by between 100 and 200 feet of thinly bedded dolomite and limestone, in part silty and argillaceous, that mark the base of the Fairholme Group.

Along the east slope of Mount Darrah, on the ridge between the headwaters of North Lost Creek and Goat Creek, the Elko Formation is 285 feet thick (*see* Section 10, Appendix A); to the south at North Kootenay Pass (*see* Section 12, Appendix A) it is 351 feet thick. The formation is exposed in Macdonald

Range and has been tentatively identified in several Palaeozoic outliers in the Clark Range. It probably forms the basal part of the Palaeozoic carbonate sequence on Windsor Mountain in Beaver Mines map-area (Hage, 1943).

The Elko Formation consists primarily of medium and light grey, fine- and medium-crystalline dolomite, commonly exhibiting a faint textural mottling which becomes etched into relief on weathered surfaces. Bedding, when apparent, is defined in terms of parallel zones of differing texture. Locally these are zones with discontinuous vuggy or intercrystalline porosity. Elsewhere stylolites mark bedding surfaces. Toward the base of the formation the dolomite grades through a zone of medium to dark grey, texture-mottled, medium-crystalline dolomite to a basal zone of dolomite-mottled limestone. The basal limestone zone varies in thickness from 50 to 120 feet presumably due to lateral gradations from limestone to dolomite in the upper beds. The limestone is typically dark grey, fine- to very fine-crystalline and mottled with medium- to fine-crystalline, light brown and orange-yellow dolomite. Much of the dolomite-mottled limestone resembles that of the Upper Devonian Palliser Formation. The Elko Formation characteristically forms prominent cliffs between the recessive weathering Cambrian shales and the basal beds of the Fairholme Group.

The dolomites consist of a crystalloblastic mosaic of anhedral to subhedral dolomite and are typically devoid of any 'primary' sedimentary fabric. The mottling can be related to almost imperceptible patchy variations in crystal size or amount of intercrystalline porosity. In individual specimens the vuggy and intercrystalline porosity may exceed 15 per cent.

The limestones consist of a crystalloblastic mosaic of fine- and very fine-crystalline calcite with rare to abundant disseminated very fine- to medium-grained clastic calcite. The clastic fraction consists predominantly of various organic fragments including: triaxial spicules, fragments of trilobite carapaces, brachiopod shell (?) fragments, echinoderm fragments, and forms tentatively referred to the genus *Lapworthella* Cobbold by A. G. Fischer and B. F. Howell of Princeton University. Calcispheres averaging 0.1 mm in diameter are also present. Medium-crystalline dolomite occurs as a mosaic of euhedral to subhedral grains in irregular patches with diffuse boundaries.

The limestones are arenaceous calcilutites and are texturally immature. Their mineral composition is indicative of moderate salinity and dynamic isolation from sources of allogenic clastic silicates. Their fabric indicates an environment in which there has been little or no transport and sorting of clastic particles, and in which skeletal components have made a significant contribution to clastic sedimentation. Skeletal fragments form a bimodal mixture with what appears to have been a chemically precipitated lime mud. These features are characteristic of the sheltered interiors of isolated carbonate shoals (cf. Beales, 1956) and the limestones of the Elko Formation probably represent the deposits of shoals of this type that formed on the surface of the older marine muds. Dolomite patches mottling the limestone fabric possess a crystalloblastic fabric indicative of secondary replacement. The lower part and possibly most of the dolomite sequence may represent a completely dolomitized equivalent of the calcilutite.

The Elko Formation is unconformably overlain by the basal beds of the Fairholme Group. The contact between these two units is generally sharp and apparently concordant. Locally, however, a regolith is preserved at the base of the Fairholme Group. On the ridge between North and South Lost Creeks (*see* Section 15, Appendix A), a reddish orange and yellow calcareous mudstone occurs at the base of the Fairholme sequence and fills depressions in a surface, with an apparent relief of 10 feet, developed on the top of the Elko Formation. The mudstone fills fractures in the dolomite and red and orange stains occur in the dolomite adjacent to the fractures. The stains extend 30 feet below the top of the formation. Variations in thickness of the Elko Formation along the east side of the Flathead Range are probably the result of pre-Upper Devonian erosion.

No megafossils or diagnostic microfossils have been collected from the Elko Formation. On the basis of its stratigraphic relationships with adjacent units it is assumed to be of Middle Cambrian age. It is probably a lateral equivalent of Middle Cambrian carbonate units in the Kicking Horse Pass region and in northwestern Montana.

Devonian

Devonian strata are exposed within the Lewis thrust sheet: along the east and south slopes of Flathead Range, adjacent to Flathead River south of North Kootenay Pass, in the northeastern part of Macdonald Range, at the headwaters of Harvey and Howell Creeks, and along the west side of Clark Range at Cate Creek. They form a concordant sequence about 1,750 feet thick, which in overall aspect is comparable to that from the region between Bow and Athabasca Rivers (McLaren, 1955). Three principal lithostratigraphic units are recognized, which comprise, in order of stratigraphic succession, the Fairholme Group, the Alexo Formation, and the Palliser Formation. Fossils collected from these rocks in Flathead map-area have been examined by D. J. McLaren of the Geological Survey of Canada and excerpts from his reports are presented in Appendix B.

Fairholme Group

The Fairholme Group is characterized by abrupt and conspicuous changes in lithofacies and thickness. Four main lithostratigraphic units are recognized, two of which are limited laterally as well as vertically. Their lithofacies, stratigraphic relations, and fauna indicate that they are directly comparable with the Southesk and Mount Hawk Formations of the region between the Bow and Athabasca Rivers (McLaren, 1955). They represent dolomitized biohermal reefs and biostromal banks and the contiguous deposits of a deeper-water basin. Underlying beds forming the remainder of the Fairholme Group comprise lithofacies that differ significantly from homotaxial beds in the region between Bow and Athabasca Rivers. Two new formations are proposed to accommodate these differences. The Hollebeke Formation embraces the lower part of the Fairholme Group and is overlain by the Borsato Formation.

The most complete exposures of the Fairholme Group in this region occur along the eastern and southern slopes of Flathead Range. There the relationships among the various stratigraphic units can be studied in considerable detail along the steep bare slopes.

Table III

Thickness Variations in Fairholme Group and Alexo Formation along East and South Slopes of Flathead Range, Alberta and British Columbia

Stratigraphic Unit	Section Number[1] and Thickness (feet)				
	14	13	15	16	17
Alexo Formation	103.0	–?–	61.0	61.5	23.0
Fairholme Group	1,222.5	–?–	1,034.0	1,013.0	–?–
Southesk Formation	210.5	–?–	246.0	145.0	1,091.0?
Arcs Member	101.0	–?–	155.0	75.0	—
Grotto Member	109.5	–?–	91.0	70.0	—
Peechee Member	—	–?–	—		1,091.0?
Mount Hawk Formation	472.5	–?–	402.0	435.5	? 24.0
Borsato Formation	142.5	162.0	61.0	102.5	? 61.0
Hollebeke Formation	397.0	341.0	325.0	330.0	–?–
Upper Member	230.5	208.5	206.0	224.0	243.0
Lower Member	166.5	132.5	119.0	106.0	–?–
Distance from North Kootenay Pass in miles	0	0.6 west	2.5 north	5.5 north	6.5 north

[1] For locations of sections *see* Figure 2; for detailed descriptions *see* Appendix A.

Hollebeke Formation

The name Hollebeke Formation is proposed for the light and medium grey weathering, massive to nodular, dark grey and black, very fine-crystalline limestone; the yellowish brown weathering, argillaceous and silty dolomite and limestone; and the sedimentary breccias that form the lower part of the Fairholme Group in Flathead Range and adjacent regions. Section 14, at the Interprovincial Boundary on the southeast slope of Mount Borsato at North Kootenay Pass, includes a completely exposed sequence of Hollebeke strata and is designated as the type section. The name of the formation is taken from Hollebeke Mountain, which lies a mile southeast of the type section. At Mount Borsato the formation may be divided into two members, a lower, 166.5 feet thick and an upper, 230.5 feet thick. Variations in the thickness of these units along Flathead Range are given in Table III and illustrated in Figure 4.

Lower Member

The lower member consists mainly of grey, yellowish grey, and brownish grey, fine- and medium-crystalline dolomite and limestone that is locally silty or argillaceous. Medium-crystalline, brownish grey dolomite and limestone interbeds are most common where the member is thickest. Beds of limestone and dolomite breccia occur sporadically throughout the member. The fragments are generally platy, angular, and lithologically uniform, but locally are subequidimensional and comprise a heterogeneous assemblage of limestones and dolomites. The matrix of the breccias is generally medium- to fine-crystalline dolomite or limestone similar to that which forms discrete beds in other parts of the member. The lower member weathers to a light yellowish grey, is recessive, and forms gentle slopes between the cliff-forming units above and below it (*see* Pl. II).

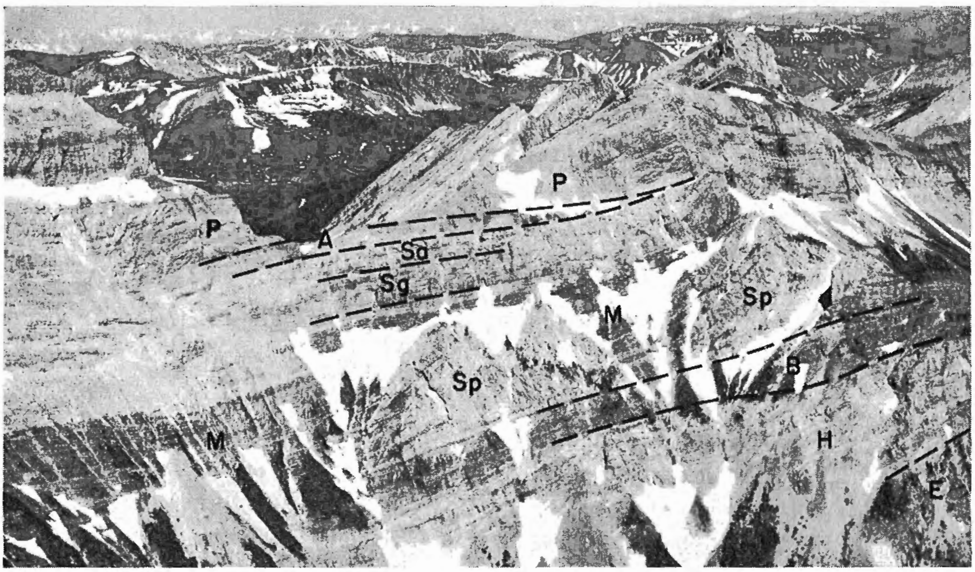

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PLATE II. Facies relationships in the Fairholme Group at the head of South Lost Creek, Flathead Range, Alberta. Looking northeast. E—Elko Formation; Fairholme Group: H—Hollebeke Formation, B—Borsato Formation, M—Mount Hawk Formation; Sp—Peechee Member of Southesk Formation, Sg—Grotto Member of Southesk Formation, Sa—Arcs Member of Southesk Formation; A—Alexo Formation; P—Palliser Formation.

Carbonate rocks typical of the lower member exhibit a crystalloblastic fabric on a microscopic scale. Diagenetic recrystallization appears to have obliterated the primary depositional fabric. Relict textural lamination is evident in the fine-crystalline limestones and dolomites. These rocks probably originated as very fine chemically precipitated grains that settled to form carbonate muds. Their association with the beds of brecciated carbonate rock is suggestive of hypersaline conditions. The breccias appear to be solution breccias and probably indicate the former presence of evaporites.

The lower member lies unconformably above the Elko Formation and forms the basal phase of the Fairholme depositional sequence. Its upper contact is gradational and is designated as the base of the lowest thick, very fine-crystalline, dense, black or dark grey limestone bed. This contact is probably diachronic as it lies within a zone of intertonguing lithofacies. This member comprises a lithofacies not known from the base of the Fairholme Group between Bow and Athabasca Rivers (McLaren, 1955), and is similar to the basal Devonian beds northeast of Elko, British Columbia (Leech, 1958) and occupies the same stratigraphic position. It may be a lithostratigraphic equivalent of the Beaverhill Formation of the subsurface sequence of the southern Alberta plains (Belyea, 1957) and of the Ghost River Formation of Bow Valley region. A single fossil collection has been obtained from these beds, 66 feet above the base of the Fairholme Group in Section 13 (*see* Appendix A). McLaren (*see* Appendix B) identified *Atrypa* cf. *A. multicostellata* Kottlowski from it and reported that there is only the most tentative suggestion that the fauna is of Flume age in terms of the established Alberta Rocky Mountain Devonian succession.

Upper Member

This member consists almost exclusively of dark grey and brownish black, fine- and very fine-crystalline limestone. Faint delicate colour lamination is common on weathered surfaces. Bedding is rarely well defined and the member characteristically forms steep slopes covered with fine scree, or prominent cliffs (*see* Plate II). Beds of breccia similar to that in the lower member occur sporadically throughout but are not common. Many of these beds are clearly lenticular or consist of coalescing lenses. The fragments are generally dark grey, fine- or medium-crystalline limestone with faint textural lamination and are tabular. The lithology of the matrix is similar to that of the enclosing beds. Individual thin beds of breccia can be traced into unbrecciated platy-weathering or massive-weathering limestone that exhibits a faint textural lamination (*see* Plate III). The breccias are of sedimentary origin and probably represent solution breccias. Stromatoporoids, tabulate corals, and *Amphipora* are common in a few beds of limestone here and there within the member. Stromatolites occur locally and in some sections form beds of stromatolitic limestone several feet thick. Stromatolitic limestone is most common in Section 17 (*see* Appendix A) where the upper member of the Hollebeke Formation is relatively thick and forms a base for a massive dolomitized reef comprising the Peechee Member of the Southesk Formation. Along Flathead Range the upper member of the Hollebeke Formation maintains a relatively constant thickness of between 200 and 245 feet.

On a microscopic scale, the dark dense limestones consist of a very fine-crystalline, light brown, crystalloblastic mosaic of calcite that encloses variable amounts of coarser, organic and inorganic, clastic calcite. The coarser clastic fraction of the limestones is consistently subordinate in volume, and typically is poorly sorted. It includes shell fragments, calcispheres, elliptical and spherical pellets of very fine-crystalline calcite up to 500 microns long, and pseudo-oolites and composite grains with pelletoid nuclei. Isolated dolomite rhombs 100 microns or less long are common in the very fine-crystalline matrix. Patches of fine- or medium-crystalline dolomite with a crystalloblastic fabric mottle the matrix locally.

R.A.P. 1-2-1957

PLATE III. Sedimentary breccia in the upper member of the Hollebeke Formation on the ridge between North Lost Creek and Goat Creek (Section 17, unit No. 7). Pick head is 7 inches long.

The limestones of the upper member of the Hollebeke Formation are texturally immature, arenaceous (skeletal[1]-pelletoidal-oolitic) calcilutites. The very fine-crystalline crystalloblastic mosaic of calcite forming the matrix appears to represent a recrystallized lime mud. Its presence and its association with pseudo-oolites and composite grains suggest an environment of deposition characterized by salinities high enough to lead to chemical precipitation of calcium carbonate. The lack of non-carbonate clastic material indicates a depositional environment that was isolated from sources of terrigenous clastic sediment. The textural immaturity of the fabric implies that there has been little sorting or transport of clastic grains and that the skeletal and pelletoidal grains represent in situ accumulations of organic detritus. The sporadic lenses of breccia are probably indicative of evaporites and may imply intermittent conditions of relatively high salinity. These environmental conditions are characteristic of the sheltered interior of a shoal such as a carbonate bank or a shallow epineritic terrace bordering an area of very subdued relief. Belyea (1958, p. 67) described similar limestones from what appear to be laterally equivalent beds in the subsurface of the Alberta Plains and has reported that they probably represent ". . . areas of quiet water deposition protected by masses of organic growth from open sea conditions." These latter

[1] 'Skeletal' is used here to denote clastic particles whose origin as components of the calcareous skeleton of some organism can logically be inferred from internal structure or surface ornamentation.

dark dense limestones occur between the areas characterized by a stromatoporoid coral-*Amphipora* carbonate facies and are gradational into evaporites (Belyea, op. cit.).

The upper member of the Hollebeke Formation occupies a stratigraphic position approximately equivalent to that of the Flume Formation and the lower part of the Cairn Formation (McLaren, 1955) but is lithologically dissimilar to both. It appears to be the lithostratigraphic equivalent of the Cooking Lake Formation of the subsurface of southern Alberta (Belyea, 1957 and 1958). On the basis of its fauna, the Cooking Lake Formation has been correlated with the Flume Formation (Belyea and McLaren, 1956). Fossils collected from the member have been identified by D. J. McLaren (*see* Appendix B) and include *Eostrophalosia* sp. H. (*"Productella* cf. *belanskii"* of Warren and Stelck), *Eleutherokomma jasperensis* (Warren), *Atrypa multicostellata* Kottlowski, *Eosyringothyris*? cf. *E. anchiasper* (J. S. Williams), *Athyris* sp., and *Productella* sp. They are reported to represent faunas that may be correlated with the Flume and Cairn Formations of the Fairholme Group of the Alberta Rocky Mountains, and with the upper Waterways Formation and possibly lower strata of the Waterways Formation of northeastern Alberta.

Borsato Formation

The name Borsato Formation is proposed for the dark brownish grey and brownish black medium- and coarse-crystalline bedded dolomites that overlie the Hollebeke Formation in Flathead Range and adjacent regions. Section 14 at the Interprovincial Boundary on the southeast slope of Mount Borsato at North Kootenay Pass is designated as the type section. The name of the formation is taken from Mount Borsato.

At Mount Borsato the formation is 142.5 feet thick and consists mainly of brownish grey, sacchroidal, fetid dolomite in beds from several inches to a few feet thick. It generally weathers to a medium brownish grey and forms relatively prominent topographic features. Variations in its thickness along Flathead Range are given in Table III and shown on Figure 4. It appears to be thinnest where it underlies the dolomitized reef masses that form the Peechee Member of the Southesk Formation. At the south end of Flathead Range thin beds of dark limestone and dolomitic limestone and partings and thin beds of brown shale are interbedded with the dolomites. At the headwaters of Harvey Creek the Borsato Formation was not recognized and beds of black shale and calcareous shale with interbeds of dark limestone occur between the Hollebeke Formation and limestones that are typical of the Mount Hawk Formation. These shaly beds appear to represent the Perdrix Formation (*see* McLaren, 1955) and to be lateral equivalents of much, if not all, of the Borsato Formation. Exposures are too incomplete to permit a detailed examination and no fossils were observed.

The dolomite beds of the Borsato Formation commonly exhibit a faint lamination that is etched into relief on weathered surfaces. Locally crossbedding is evident in this lamination. Some of the thicker beds have druze-lined vugs that are elongated parallel with the bedding. *Amphipora* are abundant locally and relict stromatoporoids and tabulate corals occur but are not common. Lenses of breccia up to 5 feet thick occur within the dolomites at the south end of Flathead Range and appear to be of sedimentary origin (*see* Section 13 of Appendix A).

On a microscopic scale, the dolomite consists of a mosaic of rhombs and subhedral and anhedral crystals that are clouded with submicroscopic inclusions. Moderate intercrystalline porosity is common. The present fabric of the rock is a result of diagenetic recrystallization. The relict lamination and organic structures and the porous fabric are indicative of a primary sediment comprising coarse calcarenite, possibly associated with in situ skeletal carbonate, deposited in an environment characterized by relatively strong wave and current action. The dolomites of the Borsato Formation probably represent diagenetically dolomitized stromatoporoid-coral-*Amphipora* biostromes and associated calcarenites that were deposited in the unprotected peripheral zone of a carbonate bank.

The Borsato Formation is gradational at the base into the Hollebeke Formation and consistently overlies this unit or is separated from it by brown shale that probably represents a tongue of the Perdrix Formation. At the top it is gradational into the Mount Hawk Formation or the Peechee Member of the Southesk Formation.

A Mount Hawk fauna occurs in a limestone bed 10 feet below the top of the formation in Section 13 (*see* Appendices A and B). Other fossils collected from it are not diagnostic of any particular horizon within the Fairholme Group. The Borsato Formation appears to be a lithostratigraphic equivalent of the organic dolomite member of the Cairn Formation (McLaren, 1955, p. 17) of the Alberta Rocky Mountains and of the dolomitized facies of the stromatoporoid limestone and dolomite unit of Belyea (1957, p. 10) in the subsurface of southern Alberta.

Mount Hawk Formation

The Mount Hawk Formation (DeWit and McLaren, 1950; emended by McLaren, 1955) in this region consists predominantly of dark grey, fine-crystalline, silty and argillaceous limestone, with dolomite, silty dolomite, and siltstone as minor constituents. Beds vary in thickness from a few inches to 18 inches; locally bedding is not apparent. The formation generally forms relatively gentle, dark grey, scree-covered slopes (*see* Pl. II).

On a microscopic scale, the limestones consist of a fine- or very fine-crystalline calcite mosaic clouded with argillaceous and carbonaceous (?) material. Coarser clastic calcite grains occur throughout in subordinate volume. The coarser clastic fraction includes: shell fragments, rounded single-crystal calcite grains with porous structure (echinoderm fragments?), calcispheres from 100 to 200 microns in diameter, and spherical and elliptical pellets of very fine-crystalline calcite up to 750 microns long. Dolomite occurs sporadically throughout the rock, generally as isolated rhombs less than 100 microns long, but occasionally as irregular patches with fine- or medium-crystalline crystalloblastic texture; it also forms a few thin beds. Quartz silt is common within the upper few hundred feet of the formation and becomes abundant towards the top. Beds containing a high proportion of silt commonly consist of dolomite rather than calcite. Relatively thin beds of dolomitic siltstone and fine-grained sandstone occur within the upper 100 feet of the formation locally (*see* Section 15, Appendix A). The limestone beds commonly exhibit a microscopic textural and compositional lamination and similar lamination occurs in some of the silty beds.

Along Flathead Range south of Goat Creek the Mount Hawk Formation limestones intertongue laterally with discrete dolomitized reef masses that form the Peechee Member of the Southesk Formation, and are overlain by dolomites of the Grotto Member of the Southesk Formation.

As has been indicated, the Mount Hawk limestones characteristically exhibit a bimodal texture. The coarse fraction consists of skeletal detritus or of fragments that can logically be inferred to be of organic origin (e.g., calcispheres and pellets). This fraction is poorly sorted and shows evidence of having undergone little transportation. It apparently represents authigenic clastic material contributed to the sediment by organisms indigenous to the basin. The fine fraction is well sorted and includes significant amounts of clastic silicates. These form a stable mineralogical assemblage consisting almost entirely of clay minerals and quartz. Their presence is one of the factors that distinguish the Mount Hawk limestones from those of the Hollebeke Formation. The fine fraction appears to represent allogenic material combined with authigenic carbonate mud. On the basis of their petrographic characteristics and their spatial relationships with the Peechee reefs (e.g., *see* Pl. II) the Mount Hawk limestones are inferred to have been deposited in a basin along the margin of a series of reef masses at least 100 feet below the reef crests.

Fossils collected from the Mount Hawk Formation in this area are reported by McLaren (*see* Appendix B) to be, in general, characteristic of comparable stratigraphic levels in the Mount Hawk Formation of the Front Ranges farther north.

Southesk Formation

The Southesk Formation (McLaren, 1955) comprises three members (Belyea and McLaren, 1957): the Peechee, the Grotto, and the Arcs.

Peechee Member

In this area the Peechee Member comprises discrete, laterally segregated bodies of massive to very thickly bedded, light grey, coarse-crystalline and very coarse-crystalline dolomite, vuggy dolomite, and dolomite breccia with rare interbeds of dark brownish grey dolomite. It is exposed in western Clark Range, 3 miles south of North Kootenay Pass; on the east slope of Flathead Range, 2 miles north of North Kootenay Pass (*see* Pl. II); 7 miles north of North Kootenay Pass at Goat Creek; and 1½ miles north of the north boundary of the map-area.

The dolomite is devoid of any recognizable organic structures and generally lacks bedding. Locally, faint thick colour-banding is discernible from a distance on weathered surfaces. Vuggy porosity is common and large cavernous vugs appear locally. The vugs are lined or filled with very coarse-crystalline white calcite. In the upper part of the member at Goat Creek (*see* Section 17, Appendix A) the distribution of white calcite-filled vugs and light grey dolomite indicate that the rock has a relict very coarse breccia fabric. The blocks are as much as several feet long and consist of coarse- and very coarse-crystalline light grey dolomite. The 'interstices' are large vugs filled with very coarse-crystalline white calcite. Elsewhere within the member vugs show faint planar orientation suggestive of relict bedding.

There are conspicuous variations in size and geometry and probably also in stratigraphic relations, between individual reef masses of Peechee dolomite. Three of these occur within the Mount Hawk Formation 2 miles north of North Kootenay Pass and are shown in Plate II. Distinct tongues of white dolomite extend into the Mount Hawk Formation from the most southerly dolomite mass. The top surface of the highest tongue can be traced from the top of the dolomitized reef, where it lies in contact with limestones of the upper part of the Mount Hawk Formation, through a stratigraphic interval of more than 100 feet to a point where the apex of the dolomite tongue passes laterally into limestones of the middle part of the Mount Hawk Formation. These spatial relations provide a measure of the magnitude of the initial dip of the tongues of dolomite along the west side of the Peechee reef and indicate that there was at least 100 feet of relief along the reef front. Furthermore, the orientation of the dolomite tongues implies that the three discrete dolomite bodies are probably erosional remnants of a more extensive reef mass that lay to the east. Each of these three dolomite bodies lies on the Borsato Formation and is overlain by the upper beds of the Mount Hawk Formation or the basal beds of the Grotto Member of the Southesk Formation. Each is widest at the base and tapers toward the top.

The larger Peechee dolomite mass at Goat Creek, 7 miles north of North Kootenay Pass (*see* Section 17 of Fig. 4 and Appendix A), is less well exposed and its geometry and stratigraphic relations are less well known. It is overlain by 23 feet of Alexo strata. The Grotto and Arcs Members were not recognized in Section 17 and their absence may be ascribed to onlap along the steep flank of the Peechee dolomite reef or to a lateral gradation into the dolomite of the upper part of the Peechee Member. In contrast to the reef masses near North Kootenay Pass the dolomitized reef mass at Goat Creek appears to have a relatively narrow base and to flare out toward the top as shown in Figure 4. This phenomenon may simply reflect the fact that the exposed section is subparallel to the reef front rather than transverse with it. A transition zone occurs around the periphery of the mass and at its base. In this transition zone fetid, brown, sacchroidal dolomite is interbedded on the one hand with white dolomite that is characteristic of the bulk of the Peechee Member and on the other with the limestones of the Mount Hawk Formation. The brown dolomite has been included in the Peechee Member of the Southesk Formation. Twenty-four feet of Mount Hawk strata occurs between the Peechee Member and the Borsato Formation in Section 17. Corals collected from these beds were identified as *Phacellophyllum* sp. by McLaren (*see* Appendix B) and were reported to be probably similar to those from the Grotto Member of the Southesk Formation in Sections 15 and 16.

It is evident from the geometry, stratigraphic relations, and relict primary fabric of the Peechee dolomite masses that they represent parts of a dolomitized biohermal reef or of reef-margin clastic aprons.

Grotto Member

The Grotto Member consists of dark grey and brownish grey, medium- and fine-crystalline dolomite. Bedding is generally discernible but rarely well defined. Beds vary in thickness from a few inches to several feet. Vuggy porosity is common locally, and vugs up to several inches long are elongated parallel with the bedding or occur in zones that parallel the bedding. The dolomite weathers to a brownish grey and produces more prominent topographic forms than underlying limestones of the Mount Hawk Formation. The base of the member is gradational into the limestones of the Mount Hawk Formation. The upper contact is generally sharp but apparently conformable. The Grotto Member was not recognized at the headwaters of Harvey Creek and presumably is a lateral equivalent of limestones that form the upper part of the Mount Hawk Formation at this locality. Its maximum thickness is about 110 feet.

The dolomites consist of a medium- to fine-crystalline crystalloblastic mosaic of subhedral and anhedral dolomite that is clouded with submicroscopic inclusions. Both intercrystalline and vuggy porosity are common. The vugs are generally filled or lined with coarse white calcite, which gives the brown dolomite a spotted appearance when viewed from a distance of several tens of feet. Corals are preserved locally as relicts in recrystallized calcite. The bedding, open fabric, and presence of relict corals suggest that the dolomites of the Grotto Member originated as relatively coarse-grained biostromes comprising both an in situ skeletal framework and skeletal fragments. The present fabric, however, appears to be the result of almost complete diagenetic dolomitization of the original rock.

Fossils collected from the Grotto Member were identified by McLaren as small *Phacellophyllum* indet., *Atrypa* sp., and *Spinatrypa* sp. (*see* Appendix B). A coral and brachiopod faunule from Section 15 is reported to suggest "a general Mount Hawk age".

Arcs Member

This member comprises white and light grey, coarse-crystalline dolomite in this region. Most beds, where discernible, are several feet thick. The dolomite forms prominent white cliffs, and constitutes an easily recognized marker unit for mapping. Lamination and cross-lamination are etched into relief on weathered surfaces locally and vuggy and intercrystalline porosity occur in some beds. Porous zones, where present, parallel the bedding.

The dolomites possess a crystalloblastic fabric that is clearly discernible on a microscopic scale. The lamination on weathered surfaces appears to be due to almost imperceptible variations in texture. The original fabric of the rock has been almost completely obliterated, presumably as the result of diagenetic dolomitization, and only the vague bedding and lamination remain as relicts. The dolomites of the Arcs Member, like those of the Grotto Member, form an extensive blanket in the upper part of the Fairholme Group and appear to represent the diagenetically altered equivalents of the deposits of a biostromal bank.

Alexo Formation

The type section of this formation is about 200 miles north of Flathead map-area, at Brazeau Gap on the North Saskatchewan River (McLaren, 1955, p. 21). Within the map-area a series of silty, fine-crystalline, thin-bedded dolomites and limestones with subordinate amounts of limestone and dolomite breccia are lithologically similar to the Alexo Formation and occupy the same stratigraphic position. This unfossiliferous sequence of beds has been assigned to the Alexo Formation.

As shown in Table III and Figure 4, the formation varies in thickness along Flathead Range from 103 to 23 feet. It is thinnest where it overlies the thick massive light grey dolomitized reefs of the Southesk Formation. The Alexo Formation forms a conspicuous thin, light yellowish grey, recessive zone between the cliff-forming Palliser Formation and the relatively resistant beds of the upper part of the Fairholme Group.

The silty dolomites and limestones characteristically have fine textural and colour lamination. The beds are generally a few inches thick and weather to a platy rubble. Mud-cracked surfaces are common. Thin lenses of breccia, developed locally, probably represent both intraformational flat-pebble conglomerates and 'collapse breccias'. Contorted bedding, presumed to be the result of slumping almost contemporaneous with deposition, occurs in the sequence but is not common. Medium grey, medium- to coarse-crystalline dolomite occurs within the formation at North Kootenay Pass (*see* Section 14, Appendix A).

The rocks of the Alexo Formation represent a heterogeneous assemblage of shallow-water sediments deposited in an environment contrasting sharply with that of the upper part of the Fairholme Group. They form a thin layer of silty quartzose carbonates and associated evaporites which appears to have filled in the irregularities remaining on the top of the Fairholme sequence as a result of biohermal reef growth. Local beds of coarse-crystalline dolomite may represent isolated dolomitized biostromes.

The Alexo Formation is typically in sharp contact above the light grey, coarse-crystalline dolomites of the Southesk Formation. It is overlain by brown, medium-crystalline dolomite or by a zone of dolomite breccia marking the base of the Palliser Formation.

Palliser Formation

Within Flathead map-area about 660 feet of strata has been assigned to the Palliser Formation. These strata consist of dark grey, fine-crystalline limestone, commonly mottled and locally interbedded with brownish grey, medium-crystalline dolomite. A detailed description of the formation considered typical for the southern Flathead Range is given in Section 18 (Appendix A).

Morro Member

This member (DeWit and McLaren, 1950), about 500 feet thick along the east slope of Flathead Range, forms the lower part of the formation. It consists primarily of mottled dolomitic limestone in which bedding is only locally apparent, and characteristically forms massive light grey cliffs. Poorly defined beds from 1 foot to 6 feet thick of grey and brownish grey, medium-crystalline dolomite form a zone up to 50 feet thick in the basal part of the member. The dolomite weathers to a light brownish grey, generally with faint colour lamination or with textural lamination etched into relief on weathered surfaces. A breccia zone as much as 8 feet thick is common at the base of the unit. The fragments are brownish grey, colour- and texture-laminated dolomite similar to that in the beds above, and range in size from small angular chips to blocks and sheets up to 18 inches long. Stromatolitic dolomite and dark grey fine-crystalline limestone are locally associated with these beds. The breccias are in sharp contact above the Alexo Formation along an essentially planar surface across which there is no apparent discordance.

Costigan Member

This member (DeWit and McLaren, 1950) is about 160 feet thick along the east slope of Flathead Range. It consists primarily of dark grey, very fine-crystalline limestone with subordinate mottled dolomitic limestone. Most of the member is distinctly bedded in units less than 12 inches thick. Much of the limestone weathers to form a nodular rubble. The limestones are gradational at the base into those of the Morro Member. The upper contact is rarely well exposed, but at least locally, black shale, assigned to the Exshaw Formation lies in abrupt contact above the Costigan Member without apparent discordance.

The details of fabric in the Palliser Formation are essentially the same as those described by Beales (1953 and 1956) from the Alberta Rocky Mountains to the north. Beales' petrogenetic interpretations are considered to apply to the limestones and dolomitic limestones observed in Flathead map-area. The limestones appear to have originated as very fine chemically precipitated grains and coarser skeletal detritus that accumulated as arenaceous lime muds. The environment of deposition was isolated from sources of allogenic clastic silicates and appears to have been the protected interior of an extensive carbonate shoal.

The breccias at the base of the Palliser Formation along the east slope of Flathead Range are of sedimentary origin. The angular character of the fragments and the poor sorting in association with dolomite are suggestive of solution breccias, indicating the former presence of evaporites. These beds may indicate the proximity of a tongue of the lower evaporite member of the Stettler Formation (Belyea, 1957, p. 15).

McLaren (1954) analyzed the faunas of the Palliser Formation from the area between Bow and Athabasca Rivers and has concluded that they are of Upper Devonian age. No fossils were collected from this formation during the present investigation.

Mississippian

Mississippian strata are exposed along the west slope of Flathead Range in Taylor Range, and in Macdonald Range. Most exposures are of strata in the Lewis thrust sheet, but isolated ones are known from fault slices immediately below the main Lewis thrust surface at the headwaters of Goat Creek and Carbondale River. The Mississippian sequence is more than 3,300 feet thick and consists primarily of limestone. It is similar in stratigraphic detail to the lithologic succession established in the Foothills to the north by Douglas (1950, 1953 and 1958), and the stratigraphic nomenclature in current use in that area has accordingly been applied to the Mississippian rocks exposed in Flathead map-area. The strata have been assigned to the Exshaw and Banff Formations, and to the Rundle Group (Livingstone, Mount Head, and Etherington Formations). Fossils collected have been identified and discussed by P. Harker and W. Fry of the Geological Survey of Canada (*see* Appendix B).

Exshaw Formation

This formation consists of fissile, black, non-calcareous shale lying with an abrupt contact on the Palliser Formation (Minnewanka limestone), but apparently gradational into the overlying argillaceous limestones and calcareous shales of the Banff Formation (Warren, 1937). No completely exposed section has been examined within the map-area, but on the provincial boundary 6,500 feet south of Mount Darrah the Exshaw is less than 39 feet thick. At several places in Flathead Range the shale of the Exshaw Formation overlies the limestones of the Costigan Member of the Palliser Formation without apparent discordance. The contrast in lithology is marked, and the change from limestone to shale is abrupt. Shale interbeds in the limestone, siltstone, and chert sequence of the lower part of the Banff Formation are megascopically indistinguishable from the Exshaw shale. No fossils were observed within the Exshaw Formation. Its age has been the subject of considerable discussion; Harker and McLaren (1958), Mountjoy (1956), and Crickmay (1956) have suggested that the Devonian-Mississippian boundary be considered as lying at its base.

Banff Formation

This formation comprises dark grey, argillaceous and cherty limestones with interbeds of black, brown, and dark grey shale. It lies between the Exshaw Formation and the Rundle Group. The base of the Rundle, at the type section on Tunnel Mountain at Banff, has been designated as the base of the lowest bed of coarse crinoidal limestone by Warren (1927 and 1937) and Beales (1950).

Within Flathead map-area about 650 feet of strata has been assigned to the Banff Formation. Three lithostratigraphic units, designated as lower, middle, and upper parts, have been distinguished within the sequence. No precise relationship has been established between these divisions and those described by Warren (1937) and Beales (1950) at the type section. The lower part and the middle part have been mapped together but can be easily distinguished where exposures are good.

Lower Part

The lower part of the Banff Formation consists of black and dark grey shale, platy siltstone, and banded chert. Together with the underlying Exshaw Formation, it forms dark grey recessive slopes between the prominent cliffs of Palliser limestone and the cliff-forming middle part of the Banff Formation. About a mile south of Mount Darrah the lower part of the Banff Formation is 109 feet thick (*see* Appendix A, Section 19).

The limestones are silty, cherty, argillaceous, and carbonaceous, and show fine textural and compositional lamination and banding. They appear to represent partly recrystallized calcilutites, calcisiltites and very fine grained calcarenites. Absence of fossils and the fine lamination indicate deposition in an environment free of benthonic organisms and lacking strong currents. Chert occurs in the limestone as bands or irregular elongate patches which invariably parallel and accentuate the banding and lamination. Dolomite rhombs less than 0.15 mm long are common throughout the chert patches and also occur in the adjacent limestone. Spherical structures from 0.02 to 0.075 mm in diameter, consisting of one or more concentric shells of 'micro-crystalline quartz' with cores of calcite or opaque organic matter, are found in the chert and the limestone. The spheres lack well-defined surface ornamentation and the 'micro-crystalline quartz' may have either a random or radial crystallographic orientation. Some of the individual spheres have single walls less than 0.001 mm thick. The silica in the structure appears to be 'primary' and the spheres are assumed to be organic structures. They are accompanied by siliceous spicules. Locally these organic structures constitute 15 per cent of the rock. They are distinct where enclosed by calcite or organic matter but may be discernible only with difficulty where isolated in chert. In some of the higher limestone beds they are corroded by calcite.

A zone about 35 feet thick, consisting primarily of chert, occurs 38 feet above the base of the formation. The chert is dark grey and black, fine laminated or colour banded. It is interbedded with lesser amounts of argillaceous and carbonaceous limestone. The zone forms a prominent black cliff within the recessive-weathering lower part of the Banff Formation and is a distinctive marker bed. The banding is produced by variations in the content of opaque organic and argillaceous material in the chert. The siliceous organic structures, which occur profusely throughout, are especially well preserved in the dark organic bands, whereas many have been partly obliterated by recrystallization within the chert bands.

Middle Part

The middle part of the Banff Formation consists of dark grey and black, dense, cherty, argillaceous limestone in beds from a few inches to one foot thick.

The unit weathers to form relatively prominent topographic forms. The middle part of the Banff Formation is 232 feet thick on the provincial boundary a mile south of Mount Darrah (*see* Section 19).

The limestones possess a regular, fine, textural and compositional lamination which is most distinct toward the base of the unit. They consist of a very fine-crystalline mosaic of calcite that encloses isolated grains of 'clastic' calcite of silt and sand grade. The coarser clastic fraction becomes more abundant and increases in grain size toward the top of the unit where it eventually dominates the texture. Angular quartz silt is common in the limestones. Brown opaque carbonaceous (?) and argillaceous (?) material clouds the matrix and occurs as wisps and fine laminae. The limestones appear to represent clastic deposits that probably originated as skeletal detritus and have undergone subsequent diagenetic recrystallization. Chert commonly obscures the carbonate fabric, occurring as irregular patches with gradational boundaries. Megascopically, the chert is black and occurs as lenticular blebs or discontinuous bands parallel with the bedding. Small rhombs of dolomite are common in the chert-rich bands or patches, but also occur in the fine-crystalline limestone. Toward the top of the unit, thin films of isotropic, brown translucent, bituminous material coat interstices in the limestone fabric.

The dark colour of the limestones, the black chert, and the fine laminations are diagnostic of the subdivision and serve to distinguish it from the upper part of the Banff Formation. A single fossil collection made from the unit was described by Harker as a "typical Banff occurrence, not relatable to any particular horizon" (*see* Appendix B).

Upper Part

This part of the Banff Formation consists of medium and dark grey, fine- to medium-crystalline limestone with wisp-like bands, lenses and patches of medium and dark grey chert. It generally occurs in beds from 1 foot to 4 feet thick. The unit forms relatively prominent topographic features but weathers to a lighter grey than the middle part of the formation below, and to a darker grey than the basal part of the Livingstone Formation above. On the north slope of Centre Mountain in the southern part of Flathead Range, the upper part of the Banff Formation is about 265 feet thick (*see* Section 20 of Appendix A).

Most of the limestone is a partly recrystallized, cherty, medium-grained skeletal calcarenite. There is a general progressive increase in grain size toward the top of the unit. The fraction that is recognizably clastic consists of subequidimensional single-crystal calcite grains, some of which are clearly echinoderm fragments, and of elongate, arcuate and tabular grains with lamellar, prismatic, and cellular structure. The latter probably represent brachiopod and bryozoa fragments. A faint textural banding is evident, especially in the lower part of the unit. This banding is accentuated by a dimensional orientation of the elongate skeletal grains. A very fine-crystalline mosaic of calcite with isolated small dolomite rhombs forms a 'matrix' that encloses the larger clastic grains. This 'matrix' commonly encroaches on the borders of the skeletal grains and is locally so abundant that these coarse skeletal fragments are limited to a few 'floating' relict grains. Chert occurs in the 'matrix' as small, irregular patches with diffuse gradational borders. The distribution of chert is related to a primary textural lamination and banding, which it accentuates. Quartz silt occurs throughout the limestone as a minor constituent. Subhedral authigenic quartz crystals and overgrowths on clastic quartz grains occur locally but are not common. Traces of brown, lustrous, opaque, bituminous material line some interstices in the clastic fabric. In general the porosity of the limestone appears to be low.

The upper boundary of the Banff Formation is placed at the base of the first bed of coarse, light grey, 'crinoidal' limestone and may be diachronic, even within the limits of the map-area. The change from Banff to Rundle strata is gradational and simply marks one stage in the overall gradual change from the Exshaw shale to the Rundle limestones and dolomites. At progressively higher stratigraphic horizons within the Banff Formation there is an overall decrease in the argillaceous and carbonaceous content of the carbonates and the clastic calcite fraction increases in grain size.

Rundle Group

Three principal lithostratigraphic units have been distinguished in Flathead map-area within the sequence of carbonate strata between the Banff Formation and the sandstones and quartzites assigned to the Rocky Mountain Formation. These units are lithostratigraphic equivalents of the Livingstone, Mount Head, and Etherington Formations of the Rundle Group established by Douglas (1950, 1953, and 1958) in the Alberta Foothills south of Bow Valley. The Rundle Group consists predominantly of carbonates, in contrast to the quartzose clastic material of the overlying Rocky Mountain Formation. As indicated by Douglas (1958, Fig. 6), the upper part of the Etherington Formation is considered to be a lithostratigraphic equivalent of the lower part of the Tunnel Mountain Member of the Rocky Mountain Formation in Banff map-area. Thus the Rundle Group in the southern Alberta Foothills apparently embraces a sequence of strata that is the lithostratigraphic equivalent of the lower part of the Rocky Mountain Formation as well as the Rundle Formation at Banff.

Livingstone Formation

At the type section in Mount Head map-area (Douglas 1958, p. 38) the Livingstone Formation consists of about 1,100 feet of medium- to coarse-crystalline limestone and medium-crystalline dolomite with subordinate argillaceous dolomitic or cherty, fine-crystalline limestone and fine-crystalline dolomite.

Strata assigned to the Livingstone Formation in Flathead map-area consist primarily of light grey, coarse-crystalline calcarenitic limestone and coarse-grained skeletal (echinoderm-bryozoa) calcarenite. Medium and light grey, fine-crystalline limestone and silty limestone occur in lesser amounts throughout, interbedded with the calcarenitic limestone. Cherty limestone is common in the lower part of the formation and interbeds of light grey, fine-crystalline dolomite, commonly silty, occur within the upper half of the formation. On the north slope of Centre Mountain (*see* Section 20, Appendix A), the Livingstone Formation is about 1,370 feet thick. Two lithostratigraphic units, subequal in thickness, are recognizable, and are referred to as the upper and lower parts. The units are not easily separable where exposures are incomplete and therefore have been mapped together.

Lower Part

The lower part of the Livingstone Formation is 676 feet thick on the north slope of Centre Mountain. Zones of thickly bedded or massive, light grey, coarse, crinoidal limestone alternate with thinner interbeds of light grey, fine- and medium-crystalline limestone. The unit forms prominent massive cliffs (*see* Pl. IV). The fine- and medium-crystalline limestones commonly have irregular, wisplike blebs of light grey calcareous chert elongated parallel with the bedding, especially in the basal part of the unit where a fine lamination is commonly etched into relief on the surface of the chert. Chert is rare in the coarse calcarenite beds. These beds locally have textural lamination and cross-lamination etched into relief on weathered surfaces.

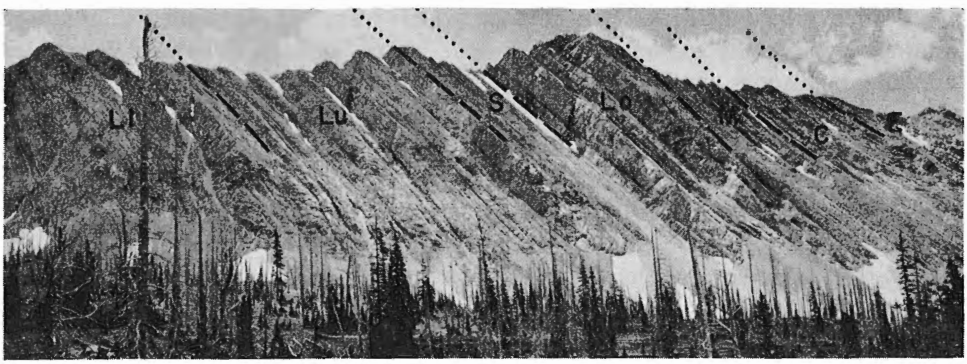

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PLATE IV. Rundle succession, a mile north of Centre Mountain, Flathead Range, British Columbia. View toward south. Ll—Lower part of Livingstone Formation; Lu—Upper part of Livingstone Formation; Mount Head Formation: S—Salter Member (base), Lo—Loomis Member, M—Marston Member, C—Carnarvon Member (top); E—Etherington Formation.

The 'crinoidal' limestones comprise a series of coarse-grained and very coarse grained skeletal calcarenites. Echinoderm columnals and plates are the dominant clastic elements but brachiopod and bryozoa fragments occur in significant volume. The calcarenites are generally well sorted and range in average grain size from 1 to 1.5 mm. Textural lamination and a preferred dimensional orientation of elongate clastic fragments are common features of the limestone fabric. Most of the calcarenites have a matrix of very fine-crystalline crystalloblastic calcite. This matrix commonly encroaches on the boundaries of the bioclastic grains, and although it may in part represent primary interstitial calcisiltite or calcilutite which has undergone diagenetic recrystallization, much of it is the product of degradational diagenetic recrystallization of the coarse bioclastic fraction. Dolomite rhombs less than 0.1 mm long are common throughout the fabric but are never abundant. Because most of the 'crinoidal' limestone possesses an interstitial matrix, porosity in most of these beds is low.

The fine- and medium-crystalline limestones, in part at least, possess a relict-clastic texture. Many of the medium-crystalline limestone beds consist of a fine-crystalline crystalloblastic matrix of calcite with subordinate, medium to very fine sand-grade skeletal calcite grains. Textural lamination and preferred dimensional orientation of clastic grains are very well developed locally. These limestones appear to represent the diagenetically recrystallized, fine-grained, lateral equivalents of the skeletal calcarenites, but they may be largely the product of extensive diagenetic degradational recrystallization of skeletal calcarenite. The occurrence of dolomite in the fabric is limited to isolated rhombs less than 0.1 mm long. Non-carbonate clastic material is limited to traces of clay and quartz silt.

The lower part of the Livingstone Formation is gradational downward into the Banff Formation. The top of the lower part has been designated as the base of the lowest prominent interbed of silty, yellow-grey, fine-crystalline dolomite. Alternating very prominent skeletal calcarenite beds and much thinner relatively recessive-weathering fine-crystalline dolomite and limestone beds occur above this horizon (*see* Pl. IV).

Upper Part

The upper part of the Livingstone Formation is 691 feet thick on the north slope of Centre Mountain (*see* Section 20 of Appendix A). Like the lower part, it consists of zones of thickly bedded or massive, coarse, light grey, 'crinoidal' limestone alternating with thinner interbeds of fine-crystalline carbonate rock, but the interbeds are more common than in the lower part and generally consist of dolomite or silty dolomite rather than limestone, especially in the basal part of the unit. The unit forms a series of prominent massive light grey ribs separated by light yellowish grey recessive-weathering zones.

The 'crinoidal' limestones are coarse-grained and very coarse-grained skeletal calcarenites, petrographically similar to those in the lower part. The skeletal fragments are less well sorted in general and are locally larger than in the lower part. Fragments of ramose bryozoa up to 4 cm long are common locally. Oölitic limestone occurs within the upper part of the unit but is not common. A few of the calcarenite beds lack the typical fine-crystalline matrix and are cemented with clear calcite. Porosity appears to be low in most.

The recessive-weathering interbeds consist primarily of fine-crystalline, light grey dolomite with up to 15 per cent quartz, of very fine sand and silt grade. Locally the dolomite is argillaceous or cherty. Fine-crystalline limestone similar to that in the lower part occurs also but is less abundant. Medium-crystalline, light grey dolomite forms recessive-weathering zones locally. The dolomite consists of a crystalloblastic mosaic of subhedral to euhedral dolomite crystals and has an intercrystalline porosity of up to 15 per cent. The rock appears to be the dolomitized equivalent of the calcarenite.

The upper part of the Livingstone Formation is gradational into the overlying Salter Member of the Mount Head Formation. The designated base of the Mount Head Formation is the lowest conspicuous bed of silty dolomite in a relatively thick sequence of beds consisting mainly of dolomite. A few beds of coarse-grained skeletal calcarenite occur above this horizon. One or more massive, very prominent, coarse-grained skeletal calcarenite units occur within the uppermost part of the Livingstone Formation. These units are important horizon markers for mapping and structural interpretation. Throughout most of Flathead Range three prominent ribs mark the top of the Livingstone Formation (*see* Pl. IV), whereas in Macdonald Range a single cliff occurs at the top of the Livingstone.

The rocks of the Livingstone Formation can be grouped into three principal lithofacies: coarse-grained skeletal (echinoderm-bryozoa) calcarenites, fine- and medium-crystalline calcarenitic limestone, and fine-crystalline silty dolomite and limestone. These lithofacies occur as alternating tongues or lentils from 1 foot to 100 feet thick and are intergradational. The coarse-grained skeletal calcarenites are also gradational into the finer skeletal limestones and argillaceous limestones of the Banff Formation.

In the southern Foothills the various lithofacies of the Livingstone Formation have been grouped as members and subdivisions of members (Douglas, 1958, p. 38). As there is an overall change in lithofacies of the formation between the Foothills and the Flathead map-area, most of these lithologic subdivisions cannot be recognized in the Flathead area. The upper part of the formation, however, with its silty dolomite interbeds, may be a lithostratigraphic equivalent of the Turner Valley Member and the lower part may be equivalent to the Pekisko Member.

Fossils collected are listed in Appendix B. The state of preservation and fragmentary nature of these fossils precludes complete identification and, therefore, their use in precise biostratigraphic correlation.

Mount Head Formation

At the type section in Mount Head map-area (Douglas, 1958, pp. 42-43) this formation is about 600 feet thick, and is divisible, in stratigraphic succession, into the Wileman, Baril, Salter, Loomis, Marston and Carnarvon Members. Within Flathead map-area a sequence of beds about 860 feet thick has been assigned to the Mount Head Formation. Only four lithostratigraphic units are distinguishable: the Salter, Loomis, Marston, and Carnarvon Members. The Wileman and Baril Members have not been recognized. In the northern part of the map-area these four members have been mapped separately, but in Macdonald Range, where exposures are less complete, the formation has not been subdivided.

Salter Member

This member consists predominantly of fine- and medium-crystalline, light grey, sandy and silty dolomite, and on the north slope of Centre Mountain (*see* Section 20, Appendix A) is about 160 feet thick. This member forms a recessive zone at the base of the Mount Head Formation, between the prominent light grey cliff-forming limestones of the Livingstone Formation and those of the Loomis Member (*see* Pl. IV). It weathers to a light yellowish grey and is distinctly bedded, generally in units from 2 to 4 feet thick.

The dolomites are predominantly light grey and light yellowish grey. They consist of a fine- or medium-crystalline, crystalloblastic mosaic of dolomite, commonly clouded with argillaceous material, and contain variable amounts of quartz as silt and very fine sand. The quartz content locally reaches 40 per cent. The more sandy and silty beds show delicate textural lamination and cross-lamination etched into relief on weathered surfaces. Irregular lacy patches of light grey chert, and irregular vugs filled with very coarse-crystalline white calcite are common in the less silty and sandy beds. Coarse-grained, skeletal (echinoderm-bryozoa) calcarenites occur in lesser amounts within the lower part of the member and relict clastic calcite grains are apparent in many of the dolomite beds.

The sequence of strata assigned to the Salter Member is gradational at the bottom and top into calcarenites of the Livingstone Formation and Loomis Member of the Mount Head Formation respectively. In the southern Foothills of Alberta the limestones of the Baril Member separate the sandy dolomites of the Salter Member from those of the Wileman Member. As the Baril Member has not been recognized in Flathead map-area, the strata assigned to the Salter Member there may be lateral equivalents of the combined Salter, Baril, and Wileman Members of the Foothills.

Loomis Member

This member consists primarily of massive, light grey weathering, cliff-forming calcarenites, with interbeds of medium- and fine-crystalline, light brownish grey, recessive weathering dolomite and fine-crystalline, light grey limestone. The alternation of thick cliff-forming limestone units and thin recessive weathering dolomite and limestone units gives the member a ribbed appearance in the steep cliff faces of Flathead Range (*see* Pl. IV). On the north slope of Centre Mountain (*see* Section 20, Appendix A), the member is 296 feet thick. The Loomis Member appears to grade into the dolomites and limestones of the overlying Marston Member.

The limestones of the Loomis Member are light and medium grey, medium- to very coarse-grained, skeletal (echinoderm-bryozoa) and oölitic calcarenites. Most of the skeletal material consists of echinoderm columnals and plates, but bryozoa and brachiopod fragments occur in significant volume. Ellipsoidal pellets of very fine-crystalline calcite are relatively rare. A similar assemblage of skeletal fragments forms the nuclei for most of the oöliths in the oölitic calcarenite beds. A few of these beds are cemented with coarse-crystalline clear calcite. The skeletal calcarenites and the remainder of the oölitic calcarenites have a matrix of very fine-crystalline crystalloblastic calcite which commonly embays the peripheries of the clastic grains. With a progressive decrease in the relative proportions of clastic grains to matrix the calcarenites grade into fine-crystalline limestones. The matrix appears to be a recrystallized carbonate mud, but in part at least represents the product of degradational recrystallization of coarse skeletal grains. The porosity of the limestones is consistently low. Two types of dolomite interbeds occur. The first is relatively thin-bedded and consists of a fine-crystalline, crystalloblastic mosaic of dolomite with rare isolated relict single crystal calcite fragments. It is presumed to have formed through diagenetic dolomitization of fine-crystalline calcarenitic limestone. The second occurs in massive beds up to 15 feet thick and consists of a medium-crystalline crystalloblastic mosaic of dolomite with 10 per cent or less intercrystalline and 'pinpoint' vuggy porosity. It is presumed to have formed through diagenetic dolomitization of skeletal calcarenite and to have inherited its 'open' fabric from the parent rock (Douglas, 1958, p. 25).

Fossils collected from the Loomis Member are listed in Appendix B. One collection from 10 feet below the top of the member contains a coral species known from the Bow Valley region where it occurs in beds that are probably correlative with the type Loomis Member (*see* Appendix B). The remainder of the material is not diagnostic of particular horizons within the Rundle Group.

Marston Member

The sequence of strata assigned to this member consists of medium to thin, alternating beds of silty dolomite and limestone. In the lower part of the member the rocks are medium and light grey but toward the top they become dark grey and black. The member generally forms a conspicuous light yellowish brown recessive weathering zone between the prominent thickly bedded and massive limestones of the Loomis and Carnarvon Members. On the north slope of the Centre Mountain the Marston Member is 106 feet thick (*see* Section 20, Appendix A). On the west slope of Flathead Range, 2¼ miles southwest of Mount Darrah (*see* Section 21, Appendix A), thin interbeds of non-calcareous shale with coalified plant remains occur in the upper part.

The limestones and dolomites generally consist of a very fine-crystalline, crystalloblastic mosaic of calcite or dolomite with less than 10 per cent of quartz silt and a variable proportion of isolated calcite fragments. The clastic calcite fraction includes single crystal grains, fragments of small, thin-shelled brachiopods, minute bryozoa 'fronds', calcispheres, and medium- or fine-grained pellets of very fine-crystalline calcite which locally form nuclei for medium-grained oölites. Many clastic grains are partly replaced by fine-crystalline, crystalloblastic calcite or dolomite. Within the upper part of the member both limestone and dolomite are clouded light brownish grey with bituminous (?) matter. Minute pyrite cubes and clots of hematite and limonite are common in these darker rocks. Delicate lamination is etched into relief on weathered surfaces of both limestones and dolomites in the upper part of the member. Bands and lenses of chert occur throughout. The carbonates of the Marston Member appear to represent fine-grained clastics deposited in a somewhat euxinic environment. The presence of coalified fragments of land plants in non-calcareous black shale in the upper part of the member appears to indicate local non-marine deposition. The carbonates are assumed to represent chemical precipitates that were deposited as carbonate muds in a restricted, shallow-water environment.

The Marston Member is gradational into the overlying Carnarvon Member. The top of the highest bed of dark grey, fine-crystalline, laminated, silty dolomite defines the top of the member. The contact is marked by a change from greyish brown weathering, relatively recessive beds to light grey weathering, relatively prominent dark grey limestone.

Fossils collected are listed and discussed in Appendix B. Unfortunately they do not provide a basis for correlation with specific faunal horizons in the Mount Head sequence to the northeast.

Carnarvon Member

This member consists of black and dark grey, fine- and cryptocrystalline limestone in beds from ½ foot to 4 feet thick. Argillaceous limestone, black crinoidal limestone and thin interbeds of calcareous black shale occur within the sequence but are not abundant. On a prominent east-west ridge, 2 miles north of Centre Mountain, on the west slope of Flathead Range, the member is 295 feet thick (*see* Section 21, Appendix A). It weathers to a light grey, mostly with a distinctly bedded appearance, and produces relatively prominent topographic forms between the recessive intervals marked by the lower part of the overlying Etherington Formation and the underlying Marston Member of the Mount Head Formation. Throughout most of the northeastern part of Macdonald Range the Carnarvon Member forms a prominent cliff below the Etherington Formation (*see* Pl. X). The Carnarvon sequence of dark grey, dense limestone is the most distinctive lithic unit in the Rundle Group, and is a useful 'marker bed' for mapping and structural interpretation.

Most of the limestone in the Carnarvon Member consists of very fine-crystalline or cryptocrystalline calcite clouded to a translucent light brown with very finely divided bituminous or carbonaceous material. It contains highly variable amounts of skeletal calcite of coarse sand grade. With increasing proportion of coarse clastic calcite, the limestones grade into skeletal calcarenites. Isolated calcispheres up to 0.1 mm in diameter, minute spicule-like structures, and occasional fragments of small thin-shelled brachiopod tests are discernible where the coarse clastic fraction is lacking. The limestones presumably originated as organic-rich lime muds.

The coarse clastic fraction consists primarily of echinoderm columnals and plate fragments. Fragments of encrusting bryozoa, echinoid spines, brachiopod shell fragments, *Endothyra*-like foraminifera, and ellipsoidal pellets of very fine-crystalline calcite are abundant locally. The structural detail of the fragments is generally very well preserved in contrast with other parts of the Rundle Group. The pores of the echinoderm fragments, and the chambers of the bryozoa fragments and the foraminifera are filled with very fine-crystalline and cryptocrystalline translucent brown calcite. The preservation of pore structures in the echinoderm fragments is in sharp contrast with other beds in the Rundle Group where such fragments are relatively homogeneous single-crystal grains, presumably as a result of diagenetic recrystallization. The fine matrix is locally absent and the coarse skeletal grains with their internal fillings of cryptocrystalline brown calcite are cemented with clear, medium-crystalline calcite. Streaks or small clots of lustrous, brown, opaque 'pyrobitumen' occur locally in the limestones. Dolomite is rare, but isolated small rhombs or irregular patches with fine-crystalline crystalloblastic texture occur locally. Chert occurs as irregular patches with gradational boundaries, which pervade the carbonate fabric locally. The coarse skeletal calcite fragments appear to have been embedded in an organic-rich lime mud. The few lenses or beds cemented with clear calcite probably represent deposits in which the fine matrix has been winnowed out from between the grains.

The Carnarvon Member appears to grade into the lower part of the Etherington Formation. The top of the highest bed of dark grey or black, very fine crystalline limestone marks the top of the Carnarvon Member. Limestones occurring above this horizon are light grey and cherty, and are interbedded with silty dolomite and thin beds of light green shale (*see* Section 21, Appendix A).

Two faunas from the Carnarvon Member in Flathead map-area are reported by Harker (*see* Appendix B) to be characteristic of the Carnarvon Member in the type area. There, the fauna of the Mount Head Formation has been assigned a Meramecian (late Mississippian) age (Douglas and Harker, 1958).

Etherington Formation

In Mount Head map-area where it was defined (Douglas, 1958, p. 62), the Etherington Formation occupies the stratigraphic interval between the sequence of predominantly fine-crystalline limestones comprising the Carnarvon Member of the Mount Head Formation, and a sequence of quartzose sandstones and cherty beds assigned to the Rocky Mountain Formation. It is 190 to 290 feet thick, and has been divided into three subequal parts (Douglas, 1958, p. 62).

Strata assigned to the Etherington Formation in Flathead map-area similarly occupy the interval between the dark fine-crystalline limestones of the Carnarvon Member and the thick sandstone succession of the Rocky Mountain Formation. They form a sequence about 435 feet thick (Section 21, Appendix A) and are divisible into three subordinate lithostratigraphic units. These units have been referred to as the lower member, middle member and upper member, and appear to be lithostratigraphic equivalents of the three subdivisions of the type area.

The lower member, 93.5 feet thick in Section 21, is recessive-weathering and forms subdued topographic features between the cliff-forming limestones of the middle member and those of the Carnarvon Member of the Mount Head Formation. It consists of cyclical alternations of relatively thin, medium- and coarse-crystalline, light grey calcarenitic limestone units; thinner platy, fine crystalline, light grey and light yellowish grey limestone and silty dolomite units; and interbeds of light green shale 0.5 foot thick. These strata contrast sharply with those of the Carnarvon Member of the Mount Head Formation; however, the contact between the formations appears to be gradational.

The middle member is 261.5 feet thick in Section 21. It is primarily light grey limestone, most of which consists of skeletal and oölitic calcarenite. Thinner interbeds of platy and flaggy, fine-crystalline dolomite and limestone occur throughout in subordinate volume and are commonly silty. This sequence of strata produces relatively prominent topographic forms between the recessive-weathering units. It is gradational into these units and is differentiated from them by its thick calcarenitic limestone beds.

The upper member is 78 feet thick in Section 21. It consists predominantly of light and dark grey, silty and cherty, fine-crystalline limestone and dolomite. Dolomitic sandstone and siltstone, and coarse-grained skeletal calcarenites are less abundant. The unit appears to mark a transition from the limestones of the middle member to the overlying sandstone sequence assigned to the Rocky Mountain Formation. It is recessive weathering.

Most of the limestone beds consist of skeletal, oölitic, and pelletoidal calcarenite. Subequidimensional single-crystal echinoderm fragments are in most places the dominant skeletal component. Brachiopod shell fragments and fragments of encrusting bryozoa are common skeletal components. Several different types of foraminifera tests, including *Endothyra*-like forms, are abundant locally. Ellipsoidal pellets of very fine-crystalline calcite, about 0.5 mm long are important clastic constituents in some beds. Echinoid spines are relatively rare. Oöliths are the dominant coarse clastic component within lenses and beds throughout much of the middle member of the Etherington Formation. They occur associated with the skeletal components and the latter commonly form nuclei for the oöliths. Most of the calcarenites are cemented with clear, medium- or coarse-crystalline calcite and lack significant porosity.

Interbeds of fine-crystalline limestone generally consist of a fine- or very fine-crystalline, crystalloblastic mosaic of calcite and commonly contain isolated single-crystal skeletal grains that appear to have been partly destroyed by degradational diagenetic recrystallization. Isolated small dolomite rhombs occur locally. Chert occurs both as discrete nodules and as irregular patches with diffuse boundaries. Within the lower member these limestones are in part argillaceous; toward the top they become silty and arenaceous, and contain up to 30 per cent quartz as silt and very fine grained sand. Quartz is virtually absent in the associated calcarenites. The fine-crystalline limestones appear to have originated as calcilutites and calcisiltites.

Dolomite interbeds are similar to the fine-crystalline limestone beds. They consist of a fine- and very fine-crystalline, crystalloblastic mosaic of dolomite. Relict (?) single-crystal calcite grains and brachiopod shell fragments occur but are not common. Chert is common as nodules or irregular anastomosing patches. The dolomites are argillaceous in the lower part of the formation where they occur in association with the thin interbeds of green shale. They become silty and sandy toward the top of the formation. The dolomites appear to grade into the fine-crystalline limestones and may be the dolomitized equivalents of these limestones.

Thin, fine-grained sandstone and siltstone interbeds occurring within the upper and middle members of the Etherington Formation are quartzose. The quartz grains generally occur in a fine-crystalline carbonate matrix and these rocks appear to be gradational into silty fine-crystalline limestones and dolomites. A distinctive bed of red and orange-yellow dolomitic siltstone lies 55 feet below the base of the Rocky Mountain Formation in Section 23 (*see* Appendix A). This bed resembles the siltstones described by Norris (1957b) from the upper part of his Todhunter Member of the Rocky Mountain Formation at Beehive Pass.

Fossils collected are discussed in Appendix B in excerpts from reports by P. Harker. Harker states that most of the collections obtained from the lower 255 feet of the Etherington strata in Section 21 suggest a correlation with the Etherington Formation in Mount Head area. A collection from 24 feet above the base of the formation has been correlated with a fauna occurring in the upper part of the Mount Head Formation in Mount Head area. No diagnostic fossils were obtained from the upper member of the Etherington Formation in Flathead area.

Pennsylvanian and (?) Permian

Rocky Mountain Formation

A distinctive lithostratigraphic unit, 600 to 700 feet thick and consisting of quartzitic and dolomitic sandstone with lesser amounts of silty and cherty dolomite, occupies the interval between the Etherington Formation and the shales assigned to the Spray River Formation in Flathead map-area. This unit is comparable to the sequence of strata that occupies the same stratigraphic interval and comprises the major part of the Rocky Mountain Formation on Tunnel Mountain at Banff, as described by Warren (1927 and 1956) and Beales (1950). It differs markedly in thickness and details of stratigraphic succession from strata overlying the Etherington Formation in Mount Head area. Accordingly, two geographically distinct standard sequences are used in attempting to establish the status of rock-units recognizable within the upper part of the Palaeozoic succession in Flathead map-area. The sandstone sequence is referred to the established section on Tunnel Mountain in the Bow Valley, whereas the underlying carbonate succession, which differs in detail from the Bow Valley sequence, is referred to the established sequence in the Mount Head area.

As stated, the criteria used in defining the top of the Etherington Formation of the Rundle Group (Douglas, 1958, p. 62) in Mount Head area are not the same as those used in discriminating between Rundle and Rocky Mountain strata at the type section of the Rocky Mountain Formation in Bow Valley. In Mount Head map-area the upper part of the Etherington Formation consists of dolomites and silty dolomites and is overlain by quartzose and cherty beds of the Rocky Mountain Formation. In Bow Valley, the base of the Rocky Mountain Formation "is drawn where relatively massive and coarse-grained fossil-fragment limestones and dolomitic, crinoidal limestones, taken as the Rundle Formation, give place upwards to fine- and medium-grained, chalky weathering dolomite" (Beales, 1950, p. 45). The stratigraphic interval assigned to the Rocky Mountain Formation in Flathead map-area has been restricted so as to exclude strata belonging by definition to the Etherington Formation. It excludes those strata, consisting predominantly of dolomite and silty dolomite, which underlie the thick quartzose sandstone succession and comprise the upper part of the Etherington Formation.

In Flathead map-area then the Rocky Mountain Formation consists of light grey quartzitic and dolomitic sandstone with minor silty and cherty dolomite and very thin interbeds of shale, chert, and cherty quartz-pebble conglomerate. Two and three-quarter miles west of Flathead Pass the Rocky Mountain Formation is 658 feet thick (*see* Section 22, Appendix A). Two subordinate lithostratigraphic units are distinguishable within the formation and these are referred to here as the lower part and the upper part.

Lower Part

The lower part of the Rocky Mountain Formation consists primarily of light grey quartzitic and dolomitic sandstone. Interbeds of fine-crystalline, light and medium grey, sandy and silty dolomite occur sporadically throughout the unit, being most common near the base. They commonly contain lenses and bands of chert. Beds are mostly several feet thick. A textural lamination, resulting from different proportions of carbonate and silica cement in the sandstones, produces a well-defined ribbed appearance which weathers into relief on exposed surfaces. Large-scale crossbedding is commonly defined by the ribbing. The sandstones, which weather to a light grey and light yellowish grey with occasional pink and rust patches, produce relatively prominent topographic forms. The lower part of the Rocky Mountain Formation is 610 feet thick in Section 22, and at least 630 feet in Section 23, 3½ miles to the east.

The sandstones consist almost exclusively of well-rounded, typically well-sorted quartz grains. Chert, tourmaline, zircon, and magnetite-ilmenite are discernible locally. The rock is cemented with quartz overgrowths or with clear medium- and coarse-crystalline carbonate. Where the carbonate 'cement' is more abundant it is more finely crystalline and presumably represents an initial carbonate matrix. The dolomitic sandstones appear to be gradational into sandy and silty dolomites in which clastic quartz grains 'float' in a carbonate matrix. Porosity is characteristically low throughout the sandstone sequence.

The strata that comprise the lower part of the Rocky Mountain Formation in Flathead map-area appear to be typical of an extensive sheet of quartz sandstone occurring at or near the top of the Palaeozoic succession in the Rocky Mountains of southern Canada and northern Montana. In a discussion of a reconnaissance study of phosphate deposits in the Canadian Rockies, Telfer (1933, pp. 569-572) has differentiated these sandstones from underlying and overlying lithostratigraphic units and has described their regional distribution. The lower part of the Rocky Mountain Formation of this report is essentially equivalent to the lithostratigraphic unit termed "the basal part of the Rocky Mountain Formation" by Telfer. It appears to be the lithostratigraphic equivalent of the upper 291 feet of the Tunnel Mountain Member of the Rocky Mountain Formation as described by Beales (1950) from the type section on Tunnel Mountain at Banff.

Fossils collected have been identified and discussed by P. Harker, and excerpts from his reports are included in Appendix B. Harker concluded that three of these collections, made within a stratigraphic interval ranging from 26 feet to about 100 feet above the base of the formation, are of Pennsylvanian age. A fourth collection made 265 feet above the base was reported to be almost certainly of Pennsylvanian age.

Upper Part

The upper part of the Rocky Mountain Formation consists primarily of fine-crystalline, grey dolomite and silty dolomite, commonly containing lenses and blebs of grey chert, with interbeds of yellow and brown shale, grey chert, cherty quartz-pebble conglomerate, and conglomeratic sandstone, all 6 inches or less thick. The dolomites occur in beds from 1 foot to 3 feet thick. They commonly contain silicified invertebrate fragments and weather white. In Section 22 (*see* Appendix A), the upper part of the Rocky Mountain Formation is 46.5 feet thick.

This lithostratigraphic unit has been observed along the west side of Flathead Range, near the north boundary of the map-area, and in Macdonald Range south of Lodgepole Creek, as well as at a number of intervening localities. It is everywhere overlain by a series of beds from 3 to 15 feet thick consisting of dark grey or black, medium- and fine-grained, cherty, phosphatic and carbonaceous, quartzitic and dolomitic sandstone. These beds are gradational into, or interbedded with, black laminated siltstones and silty shales of the lower part of the Spray River Formation. They are sharply defined above the dolomites of the Rocky Mountain Formation along an apparently planar surface without evidence of discordance. The dark sandstones, which are considered to be the basal unit of the Spray River Formation, probably represent reworked sands derived from the Rocky Mountain Formation. The base of the upper part of the Rocky Mountain Formation has been designated as the top of the highest relatively thick bed of well-sorted sandstone in a succession consisting dominantly of light grey quartzitic and dolomitic sandstone. Although the dolomites and the sandstones may be sharply defined locally, there is no apparent discordance between the adjacent beds, and the sequence appears to be conformable.

The upper part of the Rocky Mountain Formation in Flathead map-area is probably a lithostratigraphic equivalent of the upper 82 feet of the Rocky Mountain Formation at Beehive Pass, as described by Norris (1957b), and, following Norris' interpretation, the lithostratigraphic equivalent of the Norquay Mountain Member of the Rocky Mountain Formation at the type section near Banff (Beales, 1950; Warren, 1927 and 1956).

Fossils collected have been identified and discussed by P. Harker and excerpts from his reports are included in Appendix B. One collection includes the scaphopod *Plagioglypta canna*. Harker has stated that this species occurs at Lake Minnewanka, near Banff within the Norquay Mountain Member of the Rocky Mountain Formation as defined by Warren, and that this member is probably of Permian age. McGugan and Rapson (1960) have reported *Plagioglypta* in association with Pennsylvanian fusulinids from this same lithostratigraphic unit at four localities in Banff area, including the type section of the Rocky Mountain Formation. They consider the uppermost beds of this unit as probably Middle Permian. It would appear that the upper part of the Rocky Mountain Formation in Flathead map-area may include both Pennsylvanian and Permian strata.

Mesozoic

Triassic

Spray River Formation

Strata of this formation have been observed only within the Lewis thrust sheet along the west side of Flathead Range, the northwest side of Macdonald Range, and the east slope of Macdonald Range near Harvey Creek. No complete exposure was seen in the area, but on the basis of graphic calculations it is believed to maintain a relatively constant thickness of about 300 feet.

Two units are distinguishable within the Spray River Formation. The lower part consists of about 150 feet of rust-brown and dark grey, colour-laminated, platy siltstone, calcareous siltstone, and silty shale. It is recessive weathering and rarely exposed. A sequence of black, phosphatic and carbonaceous, fine-grained, quartzitic and dolomitic sandstones up to 15 feet thick marks the base of the formation. These beds appear to be unconformable on the silty dolomites of the Rocky Mountain Formation (*see* discussion of the upper part of the Rocky Mountain Group).

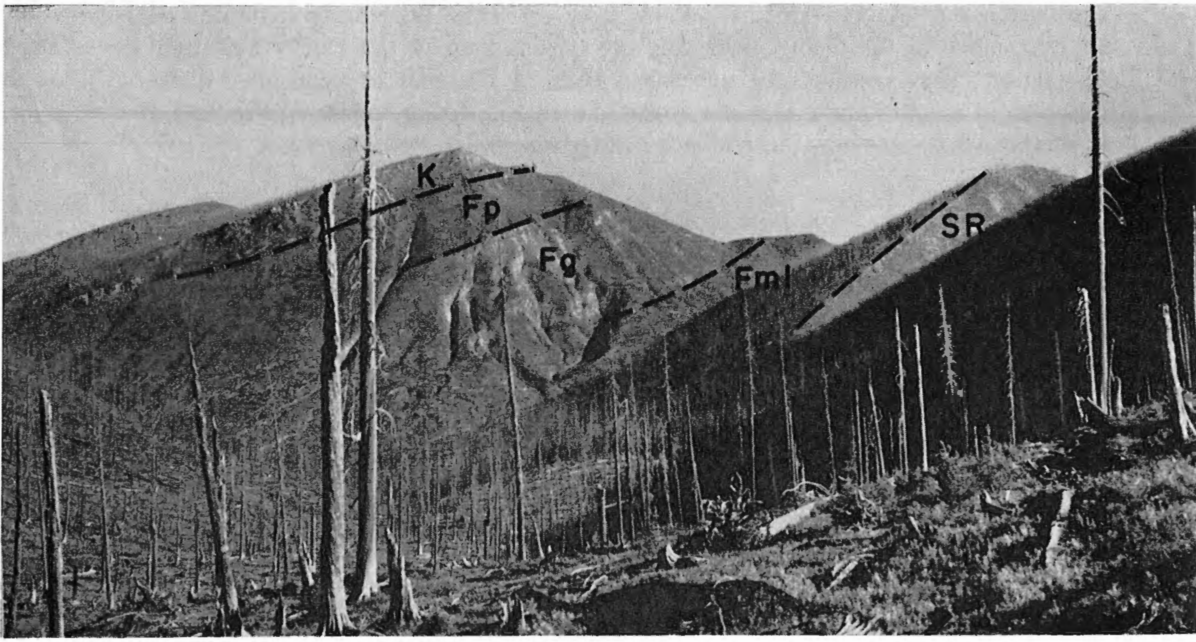
The upper part consists of light grey dolomitic or sideritic, argillaceous siltstone and fine-grained sandstone. It weathers to a light brownish yellow on exposed surfaces but has a dark reddish brown spongy crust beneath. It is gradational into the lower part through a zone of alternating, 4- to 6-inch beds of siltstone and sandstone and thinner beds of silty shale. Toward the top it becomes thickly bedded and relatively massive, and commonly produces prominent topographic forms beneath the recessive lower part of the Fernie Group. The coarse clastic fraction of the siltstones and sandstones consists mainly of carbonate grains and quartz.

No diagnostic fossils were obtained. Poorly preserved linguloid brachiopods and vertebrate fragments collected from the lower part were examined by E. T. Tozer, who reported that they are common in the Lower Triassic part of the Spray River Formation but cannot be used for dating.

Jurassic

Fernie Group

The Fernie Group in the Rocky Mountains and Foothills has recently been described by Frebold (1957) and the reader is referred to his comprehensive account. Fernie strata are present in the map-area both above and below the



R.A.P., 5-5-1957

PLATE V. Fernie sequence at the headwaters of Leach Creek. View northward. SR—Spray River Formation; Fml—middle and lower Fernie; Fg—Grey beds; Fp—Passage beds; K—Kootenay Formation.

Lewis thrust. No complete sections were, however, observed and exposures of the lower and middle Fernie are fragmentary and relatively rare. The upper Fernie is well exposed at several localities.

In Section 24, measured in the northwestern part of the map-area 6.5 miles west of Mount Darrah (*see* Pl. V), 1,235 feet of Fernie Group strata occur between the top of the Spray River Formation and the basal sandstone of the Kootenay Formation. Exposures there are incomplete and the 'Grey beds' may be tectonically thickened (*see* Pl. V). The exposed sequence is typical of that observed within the Lewis thrust sheet, and is described here in summary form.

	Thickness (feet)	Height above base (feet)
KOOTENAY FORMATION		
Sandstone, quartz-chert arenite, carbonaceous, dark grey, medium-grained, beds 6 inches to 4 feet thick; weathers light grey with rust patches, blocky, prominent........	10.0	1,246.0
Contact is marked by a sharp colour change and is conformable.		

	Thickness (feet)	Height above base (feet)
Fernie Group		
Passage Beds		
Sandstone, quartz-chert arenite, medium grey-brown, medium-grained, flecked with limonite, beds 1 inch to 18 inches thick, in part platy and coarsely crossbedded, fine colour lamination in platy beds; becomes more thickly bedded toward top; weathers light greyish brown, platy to blocky	83.0	1,236.0
Sandstone, dark greyish brown, fine-grained, beds ½ to 1 inch thick, coarse crossbedding; weathers light brown, platy	48.0	1,153.0
Shale, non-calcareous, black, with 1- to 2-inch interbeds of siltstone and very fine grained sandstone, which have fine, brown and grey laminations; sandstone interbeds increase in thickness and abundance toward top	44.0	1,105.0
Shale, non-calcareous, black and brownish black, a few ball-like calcareous and sideritic concretions locally; weathers dark grey, rubbly, recessive	132.0	1,061.0
Thickness of Passage beds	307.0	
Contact sharp but without apparent discordance		
Grey Beds		
Limestone, silty and sandy (quartz), light grey, fine-crystalline, nodular to platy, gradational locally into zones of calcareous shale, siltstone, and very fine grained sandstone, delicate crossbeds are commonly etched into relief on weathered surfaces; weathers light greyish yellow	178.0	929.0
Limestone, shaly and silty, light grey, fine-crystalline, beds poorly defined; weathers light greyish yellow, rubbly to platy	123.0	751.0
Shale, calcareous, medium grey, platy to rubbly; weathers light greyish yellow, recessive	52.0	628.0
Limestone, silty and sandy (quartz), light grey, fine-crystalline, nodular with calcareous shale partings locally, in part delicately crossbedded; weathers light yellowish grey	44.0	576.0
Limestone, shaly and silty, light grey, fine-crystalline, beds poorly defined; weathers light yellow with orange patches, platy to rubbly, gradational in zones to platy calcareous shale (forms the lower prominent light band in Pl. V)	200.0	532.0
Shale, calcareous, medium yellowish grey, fissile; grades downward through medium grey calcareous shale with silty bands into non-calcareous, medium yellowish brown shale; weathers light yellowish grey to medium grey	44.0	332.0
Thickness of Grey beds	641.0	

	Thickness (feet)	Height above base (feet)
Middle Fernie (Rock Creek Member?)		
Shale, non-calcareous, dark greyish brown, with fine colour lamination, gradational downward into highly fissile, brownish black shale; weathers dark grey	62.0	288.0
Measured thickness of middle Fernie	62.0	
Covered (no apparent discordance in attitude of bedding across covered interval)	223.0	226.0
Phosphate rock, pelletoidal and granular, black, medium-grained, becomes nodular, silty and platy toward base (exposure limited to a prospect trench)	3.0	3.0
Contact with light grey dolomitic siltstone of upper part of Spray River Formation sharp without apparent discordance		
Total thickness of Fernie Group	1,236.0	

The total thickness of 288 feet for the middle and lower Fernie beds agrees closely with that given by Frebold (1957, Fig. 3) for Fernie area to the east and Alexander Creek area to the north. Strata comprising the Rock Creek Member of the middle Fernie are exposed sporadically in gullies on the west side of Michel Creek valley near the north boundary of the map-area, and at the headwaters of McLatchie Creek. They consist of black and brownish black shales with black limestone bands containing belemnite accumulations. A few *Gryphaea* fragments also occur locally.

The name Grey beds has been used for the lower Callovian rocks of the Fernie Group (Frebold, 1957, p. 20). Frebold described three main lithofacies of the rocks that he assigned to the lower Callovian. The lithostratigraphic unit assigned to the Grey beds in Flathead map-area most closely resembles the shaly facies. This unit has been observed only above the Lewis Thrust Fault. It occurs along the periphery of the Fernie basin, east of Michel Creek on Coal Mountain, and in Flathead Valley adjacent to Squaw and McLatchie Creeks. The Grey beds characteristically form relatively prominent topographic features within the recessive interval occupied by the Fernie Group. They weather to a distinctive yellowish grey which makes them recognizable from a distance (*see* Pl. V).

The stratigraphic thickness of the Grey beds in Flathead map-area is uncertain. Several thrust faults are present within the unit a few miles south of Section 24 and, although structural discordance between individual beds is not evident in the section, the possibility exists that one or more of these faults extend through the section parallel with the bedding and that as a result the true stratigraphic thickness of the Grey beds may be considerably less than the 641 feet measured.

In Section 24 the dominant rock type of the Grey beds is an argillaceous, silty, and sandy fine-crystalline limestone, with some calcareous shale and silty calcareous shale. The limestones are generally nodular or have thin, wisp-like partings of light grey calcareous shale. Quartz, of silt or very fine sand grade, is found throughout, and where it is especially abundant the limestones possess a textural lamination which when etched into relief by weathering is megascopically discernible as delicate lamination and cross-lamination. Calcite exists as single-crystal grains or as very fine-crystalline argillaceous pellets of fine sand grade in a homogeneous matrix of very fine-crystalline argillaceous calcite. Muscovite and biotite flakes occur in a few of the sandy limestones, and small granules of pyrite or marcasite in some of the argillaceous limestone. The Grey beds within the map-area appear to contain more limestone and quartz silt and sand than at other localities to the west and north where the sequence consists mainly of shale (Frebold, 1957).

The Grey beds grade downward through yellowish brown shales into highly fissile brownish black shales that probably constitute part of the Rock Creek Member. In contrast, their upper contact is sharp. In Section 24, the Grey beds are overlain by black concretionary shales of the lower part of the Passage beds. On the east side of Coal Mountain, in a prominent gully 1,600 yards south of the north boundary of the map-area, 21 feet of dark green, medium-grained, glauconite sandstone, comprising the Green beds of the Fernie Group (Frebold, 1957, p. 28), occurs between the Grey beds and the Passage beds. The glauconite sandstone of the Green beds is in sharp contact with the underlying Grey beds but grades through an interval of 3 feet into the lower part of the Passage beds. Except for a few belemnite fragments, no fossils were observed in the Grey beds.

The Passage beds are exposed within the Lewis thrust sheet and in fault slices beneath it. They consist predominantly of black shale and are in sharp and presumably disconformable contact with the underlying beds. Upward they grade into the basal part of the Kootenay Formation. The base of the prominent dark grey, fine- or medium-grained, carbonaceous sandstones of the Moose Mountain Member of the Kootenay Formation (Norris, 1959b) marks the top of the Fernie Group. Sandstone comprising the upper part of the Passage beds is brownish grey and relatively recessive. It weathers to a distinct greyish brown in contrast to the grey of the cliff-forming sandstone of the Moose Mountain Member of the Kootenay Formation. At the base the Passage beds weather to a dark grey and are markedly recessive; at the top they weather brown and are more prominent.

Jurassic and (?) Cretaceous

Kootenay Formation

The Kootenay Formation comprises grey and black, carbonaceous sandstones, siltstones, mudstones, and shales with interbeds of coal and minor conglomeratic sandstone and conglomerate. It occupies the stratigraphic interval between the Passage beds of the Fernie Group and the non-carbonaceous, quartz-chert pebble conglomerates and sandstones of the basal part of the Blairmore Group. At the base it grades into the Passage beds of the Fernie Group and the contact is designated as the change from dark grey carbonaceous sandstone to brown sandstone. The upper contact is sharp and is marked by a change from dark carbonaceous clastic rocks to lighter, non-carbonaceous, quartz-chert pebble conglomerate and sandstone and vari-coloured mudstone and siltstone of the Blairmore Group.

In the western part of the area, within the Lewis thrust sheet, the Kootenay Formation is between 1,500 and 2,000 feet thick; no completely exposed section has been observed. Graphic calculations indicate that it is about 1,700 feet thick on the ridge between Foisey and McLatchie Creeks. In a section on Michel Ridge at the south end of Mount Taylor 1,525 feet of Kootenay strata was measured but the highest beds are covered and there is a discordance in the attitude of the bedding between the highest exposures of Kootenay strata and beds of pebble conglomerate that appear to mark the base of the Blairmore Group. Béthune (1936, p. 164) reported a thickness of 1,600 feet for the Kootenay Formation at Flathead in the central part of the area. His stratigraphic section is composite, combining measurements obtained from the limited exposures with data from borings. The lower part of his section appears to embrace the Passage beds of the Fernie Group and the upper part probably includes some Blairmore strata.

Beneath the Lewis thrust sheet, in the northeastern part of the area, the Kootenay Formation is much thinner, but precise measurement is not possible because of incomplete exposures and structural complexity. In the adjacent area to the east and northeast it is from 250 to 450 feet thick (Norris, 1959b, Fig. 3). In the northeastern part of Flathead map-area the maximum thickness is probably about 600 feet.

Norris (1959b) proposed a type section for the Kootenay Formation at Grassy Mountain in Blairmore map-area, and has designated four members in it. The lowest of these, the Moose Mountain Member, is recognizable throughout Flathead map-area. It consists of dark grey, carbonaceous, fine- or medium-grained, quartz-chert sandstone and lies in gradational contact above the brown sandstone marking the top of the Fernie Group. It is generally 40 to 50 feet thick and is commonly overlain by a coal seam that marks the base of the succeeding Adanac Member.

The Adanac Member consists of grey and black mudstone, shale siltstone, and fine-grained sandstone, and one or more coal seams. It is about 45 feet thick on Michel Ridge. Coal occurs at or near the base of the member at Coal Mountain, Michel Ridge, and Leach Creek.

The succeeding Hillcrest Member comprises a sequence of resistant, grey, fine- to very coarse-grained, carbonaceous sandstones with lesser amounts of mudstone and siltstone. Conglomeratic sandstone and lenses of pebble-conglomerate occur within it at Michel Ridge and on the ridge between Foisey and McLatchie Creeks. It is 190 feet thick on Michel Ridge.

In Blairmore and Carbondale River areas the Mutz Member forms the remaining upper part of the Kootenay Formation, lying between the Hillcrest Member and the unconformity at the base of the Blairmore Group (Norris, 1959b). It embraces a series of less resistant beds comprising grey carbonaceous mudstones, shales, siltstones, fine-grained sandstones, and one or more coal seams. It thins toward the east, mainly because of pre-Blairmore erosion. On Michel Ridge at the south end of Mount Taylor a sequence of Kootenay strata at least 1,250 feet thick occurs above the Hillcrest Member. Although this sequence of strata presumably embraces the Mutz Member it probably also includes younger strata that are not represented in the type section of the Kootenay Formation. The lower 750 feet consists mainly of shale, siltstone, and fine-grained sandstone and includes several coal seams. It is less resistant to erosion than overlying and underlying parts of the Kootenay Formation and forms a recessive weathering interval that can be recognized as far southward as the headwaters of Foisey Creek. The remaining upper part of the Kootenay Formation contains a greater proportion of resistant sandstone and no coal was observed within it.

West of Flathead area, beds of chert-, quartz- and quartzite-pebble and cobble conglomerate are interbedded with Kootenay-type dark, carbonaceous mudstones, siltstones, and sandstones and thin coal seams in the upper part of the interval between the Fernie Group and the Blairmore Group. This sequence of carbonaceous strata containing beds of conglomerate was included in the Elk Conglomerates of McEvoy (1902) and later workers, and constitutes the Elk Formation of Newmarch (1953). Newmarch's formal proposal of the term Elk Formation included a designation of a type section at Coal Creek near Fernie, British Columbia, that embraces 1,700 feet of conglomeratic strata overlying non-conglomeratic Kootenay beds. Newmarch stated (pp. 48-49) that the Elk Formation is overlain by "interbedded conglomerates, light-coloured quartz-rich sandstones, and vari-coloured shales (green, maroon, yellow, and grey)" of the Blairmore Formation, the base of which is marked by a "45-foot bed of pebble conglomerate, consisting of well-rounded pebbles of grey and black chert, brown to white quartzite with a few greyish-green quartzite pebbles." He defined the base of the Elk Formation as "the base of a coarse conglomerate which overlies number 'B' coal seam" and thereby restricted all known commercial coal seams to the underlying Kootenay Formation.

Dark grey pebble conglomerates are interbedded with Kootenay-type carbonaceous sandstones, siltstones, and mudstones near Mount Taylor, a few miles northwest of Flathead map-area. These are overlain by non-carbonaceous sandstone and conglomerate typical of the lower part of the Blairmore Group. In Flathead area beds of coarse sandstone occur in the upper part of the Kootenay Formation but these are not conglomeratic and conglomerates were not observed in association with them. These beds and the conglomerates near Mount Taylor may be lateral equivalents of the Elk Formation. However, the number 'B' coal seam used in defining the base of the Elk Formation does not appear to be present in Flathead map-area and in view of the fact that conglomerates are found in the lower part of the Kootenay Formation, the occurrence of beds of conglomerate is not, in itself, a valid basis for discriminating the Elk Formation. This difficulty in distinguishing between the Elk and Kootenay Formations probably reflects the fact that the Elk Formation is a local conglomeratic facies of the upper part of the Kootenay Formation.

The sandstones of the Kootenay Formation consist of angular to subrounded grains of quartz, dark-coloured chert, fine-grained quartzite, cherty argillite, and cherty siltstone. Wisps and granules of coalified carbonaceous material are common throughout the matrix and occur in association with shreds of mica and small amounts of clay. The sandstones are cemented with chert or with quartz overgrowths. Pebbles in the lenses of conglomerate and beds of conglomeratic sandstone in the lower part of the Kootenay Formation consist primarily of dark-coloured chert, cherty siltstone, and cherty argillite. Some of the chert pebbles contain abundant siliceous spherical structures less than 0.1 mm in diameter that are apparently of organic origin and are directly comparable with micro-structures observed in chert in the lower part of the Banff Formation. At least part of the chert that forms the conglomerates and sandstones of the Kootenay Formation appears to have been derived from Banff rocks. Wisps and clots of coalified plant material occur locally in the matrix of the conglomerates and further accentuate the characteristic dark colour imparted by the chert fragments.

The siltstones and shales of the Kootenay Formation generally have more carbonaceous material than the sandstones. Coalified plant debris is either finely divided or occurs as minute wisp-like clots. Carbonate is abundant locally and the siltstones and shales grade into carbonaceous, silty or argillaceous limestones and sideritic limestones. Coal seams are commonly associated with the shales but are rarely well exposed.

Fragmentary plant fossils are common throughout most of the Kootenay Formation. Some of the coarse-grained sandstones within the lower few hundred feet contain numerous internal and external moulds of relatively large 'branch-like' fragments of plants covered with thin layers of bright coal. Small imprints of minute plant fragments are common in mudstone beds. No fossils were collected but the flora of the formation in the surrounding district is relatively well known. A single flora is reported to occur within the plant-bearing part (Bell, 1956). The lowest florules recorded from the formation were collected 230 feet above its base in Fernie area, and 25 feet above the basal sandstone unit in Blairmore area. The Kootenay flora extends into the Elk Formation at Fernie (Bell, 1956, p. 5). This macroflora has been dated by Bell (1956, p. 8) as Neocomian-Barremian (mid-Lower Cretaceous). Rouse (1959) studied the microflora of the formation in the Crowsnest Pass of southeastern British Columbia, and stated that it seems to be more closely related to the Upper Jurassic microfloras from Europe and Russia than to the Lower Cretaceous.

The cast of a large ammonite was reported by Newmarch (1953, p. 47) from the top of the basal sandstone unit of the Kootenay Formation at Coal Creek, in Fernie area. Frebold (1957, p. 35) has used this ammonite to date the Moose Mountain Member as Upper Jurassic (Upper Portlandian).

Cretaceous

Blairmore Group

The term 'Blairmore Formation' was introduced by Leach (1914) in Blairmore map-area for strata that he had formerly referred to the "Dakota (?) Formation". Rose (1917) redefined the Blairmore Formation to include a basal pebble-conglomerate unit which he reported as unconformable over the coal-bearing Kootenay sequence. Bell (1956, pp. 9-10) has discussed the regional relationships that form the basis for elevating the Blairmore to group status.

In Flathead map-area, strata lying above the carbonaceous Kootenay sequence and below the alkaline pyroclastic rocks and volcanic-rich sediments of the Crowsnest Formation have been assigned to the Blairmore Group. These strata are lithologically similar to the Blairmore Group in the type area, and occupy the same stratigraphic position.

Blairmore strata occur within the Lewis thrust sheet in the Fernie basin along the western side of the map-area, in Flathead Valley near Shepp Creek, and at Flathead townsite, as well as below the Lewis thrust sheet in the northeastern part of the map-area. They appear to embrace most or all of the 'Flathead beds' described by McEvoy (1902).

No complete section of the Blairmore Group has been observed in Flathead area, but certain generalities concerning part of the stratigraphic succession were found to be consistent throughout the map-area. The base of the group is marked by a non-carbonaceous, quartzitic pebble-conglomerate and sandstone unit, consisting of chert, quartzite, quartz, cherty argillite, and cherty siltstone fragments. The basal bed in the unit is a pebble-conglomerate. In the northeastern part of the map-area this bed is estimated to be consistently less than 50 feet thick and the pebbles in it average one inch in diameter. It is gradational upward into coarse-grained sandstones, in part conglomeratic, which, together with it, form a unit less than 300 feet thick. In the western part of the map-area conglomerate lenses and beds occur throughout the unit and its thickness is between 450 and 550 feet. The pebbles average 2 inches in diameter with occasional cobbles up to 5 inches.

An extensive cover of drift and structural complexities obscure stratigraphic relationships within most of the remainder of the Blairmore Group in the northeastern part of the map-area. Green and greenish grey feldspathic sandstone and quartz-chert sandstone, interbedded with yellowish grey and green mudstone and minor red mudstone and brown cryptocrystalline limestone, occur within the upper part of the group. At the top of the Blairmore Group non-feldspathic, quartz-chert sandstones appear to grade into the 'volcanic-rich' sandstones and mudstones and the tuffs and agglomerates of the Crowsnest Formation. At the only locality where the uppermost beds of the Blairmore Group were examined, on the ridge between Carbondale River and Lost Creek near the eastern boundary of the map-area, the gradation appears to be relatively abrupt. The highest bed consisting mainly of quartz-chert sandstone has been included in the Blairmore Group. Graphic calculations indicate that the Blairmore Group is about 1,800 feet thick in the northeastern part of the map-area.

In the western part of the map-area only the lower part of the Blairmore Group is exposed, and it is about 3,750 feet thick. West of the map-area, the group is estimated to be more than 6,000 feet thick in the structurally lowest part of the Fernie basin. No younger consolidated sediments have been reported from the Fernie basin[1]. Northwest of McLatchie Creek, the basal conglomerate and sandstone unit, 450 to 550 feet thick, consists of interbedded sandstone, conglomerate and mudstone, and grades upward into dark red and dark green mudstone. The mudstones constitute a second unit overlain by dark green, greenish grey, and brown feldspathic and volcanic-rich sandstones. The lowest of these sandstones appears to be about 800 feet above the base of the Blairmore Group. In addition to quartz, chert, and cherty argillite fragments, the sandstones contain up to 40 per cent of feldspar, fragments of alkaline igneous rocks, and a variable assemblage of ferromagnesian minerals. The igneous fraction in these clastic rocks is indicative of a distinctly alkaline source and may have been derived from local volcanic centres related to the alkaline intrusive rocks emplaced at lower stratigraphic horizons within the map-area.

No fossils were collected from the Blairmore Group in Flathead area, but in the adjacent Blairmore area two floras are known (Bell, 1956, pp. 10-15). Bell has dated the lower of these as Aptian or possibly Barremian in age, and the upper, which is restricted to the uppermost few hundred feet of the group, as Albian. Strata assigned to the Blairmore Group in Flathead map-area are probably all Lower Cretaceous.

Crowsnest Formation

The alkaline and ultra-alkaline pyroclastic rocks, volcanic-rich sandstones, conglomerates, and mudstones, and the trachytic flows comprising the Crowsnest Formation have been described in considerable detail from localities near Crowsnest Pass in Alberta. H. N. S. MacKenzie (1956) recently summarized the published data and interpretations relating to their distribution, character, and stratigraphic relationships. He has indicated that there appear to be inconsistencies in the designation of the Crowsnest-Blairmore boundary.

Strata assigned to the Crowsnest Formation in Flathead map-area have been separated from those of the Blairmore Group on the basis of their high content of feldspar and alkaline rock fragments. They exclude the dominantly non-feldspathic, quartz-chert sandstones, and the top of the highest bed of such sandstone has been designated as the top of the Blairmore Group. Feldspathic and volcanic-rich sediments below this bed have been included in the Blairmore Group.

[1] Field work during 1959 established the existence of Upper Cretaceous strata of the Blackstone Formation, comprising grey sandstones and shale, and a coquina of *Exogyra suborbiculata* Lamarck, lying directly on the Blairmore Group in the structurally lowest part of the Fernie basin. (Price, R. A., 1962: Fernie Map-area, East Half, Alberta and British Columbia; *Geol. Surv., Canada,* Paper 61-24, p. 35.)

The Crowsnest Formation consists of a series of lithic and crystal tuffs, trachyte agglomerates, trachytic and arkosic sandstones and conglomerates, tuffaceous mudstones, and minor trachyte. Exposures of the Crowsnest Formation are restricted to the northeastern part of the map-area where these strata occur below the Lewis thrust sheet. The exposures are incomplete, and the precise thickness of the formation is unknown, but graphic calculations indicate it to be about 500 feet.

J. D. MacKenzie (1914) has summarized the earliest accounts of the stratigraphy and petrography of the Crowsnest strata and has discussed their petrography and genesis. The rock types recognized in the present brief examination are essentially those described by MacKenzie, and the reader is referred to his descriptions for more data.

The dominant rock types appear to be coarse-grained orthoclase and trachyte tuff, and trachyte agglomerate. Arkosic and trachytic, volcanic-rich sandstones, mudstones, and conglomerates, which are well stratified and commonly cross-bedded, occur within the formation. The lithic fragments in the agglomerates consist primarily of homogeneous trachyte. Some of the fragments contain minor amounts of plagioclase and may represent the latites described by MacKenzie. Melanite-bearing trachytes are common. Porphyritic, analcite-rich rock fragments occur locally and are similar to the blairmorite described by MacKenzie. Angular fragments of quartzite, Rundle-type limestone, and Blairmore-type sandstone occur in a few of the agglomerate beds but are rare. Trachyte fragments up to 6 inches long have been observed locally. The fragments are angular and lack chilled borders. They were probably ejected as blocks of solidified igneous rock during explosive volcanism.

The tuffs consist of angular fragments of pink orthoclase, sanidine (?), and various alkaline rock fragments, including trachyte, melanite-bearing trachyte, latite (?), and blairmorite all in a green matrix. Either feldspar or rock fragments may be dominant locally. The matrix contains aegerine-augite, orthoclase, sanidine (?), melanite, magnetite-ilmenite, chlorite, sphene, and calcite.

The sandstones, conglomerates, and mudstones have essentially the same composition as the pyroclastic rocks but most of their larger grains are rounded, and they exhibit a higher degree of sorting.

The marine shales and siltstones of the Blackstone Formation overlie the Crowsnest strata but the contact between these two units was not observed within the map-area. Near the mouth of Lynx Creek in the western part of the adjacent Carbondale River map-area, dark grey shale, fine-grained sandstone, and chert-pebble conglomerate, comprising the basal part of the Blackstone Formation were observed in sharp contact above analcite-bearing agglomerate of the Crowsnest Formation.

No fossils have been collected from the Crowsnest Formation in Flathead map-area. A fossil flora from the Crowsnest strata in the Crowsnest Pass district has, however, been described by Bell (1956, p. 16), who considered it to be possibly of Albian age.

Alberta Group

Alberta Group strata are exposed in front of the Lewis thrust sheet in the northeastern part of the map-area and in windows through the Lewis thrust sheet along Cate Creek in the southeast and at the headwaters of Harvey Creek in the southwest. The exposures are typically incomplete and fragmentary and consequently details of the stratigraphic succession are imperfectly known. The character and stratigraphic relationships of Alberta Group rocks east of Flathead area have been described by Stott (1958).

Within the map-area strata lying above the Crowsnest Formation and below the light greenish or yellowish grey, quartz and chert sandstones of the Belly River Formation have been assigned to the Alberta Group. Although exposures of these strata are fragmentary, it appears to be possible to map the Blackstone, Cardium, and Wapiabi Formations separately.

Blackstone Formation

The Blackstone Formation has been recognized only in the northeastern part of the map-area, where it consists primarily of dark grey shale and siltstone, with an estimated thickness of 300 feet. Stott (1958) reported a thickness of 262 feet for this formation on Lynx Creek in the western part of the adjacent Carbondale River map-area.

Cardium Formation

Strata comprising part of the Cardium Formation were recognized with certainty only in the northeastern part of the map-area. They may be present in the southwest, at the headwaters of Lodgepole Creek, but have not been differentiated there from the Wapiabi Formation. In the vicinity of Carbondale River and Lost Creek, the formation consists primarily of dark grey, fine- to medium-grained sandstone with interbedded siltstone and silty shale. The sandstone weathers to form a flaggy or rubbly scree and the bedding is rarely well defined. The stratigraphic relationships at the boundaries of the unit were not observed. Sandstones and siltstones assigned to the Cardium Formation occupy a stratigraphic interval about 125 feet thick. Stott (1958) reported a thickness of 162 feet for this formation on Lynx Creek, east of the area. The Cardium sandstones characteristically form relatively prominent topographic features within the zones of subdued relief underlain by the Alberta Group.

Wapiabi Formation

Wapiabi strata are exposed in the northeastern part of the map-area in front of the Lewis thrust sheet and in the southeastern and southwestern parts in windows through the thrust sheet. The exposures are incomplete. Most consist of the more resistant beds of siltstone and silty or calcareous shale. The formation apparently consists primarily of less resistant shales.

The upper part of the Wapiabi Formation is well exposed along the headwaters of a tributary of Harvey Creek in the southwestern part of the map-area.

The overlying Belly River Formation is gradational into it. The basal sandstone of the Belly River Formation is underlain by about 45 feet of interbedded sandstone and silty shale. The latter grades downward into 330 feet of silty dark grey shale. A prominent unit consisting of at least 50 feet of nodular and flaggy, dark grey, fine-grained, carbonaceous sandstone occurs at the base of the 330-foot silty shale unit.

Fossils collected from this formation along Howell Creek, immediately south of the map-area, were examined by J. A. Jeletzky of the Geological Survey of Canada who reported that they include *Scaphites ventricosus* Meek and Hayden s. lato and *Inoceramus* sp. He reported the *Scaphites* to be characteristic of the generalized zone of *Scaphites ventricosus* which occurs almost exclusively in rocks of Wapiabi age and which is Coniacian and Santonian in terms of the international standard stages. A collection from the lower part of the formation on South Lost Creek, 2½ miles east of the provincial boundary, is reported by Jeletzky to contain *Inoceramus* cf. *deformis* Meek s. lato which he tentatively correlated with the *Scaphites preventricosus* and *Inoceramus deformis* zone. This zone, according to Jeletzky, occurs either within the lowermost 50 to 60 feet of the Wapiabi Formation or within the Cardium Formation. Fossils indicative of the Wapiabi Formation have been reported by Olsson and Caster (1935) from Cate Creek in the southeastern part of the map-area.

Belly River Formation

Belly River strata underlie much of the northeastern part of the map-area. They are also associated with the Wapiabi strata in the southwestern and southeastern parts of the area. The formation is very poorly exposed and details of the stratigraphic succession in the map-area are unknown. Most exposures consist of greenish and yellowish grey, medium-grained, massive or crossbedded, quartz and chert sandstone. Greenish grey mudstone and shale with thin interbeds of fine-crystalline limestone occur locally. The basal sandstone generally forms relatively prominent topographic features above the recessive-weathering strata of the Wapiabi Formation. At Harvey Creek it is at least 125 feet thick and consists of light greenish and yellowish grey, fine- to medium-grained quartz and chert sandstone that is massive and shows large-scale poorly defined crossbedding.

Cenozoic

Eocene and Oligocene

Kishenehn Formation

The name Kishenehn Formation was proposed by Daly (1912, p. 87) for freshwater clays, sandstones, and lignites occurring in Flathead Valley near the International Boundary. These rocks are the "Tertiary rocks" of Dawson (1886, p. 52B) and the "Tertiary lake beds" of Willis (1902, p. 327). Both Willis and Daly concluded that the freshwater sediments occurred in a structural trough bounded by a prominent gravity fault that follows the east side of Flathead

Valley. North of the International Boundary, near Couldrey and Howell Creeks, MacKenzie (1916, p. 32) recognized two distinct facies in the Kishenehn Formation, one consisting mainly of coarse gravel and sand and the other of clay, marl, and lignite.

Strata assigned to the Kishenehn Formation in Flathead map-area consist almost exclusively of partly indurated conglomerate and appear to represent the coarse facies described by MacKenzie. The conglomerates are typically poorly sorted and most have a matrix of carbonate sand and silt. The fragments appear to have been derived exclusively from the Palaeozoic formations of the area. Boulders up to 4 feet in diameter occur locally and those of 1 foot are relatively common. Variations in fragment size commonly result in a crude stratification (*see* Pl. VIII). The smaller fragments are typically subangular, but larger cobbles and boulders are commonly well rounded.

R.A.P., 10-5-1957

PLATE VI. Kishenehn Formation (?) conglomerate and breccia on crest of flat-topped ridge in the central part of Macdonald Range 1½ miles north of Shepp Creek (see Pl. VII). Pick handle is 13 inches long.

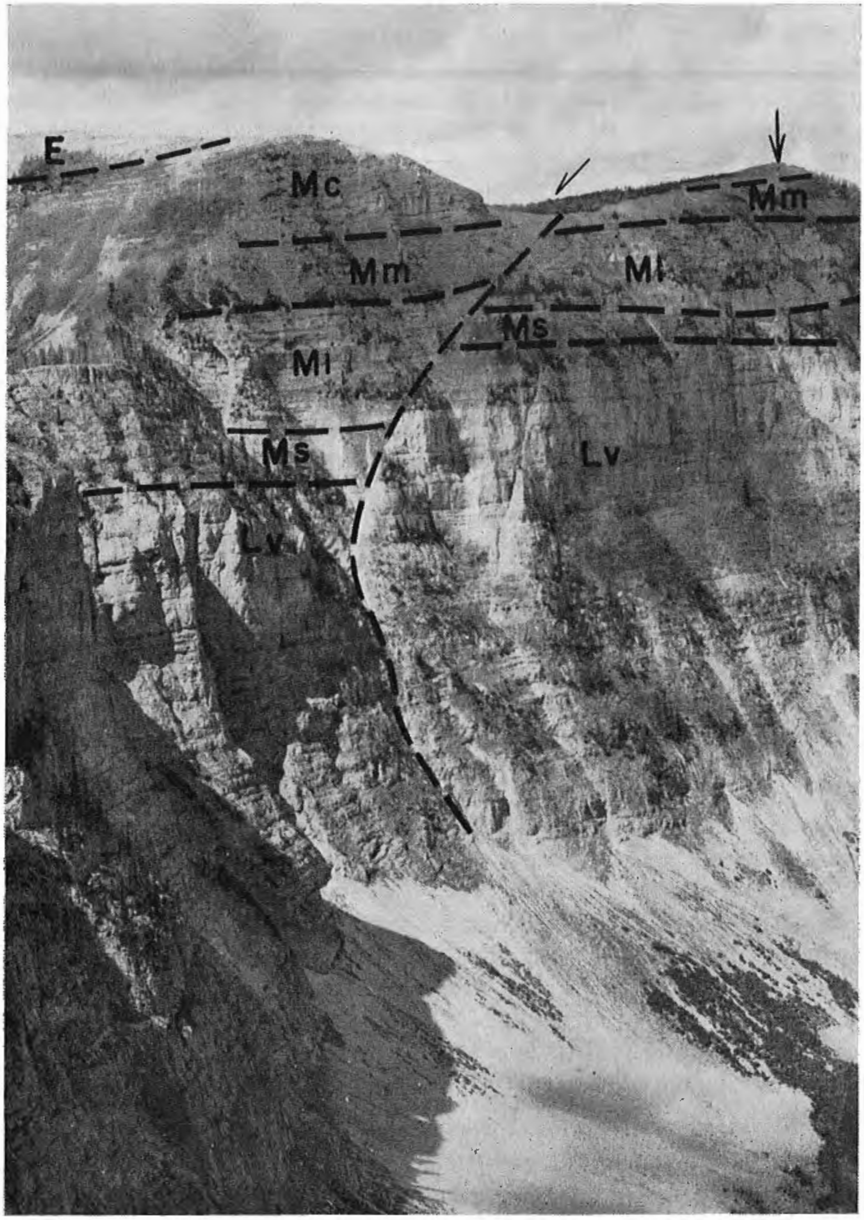
Exposures of Kishenehn strata are limited to the southern part of the area adjacent to Flathead Valley. The conglomerates form rounded hills along the east side of Flathead Valley near Cate Creek and also occur as isolated patches mantling the Palaeozoic rocks of the eastern slope of Macdonald Range. All exposures in Flathead area and in the region to the south are limited to the downthrown side of the Flathead fault.

The Kishenehn conglomerates near Cate Creek may be as much as 1,000 feet thick and apparently overlie east-dipping Mesozoic rocks that are exposed along the west side of Flathead Valley. They are relatively coarse and stratification is only evident locally. The texture of the conglomerates changes toward the Flathead fault; they become less well sorted, more coarse and angular, and relatively massive. Locally they grade into coarse sedimentary breccia. A tectonic breccia along the Flathead fault zone marks the eastern limit of the Kishenehn strata and separates them from strata of the Palliser Formation and the Fairholme Group. Brecciation along the Flathead fault zone affects both the sedimentary breccia of the Kishenehn Formation and the adjacent Devonian rocks.

On the south side of Cate Creek the sequence of Palaeozoic formations represented by fragments in successive beds of Kishenehn conglomerate is the inverse of the normal stratigraphic sequence. The lowest exposures of conglomerate, at the level of the creek, contain boulders, cobbles, and pebbles derived from the Rundle Group and the lower part of the Rocky Mountain Formation. Younger beds, exposed about 500 feet above the level of the creek, consist almost exclusively of fragments derived from the Palliser Formation and parts of the Fairholme Group. The sequence of conglomerate beds at this locality forms a record of the progressive erosion of the Palaeozoic cover of some nearby area.

The distribution, composition, and fabric of the conglomerates near Cate Creek indicate that they were derived from the uplifted area east of the Flathead fault in Clark Range. The conglomerates are restricted to the downthrown side of the Flathead fault and are preserved in a structural trough that has developed along the fault. They have been derived from the upper part of the Palaeozoic sequence and the only logical source area for detritus derived from the stratigraphic interval embracing the Rocky Mountain Formation and the Fairholme Group is Clark Range. Finally, the general increase in angularity and fragment size and concomitant decrease in degree of sorting in the conglomerates toward the Flathead fault and Clark Range show that the coarse detritus was transported westward from the uplifted area east of the Flathead fault. This coarse facies of the Kishenehn Formation at Cate Creek appears to represent fanglomerates and coarse breccias that accumulated along the scarp of the Flathead fault. The absence of detritus derived from Purcell and lowermost Palaeozoic rocks indicates that deposition occurred prior to the complete removal of Palaeozoic strata that formerly covered the Purcell rocks of Clark Range. Brecciation and tiltnig of the Kishenehn beds are related to later displacement on the Flathead fault and are considered in Chapter IV.

The isolated patches of Kishenehn conglomerate west of Flathead River mantle Rundle Group and younger strata of the east slope of Macdonald Range. There is an angular discordance between the attitude of a crude stratification discernible locally in the conglomerates and the bedding of the underlying Palaeozoic rocks. The fragments in the conglomerates have been derived from the upper part of the Rundle Group and, in part, from the Rocky Mountain Formation. Pebbles 2 to 3 inches in diameter are common; boulders 1 foot or more in diameter occur locally but are rare. The crude bedding in the conglomerates consistently dips toward the Flathead fault.



R.A.P., 10-4-1957

PLATE VII. Normal fault in central Macdonald Range a mile north of Shepp Creek. View westward. Lv—Livingstone Formation; Mount Head Formation: Ms—Salter Member, Ml—Loomis Member, Mm—Marston Member, Mc—Carnarvon Member; E—Etherington Formation. Arrow marks location of conglomerate and breccia shown in Plate VI.

The highest patch of coarse detrital rock assigned to the Kishenehn Formation occurs at an elevation of almost 7,500 feet in north-central Macdonald Range (*see* Pls. VI and VII), and is more than 2,000 feet above the present floor of Flathead Valley. The rock consists of relatively massive conglomerates and breccias and is underlain by the basal beds of the Carnarvon Member of the Mount Head Formation. The fragments in the Kishenehn Formation have been derived from the Mount Head and Etherington Formations.

A peculiar feature of the Kishenehn rocks in Macdonald Range is that they lie upon beds that would normally occur up to 1,000 feet below those from which the constituent fragments of the conglomerates were derived. For example, detritus derived from the Mount Head and Etherington Formations lies on the lowest beds of the Carnarvon Member of the Mount Head Formation in north-central Macdonald Range, and detritus derived from the Mount Head, Etherington, and Rocky Mountain Formations lies on the Livingstone Formation on the east slope of Macdonald Range. In contrast, the Kishenehn strata near Cate Creek were derived from Palaeozoic formations and overlie Mesozoic beds. The isolated exposures of Kishenehn rocks in Macdonald Range may represent detritus filling local channels that were eroded in bedrock, whereas the Kishenehn rocks near Cate Creek represent detrital fill that accumulated in a structural rather than an erosional depression.

R.A.P., 9-2-1957

PLATE VIII. Kishenehn Formation: fanglomerate on east side of Flathead Valley north of Cate Creek. Stratification as defined by variations in fragment size dips to the east parallel with the handle of the pick (13 inches long).

No fossils were obtained from the Kishenehn strata of Flathead map-area. They have been correlated with the coarse facies of the Kishenehn described by MacKenzie (1916) from localities between 8 and 15 miles south of Flathead map-area on the basis of their lithology and stratigraphic and structural relationships. Russell (1954) collected a single mammalian fauna from several localities in the Kishenehn beds described by MacKenzie. In discussing this fauna, Russell (1954, p. 94) has stated:

> It is evident that the affinities of the Kishenehn mammalian fauna are with those of the Duchesne River Formation (uppermost Eocene) and the Pipestone Springs beds (basal Oligocene). Possibly a time intermediate between these two is represented by the Kishenehn.

Trachyte and Syenite

Relatively small bodies of alkaline igneous rock occur in the northeastern part of Macdonald Range. These vary in form from narrow dykes to irregular anastomosing stock-like masses with a maximum surface area of 2 square miles. The larger and more prominent ones lie south of Flathead map-area and are shown, in part, in Figure 16. Two bodies are shown on the map, one at the headwaters of Harvey Creek, and the other on the east flank of the Macdonald Range between Shepp and Harvey Creeks.

The body at the headwaters of Harvey Creek apparently comprises the northern edge of a small stock that lies mainly south of the map-area. The rock there is a trachyte. It has been emplaced in the carbonate rocks of the Fairholme Group and the Elko Formation. The rock consists of subhedral, lath-shaped orthoclase phenocrysts up to 5 mm long, clouded with kaolinite (?) and sericite (?), and set in a groundmass of minute subparallel orthoclase laths with disseminated granules of iron oxides. The groundmass comprises about 65 per cent of the volume of the rock and has been extensively altered to kaolinite (?) and sericite (?). The trachytic texture and the composition appear to be uniform throughout most of the mass. A specimen from the eastern side of the body shows evidence of extensive granulation and partial development of mortar structure. The cataclastic fabric suggests that the body was emplaced prior to displacement along the adjacent Lewis Thrust Fault. The distinctive texture and composition of the trachyte are similar to that of lithic fragments both in the Crowsnest Formation in the northeastern part of the map-area, and in the Blairmore Group in the western part.

The alkaline igneous body on the east slope of Macdonald Range between Shepp and Harvey Creeks is the largest in the map-area. Although partly obscured by surficial deposits, it apparently has a surface area of one-sixth of a square mile. Fernie shales adjacent to the body have at least locally been altered to hornfels. The intrusion consists of massive, porphyritic, orthoclase syenite. Subhedral to euhedral tabular phenocrysts of orthoclase averaging 2 mm in length comprise about 40 per cent of the rock. All are clouded with kaolinite (?), most are zoned, and some show corroded borders. The groundmass consists of stubby prisms of aegerine-augite less than 1 mm long (10 per cent of the volume), rounded and euhedral dark brown melanite grains less than 1 mm in diameter (5 per cent of the volume), and a mosaic of minute anhedral orthoclase (?) grains, clouded with kaolinite (?) and enclosing minute grains of aegerine-augite, plagioclase, melanite, sphene, magnetite-ilmenite (?), and zircon. The rock is mineralogically similar to many of the fragments in the Crowsnest Formation but lacks the characteristic trachytic texture.

A small intrusion occurs about ½ mile north of the south boundary of the map-area, at the headwaters of Harvey Creek. It is an irregular anastomosing body 200 feet long and up to 30 feet wide. In overall aspect the body is dyke-like and trends east-west across the stratification of the Fairholme and Alexo strata, in which it has been emplaced. The texture and gross mineralogical composition are similar to that of the trachyte body to the south but, unlike the latter, it locally contains up to 5 per cent of small plagioclase, apparently oligoclase laths. The adjacent limestones show no megascopic evidence of alteration along the periphery of the trachyte.

Trachyte dykes up to 6 feet thick cut the Etherington Formation at the headwaters of Shepp Creek. Tabular phenocrysts of orthoclase up to 6 mm long, set in a groundmass of minute feldspar laths and cryptocrystalline rock, impart a foliation parallel with the walls of the dyke.

A small igneous mass occurs in the basal part of the Blairmore Group at the south end of the ridge between McLatchie and Foisey Creeks. It consists of a series of interconnected pod-like bodies less than a foot thick, elongated parallel with the basal bed of the Blairmore Group. The rock consists of a dense greenish grey cryptocrystalline groundmass with microlites of orthoclase (?) and apparently represents a devitrified trachytic glass. It locally transects the sedimentary fabric of the basal conglomerate bed of the Blairmore Group and encloses pebbles of the conglomerate.

The trachytes and syenites were probably emplaced during the period of volcanism that resulted in substantial contributions of alkaline detritus to the sediments of the Blairmore Group and culminated in the deposition of the fragmental volcanic rocks of the Crowsnest Formation. The distinctive volcanic detritus in the Blairmore Group and Crowsnest Formation has the same composition and texture as the intrusive rocks. Furthermore, the intrusive rocks cut the bedding of stratigraphic units ranging through the Palaeozoic succession to the basal beds of the Blairmore Group, demonstrating that some, if not all, of the intrusions are younger than the lowest beds of the Blairmore Group.

The age relationships between the emplacement of the syenites and trachytes and movement on the faults in the area are less clearly defined. Few fault surfaces are well exposed and actual truncation and offsetting of alkaline intrusions along faults were not observed. In general, however, the positions of the faults can be located with reasonable accuracy, and where the alkaline intrusive rocks lie near a fault they appear to terminate abruptly against the projected trace of the fault surface. Moreover, cataclastic structures have been observed in the trachytes and syenites near the Lewis Thrust Fault at the headwaters of Harvey Creek. These relationships suggest that the alkaline intrusions were emplaced prior to displacement along the faults in the region but do not preclude the possibility that they may be younger.

Chapter III

STRUCTURAL GEOLOGY

Two groups of structures of different age and origin occur in superposition in Flathead map-area. The older group marks a horizontal shortening and complementary thickening of the mass of exposed sedimentary and volcanic strata. It is characterized by thrust faults, subparallel with the bedding, and related folds. The faults delimit individual thrust plates or sheets, the largest of which, the Lewis thrust sheet, appears to have been displaced horizontally at least 32 miles. The deformation that produced the older group of structures consisted mainly of a near-horizontal translation of essentially unmetamorphosed sedimentary and volcanic strata. All individual structures produced during this phase of the deformation fall into one of two kinematic patterns that occur in superposition. Both patterns involved overriding of thrust sheets upon underlying structural units, one was to the northeast the other to the east. During the initial stages of deformation the anisotropy of the layered rock mass played a fundamental role in determining the form and orientation of the structures developed. This anisotropy persisted in modified form, and affected the manner in which the rocks reacted during subsequent deformation.

The younger group of structures marks a horizontal extension and complementary thinning of the mass of sedimentary and volcanic strata. It is characterized by 'high-angle' faults, most or all of which have normal displacement. These faults outline individual blocks that have been rotated about horizontal or subhorizontal axes and have undergone differential vertical displacement. The most prominent component of the younger group of structures is the Flathead fault or fault zone, which has a stratigraphic separation near the south boundary of the map-area of more than 20,000 feet. Many of the other faults are interpreted as secondary, having formed in response to movement along the Flathead fault. Sediments derived from an uplifted block and deposited during faulting in an adjacent structural trough provide a partial record of this phase of the deformation.

The 'high-angle' faults are inferred to persist to relatively great depth and to involve the crystalline basement extending under the area from beneath the Western Plains. In contrast, the thrust faults dominating the older group of structures are probably restricted, within the map-area, to the thick mantle of essentially unmetamorphosed sedimentary and volcanic rocks lying on the crystalline basement.

The Lewis Thrust Fault and the Flathead fault are the two most prominent structural features within the area. Both are structures of regional dimensions in the Rocky Mountains of southern Canada and northern Montana (*see* Fig. 1).

Mechanics of Deformation

Structures in Flathead map-area possess certain distinctive geometrical attributes that impart a particular 'structural style' to the area. These geometrical attributes form the basis for any analysis of the mechanics of deformation within the area. The present mineral content and fabric of the rocks provide some indication of the physical environment within which the deformation occurred. Knowledge of the physical environment and mechanics of deformation provides a helpful framework in the interpretation of individual structures.

Physical Characteristics of the Rocks

Exposed rocks comprise a distinctly layered sequence of unmetamorphosed sediments with minor intercalated volcanic rocks. The layering is expressed as a succession of relatively homogeneous, sheet-like, lithologically distinct rock-units and as numerous distinct beds within each. Minute details of sedimentary structure and texture are preserved in the rock fabric. The present mineral content and fabric indicate that the most significant post-depositional physical and chemical changes imposed on the rock occurred during diagenesis. Evidence of major changes during deformation, such as the development of metamorphic fabrics and new mineral assemblages, is lacking, except perhaps within narrow zones bordering some of the faults. During deformation the physicochemical environment was not sufficiently different from that now prevailing to induce perceptible metamorphism. Differential movement during deformation was effectively limited to discrete widely spaced surfaces within the overall fabric and does not appear to have pervaded the entire fabric.

Physical properties vary with direction in these layered rocks and the gross fabric is distinctly anisotropic. A primary anisotropy, acquired while the rock was being deposited, consists of surfaces along which stress was most easily relieved. These parallel the bedding. Displacements occur along layers of 'weak' rock between 'stronger' layers, and along bedding surfaces which are in reality surfaces of physical discontinuity. Such displacement is termed interstratal slip. A secondary anisotropy, acquired during deformation, consists of the original surfaces of weakness rotated into new positions and combined with later faults, joints, etc.

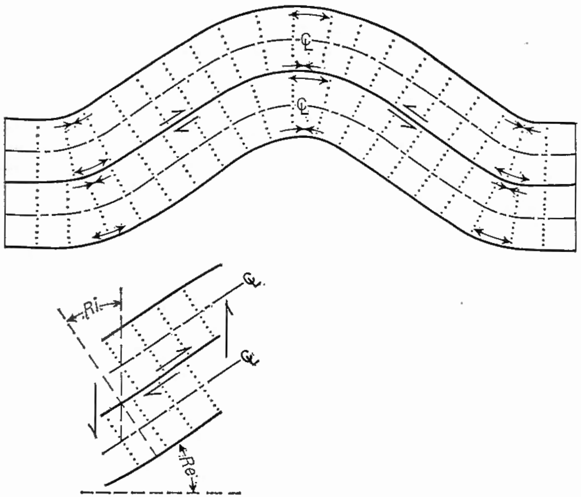
The shape and orientation of structures developed in an anisotropic fabric depend on the nature and orientation of the planes of weakness as well as on the regional orientation of the principal stresses. Distinct layering, for example, facilitates interstratal slip, and favours the development of faults that follow the bedding and folds formed through a combination of flexure and interstratal slip. Folding of this type is termed flexural-slip folding and results in parallel folds rather than in similar ones. Similarly, during deformation of a fabric embracing older structures that are oblique to the principal axes of the new stress field, movement may occur along surfaces of weakness related to the older structures even though these surfaces are transverse to the new stress field. Bedding faults, flexural-slip folds, and rejuvenated transverse folds and faults of these types occur in Flathead map-area.

Folds

Many of the folds are sufficiently well exposed to provide a clear and consistent picture of their gross geometry (*see* Pl. XI). All are parallel folds, that is individual beds can be traced through a fold without any apparent change in thickness even though formations may change in thickness where the bedding has been truncated and offset locally along small faults. Although these folds may not be precisely parallel in detail, their kinematic and geometric attributes will best be understood if they are considered as ideal parallel folds. The kinematic significance of ideal parallelism in folded bedding is that the direction of differential movement between adjacent fabric components in the rock during folding is everywhere parallel with the bedding. If this condition is not satisfied, tectonic variations in the thickness of beds will result and the folds will depart from ideal parallelism.

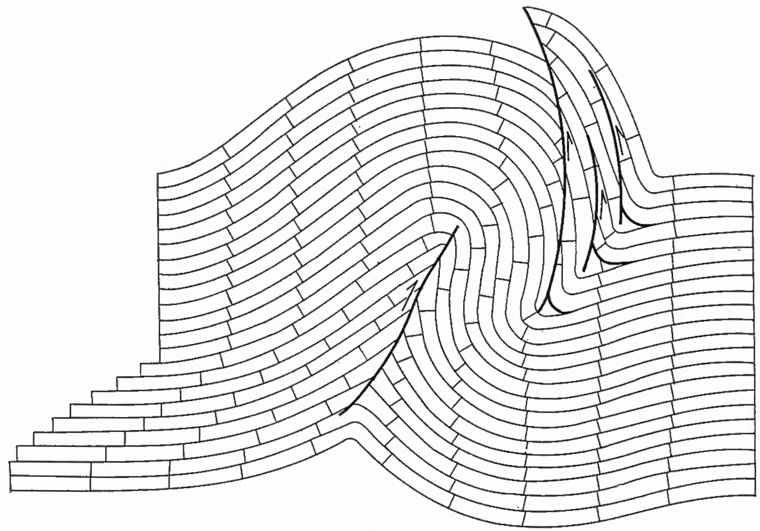
The kinematic model generally proposed for ideal parallel folds involves a combination of flexure and interstratal slip in a layered or stratified mass (Billings, 1954, p. 89; Fairbairn, 1949, p. 172; de Sitter, 1956, p. 180; Weiss, 1959, p. 92). Individual beds are flexed with simultaneous slip of one bed over another. Flexure of an individual bed involves extension on the convex side and compression on the concave side of an internal surface of no strain. The extension and compression occur parallel with the surfaces of the bed, are symmetrical about the axis of curvature of the flexure where it is cylindrical, and vary in magnitude as a function of the curvature of the flexure (*see* Fig. 5). They are essentially complementary, and consequently the thickness of the bed remains unchanged and the extension and compression are not cumulative from one bed to another.

Flexure of a layered or stratified mass results in interstratal slip within the mass because during flexure the layering itself is subjected to an external rotation or simple shear that induces a complementary shear between the layers (*see* Fig. 5). The amount of shear or interstratal slip depends on the amount of external rotation imposed on the layering. In the hypothetical fold of Figure 5, the left limb has undergone left-hand external rotation from an initial horizontal position through an angle of shear (Re) of about 30 degrees. The complementary right-hand shear within the limb is expressed as interstratal slip and attains a maximum angle of shear (Ri) of about 30 degrees. Changes in the amount of interstratal slip from one part of a fold to another are related to the curvature in the bedding. Where the bedding has been deformed into a series of parallel curves, the extension on the convex side of one bed occurring adjacent to compression on the concave side of the adjoining bed implies that there has been shear or slip



5a

Intra-and interstratal strains associated with flexural slip folding. Right section of a cylindrical fold. Dotted reference lines divide cross-sections of strata into elements that were formerly rectangles of uniform dimensions symmetrically arranged about centre lines (℄) of beds. Arrows show direction of compression on concave side and of extension on convex side of internal surface of no strain in each bed. Half arrows show direction of simple shear (interstratal slip) between beds. Offset element of left limb shows relationship between external rotation of a segment of a fold limb and interstratal slip within the segment. Large vertical arrows indicate direction of external rotation and *Re* is the angle of external shear. Smaller diagonal arrows indicate direction of complementary simple shear (interstratal slip) and *Ri*, the angle of internal shear, is dependent on *Re*



5b

Flexural-slip folds and flexural-slip thrust faults. Strata are of uniform thickness and length. Interstratal slip is shown by reference lines drawn perpendicular to the bedding so as to divide the centre line of each bed into ten equal segments. Progressive increase in curvature of strata toward apices of folds is accommodated, where radius of curvature becomes equal to the thickness of a stratum, by flexural-slip thrust faults that are kinematically concordant with the interstratal slip

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FIGURE 5. Flexural-slip folding.

between the beds and that this shear or slip has the same symmetry as the extension and compression. The interstratal slip, unlike the extension and compression, is cumulative from one bed to the next. Its symmetry is related to the overall symmetry of the fold (cf. Fig. 5). The axis of symmetry for the interstratal slip corresponds with the axis of a cylindrical fold only if the fold is symmetrical. However, the direction of slip is perpendicular to the axis of a cylindrical fold even if such a fold is asymmetrical and thus the fold axis is parallel with the kinematic axis (*see* also Weiss, 1959).

In parallel folds the radius of curvature of bedding surfaces increases upward in anticlines and decreases upward in synclines; the anticlines become broader and the synclines narrower (*see* Fig. 5). The amount of curvature that can be imposed on a bed in a parallel fold is limited by the thickness of the bed. As the radius of curvature along a segment of a bed in the axial region of a parallel fold approaches this critical limit, the adjoining bed on the concave side will be forced out of the constricted axial region, and the entire fold will become extended along the axial plane perpendicular to the axis.

Transfer of material out of the axial region of a flexural-slip fold can be accomplished without disrupting the kinematic symmetry of the fold by additional slip along bedding surfaces in either limb. However, displacement of beds out of the constricted axial region of one fold implies that the distance between points on the same bed in the axis of this fold and in the axis of an adjoining fold is decreased, that is the beds must be shortened. Shortening of beds in the limb of a flexural-slip fold can be produced by thrust faults that rise out of the zones of bedding slip in the limbs and cut across the bedding. Movement along such thrust faults and interstratal slip are parts of a single folding process. Moreover, as successive bedding surfaces in the constricted axial region of the fold contribute to the overall movement along the fault, displacement along it would increase in the direction of the adjoining fold.

Many of the less prominent faults in Flathead map-area lie in positions that indicate that they are kinematically related to flexural-slip folds. These faults occur in the limbs of folds and are nearly parallel with the fold axes. They dip in the direction of the bedding, and the direction and sense of displacement along them agree with those of the interstratal slip. Most cut bedding surfaces at relatively low angles. They arise within the fold limb and the amount of movement increases in the direction of an anticlinal axis. As a result of displacement along these faults the stratigraphic sequence between adjacent fold axes is 'shortened' and 'thickened' and the separation between adjacent fold axes measured parallel with the curvature of the folds is shortened. Deformation on these faults is considered to be an integral part of the flexural-slip folding process and the faults are referred to here as flexural-slip thrust faults. The characteristics of flexural-slip thrust faults are similar to those of the "back-limb thrust faults" described by Douglas (1950, pp. 88-95) except that they develop in both steep and gentle limbs of folds whereas "back-limb thrust faults" develop only in the latter.

Faults

Data on the experimental deformation of rocks provide some insight into the geometric relations between faults and bedding in the anisotropic fabric of layered rocks such as those of the Rocky Mountains of southern Canada. Tests made under conditions of triaxial stress furnish an empirical basis for specifying the critical relationship between normal and shear stress components on the plane of failure in rocks that fail in 'brittle shear' (Hubbert and Rubey, 1959; Jaeger, 1956; and references cited therein). Within the stress range probable to the upper part of the crust, this relationship can generally be approximated by the Coulomb-Navier equation:

$$\tau_c = \tau_0 + \sigma_c \tan \phi \qquad (1)$$

Here, τ_c is the shear stress at failure on the plane of failure; σ_c is the corresponding normal stress; τ_0 is the shear strength of the rock at zero normal stress; and $\tan \phi$ is the coefficient of internal friction with ϕ as the angle of friction, a property of the rock.

For convenience, we may express the stress components acting on any plane through a point in terms of the principal stresses that define the condition of stress at that point (Jaeger, 1956). The most elegant representation of this relationship is the Mohr diagram (Fig. 6). Normal stress (σ) is plotted on the abscissa and shear

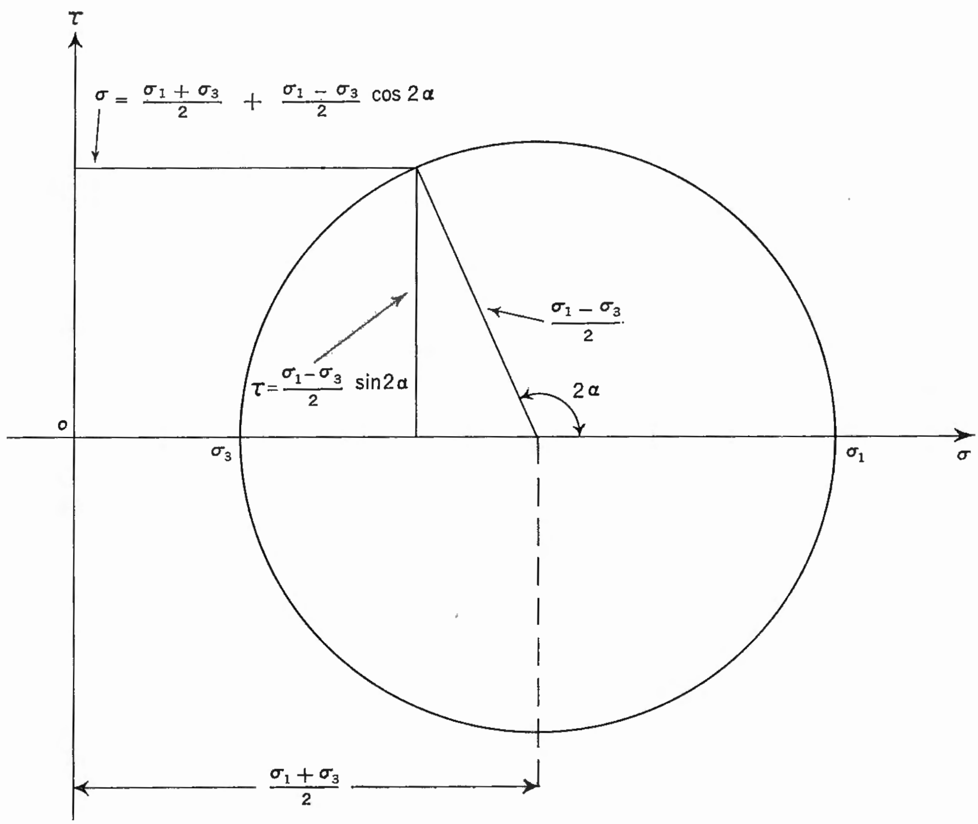


FIGURE 6. Mohr stress circle (after Hubbert and Rubey, 1959).

stress (τ) on the ordinate. Tension is arbitrarily assigned a negative value. In two dimensions, assuming that all quantities can vary independently of the intermediate principal stress (σ_2), the Mohr diagram is a circle passing through the maximum and minimum principal stresses (σ_1 and σ_3 respectively), with a radius equal to the maximum shear stress $\left(\dfrac{\sigma_1 - \sigma_3}{2}\right)$, and with the mean principal stress $\left(\dfrac{\sigma_1 + \sigma_3}{2}\right)$ as a centre. This circle is the locus of the normal and shear stress components on any plane as the angle α between the plane and the minimum principal stress changes, where 2α is the counterclockwise angle between a radius vector of the Mohr circle and the positive direction of the σ-axis. For any condition of stress specified in terms of principal stresses, the Mohr circle provides a graphic portrayal of the relationship between the shear stress and normal stress components acting on any plane in terms of the orientation of that plane relative to the principal stresses. Because of the choice of coordinate axes the Coulomb-Navier equation can also be plotted on the Mohr diagram. Thus by plotting both the Coulomb-Navier equation and an appropriate Mohr circle on the same set of coordinate axes, it is possible to specify the critical relationship between the principal stresses at failure and the appropriate orientation of the plane of failure relative to the principal stresses (Fig. 7).

The Coulomb-Navier criterion for failure in an isotropic material states that the normal and shear stress components on some plane in the material must have the critical relationship expressed in equation (1), and therefore must lie on a straight line defined by this equation. For a given condition of stress defined in terms of principal stresses, the normal and shear stress components on any plane are given by the Mohr circle. The normal and shear stress components on the plane of failure form a

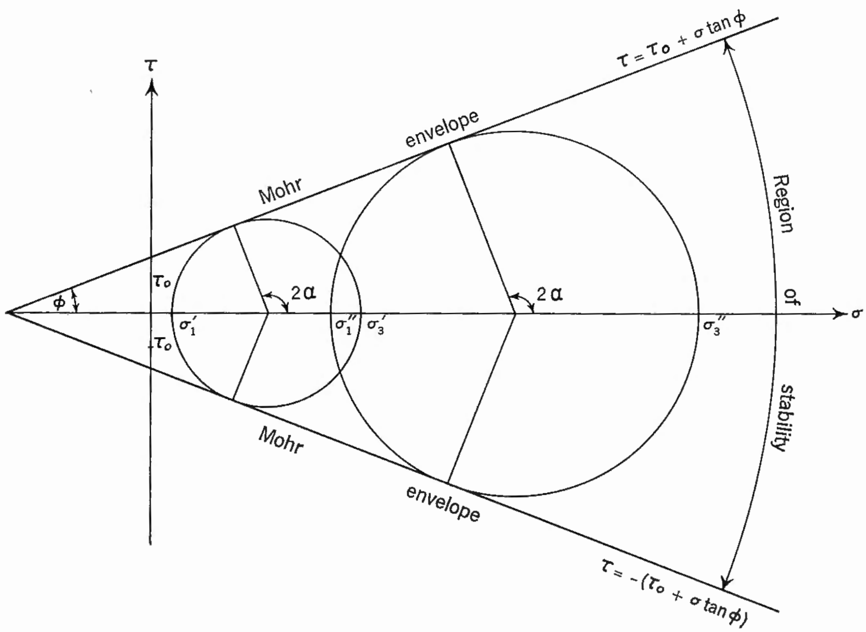


FIGURE 7. Mohr envelope for failure according to Coulomb-Navier criterion (after Hubbert and Rubey, 1959).

point common to both a straight line defined by equation (1) and a Mohr circle. Equation (1) defines two straight lines that are symmetrical about the σ-axis, and these delimit a Mohr envelope. Any condition of stress represented by a Mohr circle that lies entirely within the envelope is stable and will not lead to shear failure as there are no points common to the Mohr circle and the lines delimiting the envelope. Any condition of stress represented by a Mohr circle that extends beyond the limits of the envelope is unstable and will be preceded by shear failure as it must have points in common with the Mohr envelope. The limiting case is a circle that is tangent to the envelope. The points of tangency define the normal and shear stress components on two symmetrical planes of failure and the orientation of these symmetrical planes relative to the principal stresses. It is evident from Figure 7 that, for an isotropic rock, the orientation of the planes of shear failure will remain constant as the condition of stress at failure (the mean principal stress) changes, and will be a function of the angle of friction (ϕ) characteristic of that particular rock. The angle ϕ varies from one rock type to another but a representative value would be about 30 degrees (Hubbert and Rubey, 1959, p. 124). In so far as the principal stresses tend to be horizontal and vertical at relatively shallow depths the dip of thrust faults and the hade of normal faults should be about 30 degrees.

The Coulomb-Navier equation and the Mohr circle provide a basis for a graphic analysis of the influence of anisotropy on shear failure in a simple model of a layered rock mass, such as in the Rocky Mountains of southern Canada. If only the surfaces of physical discontinuity that delimit individual beds are considered, the rock fabric can be treated as a layered medium with a shear strength τ_0 and a coefficient of internal friction tan ϕ, except along the series of parallel surfaces delimiting the layers, where the shear strength is τ_0' ($\tau_0 > \tau_0'$) and the coefficient of internal friction is tan ϕ' (ϕ' is designated as equal to ϕ). The critical relationship for failure along surfaces cutting the layering is given by equation (1), that for surfaces between the layers by:

$$\tau_c' = \tau_0' + \sigma' \tan \phi' \qquad (2)$$

These two equations are plotted as partial Mohr envelopes in Figure 8.

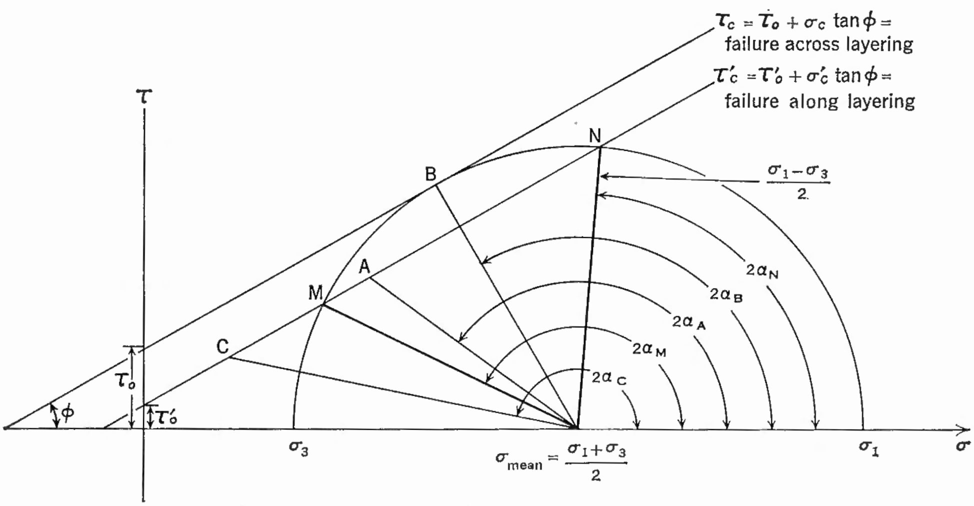


FIGURE 8. Shear failure in a layered anisotropic medium.

As the shear stress and normal stress components on any plane depend not only on the magnitude of the principal stresses but also on the orientation of that plane relative to the principal stresses, it follows that if the mechanical properties of the layered medium remain fixed, the critical factor in determining whether failure will occur along the layering or across it is the orientation of the layers relative to the principal stresses. The two partial Mohr envelopes of Figure 8 can be used to determine the limits of orientation between which failure will occur along the layers rather than across them.

Consider that series of stress conditions characterized by the mean principal stress σ_M. If the orientation of the layering is given by the angle $2\alpha_A$, as the maximum shear stress $\frac{\sigma_1 - \sigma_3}{2}$ (given by the radius of the Mohr circle) increases, the normal and shear stress components in the plane of the layering will reach the critical relationship 'A' on the Mohr envelope of equation (2) before those on any surfaces that cross the layers reach the critical relationship 'B' on the Mohr envelope of equation (1). Consequently, failure will occur along the layering rather than across the layering; the surface of failure will intersect the minimum principal stress at an angle α_A rather than at the angle α_B; and the maximum shear stress will be less than that required for failure across the layering. If, on the other hand, the orientation of the layering is given by the angle 2 α_C it can similarly be seen from Figure 8 that, as the maximum shear stress increases, failure will occur along a surface that crosses the layering and intersects the minimum principal stress at an angle α_B before the critical relationship for failure along the layering is reached.

It is evident from Figure 8 that any orientation of the layering relative to the minimum principal stress between the angles α_M and α_N leads to failure along the layering and that the shear stress that will produce it is less than that required fo failure across the layering. For orientations of the layering at α_M or α_N, failure may occur either along or across the layering.

Several important relationships emerge from a consideration of the influence of the anisotropy of a bedded but otherwise essentially homogeneous rock mass (*see also* Jaeger, 1960).

1. Within a specific range of favourable orientations failure occurs as bedding plane faults, and the orientations of these faults relative to the principal stresses can deviate significantly from that of faults developed under similar circumstances in isotropic rocks.

2. Although failure in an isotropic rock results in the development of two complementary sets of faults, in a layered rock in which the layering lies within the favourable range of orientations only one set of faults will develop and this set will lie in the plane of the bedding.

3. If the layering in an anisotropic layered rock is favourably oriented, failure may occur when the maximum shear stress is significantly lower than that required for failure across the layering.

Several characteristics of faults in Flathead area assume a particular significance in the light of the foregoing discussion. Many of the thrust faults maintain a relatively constant stratigraphic position over a large area. This tendency toward parallelism between thrust fault surfaces and the bedding is a characteristic of both the small faults and the larger faults such as the Lewis thrust. Most of the thrust faults are surfaces along which successively higher structural units have undergone a relative eastward or northeastward translation. A complementary set of thrust faults marking a relative westward or southwestward translation of successively higher structural units is effectively absent. These relationships imply that during thrust faulting, the bedding in the anisotropic layered rocks of the area lay within the range of orientations that favoured failure along the bedding, and in addition, that within this range of favourable orientations the beds dipped toward the west rather than the east. In contrast, the gravity faults show no well-defined tendency to follow the bedding and, therefore, the bedding is inferred to have been unfavourably oriented during this phase of the deformation.

As indicated in the preceding discussion of failure in isotropic rocks, in so far as the principal stresses at relatively shallow depths in the earth's crust tend to be nearly vertical and horizontal, the dip of thrust faults in an isotropic fabric should be about 30 degrees and that of gravity faults should be about 60 degrees. In Flathead map-area during the period of thrust faulting the bedding apparently lay within the favourable range symmetrically distributed about a dip of 30 degrees toward the west. During the subsequent period of gravity faulting, however, it lay in general outside the favourable range symmetrically distributed about a dip of 60 degrees. The favourable range of orientations of bedding for bedding thrust faults probably overlaps that for gravity faulting along the bedding as is implied, for example, in the model illustrated in Figure 8 where the magnitude of the favourable range is about 70 degrees and the overlap between the favourable range for thrust faulting and that for gravity faulting is about 35 degrees. Under these conditions, the occurrence of thrust faults that parallel the bedding together with gravity faults that transect the bedding suggests that, in overall aspect, the dip of the bedding in Flathead area was less than 30 degrees throughout much of the period of faulting. A plausible hypothesis is that, when thrusting started, the bedding dipped gently west and failure was by thrust faults along the bedding planes. Later, gravity faulting occurred along steeply dipping surfaces cutting beds that even at this stage in the deformation still retained a relatively shallow average dip and were, in general, unfavourably oriented for gravity faulting to occur along them.

Most of the thrust faults in Flathead map-area are recognizable primarily as persistent surfaces of stratigraphic discontinuity. They are marked on a local scale by an abrupt departure from the established stratigraphic sequence in the form of a repetition or an omission of stratigraphic units. Two main factors are taken into consideration in describing the stratigraphic attributes of a fault: first, whether the fault has resulted in a repetition or an omission of part of the normal stratigraphic sequence, and second, whether the fault places younger beds over older beds or older over younger ones. These stratigraphic attributes are dependent on the relative orientation of the bedding when faulting started. Where the fault surface is a relatively simple plane and the direction of movement can be ascertained, the attitude of the beds with respect to the fault plane when faulting started can be

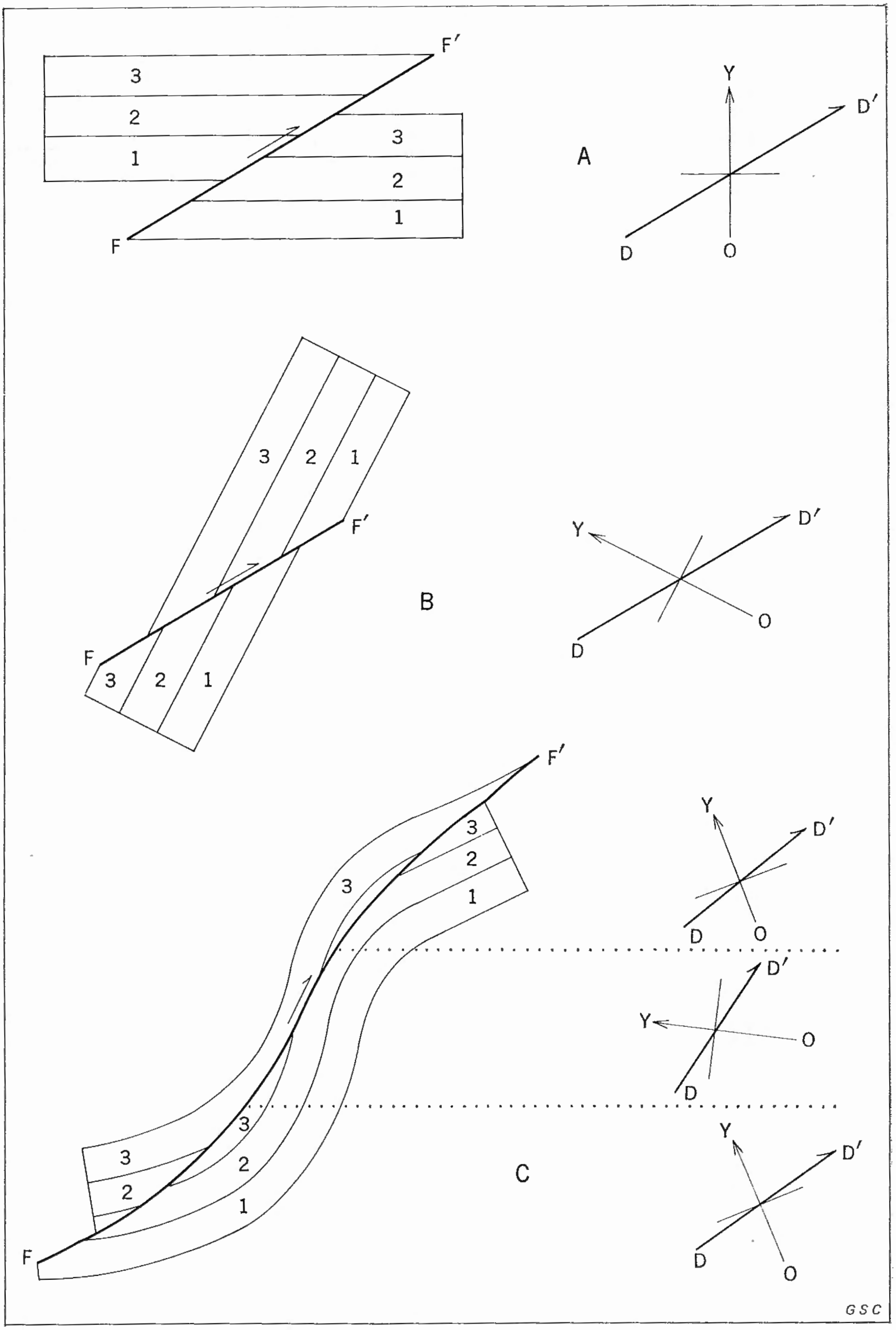


FIGURE 9. ***Examples of the results of thrust faults on differently oriented strata. (D-D′, direction of relative displacement along fault; O-Y, direction of stratigraphic succession of beds 1, 2, and 3 from oldest to youngest).***

determined from the stratigraphic attributes of the fault. It can then be determined whether or not the fault cuts pre-existing structures.

Two simple, hypothetical faults are shown in Figure 9. The fault in section A cuts upwards through the stratigraphic succession in the direction of displacement of the hanging-wall so that older units lie above younger, and the stratigraphic succession is repeated and thickened. In contrast, the fault in section B cuts down through the stratigraphic succession in the direction of displacement of the hanging-wall, so that younger units lie above older, some units are missing, and the stratigraphic succession is thinned. Section C illustrates a hypothetical fault that combines conditions A and B. The difference in stratigraphic attributes along this fault are due to differences in orientation of the bedding with respect to the direction

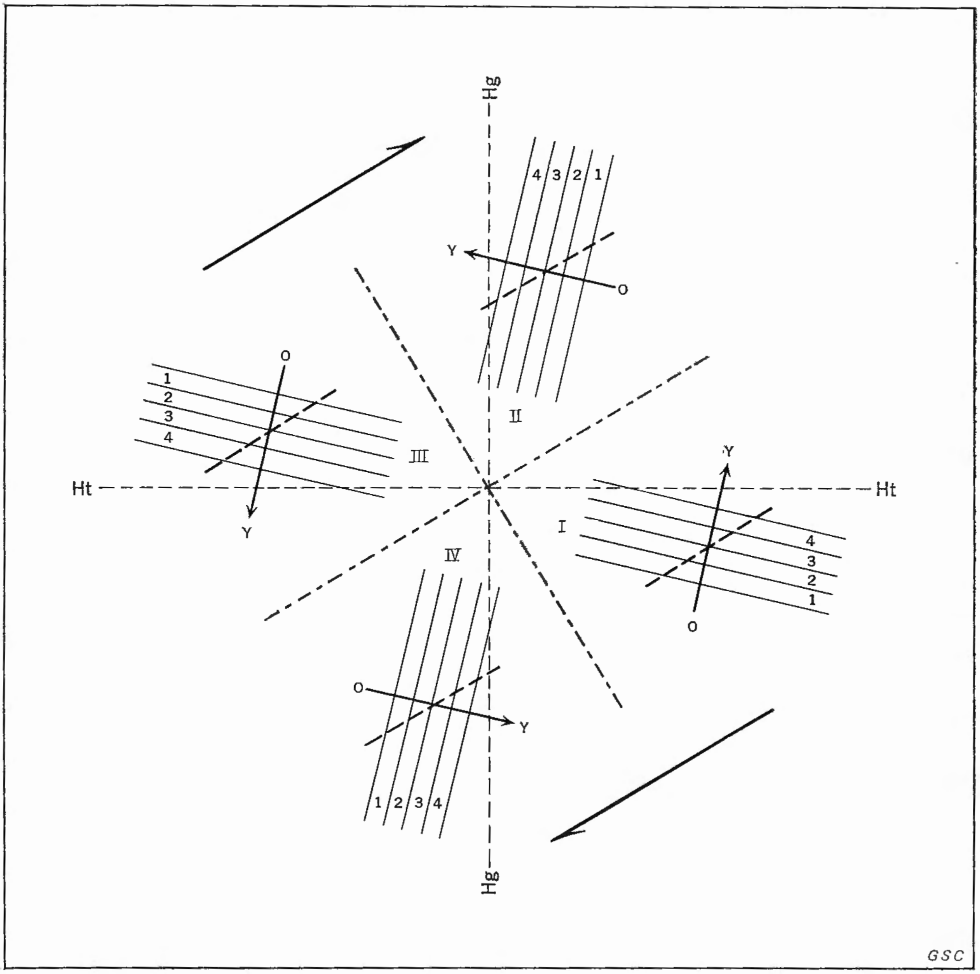


FIGURE 10. Difference in direction of stratigraphic succession relative to direction of fault displacement (sections in a plane common to both directions; heavy 'half arrows' indicate direction of fault displacement; O-Y, direction of stratigraphic succession for beds 1, 2, 3, and 4 from oldest to youngest; dashed lines indicate incipient fault surfaces; Ht, horizontal datum for thrust faults; Hg, horizontal datum for gravity faults).

of fault displacement. These differences are due in turn to tilting or folding of the beds before faulting.

A simplified analysis of the geometric significance of variations in the orientation of stratigraphic succession with respect to the direction of the fault displacement provides a framework for the interpreting of the stratigraphic attributes of faults. The range of variation in the orientation of the stratigraphic succession relative to direction of fault displacement is illustrated in Figure 10. Four groups of orientations are evident, each of which results in specific stratigraphic attributes along a fault. The range of each of the groups is limited to the quadrant bounded by the broken lines, parallel with and perpendicular to the direction of fault displacement. The conditions that characterize quadrant I result in the strata being repeated across the fault, in older beds overyling younger, and in a thickening of the stratigraphic sequence. In quadrant III the strata are also repeated and the succession thickened, but younger beds overlie older. The conditions characterizing quadrants II and IV result in strata being omitted across the fault and the stratigraphic sequence being thinned, but in these also as in quadrants I and III, the direction of stratigraphic succession is reversed.

The interpretation of the stratigraphic attributes of a fault is easier if these idealized geometric relationships are referred to a horizontal datum plane. The lines labelled Ht and Hg in Figure 10 represent horizontal datum surfaces for thrust faults and gravity faults respectively.

Effect on the stratigraphic succession of the orientation of the succession with respect to the direction of fault displacement for each quadrant is summarized below.

Table IV

Quadrant I	The path of the fault rises in the stratigraphic succession in the direction of motion of the hanging-wall and older units are displaced on to younger units. Stratigraphic units are repeated across the fault and the stratigraphic sequence thickened.
II	The path of the fault falls in the stratigraphic succession in the direction of motion of the hanging-wall and younger units are displaced on to older units. Stratigraphic units are omitted across the fault and the stratigraphic sequence thinned.
III	The path of the fault falls in the stratigraphic succession in the direction of motion of the hanging-wall and younger units are displaced on to older units. Stratigraphic units are repeated across the fault and stratigraphic sequence thickened.
IV	The path of the fault rises in the stratigraphic succession in the direction of motion of the hanging-wall and older units are displaced on to younger units. Stratigraphic units are omitted across the fault and the stratigraphic sequence thinned.

Although the effect on the stratigraphic sequence of a fault in each of the four quadrants is the same regardless of which horizontal datum surface is used (i.e., Ht for thrust faults and Hg for gravity faults), the dip of the bedding differs by 90 degrees.

The 'stratigraphic attributes' indicated in Figure 10 and summarized above can be used to interpret the geometric relationships between faults and the stratigraphic succession in Flathead map-area. Most of the thrust faults are of the type shown in quadrant I, whereas virtually all the gravity faults are of the type shown in quadrant II. During displacement along these faults therefore the dip of the beds must have lain within that range characteristic of these quadrants relative to the horizontal datum surfaces Ht and Hg respectively. Several of the less prominent thrust faults in the area exhibit the characteristics of quadrant II, III, or IV, and the bedding appears to have been rotated into the position characteristic of these quadrants prior to the development of these faults. This indicates that these thrust faults cut pre-existing structures. The significance of the stratigraphic attributes of each of these faults is considered in more detail later, where the structures in the map-area are systematically described.

The path of a fault through the sequence of beds it cuts can be used to determine the relationships between the shape of the fault and the structure of these beds during the initial movement along the fault (Douglas, 1950, Fig. 20; and 1958, Fig. 25), and the total fault displacement. At the inception of faulting the path of a fault through the stratigraphic sequence that it cuts is dependent on the orientation of the stress field and the nature and orientation of any older structural features that may occur within this sequence of beds. With progressive displacement along the fault the path may be altered because of contemporaneous deformation within the rocks on either side. Examples of this were considered in discussing flexural-slip thrust faults. Where contemporaneous and kinematically related flexural-slip folding and thrust faulting have occurred, the angles of intersection of bedding and thrust faults, the intercepts of stratigraphic units along thrust faults, and consequently, the paths of thrust faults may undergo changes with progressive fault displacements that differ on either side of the faults. The final path of the fault may differ significantly from the initial path and the path along the hanging-wall may differ locally from that along the foot-wall. These modifications developing with progressive displacement involve changes in the intercepts of stratigraphic units on either side of the fault but not in their order of succession. For example, if a fault plane in a particular place rises in the succession, falls, and then rises again the intercepts of the stratigraphic units measured along the fault may change during displacement but the order of stratigraphic succession remains unchanged. Thus it appears that the stratigraphic succession along a fault provides a reliable basis for reconstructing the gross spatial relationships between the fault and the stratigraphic layering during incipient faulting, whereas the apparent thickness of beds must be used with reservation. These concepts have been employed in interpreting the Lewis Thrust Fault in relation to structures above and below it and are considered in more detail below.

The Lewis Thrust Sheet and Related Structures

The Lewis Thrust Fault was named by Willis (1902), who clearly described its basic features from observations made between Waterton Lakes, Alberta, and St. Mary Lake, Montana. Subsequent work has shown that the frontal or eastern trace of the Lewis thrust can be followed with certainty from Marias Pass, at the north end of the Sawtooth Range in Montana, northward almost to the Bow River Valley in Alberta. The thrust is thus continuous for more than 200 miles along strike. As shown in Figure 1, it crosses Flathead map-area about midway along its established length.

Most of the rocks exposed within the map-area comprise parts of the Lewis thrust sheet and have been thrust over entirely different rocks. Rocks underlying the Lewis thrust sheet are exposed in the northwestern part of the map-area where they lie above the Coleman fault of the Foothills belt. They are also exposed in fensters along Cate Creek in the Clark Range and at the headwaters of Howell and Harvey Creeks in Macdonald Range.

Structural data discernible within the map-area provide evidence for the following fundamental features of the Lewis thrust sheet:

1. the position of the thrust fault relative to stratigraphic units within the thrust sheet, both along and across the regional tectonic strike;
2. the spatial form of the thrust fault in relation to that of the beds above and below; and
3. the shape and orientation of minor structures within and below the thrust sheet, which form the basis for a kinematic analysis of the thrust sheet.

In discussing these data the map-area falls conveniently into several minor tectonic subdivisions each of which is characterized by homogeneity of tectonic style, and bounded by major structural elements (*see* Fig. 11) .

The Howell-Squaw thrust fault divides the Lewis thrust sheet into two parts: the Howell-Squaw thrust plate and the eastern part. The North Kootenay Pass transverse monocline (trending northeast) and the Flathead Valley graben and Harvey fault (trending northwest) divide these two parts into six smaller subdivisions:

1. the Clark Range segment of the Lewis thrust sheet
2. the Macdonald dome
3. the Flathead Range segment of the Lewis thrust sheet
4. the Squaw thrust plate
5. the Fernie basin
6. the Howell Creek structure.

The Carbondale River-Goat Creek structure lies below the Lewis thrust sheet and forms a part of the Coleman thrust plate.

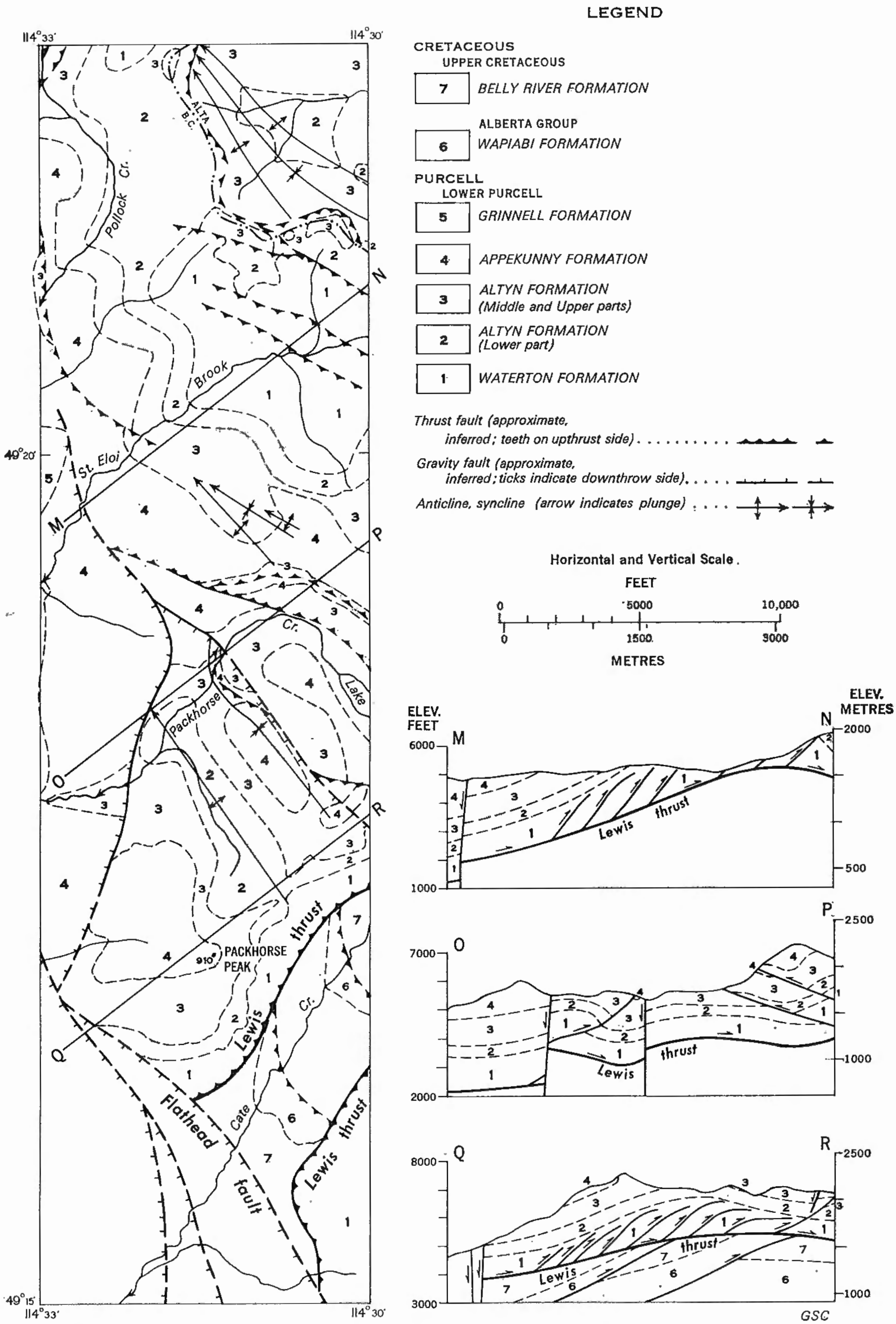


FIGURE 12. Map and sections showing structures in western Clark Range.

The Clark Range Segment of the Lewis Thrust Sheet

The Lewis Thrust Fault

Within most of Clark Range, the Lewis Thrust Fault appears to maintain a stratigraphic position relatively constant to the overlying Purcell beds. Southeast and east of the map-area (Douglas, 1952; Clark, 1954; Norris, 1959a) Waterton strata lie immediately above the Lewis thrust. At Cate Creek, around a window in the thrust sheet, Waterton strata lie immediately above the thrust. In the upper valley of St. Eloi Brook, Waterton strata exhibit marked imbrication and tight folding and are presumed to be immediately above the Lewis thrust. At the north end of Clark Range, the Altyn, Appekunny, and Grinnell Formations are successively truncated against the underlying thrust within a relatively narrow zone. At the south end of Flathead Range, beds of the Siyeh Formation lie immediately above the thrust. Thus, within Clark Range, the Lewis thrust is directly overlain by strata of the Waterton Formation except along the north and northeast end of the range, where stratigraphic units are abruptly truncated to the north against the thrust, and the Siyeh Formation lies above the fault.

The Lewis Thrust Fault is flat or dips at low angles within most of Clark Range. Where exposed in the valley of Cate Creek, the thrust surface is warped into a broad anticline with its crest at an elevation of about 5,500 feet (*see* section Q-R, Fig. 12). This structure plunges at less than 15°NW. Three and a half miles to the northeast of the anticline, at the eastern edge of the map-area, the thrust is inferred to occur beneath the bed of St. Eloi Brook at an elevation of about 5,000 feet (*see* section M-N of Fig. 12). Along the north end of Clark Range, the thrust strikes, in general, east-west, and dips between 10 and 20°S. It is along this southward-dipping part that the Altyn Formation and part of the Appekunny Formation are cut out. Along most of the western edge of the range, where the Appekunny, Grinnell, and Siyeh beds dip to the west, the thrust is assumed to maintain a relatively constant stratigraphic position with respect to the overlying beds, and dip toward the west also.

Structures Associated with the Lewis Thrust Fault

Purcell strata overlying the Lewis thrust within Clark Range, although relatively flat in overall aspect, are disrupted by a complex of minor faults and folds. Most of these structural features differ in attitude from the underlying Lewis Thrust Fault, and are separated from it by a basal zone of imbrication and tight folding, or comprise small thrust plates that wedge out against the Lewis thrust at depth.

In Cate Creek valley, such a zone of imbrication and tight folding occurs immediately above the Lewis thrust, affecting beds of the Waterton Formation (*see* Pl. I, and cross-section Q-R of Fig. 12). Numerous small thrust faults strike about N30°W and dip southwest toward the Lewis thrust, converging with it at moderate angles. Individual thrust faults are parallel or subparallel with bedding over most of their length, and delimit small thrust slices, many of which include tightly folded beds. The axes of the folds strike about N30°W and plunge gently to the northwest. All the thrusts pass upward into bedding surfaces, and within short distances no stratigraphic throw is apparent. The imbrication appears to vary in intensity with its position on the underlying anticline in the Lewis thrust, culminating immediately west of its crest. The result is a thickening of the Waterton Formation, especially immediately west of the anticlinal crest. The effect of this thickening is evident at higher structural levels of the northwest-plunging anticline immediately east of Packhorse Peak. This fold has a much greater closure than the fold in the Lewis thrust surface and its axial surface is offset relatively to the west. Wapiabi and Belly River strata exposed in the window in the Lewis thrust on Cate Creek are cut by southwest-dipping faults and folded along northwest-plunging axes. Thus, tectonic elements above and below the Lewis thrust are roughly parallel.

A northwest-trending dome, with Waterton strata in its core, occurs in the upper valley of St. Eloi Brook. Two northeast-dipping thrust faults southwest of the dome are exposed in the upper valley of Packhorse Creek. Furthermore northwest-trending folds and an associated southwest-dipping thrust fault lie between St. Eloi Brook and Gardiner Creek. These thrust faults outline a broad wedge whose apex coincides with the core of the dome. Steeply dipping imbricate thrust plates and tight folds within the core of the dome mark a local tectonic thickening of the Waterton Formation and the lower part of the Altyn Formation. The imbrication and folding increase in intensity with depth within the limits of the exposures and are similar to that observed above the Lewis thrust in the Cate Creek window. The Lewis thrust is therefore assumed to occur at a relatively shallow depth below the valley floor in the core of the dome (*see* cross-section M-N of Fig. 12). Within the core of the dome, trends of fold-axes are arcuate and concave eastward, with a point of maximum curvature occurring at the culmination of the dome. Southwest of the culmination they plunge southeast and northwest of it to the west. These relationships indicate left-lateral shearing within the Lewis thrust sheet, such that the parts of it lying within, and to the south of the dome moved northeastward and up relative to parts to the north.

Two steep, east-trending faults occur at the northeast end of Clark Range. The most westerly fault, 1½ miles south of North Kootenay Pass, strikes east but is vertical. It appears to be a left-hand tear fault, but the south side is also up relative to the north. The maximum stratigraphic separation is 500 feet. The second fault crosses the upper valley of Pollock Creek a short distance south of the provincial boundary. It also strikes east, but its dip changes from near vertical at its western end to moderate to the south at its eastern end, where it merges with a west-dipping thrust fault. It is a left-hand tear fault. The stratigraphic separation of both the thrust and tear faults is estimated to be less than 1,500 feet and decreases rapidly toward the west. These faults are kinematically related to the arcuate structural trends in the dome at St. Eloi Brook, and are also in part due to the abrupt change in stratigraphic position of the Lewis thrust in the thrust sheet at North Kootenay Pass.

The Siyeh Formation extends across North Kootenay Pass from Clark Range to Flathead Range without disruption by transverse faults. It forms part of a west-dipping sequence comprising Flathead Range and the west flank of Clark Range.

A transverse, northwest-facing fold, the North Kootenay Pass monocline, is superimposed on this west-dipping sequence near the pass. At the north end of Clark Range two thrust splays diverge from the Lewis thrust at the apex of the re-entrant in its trace, and continue southward along the western side of Clark Range. The most westerly of these can be followed to the west flank of the St. Eloi Brook dome where it terminates in minor folds. The more easterly thrust and a splay above it, terminate against the tear fault just described. There is a general decrease in stratigraphic separation southward on these thrusts. These features are interpreted as indicating that the Flathead Range segment of the thrust sheet has undergone some eastward displacement relative to structurally lower parts of the Clark Range segment. It is evident from the continuity of stratigraphic units and minor structures between Flathead and Clark Ranges, and the structural equivalence and continuity of the eastern part of Flathead Range with the western part of Clark Range, that both constitute parts of a single thrust sheet.

Apart from the structures indicating minor independent displacement of the Flathead Range segment relative to the Clark Range segment, a consistent kinematic pattern is evident within the Clark Range segment. In the discussion of the mechanics of folding it was suggested that folds in the map-area formed in response to a flexural-slip process. If so, fold axes are kinematic axes and their orientation indicates the kinematic pattern when the folds developed. The pattern so suggested indicates that the trend of the movement in the Clark Range segment of the Lewis thrust sheet was northeast. Relationships along the north end of the range, near the North Kootenay Pass monocline and the zone in which Purcell strata are truncated against the Lewis thrust, indicate, however, that there the movement was more northerly. The kinematic pattern at the north end of Clark Range is rotated counterclockwise relative to the main part of the range. This horizontal rotation and the left-handed tear faults spatially associated with it are interpreted as minor features that developed as local adjustments along a zone of minor convergence between the North Kootenay Pass monocline and related transverse structures, and the regional displacement of the sheet.

The Macdonald Dome

The Macdonald dome occupies the south-central part of the map-area. It is separated from Clark Range by the Flathead fault and the Flathead Valley graben. In Cate Creek valley, at the south boundary of the map-area, the Lewis thrust, exposed in the Cate Creek window, abuts the Flathead fault zone. There the Flathead fault zone consists of three southwest-dipping gravity faults, which have an aggregate stratigraphic separation of about 20,000 feet. The Lewis thrust, therefore, occurs at considerable depth below the Flathead Valley graben. The Shepp fault marks the western boundary of the graben and the displacement along it is much less than that along the Flathead fault zone. West of the Shepp fault the Lewis thrust must therefore be fairly deep beneath the Macdonald dome. The southwest side of the dome is bounded by the Harvey fault, a southwest-dipping gravity fault.

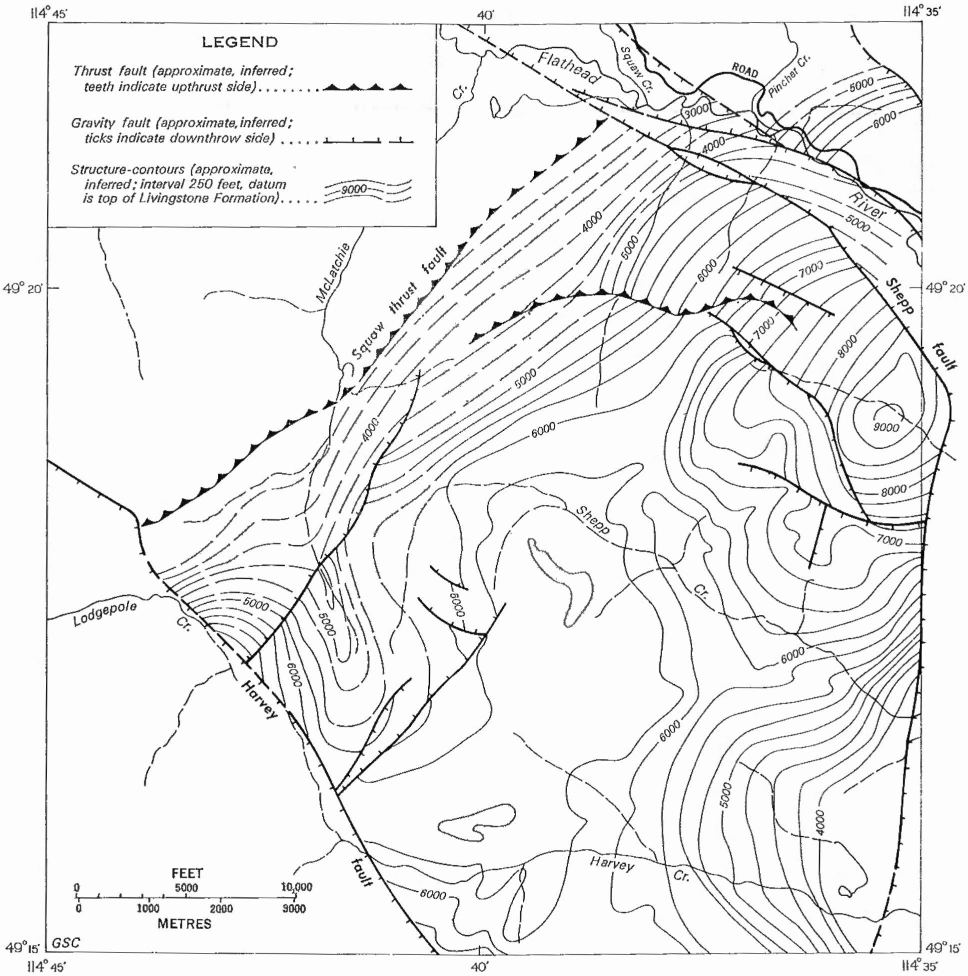


FIGURE 13. Structure contours on top of the Livingstone Formation in the Macdonald dome.

The Macdonald dome is a broad structure with a relatively flat top (*see* Pl. X). The southeast flank dips gently toward Flathead Valley and the Flathead fault; the northwest side is marked by the North Kootenay Pass monocline. The shape of the dome is illustrated in Figure 13 by structure contours of the top of the Livingstone Formation.

The stratigraphic position and shape of the Lewis thrust beneath the dome is unknown. Minor structures in the dome appear to be related primarily to the younger gravity faults. The broad gentle character of the dome suggests a relatively thick stratigraphic sequence below it and above the Lewis thrust, indeed structures of this type are characteristic of much of the interior of Clark Range, where the Lewis thrust sheet is known to be relatively thick.

The Flathead Range Segment of the Lewis Thrust Sheet

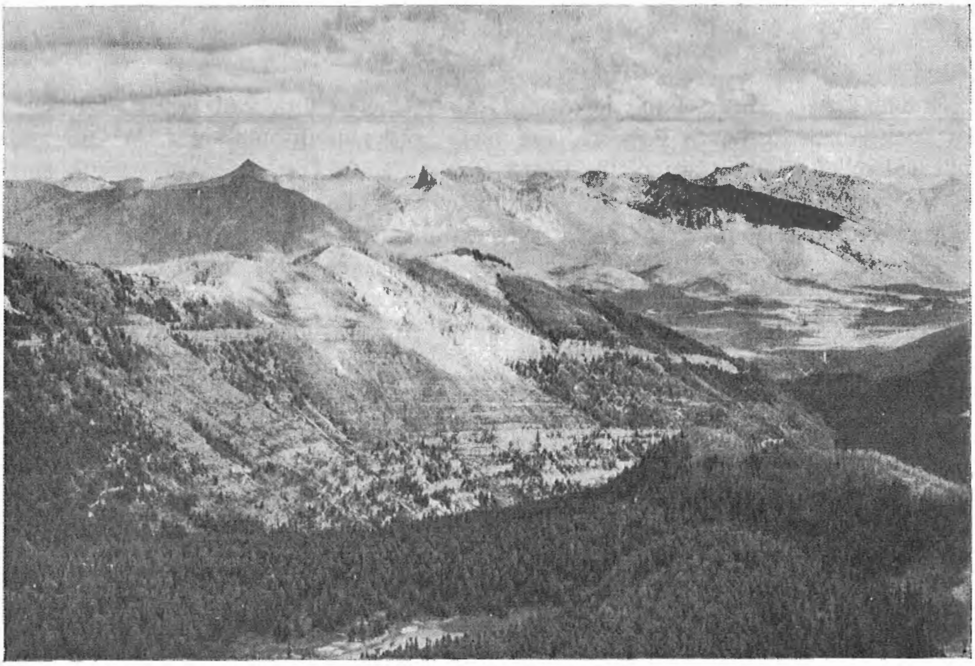
Lewis Thrust Fault

The Lewis Thrust Fault is exposed along the east side of Flathead Range between North Kootenay Pass and the north border of the map-area. Within this interval relief on the trace of the thrust reaches 1,600 feet. Along the south end of the range, the thrust is directly overlain by beds of the upper part of the Siyeh Formation. Near South Lost Creek, Siyeh sediments are abruptly truncated against the thrust surface, and the Purcell lava lies directly above the thrust to the north. The zone of truncation of about 600 feet of Siyeh strata against the thrust surface appears to coincide with the core of an anticline in overlying beds, which anticline extends from South Lost Creek to Mount Darrah. Except for this zone of discordance, the thrust closely parallels the overlying beds. It is also nearly parallel with the bedding in the underlying units, which there form part of the Carbondale River-Goat Creek structure (*see* Pl. IX).

Between North Kootenay Pass and Goat Creek, the Lewis thrust maintains a relatively constant attitude, with a general north-south strike and a dip of between 30 and 40°W. Beyond Goat Creek, the dip flattens and a small salient of the thrust sheet extends eastward over the Carbondale River-Goat Creek structure on to Belly River strata of the Coleman thrust plate. The Lewis thrust in the eastern part of Flathead Range maintains a stratigraphic position relatively constant to overlying beds. The thrust surface therefore conforms roughly to the general structure of the eastern part of Flathead Range (*see* cross-sections A-B and C-D).

R.A.P., 3-4-1957

PLATE IX. Lewis Thrust Fault on the ridge between North Lost Creek and South Lost Creek. Pick head marks position of west-dipping thrust surface along which Siyeh strata, on the left, overlie overturned Rocky Mountain strata.



R.A.P., 6-6-1957

PLATE X. East flank of Macdonald dome at Harvey Creek. Looking east. Carnarvon Member of Mount Head Formation forms upper cliff; Loomis Member forms lower cliff. Flathead Valley and Clark Range in background.

Structures Associated with the Lewis Thrust Fault

The Flathead Range segment of the Lewis thrust sheet comprises a relatively steep, west-dipping homoclinal sequence of Purcell and Palaeozoic strata. A complex of minor structures forms a structural depression on its west flank south of the headwaters of Corbin Creek. A culmination occurs north of the map-area and coincides with the small salient in the thrust sheet north of Goat Creek (*see* Fig. 1). The minor structures fall into three main groups:

1. northwest-plunging structures along the east slope of the range and on the west slope adjacent to Squaw Creek;
2. north-trending, west-dipping thrust faults, along which stratigraphic units are both thinned and thickened;
3. steep, west-plunging, overturned folds along the North Kootenay Pass monocline.

These three groups appear to be related to the two principal kinematic patterns in the structures of the Lewis thrust sheet.

Several small, northwest-plunging folds occur above the Lewis thrust: along the east side of Flathead Range, south of the Carbondale River in Purcell lava, at the headwaters of North Lost Creek in Palaeozoic and Purcell strata, and between Lost Creek and Goat Creek in Kintla strata. The plunge of these folds as determined graphically from bedding attitudes measured on their limbs is consistently about

30 degrees at N30°W. The closure on the folds decreases upward, either gradually or more rapidly by truncation by overlying west-dipping thrust faults. The folds terminate downward on the Lewis Thrust Fault or on smaller faults immediately above it. These folds within Flathead Range correspond to the principal kinematic pattern followed by the fold axes in Clark Range. They are interpreted as being due to local adjustments caused by relatively abrupt cross-cutting of the thrust faults on which they lie. A geometrical analysis of the kinematic relationships between thrust faults of this type and related folds has been presented by Rich (1934), Douglas (1950), and Wilson and Stearns (1958).

The northwest-plunging anticline and syncline in the southwestern part of Flathead Range next to Squaw Creek are characterized by sinuous axes. Where the rigid Palaeozoic strata of the west limb of the anticline are obliquely truncated by the Squaw thrust, the fold axes swing north and become subparallel with the strike of the thrust. Down the plunge of the folds, where less rigid Fernie strata lie adjacent to the Squaw thrust, the axes swing back to the northwest and the Palaeozoic strata of the folds plunge under the Squaw thrust plate. The northwest-plunging folds appear to form a part of the kinematic pattern characteristic of most of the folds in Clark Range and the northwest-plunging folds along the east slope of Flathead Range. The sinuous course of their axes appears to be the result of interference between this pattern and a second pattern associated with the Squaw thrust.

Several north-trending, west-dipping, thrust faults occur immediately west of the crest of the Flathead Range. Two principal ones dominate the group. The more westerly of these passes immediately east of Centre Mountain, where it is marked by a zone of truncated beds and by tectonic thinning of the Banff Formation. Upper and middle Banff strata above the fault lie adjacent to beds of the lower part of the Banff Formation, and of the still lower Exshaw and Palliser Formations. To the north and south the thrust rises in the stratigraphic succession and is characterized by tectonic thickening of stratigraphic units rather than by tectonic thinning. Tear faults occur at two places along the trace of the fault: 2 miles north of Flathead townsite and 2 miles east of the summit on the British Columbia Forest Service Flathead Road. Both tear faults are nearly vertical and mark changes in the stratigraphic position of the thrust fault. The more northerly causes a 'step' in the longitudinal profile of the thrust fault, along which it rises toward the north about 1,000 feet in the stratigraphic sequence. The more easterly of the principal west-dipping faults can be followed from within the Palliser Formation on the peak immediately north of North Kootenay Pass to beyond the north border of the map-area. Throughout its length the fault is characterized by tectonic thickening of stratigraphic units. Southwest of Mount Darrah, it truncates one of the north-west-plunging anticlines on the east slope of Flathead Range.

The group of north-trending, west-dipping, thrust faults differs from other Flathead Range structures in form and orientation. Tectonic thinning across faults of this group and the apparent truncation of northwest-plunging structures against them locally indicate that they have been superimposed discordantly across the northwest-plunging structures in the Lewis thrust sheet. Instead they are concordant with structures related to the Squaw thrust and thrust splays diverging from the Lewis thrust at the bend in its trace at North Kootenay Pass. In the kinematic pattern so displayed movement of successively higher structural units is directed eastward rather than northeastward, as is characteristic of the earlier pattern.

A series of small, closely spaced, thrust faults immediately above the Lewis thrust at the headwaters of Goat Creek is also concordant with the later kinematic pattern. The lowest or more easterly of these faults thicken the Purcell lava and are clearly imbricate splays from the Lewis thrust. Higher faults, however, terminate along bedding surfaces across which there is no stratigraphic separation and may have originated in zones of interstratal slip. The faults of this group increase in stratigraphic separation, and presumably in displacement, toward the north. Like the west-dipping faults in Flathead Range, individual thrust faults produce both tectonic thinning and thickening, and therefore, by inference, are superimposed discordantly on earlier structures. The faults are restricted to the interval along which the Lewis thrust overlaps the Carbondale River-Goat Creek structure and to the salient in the Lewis thrust sheet north of the map-area. They appear to have developed in a zone of right-hand rotation in the Lewis thrust sheet. Apparently the Carbondale River-Goat Creek structure has retarded the movement of the part of the thrust sheet lying south of Goat Creek with respect to the part lying north of it, resulting in this rotation.

Two southwest-plunging folds and a small east-dipping thrust fault occur along the west slope of Flathead Range at the north edge of the map-area. These structures lie north of the minor structural depression in the Lewis thrust sheet near Corbin Creek and are related to the salient in the sheet north of the map-area. Like the small thrust faults at the head of Goat Creek, they suggest a right-hand rotation within the Lewis thrust sheet of that part of the sheet lying north of the truncated and overridden Carbondale River-Goat Creek structure. The small fault is a flexural-slip thrust fault developed on the east limb of the anticline. To the south it passes into a small asymmetric anticline which is overturned to the west and merges with the main anticline to the southwest. Both of the main folds decrease in amplitude to the southwest toward the structural depression along the homoclinal sequence of the Flathead Range segment of the thrust sheet.

A steep, west-plunging, northward overturned anticline and syncline occur at the south end of Flathead Range northeast of Flathead. These folds involve Palaeozoic and Kintla strata and pass downward in a complex of small-scale folds and thrust faults. They are disharmonic above lower Purcell strata of Clark Range and lie above a zone of *décollement* in northwest-facing Kintla and Sheppard strata of the North Kootenay Pass monocline. Upward and toward the north, the folds terminate above a thrust that lies within the axial region of the syncline. This fault merges with the more westerly of the principal north-trending, west-dipping, thrust faults in Flathead Range. A statistical examination of the orientation of bedding within the folds indicates that their axes plunge at about 40°W. The orientation of the fold axes diverges significantly from the directions established for the two

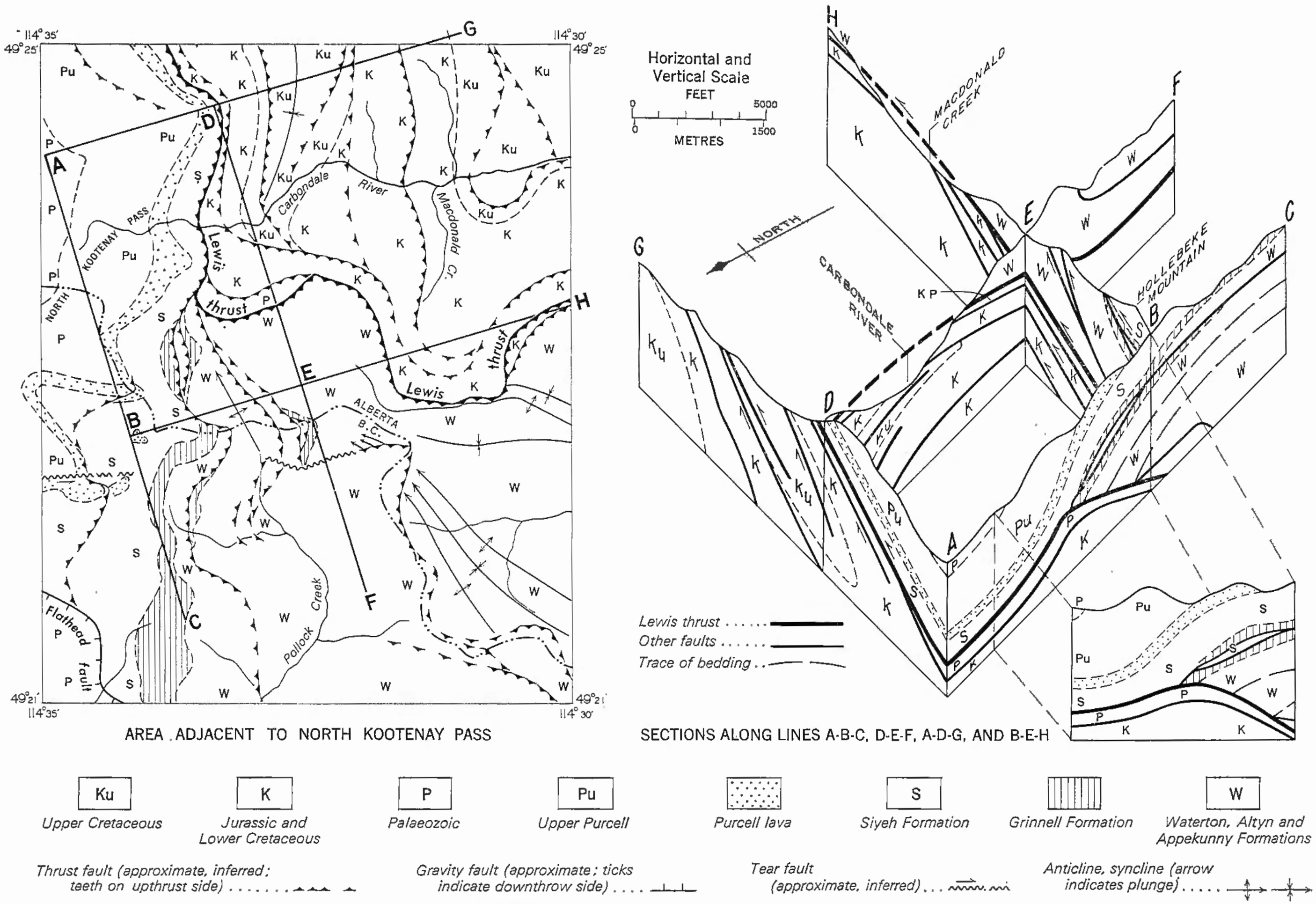


FIGURE 14. North Kootenay Pass monocline.

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principal kinematic patterns of Clark and Flathead Ranges. Nevertheless, the folds appear to be the result of deformation that produced displacements on the north-trending, west-dipping, thrust faults. This eastward-directed movement of successively higher structural units was oblique to the northwest-facing North Kootenay Pass monocline. *Décollement* along bedding surfaces within the monocline would result in folds whose orientation would reflect both the orientation of the pre-existing monoclinal flexure and the regional orientation of the kinematic field which they formed. The steep west plunge of the folds was probably inherited from the pre-existing southwesterly plunge of the monocline.

The North Kootenay Pass Monocline

An abrupt change in the stratigraphic position of the Lewis Thrust Fault relative to the overlying beds occurs at the boundary between Clark and Flathead Ranges. This change is directly related to transverse structures above and below the thrust, and involving the thrust itself (*see* Fig. 14).

Beneath most of Clark Range, the Lewis Thrust Fault is relatively flat and is directly overlain by the Waterton Formation. Along the west side of the range, where the strata above the thrust dip to the west, the thrust is assumed to maintain its stratigraphic position relative to the overlying sequence and to dip to the west also. Flathead Range is structurally continuous with, and equivalent to, the west side of Clark Range. Under Flathead Range, the Lewis thrust dips moderately to the west and is directly overlain by the upper part of the Siyeh Formation or the Purcell lava. The relatively abrupt truncation of the Altyn, Appekunny, and Grinnell Formations and part of the Siyeh Formation along the north end of Clark Range contrasts sharply with the relationships of the fault relative to the layering in overlying strata to the north and south. Along the north end of Clark Range, between North Kootenay Pass and Mount McCarty, the zone where part of the Lewis thrust sheet is truncated against the thrust fault coincides with a south-dipping part of the fault. At North Kootenay Pass, the northwest-facing, transverse, North Kootenay Pass monocline is superimposed across the west-dipping sequence extending from Flathead Range to the west side of Clark Range, and lies above the zone of truncation of Purcell strata against the Lewis thrust. These relationships form the basis for the geometric interpretation shown in the fence diagram of Figure 14. The northwest-facing North Kootenay Pass monocline lies directly above the zone along which most of the Purcell sequence is truncated against the Lewis Thrust Fault. A parallel transverse monoclinal flexure occurs in the Lewis thrust surface but faces southeast rather than northwest. In any cross-section through the North Kootenay Pass monocline, the Lewis thrust occurs at a higher elevation and has younger strata immediately above it in the Flathead Range segment than in the Clark Range segment. The relationships across the zone of abrupt truncation along the Lewis Thrust Fault are comparable to those of a tear fault. This 'tear fault' does not cut strata below the thrust sheet, nor does it cut strata above the Siyeh Formation within the thrust sheet. It forms an abrupt transverse 'step' in the stratigraphic position of the Lewis Thrust Fault relative to overlying beds. The 'step' does not define the boundary between two separate thrust sheets.

The North Kootenay Pass monocline in the Lewis thrust sheet can be followed from North Kootenay Pass, near the east boundary of the map-area, to the south end of the Fernie basin along Lodgepole Creek on the west boundary. Along the north side of Clark Range, the south-dipping part of the Lewis Thrust Fault forms the base of the southeast-facing monocline in the thrust surface. The Lewis thrust presumably extended over the Carbondale River-Goat Creek structure, and the top of the southeast-facing monocline in the thrust surface probably occurred north of Carbondale River at the east boundary of the map-area. The remaining northern part of the Carbondale River-Goat Creek structure would have underlain a structurally high part of the Flathead Range segment of the Lewis thrust sheet. To the southwest, the North Kootenay Pass monocline is represented in the Flathead Valley graben by the northwest-facing Rundle Group strata immediately southeast of Flathead, in the Macdonald Range by the northwest flank of the Macdonald dome on the southeast side of McLatchie Creek valley, and at the south end of the Fernie basin by steep, north-plunging folds that form the north flank of Macdonald Range. In each of these areas, the North Kootenay Pass monocline is interpreted as having the same significance relative to the stratigraphic position and gross shape of the Lewis thrust surface as at North Kootenay Pass. The Lewis Thrust Fault is assumed to occur at a higher stratigraphic level, relative to overlying beds, to the northwest of the monocline than to the southeast.

The path of the Lewis Thrust Fault through the stratigraphic layering was determined by the shape and orientation of the stress field and the structure of the layering when and where the thrust sheet originated, and once established it persisted without conspicuous modification during the life of the fault (*see* Fig. 15). On the other hand, the shape of the thrust surface and the attitude of the beds in the thrust sheet were probably modified as faulting progressed, particularly near such a feature as the transverse step beneath the North Kootenay Pass monocline.

During relative northeastward movement of the Lewis thrust sheet, the transverse step in the thrust surface was probably rotated from an initial nearly vertical position to one more gently dipping as the thrust sheet advanced over foot-wall strata that lacked a corresponding transverse step or 'tear fault'. Flattening of the thrust surface during movement of the thrust sheet over a comparatively flat surface would result in the development of a northwest-facing monocline in the beds above the fault. Similar relationships between transverse flexures and transverse steps or 'tear faults' in an underlying thrust fault have been described from the Cumberland Plateau in Tennessee (Wilson and Stearns, 1958).

The Squaw Thrust Plate

General Features

The Squaw thrust plate lies within the Lewis thrust sheet above the west-dipping Squaw thrust. North of Flathead River and east of McEvoy Creek the thrust plate is truncated by the Flathead fault. On the downthrown, south side of the Flathead fault the Squaw thrust fault and the prominent folds and faults within the Squaw thrust plate are thought to be represented by faults that cut the Fernie and Spray River strata along McLatchie Creek valley.

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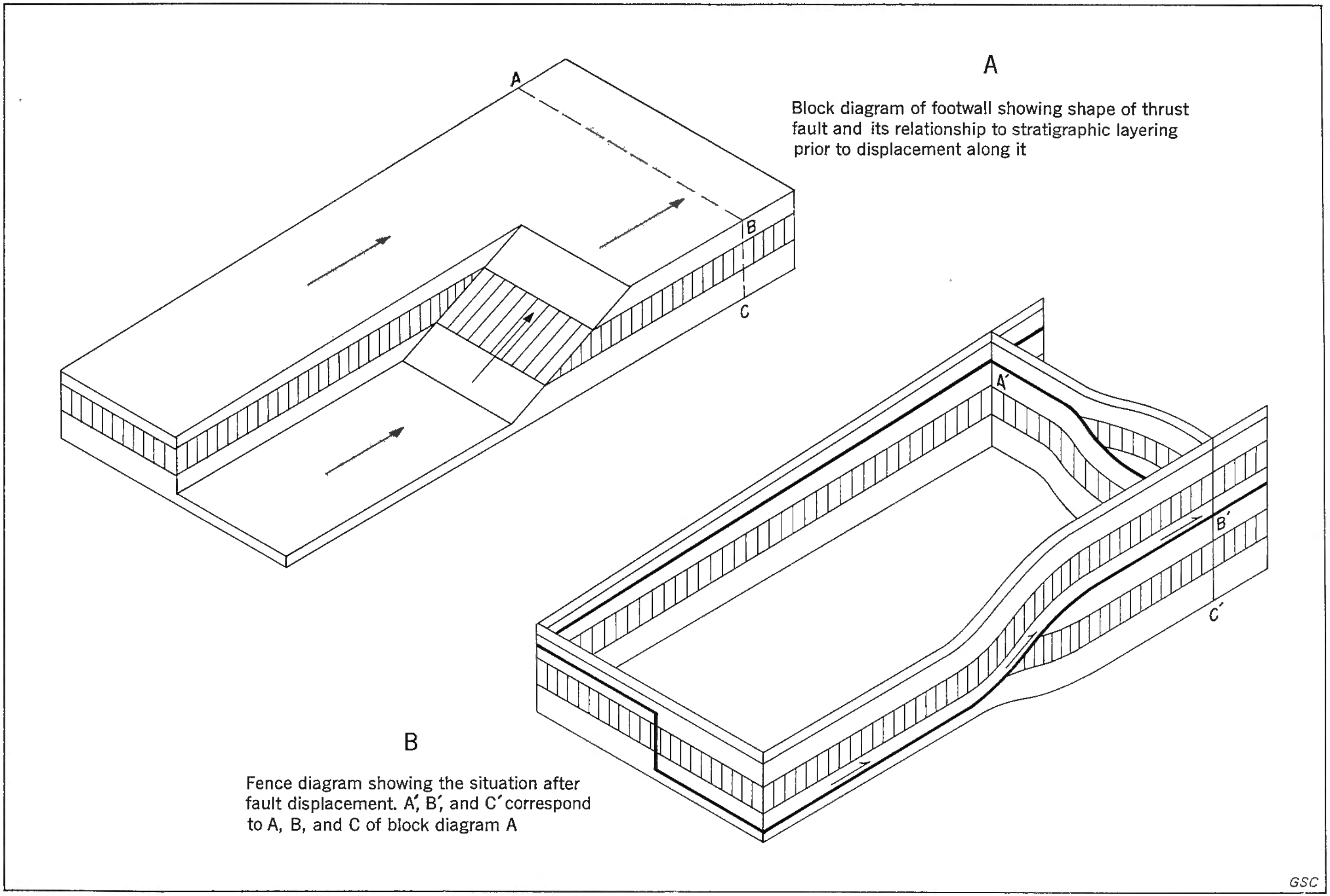
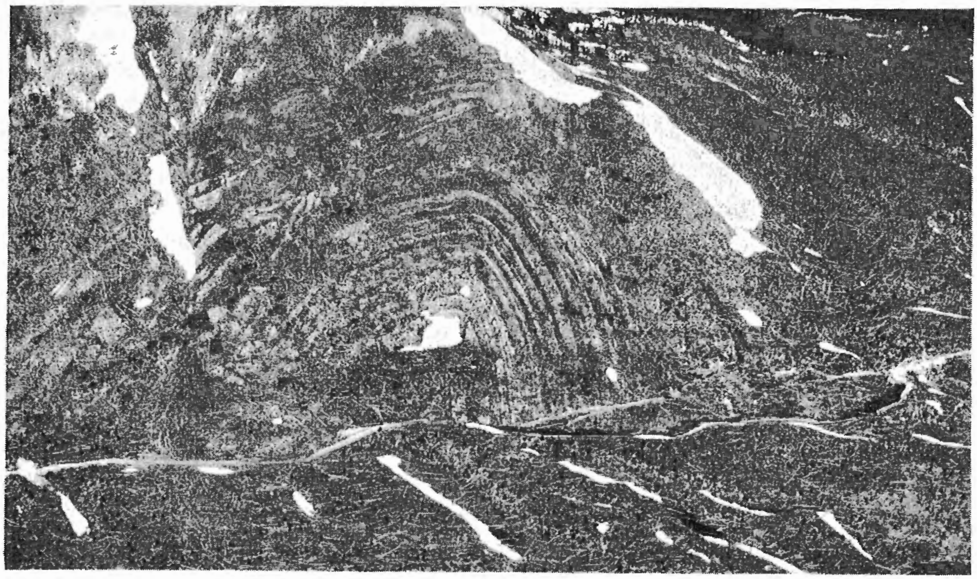


FIGURE 15. *Idealized fence and block diagrams illustrating the geometric relationships between a discontinuous transverse 'step' in the stratigraphic position of a thrust fault and a transverse monoclinal flexure within a thrust sheet.*

The Squaw thrust plate includes a group of doubly-plunging folds with Rundle and Rocky Mountain strata exposed in their cores. These folds have parallel sinuous axes which alternately strike north and northwest as their axial planes are gently folded about steep west-plunging axes. A structural culmination across the group of folds lies north of Mount Corrigan. Two prominent folds dominate the group: the Squaw Creek anticline, near the eastern margin of the thrust plate, and the Barnes anticline, in the western part of the plate. The shape of these folds is intimately related to movements along a group of prominent, north-trending, west-dipping thrust faults, including the Squaw thrust and several less prominent faults that lie within the western part of the plate. North-striking segments along the Squaw Creek and Barnes anticlines are bounded by these faults. The anticlines are characteristically symmetrical and open, but become asymmetrical, tight, and overturned along segments underlain by the faults.



R.A.P., 3-5-61

PLATE XI. Northwestward along axis of Squaw Creek anticline near Flathead Pass. Etherington and Mount Head strata in core; Rocky Mountain strata in east limb. West limb disrupted by thrust faults. Note parallelism of bedding through fold.

The Squaw thrust extends along the west side of Flathead Range from near the mouth of Squaw Creek to the east side of Coal Mountain at the north boundary of the map-area. North of the map-area it lies on the east side of Middle Mountain and east of Tent Mountain. Along most of its length the Squaw thrust is discordant with folds above and below it. It overlaps minor folds along the west side of Flathead Range. Along the east side of Squaw Creek valley the overturned east limb of the Squaw Creek anticline is thrust into contact with the west-dipping homoclinal sequence of Flathead Range. To the north, the Squaw Creek anticline diverges from the fault and other folds appear between the two structures. Older stratigraphic units generally occur in the hanging-wall of the Squaw thrust, but at several localities the reverse is so and younger stratigraphic units in the hanging-wall lie above the older units. A few miles south of Flathead Pass, for example, Rocky Mountain strata lie above Mount Head strata. North of the map-area, on the east side of Middle Mountain, Kootenay and uppermost Fernie strata in the hanging-wall of the fault lie adjacent to lower Fernie and Spray River strata in the foot-wall. These relationships between stratigraphic units across the fault and the spatial relationships between the fault and adjacent folds indicate that the Squaw thrust has been discordantly superimposed across earlier northwest-striking folds and has in part at least truncated and offset these structures.

A fault zone comprising several north-trending, west-dipping thrust faults occurs in the western part of the Squaw thrust plate and obliquely transects the Barnes anticline. The zone extends from the north boundary of the map-area, a mile west of Michel Creek, to the Flathead fault, 1½ miles east of the mouth of McEvoy Creek. Four principal faults appear to be distinguishable within the zone. The most northerly of these thickens the Fernie Group on the west flank of the Squaw Creek anticline and appears to pass into the axial region of a syncline southward. The axial plane of the Barnes anticline is cut by a fault with right-lateral offset at the south end of Limestone Ridge. Where it crosses the axial region of the anticline, this fault dips steeply to the northwest, almost perpendicular to the axis of the fold. To the north it appears to pass into the bedding of the overturned east limb. To the south it is roughly parallel with the bedding in the west limb. Two thrust faults, both apparently west-dipping, extend along the west limb of the Barnes anticline. The trace of the more easterly of these faults is nearly parallel with the west limb of the Barnes anticline but transverse to a northwest-plunging syncline to the west of it. Southward it abuts the Flathead fault. The northwest-plunging syncline lying west of this more easterly thrust fault appears to have been obliquely truncated and offset upward and eastward along it. The more westerly fault appears to be a splay developed above the more easterly fault. Where the zone of north-trending west-dipping thrust faults crosses the Barnes anticline, the attitude of its axial plane changes from essentially vertical with a northwest strike to west-dipping with a north strike. These relationships indicate that the north-trending faults have been superimposed discordantly across pre-existing northwest-trending folds.

The Squaw thrust and the zone of north-trending, west-dipping thrust faults in the Squaw thrust plate are concordant with the younger kinematic pattern present in the structures in Flathead Range and the northwestern part of Clark Range. They have resulted in shortening of part of the Lewis thrust sheet about a north-south axis and in modifications of the initial shape and trend of the Squaw Creek and Barnes anticlines. These folds originated while the older structures in Clark Range and parts of Flathead Range were developing in response to a relative northeastward displacement of the Lewis thrust sheet and shortening about a northwest-southeast axis.

Minor Structures

Complex minor structures in the Squaw thrust plate can be attributed mainly to the discordant superposition of the structures of one kinematic pattern over those of another. The shape and orientation of folds formed in conjunction with the older kinematic pattern were partly modified during deformation associated with the younger pattern. Individual folds were re-activated and their axial planes were locally rotated toward parallelism with the younger kinematic pattern. These modifications appear to have been accomplished by displacement along bedding surfaces and minor faults.

East-dipping faults occur in the east limb of the Squaw Creek anticline, along the north-striking part of its axial plane adjacent to Squaw Creek. These faults thicken the stratigraphic sequence in this limb of the anticline and terminate to the east against the underlying Squaw thrust. This segment of the anticline lies directly above the Squaw thrust. Stratigraphic relationships across the thrust and the apparent truncation of the east-dipping faults against it suggest that the Squaw Creek anticline has been truncated by the Squaw thrust and displaced across an intervening syncline on to the west-dipping sequence of Flathead Range (*see* cross-section C-D). The east-dipping faults are inferred to terminate at depth in the core of the overridden syncline. They appear to be flexural-slip thrust faults that have provided local adjustment to the tight folding of the syncline and the adjacent Squaw Creek anticline prior to the truncation of these structures by the Squaw thrust. Beds in the axial region of the syncline have been displaced along the east-dipping faults up the short east limb of the Squaw Creek anticline relative to those on the crest of the anticline.

Similar east-dipping faults occur above the zone of west-dipping thrust faults along the west flank of the Barnes anticline. They also lie in the east limb of an anticline that appears to have been thrust eastward over an adjacent syncline. These east-dipping faults are inferred to bear the same relationship to the Barnes anticline and related thrusts as those described above to the Squaw Creek anticline and the Squaw thrust.

The structural complex forming Coal Mountain, along the eastern edge of the Squaw thrust plate near the north boundary of the map-area, has been described in detail by Norris (1957a) and only the gross characteristics are considered here. Lower Kootenay and upper Fernie strata capping the mountain form a complexly faulted anticlinorium. South of Coal Mountain and east of Michel Creek, Spray River and Rocky Mountain strata are exposed in the core of the anticlinorium. There the fold is a simple anticline and no faults are apparent within it. The small, tight folds and thin thrust slices on Coal Mountain terminate above the Spray River Formation within the Fernie Group and are disharmonic relative to the underlying anticline. The faults that dominate the structure along the crestal region of the anticlinorium on Coal Mountain are inferred to be flexural-slip thrust faults that terminate with depth along the bedding of Fernie strata, in synclines on either side of the anticlinorium. This implies that the total foreshortening of successive stratigraphic units between the crests of the anticlinorium and the Squaw Creek anticline is essentially constant, but that, whereas higher stratigraphic units form broad, gentle anticlinoria and a synclinorium and are foreshortened along numerous minor thrust faults, lower stratigraphic units form tight, unfaulted folds. The horizontal shortening at lower stratigraphic levels is primarily a result of flexure whereas that at higher stratigraphic levels is mainly due to displacements perpendicular to the axis of flexure along numerous minor thrust faults, and only partly the result of flexure.

The Fernie Basin

The Fernie basin extends along the west side of the map-area from the valley of Lodgepole Creek to the north boundary. It lies northwest of the northwest-facing North Kootenay Pass monocline, and west and northwest of the northwest-plunging folds in the Squaw thrust plate. In contrast to adjacent parts of the Lewis thrust sheet, the structure within the Fernie basin is simple. West of the region encompassed by the map-area broad open folds involving strata of the Blairmore Group occupy the central part of the basin. That part of the Fernie basin lying within the map-area comprises the east limb of the most easterly syncline.

Structures within the Fernie basin are disharmonic relative to those along its margins. At the southwest end of the basin the Howell Creek structure and a group of prominent folds in Palaeozoic strata west of the Howell Creek structure plunge steeply beneath the basin. The folds, with their large structural relief in the Palaeozoic sequence, have little or no structural expression in the Kootenay and Blairmore strata of the basin. Along the valley of McLatchie Creek, Fernie strata are cut by several northwest-dipping thrust faults extending along the North Kootenay Pass monocline, which there forms the northwest flank of the Macdonald dome. These faults are part of the Howell-Squaw thrust fault zone. North of Flathead River northwest-plunging folds in the Squaw thrust plate pass under the basin with little or no structural expression in the Kootenay and Blairmore strata defining its east side. The structural relief on the top of the Spray River Formation has been largely obliterated by a complex of small faults developed within the overlying Fernie Group. Several of these faults have been observed along the east side of the basin a few miles north of Flathead River. These faults produce a local tectonic thickening of the Fernie Group above two northwest-plunging folds in Spray River Formation. Above the Fernie Group, the Kootenay Formation is essentially unfolded. Kootenay and Blairmore strata lying within the Fernie basin appear to have undergone some displacement along the 'incompetent' Fernie Group strata independent of the underlying Spray River Formation and Palaeozoic sequence.

The Howell Creek Structure

General Features

The Howell Creek structure occupies the southwest part of the map-area and extends southward beyond its boundary along the headwaters of Howell and Twentynine Mile Creeks. Only the northern end of the structure lies in the map-area, and extensive surficial deposits obscure some of the structural relationships at lower elevations. To facilitate the description and interpretation of the structure, data from the adjacent area have been compiled with those from Flathead area (*see* Fig. 16).

The most striking feature is the occurrence within the structure of strata of the Upper Cretaceous Alberta Group and Belly River Formation, bounded on all sides by older rocks along faults with stratigraphic separations of between 4,000 and 15,000 feet. The interpretation of relationships across the principal faults forms the basis for determining whether the Upper Cretaceous strata are allochthonous and a part of the Lewis thrust sheet, or autochthonous and exposed in windows through the thrust sheet. Three principal faults occur in the structure. These are shown on the geological map of Figure 16 and the interpretation of relationships across them is illustrated in the accompanying fence diagram.

The Harvey fault marks the northeastern boundary of the Howell Creek structure. Its surface trace follows a prominent northwest-trending scarp from the headwaters of McLatchie Creek to beyond the mouth of Twentynine Mile Creek. The fault surface is not exposed, but its straight trace and the prominent scarp adjacent to it indicate that it has a relatively steep dip. Along the divide between Lodgepole and McLatchie Creeks the fault can be traced accurately along an interval where the relief is 1,000 feet on its trace. Graphic calculations indicate that the fault there dips to the southwest at about 45 degrees. The stratigraphic relationships across the fault consistently indicate that the southwest side is downthrown relative to the northeast side. Along the south side of the Fernie basin, immediately north of Lodgepole Creek, thrust faults cutting Fernie Group strata in the foot-wall of the Harvey fault are truncated along the fault. The base of the Kootenay Formation is offset across the fault and downthrown about 1,500 feet to the southwest. The throw across the fault decreases progressively toward the northwest. East of the mouth of Twentynine Mile Creek, the base of the Mount Head Formation is downthrown some 3,000 feet to the southwest across the fault. These relationships indicate that the Harvey fault is a southwest-dipping gravity fault that has developed across the pre-existing thrust structures.

The Howell fault crosses the south end of the ridge between Howell Creek and Twentynine Mile Creek and is abruptly truncated to the northeast against the Harvey fault. Graphic calculations indicate that, at this locality, the strike of the fault is N20°E and its dip is 30°W. Along the fault the Upper Cretaceous sequence overlies Spray River, Rocky Mountain, and Rundle strata, which comprise the downthrown structural equivalent of the Macdonald dome. Therefore, the Howell fault and the Upper Cretaceous strata in its hanging-wall must occupy a position above that of the Palaeozoic rocks in the Macdonald dome.

A second major fault occurs on the downthrown side of the Harvey fault and lies above and to the west of the Howell fault. Along this fault the Upper Cretaceous sequence in the Howell Creek structure is overlain by Purcell and Palaeozoic strata. These strata dip to the north beneath the Fernie basin. Thus, the second major fault, the Upper Cretaceous sequence in its foot-wall, and the Howell fault below it, all lie structurally below the Fernie basin. However, they also lie structurally above Palaeozoic strata on the downthrown side of the Harvey fault that are the offset equivalents of the strata of the Macdonald dome. On the upthrown northeast side of the Harvey fault Fernie and Spray River strata along McLatchie Creek valley occupy the structural position between the Fernie basin and the Macdonald dome. The faults that tectonically thicken this stratigraphic interval are the correlatives of those involved in the Howell Creek structure on the opposite side of the Harvey fault. In contrast to the principal faults within the Howell Creek structure, these faults are characterized by relatively small stratigraphic separations, both individually and cumulatively, and do not have Upper Cretaceous beds exposed along them.

The Upper Cretaceous sequence within the Howell Creek structure thins progressively toward the south by convergence of the faults above and below it. South of Twentynine Mile Creek the faults bounding it meet and the structure extends farther south as a single fault which tectonically thickens the Purcell-Palaeozoic sequence. Thus the south end of the Howell Creek structure is comparable to that part of the structure lying northeast of the Harvey fault along McLatchie Creek valley. At both localities the Howell Creek structure is represented by one or more west-dipping faults which are subparallel with the bedding and which result in a repetition of a westward-dipping stratigraphic sequence of rocks lying above the Lewis Thrust Fault. The exposed part of the Howell Creek structure embraces the eastern edge of a thin wedge or lens of Upper Cretaceous strata bounded above and below by older strata along two prominent faults. These faults meet at its northern and southern peripheries to form one or more simple west-dipping faults which repeat the west-dipping sequence of the Lewis thrust sheet (*see* the fence diagram of Fig. 16).

The wedge or lens of Upper Cretaceous strata can be related structurally to the Lewis Thrust Fault in terms of the direction of displacement along the Howell fault (*see* Fig. 17). Downthrow to the west along the west-dipping Howell fault

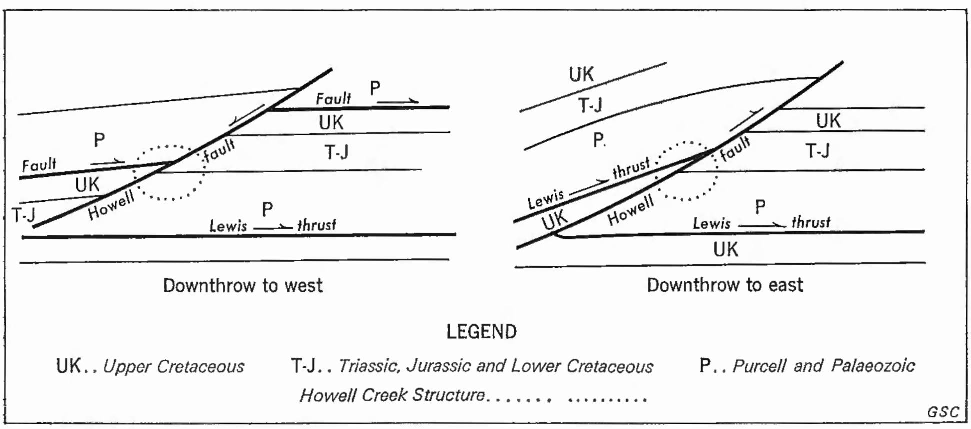


FIGURE 17. Effect of displacement on the Howell fault in opposite directions.

involves a lateral extension of the Lewis thrust sheet and implies that the Upper Cretaceous strata originally occupied a position above the Lewis Thrust Fault within the Lewis thrust sheet. Downthrow to the east along the Howell fault involves a lateral contraction of the Lewis thrust sheet and implies that the Upper Cretaceous strata originally occupied a position below the Lewis thrust sheet in the foot-wall sequence. The former interpretation implies that the prominent fault that overlies the Upper Cretaceous strata and has up to 3 miles of stratigraphic separation is a thrust fault that lies above and is distinct from the Lewis Thrust Fault; but no thrust faults of this magnitude have been observed above the Lewis thrust around the periphery of the Howell Creek structure. The latter interpretation implies that this fault is a segment of the Lewis Thrust Fault which has been offset and displaced along the Howell fault upward and eastward relative to a more easterly segment. This interpretation is compatible with relationships around the periphery of the Howell Creek structure.

The spatial relationships of the Howell fault indicate that it is a west-dipping thrust fault that has developed discordantly across the pre-existing Lewis thrust sheet. The Howell fault is nearly parallel with the bedding in the rocks adjacent to it and has a relatively low dip. These features are typical of thrust faults in the region but not typical of the gravity faults. The Howell Creek structure is the downthrown structural equivalent of thrust faults lying northeast of the Harvey fault along McLatchie Creek valley. These faults, in turn, are downthrown equivalents of the Squaw thrust and overlying faults in the Squaw thrust plate on the north side of the Flathead fault. Thus the Howell Creek structure and the structures of the Squaw thrust plate comprise parts of a single, persistent, major structure which has been offset along younger gravity faults. As indicated in the discussion of the Squaw thrust plate, the deformation expressed in these structures agrees with that expressed in the younger structures in Flathead Range and the northwestern part of Clark Range and involved a lateral shortening of the Lewis thrust sheet about a regional north-south axis. This lateral shortening has been superimposed discordantly across structures formed during an earlier period of deformation, involving lateral shortening about a regional northwest-southeast axis. The Howell Creek structure can be fitted into this regional structural framework if thrust displacement along the Howell fault is assumed. The Howell fault has therefore been interpreted as a west-dipping thrust fault along which the Lewis Thrust Fault has been truncated and offset. Stages in the development of the structure are illustrated in Figure 18.

Thus, the Howell fault is considered to be one of the group of younger thrust faults that discordantly truncate and offset pre-existing structures. It is presumably the lateral equivalent of the most easterly fault on the northwest flank of the Macdonald dome along McLatchie Creek valley and of the Squaw fault. The Upper Cretaceous strata above the Howell fault are exposed in a window through the Lewis thrust sheet and are elsewhere bounded at the top by the Lewis Thrust Fault. They represent rocks from below the Lewis thrust that have been displaced along the Howell fault to an elevation above Palaeozoic strata of the Lewis thrust sheet farther east. Southeast of the point where the Howell fault and

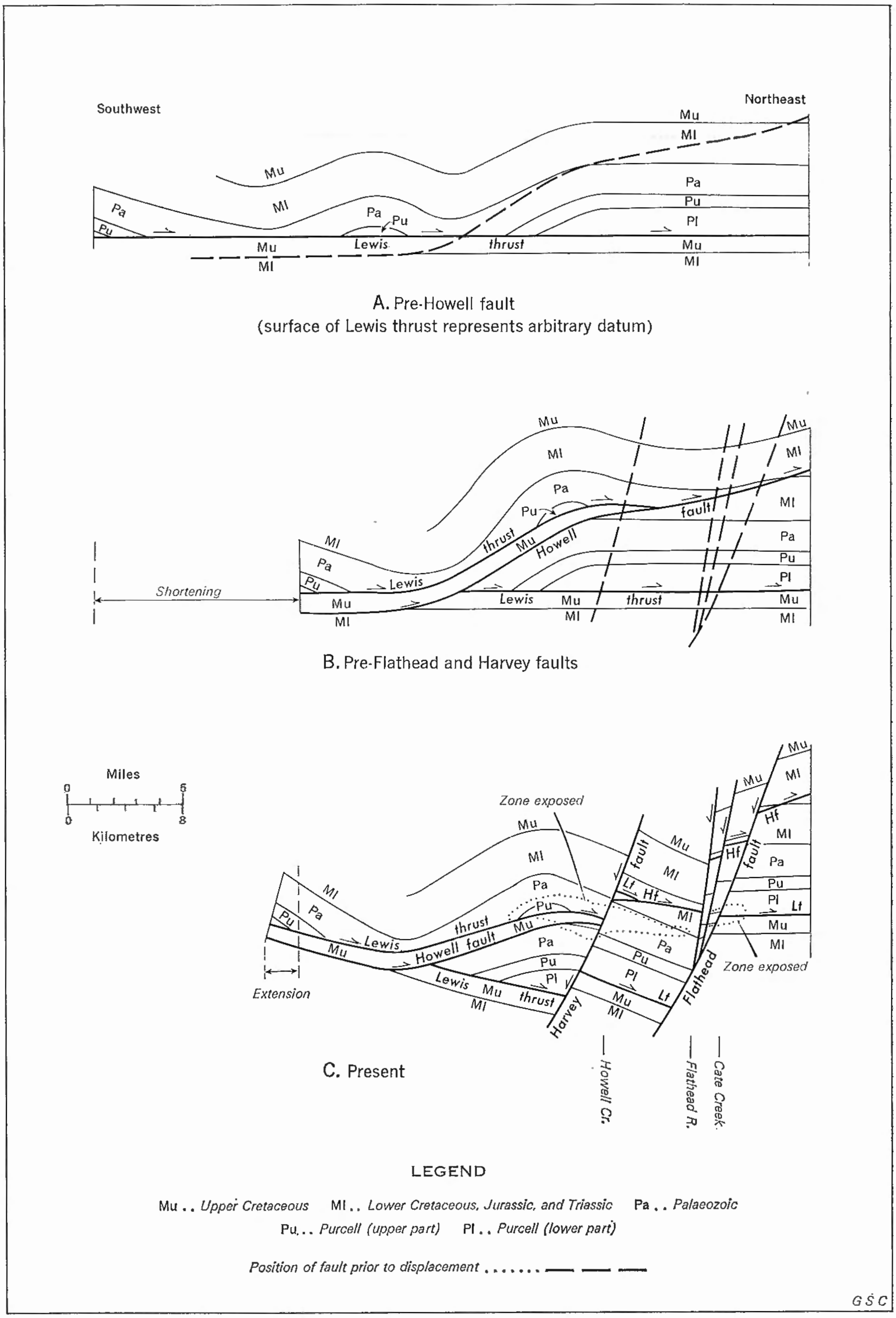


FIGURE 18. ***Diagrammatic southwest to northeast structure-sections across Cate and Howell Creeks showing stages in the development of the Howell Creek structure.***

the Lewis thrust meet at the surface, higher structural levels along the Howell fault are exposed and the strata in both the foot-wall and the hanging-wall of the fault are parts of the Lewis thrust sheet.

The Lewis Thrust

Within the Howell Creek structure the Lewis thrust is characterized by rapid changes in position relative to the stratigraphic layering of the thrust sheet both along and across the regional northwest strike. The relationships across the fault there are of particular significance because of their implications with regard to the path of the fault on a regional scale and the age of the fault relative to other structures in this region.

In the Howell Creek structure, the trace of the Lewis Thrust Fault rises within the stratigraphic succession of the overlying beds toward the northwest, from member C of the Kintla Formation on Twentynine Mile Creek to the upper part of the Mount Head Formation north of Harvey Creek. Within this interval the fault is folded about a northwest-trending anticlinal axis with a shallow northwest plunge. Because of this progressive truncation of successively younger hanging-wall strata in the direction of plunge, a corresponding anticline in the strata above the fault is characterized by a steeper northwest plunge. The relationship between the steep plunge of this anticline and the rapid change in stratigraphic position of the Lewis thrust is similar to that between the North Kootenay Pass monocline and the abrupt transverse step in the position of the Lewis thrust beneath it. This similarity is particularly pertinent in view of the direction of relative displacement inferred for the underlying Howell fault. The Howell fault has been interpreted as having developed discordantly across the pre-existing North Kootenay Pass monocline and as being characterized by a relative eastward displacement of the hanging-wall. This implies that where the Howell fault cuts the North Kootenay Pass monocline, that part of the monocline overlying the fault has been displaced eastward across the strike of the monocline. As the North Kootenay Pass monocline marks a zone along which the Lewis thrust rises to the northwest relative to overlying stratigraphic units, the offset part of the Lewis Thrust Fault lying in the hanging-wall of the Howell fault, and corresponding to the North Kootenay Pass monocline, is also characterized by a rise in stratigraphic position toward the northwest relative to overlying beds. This similarity indicates that the north end of the Howell Creek structure is a segment of the North Kootenay Pass monocline that has been displaced toward the east along the Howell fault relative to underlying strata.

Several west-dipping faults occur above the Lewis thrust along the west side of the Howell Creek structure. The traces of these faults are more or less parallel with the trace of the bedding and are marked, in general, by zones along which younger strata overlie older strata with the omission of the intervening stratigraphic units. Locally, as at the western headwaters of Harvey Creek, one of these faults is marked by a zone along which older strata overlie younger, repeating part of the stratigraphic sequence. The stratigraphic relationships across these faults may have some bearing on the path of the Lewis thrust

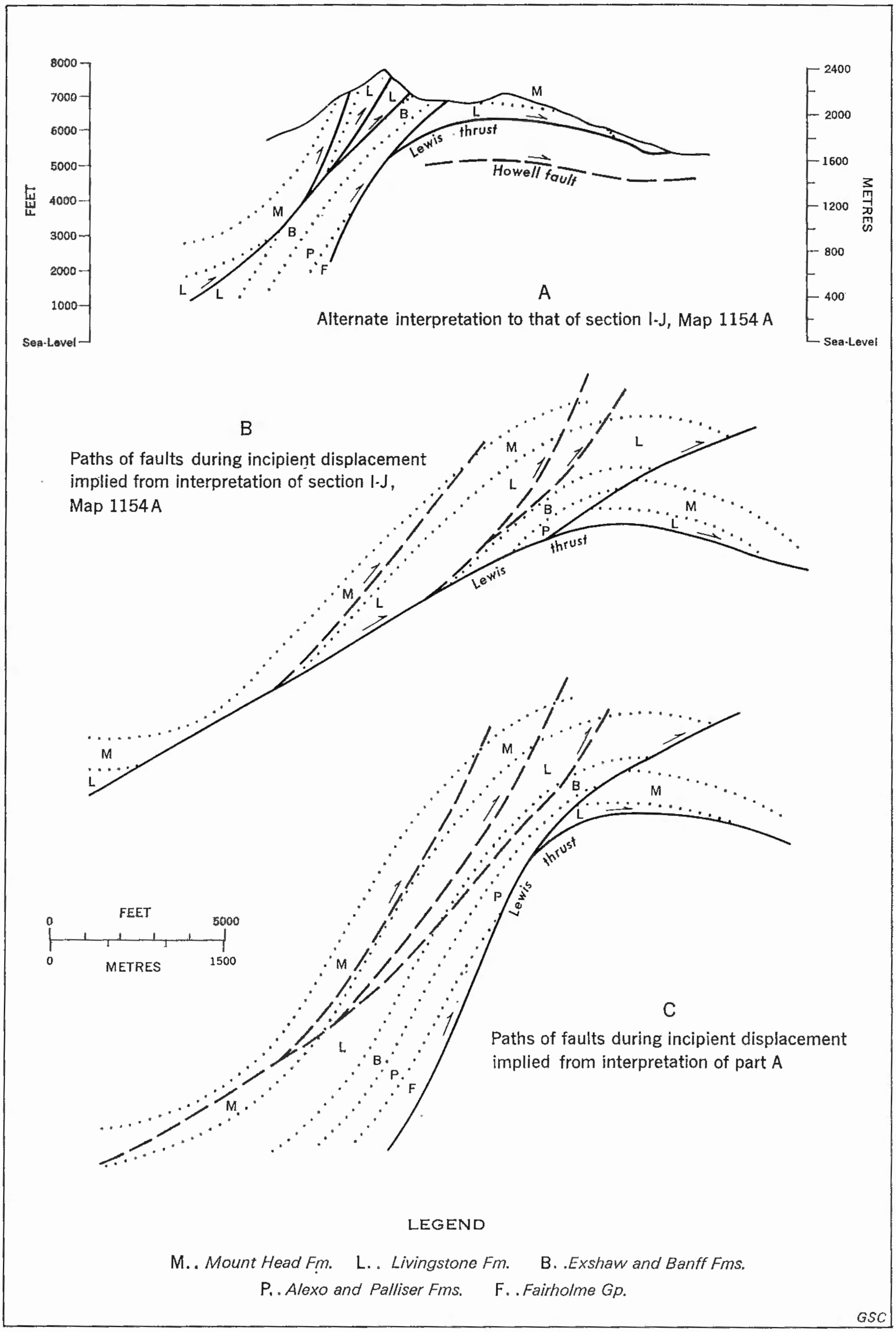


FIGURE 19. Interpretations of faults along the west side of Howell Creek structure.

southwest of the Howell Creek window. In section I-J and in the fence diagram of Figure 16 these faults have been interpreted as small splays from the Lewis thrust. The implications of this interpretation with regard to the path of the Lewis thrust through the strata in its hanging-wall are illustrated in Figure 19b. This interpretation implies that the path of the Lewis thrust rises in the stratigraphic succession to the southwest relative to the hanging-wall sequence, and furthermore, that the Lewis thrust has truncated and offset a pre-existing anticline, part of which now occurs within its hanging-wall in the Howell Creek structure. An alternate interpretation of the west-dipping faults is illustrated in Figure 19a, a structure section along the same line as that of section I-J. This interpretation implies that the path of the Lewis thrust falls in the stratigraphic succession southwest, relative to the hanging-wall sequence, and that the west-dipping faults have developed across strata that had previously been rotated into a steeply dipping position. It also implies that the Lewis thrust dips very steeply along the west side of the Howell Creek window toward the underlying Howell fault. Although the basic relationships that characterize either of these interpretations will satisfy available surface data, the interpretation shown in section I-J appears to the writer to be the more probable.

In the southeastern part of the Howell Creek window the Lewis thrust occupies a position within the Palaeozoic sequence relative to hanging-wall strata. To the northeast, in the Cate Creek window, and under adjacent parts of the Clark Range, strata of the Waterton Formation lie directly above the Lewis thrust. Thus from the Howell Creek window, above the Howell fault, to the Cate Creek window, northeast of the Flathead fault, the Lewis thrust lies at progressively lower stratigraphic levels relative to the strata in its hanging-wall. This northeastward drop in stratigraphic position amounts to about 8,000 feet, and is opposite to the path southwest of the Howell fault in the Howell Creek window, and northeast of the Flathead fault beneath Clark Range, where the fault rises in the hanging-wall beds toward the northeast. Between the southwest side of the Howell window and the eastern slopes of Clark Range, the path of the Lewis thrust, relative to the strata in its hanging-wall, rises toward the northeast to a position within the Palaeozoic sequence, then falls to a position within the Waterton Formation of the Purcell sequence, and finally, after following the Waterton Formation beneath most of the Clark Range (Norris, 1959a; section C-D), rises to higher stratigraphic levels in the eastern part of the thrust sheet (Hage, 1943; Douglas, 1952). The path of the thrust is dependent on the relative orientations of the thrust and the strata during incipient displacement. A path that alternately rises, falls, and rises within the stratigraphic sequence indicates that the fault truncated pre-existing structures (*see* Fig. 20). A broad syncline, truncated by the Lewis thrust, occupies a position in the Lewis thrust sheet between the Howell Creek window and the Cate Creek window.

An estimate of the minimum displacement along the Lewis thrust can be made by considering the minimum amount by which the top of the Waterton Formation has been offset in the direction of relative displacement of the Lewis thrust sheet. It has been inferred from the orientation of folds and associated thrusts faults in Clark Range that the Clark Range segment of the thrust sheet has been displaced northeastward. Therefore, the minimum possible offset of the top of the Waterton Formation in this direction can be estimated by comparing the path of the Lewis thrust in the hanging-wall succession with that in the foot-wall succession along a southwest to northeast line of section through the Howell Creek window.

The northeastern limit of Waterton strata in the Lewis thrust sheet lies near Linnet Lake in Waterton map-area (Douglas, 1952) and near Whistler Mountain in Carbondale map-area (Norris, 1959a). By extrapolating a line joining these two localities northwestward Waterton strata can be inferred to lie about 20 miles northeast of the southern limit of exposure of Alberta Group strata in the Howell Creek window.

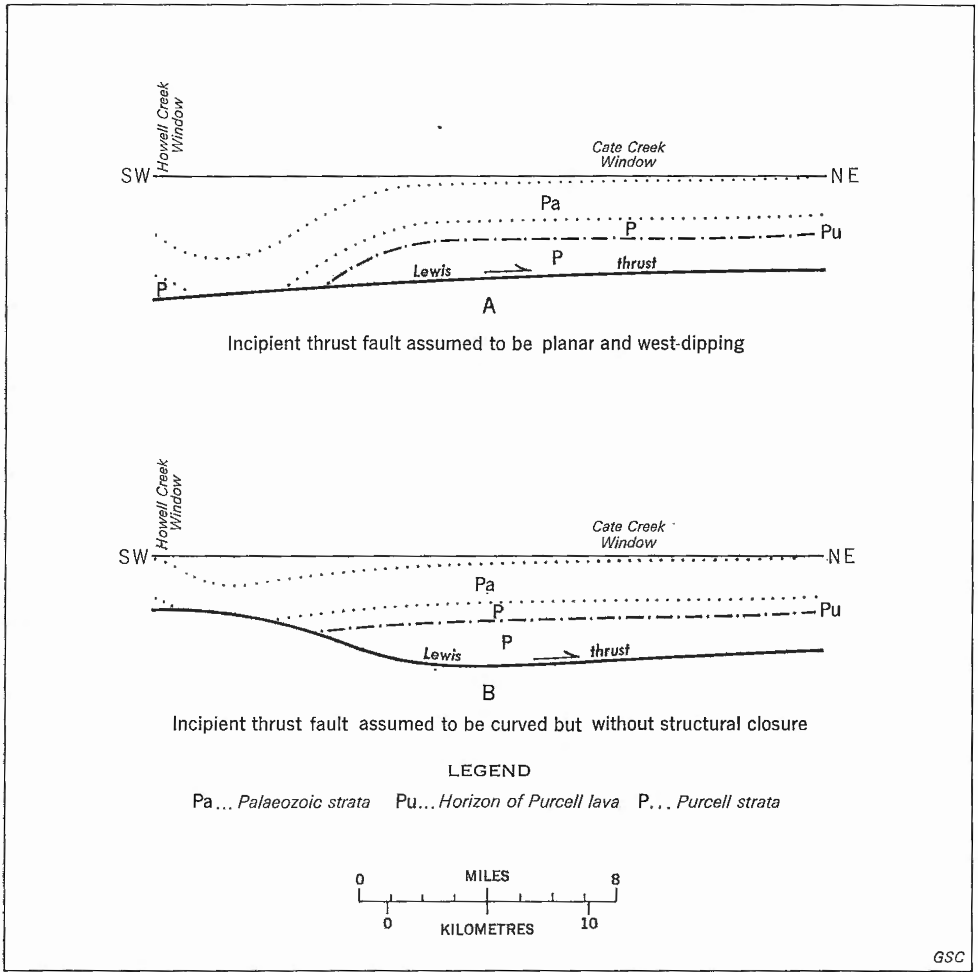


FIGURE 20. Schematic structure-sections illustrating the relationships between folding and the configuration of the Lewis Thrust Fault during incipient displacement.

Estimates of the eastern limit of Waterton strata along the foot-wall of the Lewis thrust are less reliable. Within both the Howell Creek and Cate Creek windows the path of the Lewis thrust relative to the foot-wall strata is restricted to the stratigraphic interval embracing the lower part of the Belly River Formation and the upper part of the Alberta Group. The thrust is assumed to follow this stratigraphic interval between the Howell Creek window and the central part of Clark Range. Northeast of the Cate Creek window, in Carbondale map-area (Norris, 1959a), the Lewis thrust overlaps fault slices of older Mesozoic strata that form the southern part of the Carbondale River-Goat Creek structure, and its stratigraphic position relative to the foot-wall beds presumably changes rapidly. As the relationships between the Lewis thrust and the Carbondale River-Goat Creek structure are discussed in detail elsewhere, it will suffice to note here that within this interval the path of the thrust along its foot-wall does not fall as low as the lower part of the Palaeozoic sequence. Northeast of the Carbondale River-Goat Creek structure the Lewis thrust lies on Belly River strata. Thus from the Howell Creek window, northeastward to the edge of the Lewis thrust sheet the foot-wall of the Lewis thrust consistently lies above the lower part of the Palaeozoic succession, and the Purcell strata in Clark Range must originally have lain southwest of the Upper Cretaceous strata in the Howell Creek window. These Upper Cretaceous strata have been displaced at least 5 miles to the east along the Howell fault relative to underlying strata of the Lewis thrust sheet. Thus the total separation along a northeast-southwest line on the Lewis thrust between the eastern limit of Waterton strata in the thrust sheet and the Upper Cretaceous strata of the Howell Creek window is at least 25 miles.

The top of the Waterton Formation occupies a position in the normal stratigraphic succession 3.5 miles below the Upper Cretaceous strata of the Howell Creek window. Assuming that the foot-wall of the Lewis thrust cuts downward in the stratigraphic succession west of the window at an average angle to the bedding no greater than 30 degrees, the northeastern limit of Waterton strata along the foot-wall lies at least 7 miles southwest of the window. Since, as has been shown above, the eastern limit of Waterton strata along the hanging-wall of the thrust is at least 25 miles northeast of the Upper Cretaceous strata in the window, the minimum displacement along the Lewis thrust along a line passing through the Howell Creek window must be 32 miles.

The Carbondale River-Goat Creek Structure

General Features

The Carbondale River-Goat Creek structure occupies most of the northeastern part of the map-area and extends from the vicinity of Goat Creek near the north boundary to Whistler Mountain in the adjoining Carbondale River map-area (Norris, 1959a). It lies within the Foothills above the Coleman fault (Norris, 1955) and below the Lewis thrust. The structure consists of three tight, almost isoclinal folds that are overturned to the northeast (*see* section C-D). Southwest-dipping faults occur within and between the limbs and are in general nearly parallel with them.

The steeply dipping strata of the Carbondale River-Goat Creek structure are in sharp contrast with Belly River and Wapiabi strata of the Coleman fault plate that lie along the northeastern flank of the structure. Although the latter strata are largely obscured by extensive surficial deposits, they apparently form several broad northwest-trending folds (*see* section A-B). North of Lost Creek no stratigraphic separation is evident between southwest-dipping Belly River strata forming a limb of one of these folds and vertical to overturned strata forming the northeastern flank of the Carbondale River-Goat Creek structure. The two sequences are interpreted as the limbs of a syncline overturned to the northeast (*see* section A-B). Southeastward from Lost Creek the overturned sequence appears to overlap the adjacent anticline on the northeast along a thrust fault that lies in the axial region of the intervening overturned syncline (*see* section C-D).

At the northwest end of the Carbondale River-Goat Creek structure, near Goat Creek, the three folds are progressively overlapped toward the north by the Lewis thrust sheet. South of Carbondale River part of the overturned sequence of the southwestern syncline overlaps the southwest-dipping and southwest-facing strata of the other limb along a southwest-dipping fault. On the northwest slope of Mount McCarty these overturned strata lie in fault contact above the overturned strata of the northeastern syncline and are overlain, in turn, by the Lewis thrust sheet. East of Mount McCarty, near Gardiner Creek, the Lewis thrust sheet overlaps the southwestern overturned sequence and lies in fault contact above the overturned strata of the northeastern syncline (Norris, 1959a). This relationship persists to the southeast as far as Whistler Mountain on the east side of Castle River. There the Lewis thrust sheet overlaps the northeastern overturned sequence and lies above Belly River strata that form part of the Coleman fault plate (Norris, 1959a). Although the three folds that constitute the Carbondale River-Goat Creek structure are progressively overlapped by the Lewis thrust sheet, in a general way they conform to the shape of the base of the thrust sheet. For example, along Carbondale River the three folds are further folded as a unit along southwest-plunging axes, to form a southeast-facing monocline that conforms in general with the attitude of the Lewis Thrust Fault where it lies beneath the northwest-facing North Kootenay Pass monocline formed in the strata of the Lewis thrust sheet.

Interpretations of Faults

Anomalous stratigraphic successions appear about faults in the overturned limb of the northeastern syncline. One prominent fault lies within the stratigraphic interval embracing the Crowsnest, Blackstone, and Cardium Formations, and appears to extend along the entire exposed syncline. This southwest-dipping fault is roughly parallel with the strata on either side of it and is marked by stratigraphic omissions. Along it overturned strata representing horizons in the middle and upper parts of the Crowsnest Formation lie above overturned Blackstone or Cardium strata respectively. Near Carbondale River the fault is folded along southwest-plunging axes together with the strata adjacent to it. Figure 21 illustrates three interpretations of these structures. In each interpretation x-x′ represents the offset of the top of the Cardium Formation along the fault. Norris (1959a, section C-D) interpreted the

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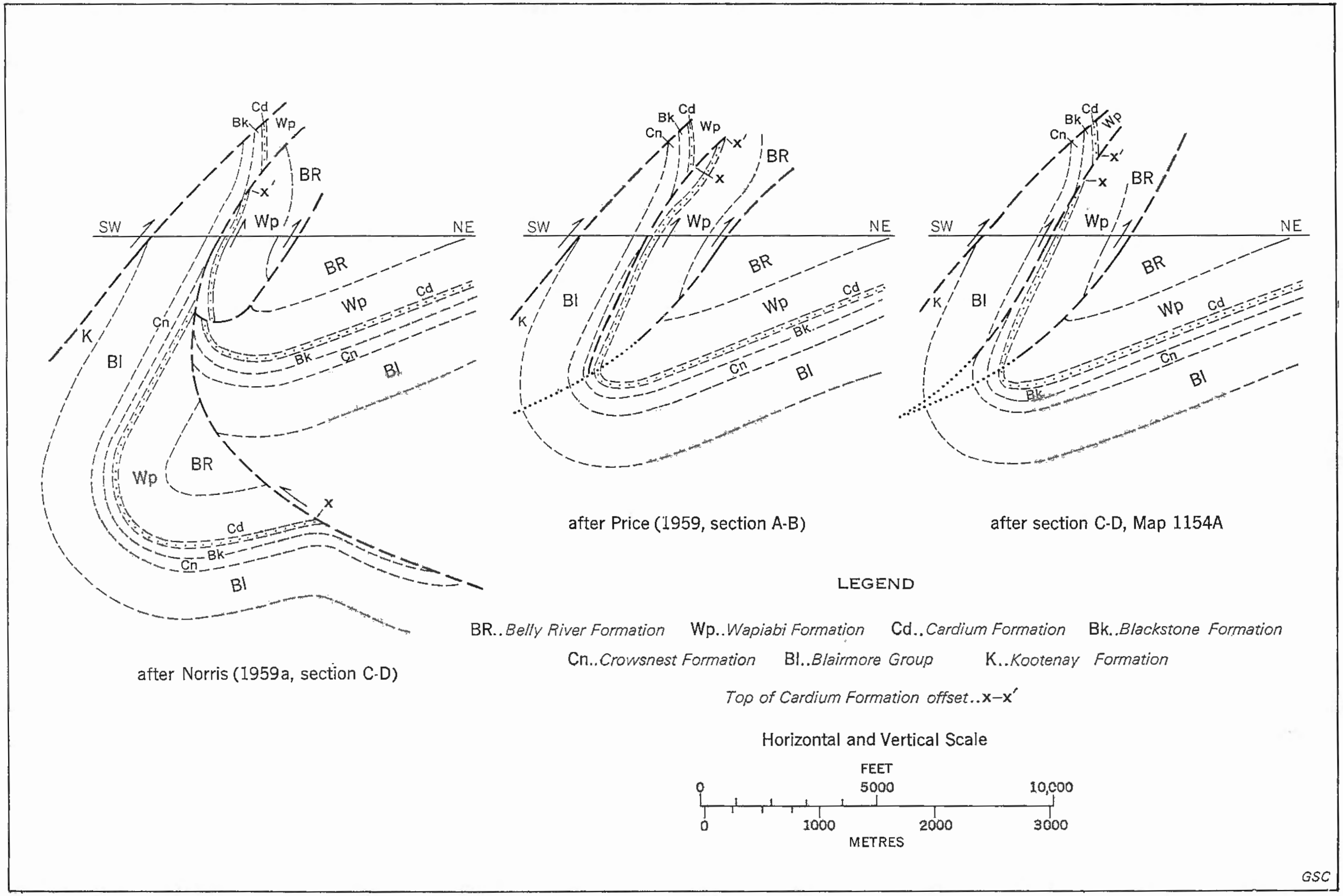

FIGURE 21. *Interpretations of fault relationships within the overturned succession in the northeastern part of the Carbondale River-Goat Creek structure.*

fault as a northeast-dipping thrust fault which has discordantly truncated a syncline and has, in part, been rotated into an overturned southwest-dipping position during subsequent folding. Price (1959, section A-B) interpreted the fault as a flexural-slip thrust fault extending out of the axial region of an adjacent syncline on the northeast, and obliquely transecting the overturned strata in the southwest limb of the syncline. A third interpretation, proposed here, is that the fault is a southwest-dipping thrust fault transecting strata that had previously been rotated into a steeply dipping and overturned position during folding. The three interpretations differ radically in their implications regarding the sense and amount of relative displacement along the fault.

A second fault occurs within this overturned sequence in the vicinity of Carbondale River. There the overturned strata are characterized by shallow dips. A fault with an apparent southwest dip is marked by a stratigraphic repetition, and along it overturned Wapiabi strata lie above overturned Cardium strata. The stratigraphic sequence across this fault suggests that displacement along it occurred after the beds had been rotated into an overturned shallow-dipping position. To the northwest and southeast this fault appears to merge within the overturned sequence with the fault discussed in the preceding paragraph.

A prominent fault marks the axial region of an anticline in the central part of the Carbondale River-Goat Creek structure. The trace of this fault indicates that it dips to the southwest. Southwest-dipping, northeast-facing strata lying in the foot-wall comprise part of the northeastern limb of the anticline. Southwest-dipping, southwest-facing strata lying in the hanging-wall comprise part of the southwestern limb. The stratigraphic sequence across the fault varies along its strike. In the vicinity of Carbondale River and South Lost Creek, Kootenay strata overlie overturned lower Blairmore strata along the fault, whereas to the northwest, on the ridge between North Lost Creek and Goat Creek, middle and lower Blairmore strata overlie overturned Kootenay strata. The variations in the stratigraphic sequence across the fault from south of Carbondale River to Goat Creek form the basis for the interpretation of the general relationships between the fault and an underlying anticline illustrated in Figure 22. This interpretation has been adopted in sections A-B and C-D.

With reference to Figure 22, at the structural level designated by the line A-A′, upright Kootenay strata in the hanging-wall of the fault overlie overturned lower Blairmore strata in its foot-wall. In contrast, at the structural level designated by the line B-B′, upright lower and middle Blairmore strata in the hanging-wall overlie overturned Kootenay strata in the foot-wall. The change in stratigraphic relationships across this fault from southeast to northwest in the Carbondale River-Goat Creek structure would thus imply that the structure plunges to the southeast beneath the Lewis thrust sheet.

Several faults occur in the upright, southwest-dipping strata of the southwestern limb of the anticline. Available data suggest that these faults consistently dip to the southwest and are more or less parallel with the bedding on either side of them. The most prominent of the faults extends from Goat Creek at least as far southeast as Carbondale River, and possibly beyond Carbondale River to the headwaters of Macdonald Creek. From North Lost Creek to Carbondale River it is marked by an omission of part of the stratigraphic sequence and it has younger beds in its hanging-wall than in its foot-wall. From North Lost Creek to Goat Creek, and possibly also in the vicinity of Carbondale River, the fault is marked by stratigraphic repetition and has older beds in its hanging-wall than in its foot-wall. A tight syncline with Alberta Group strata in its core lies southwest of the fault in the hanging-wall plate. The marked changes in the sequence of strata across the fault at different places along it can be related to the structural level of the hanging-wall strata relative to the axis of the syncline. A structural 'low' occurs along the axis of the syncline near South Lost Creek. Stratigraphic omissions across the fault are associated with higher structural levels in the northeast limb of the syncline and occur opposite the structural 'low'.

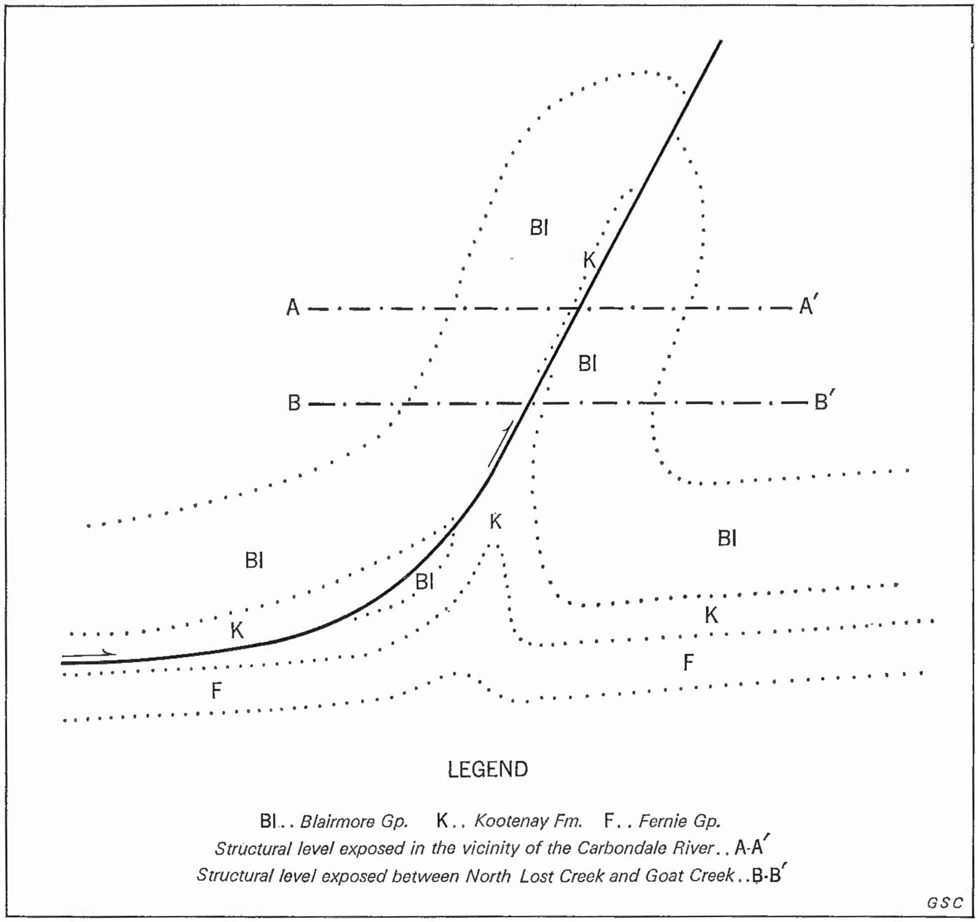

FIGURE 22. Diagrammatic southwest-northeast structure-section showing interpretation of fault relationships in the central part of the Carbondale River-Goat Creek structure.

Stratigraphic repetitions, on the other hand, are associated with lower structural levels and occur northeast and southwest of the structural 'low'. These relationships indicate the path of the fault as it crosses through the strata. At lower structural levels the path of the fault rises in the stratigraphic succession in the direction of relative displacement of the hanging-wall. There the fault cuts across beds that are upright and dip less steeply than the fault. At higher structural levels however the path falls, for there the fault cuts across beds that are upright and dip more steeply than the fault. These characteristics indicate that the fault obliquely truncates the northeast limb of a pre-existing syncline and this interpretation is shown on section C-D.

Other less prominent faults cut Blackstone and Cardium strata between South Lost Creek and Carbondale River. These faults are marked by both stratigraphic repetitions and omissions in the upright, southwest-dipping sequence. They are restricted to the stratigraphic interval between the Crowsnest Formation and the lower part of the Wapiabi Formation, and the stratigraphic separation across them appears to decrease as they are traced down the northeast limb of the syncline toward the axis. These faults have been interpreted as flexural-slip thrust faults extending up the northeast limb of the syncline from horizons in the Blackstone Formation in the axial region. They are assumed to have truncated obliquely the northeast limb of the syncline, and consequently to cut down, in part, through the strata in the direction of relative displacement of the hanging-wall.

The overturned southwest-dipping stratigraphic sequence of the southwestern limb of the syncline forms the western part of the Carbondale River-Goat Creek structure. A series of southwest-dipping faults occurs in this overturned sequence and these are marked primarily by the omission of part of the normal stratigraphic sequence. The most northeasterly of these faults lies within the stratigraphic interval embracing the Crowsnest, Cardium, and Blackstone Formations and the lower part of the Wapiabi Formation, on the ridge between South Lost Creek and Carbondale River. It is analogous to faults occurring in the same stratigraphic interval in the opposite limb of the syncline. On this basis it has been interpreted as a flexural-slip thrust fault extending up the fold limb out of the Blackstone strata in the axial region of the syncline. This implies that the northeast side has moved up relative to the southwest side and that the fault cuts progressively older beds in the overturned southwest limb of the syncline at higher structural levels.

Two prominent faults occur in the southwestern limb of the syncline immediately beneath the Purcell strata of the Lewis thrust sheet. Both dip to the southwest and both are marked by omissions in the overturned stratigraphic sequence except where they overlap the axial region of the underlying syncline. Both are overlapped by the Purcell strata of the Lewis thrust sheet. Along the lower or more northeasterly of these faults overturned Kootenay or lower Blairmore strata lie above overturned middle Blairmore strata between Goat Creek and Carbondale River. Between the north and south branches of Goat Creek, Kootenay strata that appear to comprise part of this fault plate overlap the upright strata of the northeastern limb of the syncline and lie above overturned Blairmore strata of the overturned limb of the northeastern syncline. Similarly, south of Carbondale River, the overturned strata of this fault plate can be followed across the adjacent upright limb of the syncline on to the overturned limb of the northeastern syncline at Mount McCarty. There they constitute the upper of two overturned fault plates lying beneath the Purcell strata of the Lewis thrust sheet. The overlapping relationships of this fault plate relative to adjacent structures on the northeast indicate that it has been detached from the overturned southwest limb of the syncline along the fault at its base. This implies that the plate has been displaced to the northeast relative to underlying strata and that the sense of displacement along the fault at its base is opposed to that inferred for the fault cutting Crowsnest and Alberta strata in the same fold limb. It would appear that the fault along the base of the overturned Kootenay and Blairmore sequence developed in response to 'drag' along the base of the Lewis thrust sheet during its relative eastward and northeastward translation. The stratigraphic sequence across the fault is evidently an expression of the fact that the fault developed across strata that had previously been rotated into an overturned position during folding and that dipped to the southwest more steeply than the fault. These concepts form the basis for the interpretation illustrated in sections A-B and C-D.

The highest or most southwesterly of the faults in the southwestern syncline is overlain by Rocky Mountain and Rundle strata that appear to be overturned to the northeast and north. These Palaeozoic strata form a fault plate apparently comparable to the one lying below them. This fault plate is overlapped by Purcell strata of the Lewis thrust sheet between South Lost Creek and Carbondale River and eastward from the vicinity of Macdonald Creek. It also appears to have developed in response to "drag" along the base of the Lewis thrust sheet across the steeply dipping overturned sequence of the southwest limb of the syncline.

Relationships of the Structure to the Lewis Thrust Sheet

The structural relationships between the Carbondale River-Goat Creek structure and the Lewis thrust sheet are of considerable importance in regional structural interpretation. They must be considered if the path of the Lewis Thrust Fault is to be determined and, therefore, are important in estimations of the displacement along the Lewis thrust and in determinations of its relative age in the structural development of this part of the Rocky Mountains.

From the overlapping relationships between the Purcell strata of the Lewis thrust sheet and the three fold limbs in the Carbondale River-Goat Creek structure it is obvious that the latter have been overridden by the Lewis thrust sheet. Furthermore, the nature of this structural overlap suggests that the Lewis thrust has truncated the fault plates and overturned folds of the Carbondale River-Goat Creek structure. This implies that the Carbondale River-Goat Creek structure developed prior to the movement of the Lewis thrust sheet over this part of the area but that its form was modified as a result of movement along the Lewis thrust.

The stratigraphic succession exposed within the Carbondale River-Goat Creek structure spans the interval from the top of the Rundle Group to the base of the Belly River Formation. These strata occupy a position immediately below the Purcell sequence of the Lewis thrust sheet. To the northwest and the southwest, where the Purcell strata overlap the Carbondale River-Goat Creek structure, this position is occupied by upper Belly River strata. To the southwest, Alberta and lower Belly River strata occupy this same position in windows through the Lewis thrust sheet along Haig Brook (Norris, 1959a) and Cate Creek. Strata in the Carbondale River-Goat Creek structure represent lower stratigraphic horizons than those immediately below the Lewis thrust in the windows to the southwest and the question arises as to whether the Carbondale River-Goat Creek structure lies structurally above or below the Alberta and Belly River strata in the windows.

Available data indicate that the Clark Range salient of the Lewis thrust sheet has been displaced to the northeast relative to underlying strata. If the Carbondale River-Goat Creek structure lies structurally above the Alberta and Belly River strata of the Haig Brook and Cate Creek windows, it must have been displaced from a position southwest of the windows to its present position northeast of them. This implies that the Carbondale River-Goat Creek structure has been detached along a fault that marks its base and that merges with the Lewis Thrust Fault beneath Clark and Flathead Ranges, and that the structure has undergone a relative northeastward displacement of at least 10 miles. The Carbondale River-Goat Creek structure would thus constitute a northeastern part of the Lewis thrust sheet which has been overridden, along a thrust fault splay extending up from the Lewis thrust, by Purcell strata that comprise a more southwesterly part of the thrust sheet. On the other hand, if the Carbondale River-Goat Creek structure lies structurally below the Alberta and Belly River strata of the Haig Brook and Cate Creek windows, the path of the Lewis Thrust Fault must fall in the stratigraphic succession towards the northeast, from the upper part of the Alberta Group at least to the Kootenay Formation. This implies that the Lewis thrust sheet has truncated and overlapped structures that had developed in front of it.

The available data indicate to the writer that the Carbondale River-Goat Creek structure developed in front of and below the Lewis thrust and that it has subsequently been overridden by the Lewis thrust sheet. A similar relationship has been implied from an interpretation of structures in the adjacent Carbondale River map-area (Norris, 1959a, section C-D).

The thicknesses and lithofacies of Kootenay and Blairmore strata in the Carbondale River-Goat Creek structure are closely comparable to those in the underlying Coleman fault plate but, as indicated in the discussion of the stratigraphy, differ markedly from those in the overlying thrust sheet. These relationships indicate that different parts of the original sedimentary basin occur in juxtaposition across the fault at the base of the Purcell strata that marks the upper limit of the Carbondale River-Goat Creek structure. They also indicate that there has not been a comparable lateral shortening of the original sedimentary basin between the Carbondale River-Goat Creek structure and the Coleman fault plate.

The stratigraphic relationships across many of the faults in the Carbondale River-Goat Creek structure indicate that these faults have developed across beds that had been rotated into steeply dipping and overturned positions prior to displacement along these faults. These stratigraphic relationships support the contention that, in this region, displacement along the Lewis thrust and some of the related faults has occurred, in part, subsequent to the development of the folds of the Carbondale River-Goat Creek structure. The stratigraphic relationships along the northeast side of the Carbondale River-Goat Creek structure, although they do not preclude it, do not support the existence of an important fault between that structure and the Coleman fault plate.

The Carbondale River-Goat Creek structure appears to have originated as a group of simple, northwest-trending folds and thrust plates beyond the periphery of the advancing Lewis thrust sheet. It is suggested that these relatively simple structures formed along the northwest flank of the Clark Range salient in response to differential movement within the underlying beds induced by the relative northeastward translation of the Clark Range salient over them. Continued displacement along the Lewis Thrust Fault modified the shape of the folds and faults and resulted in increased structural relief across them, and, finally, in the translation of the Lewis thrust sheet over them. The folds have been markedly attenuated in the direction of displacement along the Lewis Thrust Fault and this attenuation appears to be most pronounced southeast of the North Kootenay Pass monocline beneath the thicker part of the thrust sheet, which comprises the Clark Range salient. The general shape of the Carbondale River-Goat Creek structure essentially conforms to the base of the Lewis thrust sheet. Attenuation of the structure is least pronounced northwest of the North Kootenay Pass monocline beneath the thinner part of the thrust sheet, which comprises the Flathead Range segment. A prominent re-entrant in the Carbondale River-Goat Creek structure occurs beneath a comparable re-entrant in the overlying Lewis thrust sheet indicating that the shape of the structure has been modified by deformation related to the younger of the two kinematic patterns involved in the emplacement of the Lewis thrust sheet. The north end of the Carbondale River-Goat Creek structure appears to have been rotated toward the east during the relative eastward displacement of the Flathead Range segment of the Lewis thrust sheet. The present shape of the Carbondale River-Goat Creek structure can be attributed to the attenuation, partial rotation, and truncation of initially simple folds and thrust plates as a result of translation of part of the Lewis thrust sheet over them, first toward the northeast and then toward the east.

Summary

The Lewis thrust and related faults and folds have resulted in a horizontal contraction and vertical thickening of the stratigraphic succession exposed in Flathead map-area. The shape and orientation of these structures reflect two kinematic patterns that have been superimposed. The older of these involved a relative northeastward displacement of successively higher structural units and the younger a relative eastward displacement of successively higher structural units.

Most of the displacement of the Lewis thrust sheet appears to have conformed to the older pattern. The Lewis thrust sheet appears to have been displaced more than 32 miles to the northeast relative to underlying strata. A northwest-facing, transverse monocline within the thrust sheet extends from the vicinity of Carbondale River to the south end of the Fernie basin and is parallel with the older kinematic pattern. This monocline marks the position of a transverse 'step' along the base of the thrust sheet where the Lewis Thrust Fault changes stratigraphic position relative to overlying beds from relatively low stratigraphic horizons on the southeast to relatively high stratigraphic horizons on the northwest. The thicker part of the thrust sheet to the southeast of the monocline is characterized by broad gentle folds. In contrast, the part lying to the northwest includes tight faulted folds. The path of the Lewis Thrust Fault through the stratigraphic sequence, along a northeast-trending line through the southwest corner of the map-area, indicates that the fault has developed across pre-existing structures and that these have been truncated along it. The Lewis thrust sheet appears to have discordantly overridden folds and fault plates that developed in front of it. These structures have undergone additional deformation during the movement of the Lewis thrust sheet over them and now occupy a position beneath the thrust sheet along the northwest flank of the Clark Range salient.

The Squaw-Howell thrust fault and related structures have developed in superposition across the trend of the older structures. They mark a relative eastward displacement of successively higher structural units and conform to a second, younger, kinematic pattern that dominated the structural development of the Rocky Mountains north of Flathead map-area. Older structures have been offset and, in part, rotated during this phase of the deformation. In the southwestern part of the map-area the Lewis thrust appears to have been offset by the Howell fault and along it a western part of the Lewis thrust sheet together with Upper Cretaceous strata beneath it overlie a more easterly part of the Lewis thrust sheet.

The Flathead Fault and Related Structures

The occurrence of an important fault between Flathead Valley and the western part of Clark Range has been known for more than 50 years (Willis, 1902, pp. 343-344), but there has been much speculation as to its nature.

Data assembled during the present investigation indicate that the Flathead fault is a southwest-dipping gravity fault, and that it extends across the Flathead map-area from the west side of Clark Range at Cate Creek to the east side of the Fernie basin east of McEvoy Creek. The Flathead fault is a tectonic feature of regional dimensions. As shown in Figure 1, the structure can be traced for almost 150 miles from south of Marias Pass in Montana to north of Crowsnest Pass in British Columbia. The maximum stratigraphic separation across the fault is about 20,000 feet. Within the map-area, a complex of minor gravity faults, including antithetic faults that delimit local asymmetric graben structures, are related to the

Flathead fault. Within the Rocky Mountains of southern Canada the Flathead fault constitutes the most prominent member of a group of southwest-dipping gravity faults whose maximum stratigraphic separations lie within the range between a few thousand feet and more than 20,000 feet. These faults cut across older thrust and fold structures. The deformation along them results in an overall horizontal extension and vertical thinning of a succession of strata that had previously been tectonically shortened and thickened.

Structural Relationships Between Clark and Macdonald Ranges

The Flathead fault extends along the west side of Clark Range from the south boundary of the map-area, south of Cate Creek, to the south end of Flathead Range near Flathead. Near Cate Creek at least two other roughly parallel faults occur immediately southwest of it. The zone embracing these three faults marks the structural division between Clark Range and Flathead Valley and is termed the Flathead fault zone. Exposures within the Flathead fault zone are scarce in the map-area but more common on a ridge immediately to the south.

The most easterly of the three faults, the Flathead fault, appears to be relatively steep but its direction of dip has not been accurately determined. On the ridge south of Cate Creek, Kintla strata on the west lie adjacent to Waterton strata on the east. North of Cate Creek, Purcell lava lies on the west side against Waterton strata on the east. The stratigraphic separation across the fault is about 6,000 feet, and the southwest side is apparently downthrown relative to the northeast side. The distribution of bedrock exposures on either side of the fault indicates that it truncates both the Lewis thrust sheet and the underlying Upper Cretaceous sequence.

The central fault within the zone also appears to dip steeply. Fairholme, Alexo, and Palliser strata lie next to Purcell strata along it. Palaeozoic strata are exposed on the ridge immediately south of the south boundary of the map-area and along the north side of the valley of Cate Creek. Brecciation and intense fracturing are evident in all exposures. Individual breccia zones up to 40 feet thick strike north and northwest and dip steeply to the west and southwest. The stratigraphic separation across this fault is about 4,000 feet and the west side appears to be displaced down relative to the east side. The combined stratigraphic separation across this fault and the Flathead fault is about 10,000 feet.

Along the third and most westerly fault within the zone, indurated Kishenehn strata lie next to Palliser, Alexo, and Fairholme strata. The coarse detrital rocks of the Kishenehn Formation are highly fractured, and in part brecciated, near the fault. Blairmore and Kootenay strata exposed on the west side of Flathead Valley dip east toward the fault zone. Assuming that the continuation of these strata can be projected across the valley to a position beneath the Kishenehn Formation (*see* section I-J), the stratigraphic separation across this fault is about 10,000 feet, and the west side is apparently downthrown relative to the east side. The total stratigraphic separation across the three faults forming the Flathead fault zone is thus about 20,000 feet, with apparent downthrow to the west.

Rocks of the Kishenehn Formation exposed along the west side of Clark Range adjacent to Cate Creek provide additional information on the character of the Flathead fault zone. As indicated above, the Kishenehn Formation at this locality consists of coarse detritus that underwent only a very limited amount of transport and was derived from Palaeozoic rocks that lay to the east of the Flathead fault zone, above the Purcell strata of Clark Range. This detritus appears to overlie Kootenay and Blairmore strata unconformably and these relationships imply the existence of several thousands of feet of structural relief between Clark Range and Flathead Valley during Kishenehn time. The fabric of the Kishenehn rocks indicates that they formed as fanglomerates that were deposited along the base of a scarp on the downthrown side of the Flathead fault zone. During the deposition of these fanglomerates, when the stratigraphic separation across the fault zone was in the order of a few thousand feet, the stratification must have dipped southwestward, toward the downthrown block. At present the stratigraphic separation across the fault zone is about 20,000 feet and stratification in the Kishenehn Formation, both at this locality and in the region to the south (MacKenzie, 1916, p. 36), dips to the east and northeast toward the Flathead fault.

These relationships indicate that the Flathead fault and the two faults lying immediately southwest of it are southwest-dipping gravity faults and that a fault block embracing Macdonald Range and Flathead Valley has been downthrown more than 20,000 feet and tilted toward the northeast relative to the strata of Clark Range. A physiographic depression formed along the northeastern edge of the downthrown block during the initial stages of fault displacement and was the site of deposition of the coarse detritus of the Kishenehn Formation derived from the upthrown block. This coarse detritus formed fanglomerates that were downthrown and tilted toward the northeast during recurrent displacement along the Flathead fault zone.

Flathead Valley Graben

In the central and southern parts of the area the Flathead fault on the northeast and the Shepp fault on the southwest bound an asymmetrical graben that extends from near McLatchie Creek to beyond the south boundary of the map-area. This structure, termed the Flathead Valley graben, has formed along a curved segment of the Flathead fault. Along the southwest side of Clark Range the Flathead fault strikes north and northwest; along the south end of Flathead Range it strikes west; and along the west side of Taylor Range it strikes northwest (Map 1154A). Within this interval the Shepp fault, an antithetic east- and northeast-dipping gravity fault, is also convex toward the northeast and consequently the entire graben is arcuate and convex toward the northeast.

The curvature of the Flathead Valley graben implies that in addition to the northeast-southwest extension of the region between the Shepp and Flathead faults along the west side of Clark Range there is a left-hand strike slip on the Flathead fault that has resulted in north-south extension across the northern part of the graben. The North Kootenay Pass monocline can be traced across the graben and provides a means of measuring the magnitude of this component (*see* Fig. 11).

The offset across the Shepp fault zone is, on the other hand, right handed. This right-hand offset is considerably less than the left-hand offset across the Flathead fault and the total resultant offset between the Macdonald block southwest of the Shepp fault and the block northeast of the Flathead fault, disregarding the graben, is left-handed but not large. Thus, although there is probably some left-hand strike slip along the Flathead fault between Cate Creek and the vicinity of North Kootenay Pass, this component is relatively small compared to the dip-slip component, and the Flathead fault is fundamentally a gravity fault rather than a strike-slip or wrench fault. Indeed the strike-slip component is probably local and due to changes in strike along the Flathead fault (*see* Fig. 1). South of Packhorse Peak the fault strikes northwest and displacement has presumably been downward to the southwest. North of Packhorse Peak, along the west side of the graben, the strike of the Flathead fault swings to north-northeast thus introducing a left-hand strike-slip component. At the north end of the graben, along the south end of Flathead Range where the Flathead fault strikes west the strike-slip component is presumably right handed.

The Shepp fault and several smaller antithetic faults within the Flathead Valley graben (*see* Fig. 11) indicate that there has been extension in the part of the Flathead fault block lying within the recurved part of the Flathead fault. This extension suggests that the Flathead fault there is concave in cross-section. The antithetic faults are inferred to have provided adjustment to the downward movement of the Flathead fault block along the concave surface of the Flathead fault.

Strata within the Flathead Valley graben are cut by a series of smaller gravity faults that produce a complex of small fault blocks. Conspicuous changes in structural relief occur along the strike of the graben as a result of displacement along these smaller faults and these changes serve to outline three segments within the graben. A southern segment is structurally low and extends from near Pollock Creek to beyond the south boundary of the area. A central segment is structurally high and lies between Pollock Creek and Pincher Creek. A northern segment is structurally low and embraces the east-west trending part of the graben.

Southern Segment

The structural pattern within this segment is comparatively simple. The fault blocks within this part of the graben dip southeast transverse to the north- and northwest-striking Shepp and Flathead faults. The structural relief across the graben increases northward, as a result of an increase in stratigraphic separation across the Shepp fault from less than 1,000 feet at the south boundary of the area to about 2,500 feet north of Shepp Creek. Along the opposite side of the graben the stratigraphic separation across the Flathead fault zone decreases northward from about 20,000 feet near Cate Creek to less than 10,000 feet near Pollock Creek. This decrease is at least partly due to the occurrence of one or more southeast-dipping antithetic faults that cross the graben and merge with the Flathead fault north of Shepp Creek. The antithetic faults also mark a zone within which the structural elevation of fault blocks increases northward toward the central segment of the graben.

Central Segment

The central segment is underlain mainly by Palaeozoic rocks that represent the downthrown structural equivalent of the northeast end of the Macdonald dome. A longitudinal fault marked by an apparent downthrow to the southwest extends along the graben from Pollock Creek to near Flathead and divides it into northeastern and southwestern parts (*see* Fig. 11). In contrast with the northern and southern segments of the graben, where the structurally lowest blocks lie near the Flathead fault, in the central segment the structurally lowest block occurs near the Shepp fault.

Both the Flathead and Shepp faults can be located accurately along the margins of the central segment of the graben. The Flathead fault is convex toward the east and its dip is relatively shallow. Graphic calculations based on the surface trace 2 miles south of Hollebeke Mountain indicate a dip of 40 degrees. At this locality Rundle, Banff, and Palliser strata in the hanging-wall lie next to Siyeh strata. The Shepp fault is well exposed on either side of an unnamed east-flowing creek 2 miles north of Shepp Creek. There it strikes north and the dip changes from about 50°E at higher levels to 80°E near the level of the creek. Livingstone strata occur in the hanging-wall and Palliser and Fairholme strata in the foot-wall.

In the northeastern part of the central segment of the graben there is a progressive increase in structural elevation of blocks bounded by northeast-trending normal faults up to a block lying 2 miles south of Hollebeke Mountain. North-dipping strata lying north of this block represent the downthrown segment of the North Kootenay Pass monocline. North-dipping antithetic gravity faults cutting these strata are due to north-south extension across the northern segment of the graben. In contrast, strata south of the structurally highest block are cut by southwest-dipping antithetic faults caused by a general westerly extension across the southern segment of the graben. Thus the structural relief along the central segment of the graben is partly inherited from the North Kootenay Pass monocline and partly due to the curvature in the strike of the Flathead fault.

Northern Segment

The structural relations across what is here termed the northern segment of the Flathead Valley graben have been the subject of several widely divergent interpretations, particularly with regard to the character of the fault that crosses the southern ends of Flathead and Taylor Ranges (Dowling, 1914; Béthune, 1936; Newmarch, 1953; Henderson and Douglas, 1954). This fault is marked by an apparent downthrow to the south and separates Fernie, Kootenay, and Blairmore strata in the vicinity of Flathead from the Palaeozoic and Precambrian strata of Taylor and Flathead Ranges.

The fault is obscured by surficial deposits throughout the entire interval from the west flank of Clark Range to the west flank of Taylor Range and its position can be located accurately at only a few points. West of Squaw Creek, in the bed of a small south-flowing creek, the grey beds of the Fernie Group lie adjacent to Etherington strata along the fault, and there is an apparent downthrow to the south. Although, as has been pointed out by Béthune (1936, p. 167), a well-developed northeast-striking cleavage in the grey beds at this locality can hardly be related to a south-dipping normal fault, it does not follow that this cleavage indicates that the Palaeozoic strata have been thrust over the grey beds and that the fault is therefore a west-dipping thrust fault. Instead, the cleavage may be related to structures in the Squaw thrust plate that have been offset along a south-dipping gravity fault. The occurrence of exposures of west-dipping Kootenay strata a short distance to the east suggests that the Fernie strata do, in fact, lie above a west-dipping thrust fault that is truncated against the east-west trending fault between the grey beds and the Etherington strata.

North of Flathead, along the steep south slope of Flathead Range, the position of the east-west trending part of the fault can be located within close limits from exposures and the topographic detail discernible in vertical aerial photographs. The trace of the fault is somewhat sinuous along this slope. This could result from either a relatively planar, south-dipping gravity fault truncating the south end of Flathead Range or from a tightly folded and sharply discordant thrust fault that extends under Flathead Range and over the Mesozoic strata exposed in Flathead Valley. East of Squaw Creek a well-developed fracture cleavage occurs in Palaeozoic limestones north of the fault and in lower Blairmore sandstones south of the fault. At both localities the fracture cleavage strikes approximately east-west and dips south, suggesting that the fault also dips south.

Fernie, Kootenay, and Blairmore strata exposed in the vicinity of Flathead are characterized by thicknesses and lithofacies typical of the sequence along the east side of the Fernie basin rather than the sequence beneath the Lewis Thrust Fault in the Foothills. The facies of the grey beds as exposed in the north bank of Flathead River about a mile west of Squaw Creek, and in the bed of the unnamed south-flowing creek to the west, is similar to that along the east side of the Fernie basin from Lodgepole Creek to the north boundary of the area, and to that on Coal Mountain. This lithofacies comprises grey calcareous siltstone, shale, fine-grained sandstone, and sandy limestone. It contrasts with that immediately to the east of and below the Lewis thrust sheet in Carbondale River map-area described by Frebold (1957, p. 74) as consisting of brown shale, silty shale, and calcareous sandstone with pelecypods, belemnoids, and ammonoids. These two facies appear to represent the "shaly facies" and the "facies of the *Corbula munda* and *Gryphea* beds" respectively, of Frebold (op. cit., p. 20), which occur to the west and east respectively of the Lewis thrust at Crowsnest Pass. Béthune (1936, p. 164) gave a description of an incomplete section of Kootenay strata at Flathead, based on data obtained from bore-holes, where the formation is at least 870 feet thick. This thickness is closer to that obtained from the east side of the Fernie basin within the Lewis thrust sheet than that beneath the Lewis thrust sheet in the western Foothills. Ninety feet of conglomerate overlain by red shales with sandy interbeds was reported from bore-holes near Flathead (Béthune, 1936, p. 164). The thickness of the conglomerate and the occurrence of red shale in association with it are features that characterize the basal part of the Blairmore Group along the eastern side of the Fernie basin. In contrast, beneath the Lewis thrust sheet in the

Foothills, the basal conglomerate of the Blairmore Group is about 20 to 35 feet thick (Clow and Crockford, 1951, p. 28) and red shale is typically absent in the lower part of the sequence.

The available structural data relating to the east-west fault along the south end of Flathead and Taylor Ranges, supplemented by a consideration of the tectonic significance of the Mesozoic lithofacies near Flathead, substantiate the interpretation proposed by Dowling (1914, p. 51) that the fault is a south-dipping gravity fault and is a segment of the Flathead fault. Mesozoic strata lying south of it represent part of the Lewis thrust sheet rather than foot-wall rocks exposed in a window through the Lewis thrust.

Blairmore and Kootenay strata exposed north of Flathead form an east-striking asymmetric syncline. Their proximity to Palaeozoic strata of the central segment of the graben exposed south of Flathead River and Pincher Creek indicates that a fault, concealed by surficial deposits south of Flathead, separates them from these Palaeozoic strata. This fault is inferred to be a north-dipping normal fault. They may also be downthrown along a northeast-dipping normal fault which may be inferred to lie beneath the surficial deposits in the vicinity of Squaw Creek. The block of Blairmore and Kootenay strata forming the northern segment of the Flathead Valley graben resembles a trapdoor structure in that the relative displacement along the faults bounding it increases from west to east as though the west end of the block were partly hinged.

Several north-striking faults in southern Flathead Range are marked by stratigraphic omissions and dip to the west, in part at least, more steeply than the beds they cut. These faults are inferred to be west-dipping gravity faults that are responsible, in part, for the progressive westward decrease in throw across the Flathead fault.

Structural Relationships Along the East Side of Fernie Basin

The Flathead fault marks the east boundary of the Fernie basin from Flathead River to the north boundary of the area. Within this interval there is a progressive decrease in displacement across the fault from more than 4,000 feet at the northeast end of the Flathead Valley graben to about 2,500 feet 3 miles north of Flathead River and 1,000 feet at the west boundary of the area 6 miles north of the river. The northward decrease in displacement along the fault is accompanied by a progressive decrease in its dip. Graphic calculations indicate dips of between 50 and 60 degrees within the first 4 miles north of Flathead River and 40 degrees or less near the northwest corner of the map-area. Both the decrease in dip and the decrease in displacement along the fault may indicate that part of the displacement between the Flathead fault block and the eastern block has been accommodated by interstratal slip within the west-dipping Mesozoic sequence along the east side of the Fernie basin.

Along the east side of the Fernie basin the Flathead fault consistently truncates the fold and thrust structures of the Squaw thrust plate. Not all individual structural elements within the thrust plate can be correlated with structures on the downthrown, southwest side of the fault. The Squaw thrust and two thrusts lying west of it are thought to be represented by the faults on the downthrown side of the Flathead fault along McLatchie Creek valley. However, the prominent folds in the Squaw thrust plate are not evident there. This apparent discordance across the Flathead fault is believed to be due to a southward termination of many of the folds in the thrust plate against the Squaw thrust, and to the disharmonic structural relationships at the base of the Kootenay-Blairmore sequence. A progressive southward decrease in structural relief across the folds in the Squaw thrust plate is apparent in the region immediately north of the Flathead fault, and the development of disharmonic structures above the Palaeozoic sequence on incompetent Fernie shales has been considered in the discussion of the Fernie basin segment of the Lewis thrust sheet.

Gravity Faults in Macdonald and Clark Ranges

The Harvey Fault

The Harvey fault is a steep, southwest-dipping gravity fault in Macdonald Range, along the headwaters of Howell, Harvey, and Lodgepole Creeks. It truncates and offsets the complex Howell Creek structure and the southeast end of the Fernie basin (*see* Map 1154A). It is intimately related to the Flathead fault and is probably a splay from it. Within the map-area the maximum displacement across the Harvey fault is some 3,000 feet. The fault is relatively well exposed only along the southeast edge of the Fernie basin, north of Lodgepole Creek, where direction of dip and relative displacement can readily be determined. West of the map-area, within the Fernie basin, the displacement across the fault progressively decreases and the fault appears to die out a short distance beyond the boundary of the map-area.

Several minor northeast- and northwest-striking faults in the Macdonald dome along the headwaters of Harvey, Shepp, and McLatchie Creeks (*see* Plate VII) are closely related to the Harvey fault. The two northeast-striking faults terminate against the Harvey fault on the southwest. They are northwest-dipping gravity faults one of which has an antithetic fault and a small asymmetric graben associated with it. Displacement along them is, in part, responsible for the decrease in throw across the Harvey fault toward the northwest. The northwest-striking faults are minor gravity faults which occur in the downdropped block of the more southerly of the northeast-striking faults. The Harvey fault and the minor faults associated with it appear to be related to the change in curvature along the Flathead fault in the central part of the map-area. They are assumed to have developed in response to adjustments necessitated by the northeastward tilting of the strata of Macdonald Range along the Flathead fault and the curvature of the Flathead fault itself.

Faults in Northeastern Macdonald Range

Several gravity faults occur in the northeastern part of Macdonald Range. The fault surfaces are exposed locally and are steep and convex toward the downthrown block as shown in Plate VII. The two most prominent faults in this group dip to the south and southwest. The sense of displacement along them is the same as that of the Harvey and Flathead faults, and like the Harvey fault they are assumed to be structures that have provided local adjustment to the curvature of the Flathead fault.

The obvious convexity in the dip of some of these faults is noteworthy. It seems probable that some of these faults flattened to the point where they paralleled the bedding at higher stratigraphic levels and displacement along them resulted in monoclinal draping of the overlying beds. The transverse fold pattern along the east side of the Macdonald Range, shown in Figure 13, may reflect the presence of gravity faults at depth.

Faults in Clark Range

Two gravity faults have been mapped in Clark Range east of the Flathead fault near Packhorse Creek and St. Eloi Brook. Both faults have steep dips and, where they cut less steeply dipping beds, both are marked by the omission of part of the stratigraphic sequence. These faults are west-dipping and are related to the Flathead fault. The sense of displacement along them is the same as that along the Flathead fault, and one of them is a splay from it.

Summary

The Flathead fault is a west- and south-dipping gravity fault. It is a tectonic feature of regional significance in the central part of the Rocky Mountains of southern British Columbia and northern Montana. A physiographic depression lying along the west side of the fault and occupied by Flathead River contains Tertiary sediments that owe their origin to displacement along the Flathead fault. Within Flathead map-area this depression follows an asymmetric graben bounded on the east by the Flathead fault and on the west by the smaller antithetic Shepp fault. The Flathead fault and the system of smaller faults associated with it post-date structures developed during displacement of the Lewis thrust sheet. They have resulted in a series of fault blocks which have been differentially displaced vertically and tilted eastward. In contrast with the horizontal contraction and vertical thickening about north- and northwest-trending axes expressed in the thrust structures, the gravity fault structures indicate a horizontal extension and vertical thinning of this mantle about a northwest-trending regional axis. The throw across the Flathead fault is about 20,000 feet near the south boundary of the map-area suggesting that these structures probably persist to great depth.

Chapter IV

ECONOMIC GEOLOGY

Petroleum and Natural Gas

Although no wells have been drilled to test the petroleum and natural gas potential of the area, the results of drilling in nearby parts of the Foothills are encouraging. Commercial quantities of natural gas and gas-condensate have been discovered in Mississippian and Devonian rocks in the Pincher Creek and Waterton fields, and the general stratigraphic and structural characteristics of the reservoirs in those fields provide additional criteria for evaluating the prospects in Flathead area. The reservoir rocks comprise porous crystalline dolomite of the upper part of the Mississippian Livingstone Formation, and, in part of the Waterton field, Upper Devonian rocks. The reservoirs are structural culminations along the eastern edges of thrust sheets (Erdman, *et al.,* 1953; Fox, 1959). They occur beneath and to the east of the Lewis thrust sheet but to date no discoveries have been made within the sheet itself.

Reservoir Rocks

Lithofacies, and hence prospective reservoir conditions, differ significantly between the two principal structural subdivisions in the area, the Lewis thrust sheet and the Foothills. The Palaeozoic facies of the Foothills is not exposed in the map-area, and its characteristics in the subsurface there can only be deduced by interpolating between the Palaeozoic rocks of the Lewis thrust sheet and those exposed in Blairmore and Livingstone Ranges (Norris, 1955 and 1959a) and encountered in the Waterton and Pincher Creek fields.

Data for the evaluation of potential reservoir rocks in the Palaeozoic sequence of the Lewis thrust sheet have been discussed under stratigraphy of the area and are summarized here. Porous carbonate strata occur at several horizons, the more important of which are:

1. the massive medium-crystalline vuggy dolomite of the Cambrian Elko Formation,

2. the dark, fetid, medium- to coarse-crystalline bedded dolomite of the Borsato Formation in the Devonian Fairholme Group,

3. the massive, very coarse crystalline, vuggy dolomite of the Peechee Member of the Southesk Formation in the Devonian Fairholme Group,

4. the fetid, medium- to coarse-crystalline, bedded dolomites of the Grotto and Arcs Members of the Southesk Formation in the Devonian Fairholme Group,

5. the medium-crystalline dolomite and dolomite calcarenite of parts of the Livingstone Formation and the Loomis Member of the Mount Head Formation in the Mississippian Rundle Group,

6. the coarse-grained skeletal calcarenites of the Livingstone Formation, the Loomis and Carnarvon Members of the Mount Head Formation, and the Etherington Formation in the Mississippian Rundle Group.

The most promising of the porous strata appear to be the dolomites of the Peechee Member of the Southesk Formation in the Fairholme Group. In addition to its high porosity, this lithofacies forms discrete reef masses that are at least partly circumscribed by less porous and permeable strata of the Mount Hawk Formation. Porous horizons are less conspicuous in the Rundle Group. The medium-crystalline dolomite and dolomitic calcarenite lithofacies form a relatively small part of the Rundle Group, and though the skeletal calcarenites are much more abundant, they are generally characterized by a dense fine-crystalline matrix and occasionally by a coarse-crystalline cement that fills virtually all of the primary intergranular pores.

Porous marine clastic rocks occur in parts of the Mesozoic sequence: in the Spray River Formation, parts of the Fernie Group, and the Cardium Formation. Well-sorted porous sandstones also occur in the lower part of the Blairmore Group. Although these strata have not yielded commercial quantities of petroleum or natural gas in this region, they might be considered as possible reservoir rocks.

Prospective Structures

The Squaw Creek and Barnes anticlines lie above the Squaw fault in the Lewis thrust sheet. Pitch culminations occur in these folds due west of Centre Mountain and Flathead Pass respectively. The structural closure between the valley of Flathead River and the pitch culminations is a few thousand feet. Mount Head strata are exposed within the cores of the folds over the pitch culminations. The Livingstone Formation and probably most of the Fairholme Group occur above the Squaw fault within the culminations.

A northeast-trending structural culmination occurs in the Macdonald dome between Flathead River and McLatchie Creek (*see* Fig. 13). Fairholme strata are present in the subsurface beneath the dome. The dolomite lithofacies of the Peechee Member of the Southesk Formation occurs east of the dome on the west flank of Clark Range north of Pollock Creek and laterally equivalent beds at the headwaters of Harvey Creek comprise dense limestones of the Mount Hawk Formation. The western limit of the dolomite lithofacies may occur beneath the Macdonald dome.

In Clark Range, on Cate Creek, a window in the Lewis thrust marks a culmination in a northwest-striking anticline in the Lewis thrust sheet. It seems probable that this structural culmination is reflected in Palaeozoic strata of underlying thrust sheets. Another culmination occurs along this structure southwest of the map-area at Sage Creek and Palaeozoic strata were encountered beneath the Lewis thrust within this culmination in the Pacific-Atlantic Flathead No. 1 Well (Clark 1954). Although the gas from several seeps at this locality contains a light condensate and is combustible, gas encountered in the Livingstone Formation in the lower fault plate in the well is reported to be incombustible and to contain 69 per cent carbon dioxide (B.C. Dept. of Mines, 1956).

Palaeozoic strata may occur above the Coleman fault beneath the Carbondale River-Goat Creek structure in the northeastern part of the area. However, the eastern limit of Palaeozoic rocks in the Coleman fault plate at this locality cannot be delimited from surface data alone.

Coal

Coal seams of mineable thickness occur in the Kootenay Formation throughout the map-area, where extensive search for commercial deposits of coal took place during the early part of the twentieth century (Dowling, 1914). At a number of places coal seams were trenched and opened along adits, but these have subsequently caved and become overgrown.

Within Flathead area one or more coal seams generally occur in the Adanac Member of the Kootenay Formation, between the resistant sandstones of the Moose Mountain and Hillcrest Members, and several seams are commonly present in the recessive interval above the Hillcrest Member. Potential sites for strip mines may occur along the west side of the Fernie basin where the Kootenay Formation locally forms dipslopes. There are few exposures of the Kootenay strata that underlie parts of Flathead Valley and the prospects in this part of the area probably cannot be evaluated without exploratory drilling. Both the west side of the Fernie basin and Flathead Valley are more than 20 miles from the nearest railway and any evaluation of coal prospects in these areas must take into account this additional transportation cost.

Commercial production of coal from mines at Coal Mountain in the northern part of Flathead area began in 1908 and continued intermittently for 40 years (Norris, 1956). Norris has outlined some of the difficulties involved in underground mining at Coal Mountain and has described several sites that are apparently favourable for stripping operations.

Phosphate

Phosphatic sedimentary rocks occur at several horizons in the stratigraphic succession of Flathead map-area. Some of these beds have been exposed in prospect trenches and pits, probably during the course of a regional investigation of phosphate deposits in the southern part of the Canadian Rocky Mountains undertaken by the Consolidated Mining and Smelting Company during the period prior to 1935 (Telfer, 1933).

The stratigraphic distribution of phosphatic rocks in the Flathead area as established from the author's field observations and data presented by Telfer can be summarized as follows:

1. the lower part of the Banff-Exshaw sequence—oolitic and nodular phosphate rock,

2. the upper part of the Rocky Mountain Formation—nodular and oolitic phosphate rock, phosphatic shale, and phosphatic dolomite,

3. the base of the Spray River Formation—nodular phosphatic sandstone,

4. the base of the Fernie Group—nodular and oolitic phosphate rock and phosphatic shale,

5. the Rock Creek Member of the Fernie Group—phosphatic sandstone and phosphatic shale.

The phosphate deposits are all of low grade where they have been examined to date and no significant commercial production has been obtained from them.

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APPENDIX A

Stratigraphic Sections

Section 1

The upper part of the Altyn Formation is well exposed on the south side of St. Eloi Valley near the headwaters of St. Eloi Brook. The following description is based on the reconnaissance examination of exposures south of St. Eloi Brook at longitude 114°30′. The section is accessible from the British Columbia Forest Service road in Flathead Valley at the mouth of Pollock Creek by way of St. Eloi Valley.

Unit		Thickness (feet)	Height above base (feet)
	APPEKUNNY FORMATION		
18	Argillite and dolomitic argillite, medium green, massive beds 1 foot to 3 feet thick alternate with platy beds; weathers medium brown and greenish brown, platy to blocky; toward top becomes less dolomitic, thin beds of arenaceous (very coarse quartz sand) argillite and coarse-grained sandstones and pebble conglomerates occur locally in upper part; first prominent, coarse-grained, white quartzite bands occur 335 feet above base	335.0	1,754.0
	Measured thickness of Appekunny Formation	335.0	
	ALTYN FORMATION		
	Upper Part		
17	Dolomite, argillaceous, medium grey and medium greenish grey, dull reddish brown in zones 10 to 30 feet thick, sparse elliptical 'concretions', fine-crystalline, beds 1 inch to 4 inches thick: weathers light yellowish brown, in part light greenish brown, locally dull red; top of highest red dolomite is marked by a slight recessive zone with green dolomitic argillites of Appekunny above; contact transitional	335.0	1,419.0
16	Dolomite, argillaceous, dull red, fine-crystalline, with light grey grey-weathering, elliptical 'concretions' 1 inch thick and 4 inches long; weathers dull red, platy. This unit is the lowest bed of red dolomite	4.0	1,084.0
15	Limestone, and dolomitic limestone, argillaceous (?), fine-crystalline, beds $\frac{1}{2}$ inch thick near base, 2 to 3 inches thick near top; elliptical, grey-weathering 'concretions' 1 inch thick and 6 inches long elongated parallel with bedding, local fine textural lamination is continuous through 'concretions' with spacing of laminae increasing abruptly at their periphery to give closer spacing in matrix and wider spacing in 'concretions'; beds pinch and swell; weathers light yellowish brown, platy, cliff-forming	305.0	1,080.0

Unit No.		Thickness (feet)	Height above base (feet)
	UPPER PART OF ALTYN FORMATION—*Continued*		
14	Argillite, black, colour-laminated in part, ⅛-inch laminae, becomes dark grey toward top, grades into overlying unit, sharply defined against underlying unit; weathers black to dark grey at base, medium grey at top, platy	50.0	775.0
13	Limestone, medium grey, fine-crystalline, abundant elliptical 'concretions' 2 inches thick and 6 inches long; weathers light grey, beds 2 feet to 4 inches thick with faint textural lamination that passes through 'concretions' and is compressed adjacent to them; weathers light yellowish brown, platy	60.0	725.0
12	Limestone, medium grey, fine-crystalline, arenaceous (medium-grained quartz sand), beds 1 inch to 4 inches thick; laminated on abundance and size of quartz; weathers medium brown with gritty surface, blocky	15.0	665.0
11	Limestone, medium grey, fine-crystalline, angular quartz sand locally; weathers to banded light grey and light yellowish brown with surface lamination; a few grey-weathering elliptical 'concretions' locally	55.0	650.0
	Thickness of Upper Part	824.0	
	Lower Part		
10	Limestone, argillaceous, medium to dark grey, fine-crystalline, ⅛-inch colour laminations; weathers medium grey, fissile, recessive	92.0	595.0
9	Limestone, medium grey, very fine-crystalline, beds 1 inch to 3 inches thick; weathers light grey, platy	9.0	503.0
8	Argillite, black beds 3 to 5 feet thick intercalated with medium grey limestone that weathers banded yellowish brown and grey	27.0	494.0
7	Covered (debris is platy, medium grey-weathering limestone)	74.0	467.0
6	Argillite, dark grey to black, slightly calcareous, fine colour laminations; weathers dark grey, fissile, recessive	80.0	393.0
5	Argillite, and argillaceous dolomite, medium to dark grey, a few 1-inch limestone interbeds, very thin bedded; weathers uniform medium yellowish brown, platy	145.0	313.0
4	Limestone, and argillite, dolomitic, alternating 20- to 30-foot units, lithologic detail as in underlying two units	80.0	168.0
3	Limestone, dark grey, fine-crystalline, beds 1 inch to 3 inches thick; weathers medium blue-grey banded with yellow-brown, surface laminations, platy	28.0	88.0
2	Argillite, black, gradational into fine-crystalline dolomite; weathers medium brown, fissile	30.0	60.0
	Thickness of Lower Part	565.0	
	Total thickness of Altyn Formation	1,389.0	
	WATERTON FORMATION		
1	Limestone, medium grey, fine-crystalline, beds 1 inch thick; weathers to distinct banded, light yellowish brown and light grey, platy, prominent	30.0	30.0
	Measured thickness of Waterton Formation	30.0	
	Base of continuous exposure, underlying beds disturbed.		

Section 2

The Grinnell Formation is almost completely exposed at the headwaters of Pollock Creek. The following section, measured at this locality, lies 2½ miles due east of Flathead. It is accessible from Flathead by way of the steep road to the British Columbia Forest Service 'Pollock Lookout', which is 0.75 mile southwest of the section.

Unit No.		Thickness (feet)	Height above base (feet)
	SIYEH FORMATION		
38	Argillite, black and dark grey, siliceous, platy	1.0	413.0
37	Argillite, dolomitic, light greyish green, platy; weathers light brownish yellow, platy, recessive	8.0	412.0
36	Quartzite, white, medium-grained, flecked with limonite, beds 1 inch to 4 inches thick, with partings of light greyish green argillite; weathers light grey, platy to flaggy	1.5	404.0
35	Argillite, dolomitic, banded and laminated, black and light greyish green, platy, a few medium-grained quartzite beds less than 2 inches thick; weathers medium grey, platy	7.5	402.5
	Measured thickness of Siyeh Formation	18.0	
	GRINNELL FORMATION		
34	Quartzite, white and very light green, coarse-grained, beds 2 to 12 inches thick; weathers light grey, blocky to flaggy, prominent...	6.0	395.0
33	Sandstone, quartzitic, medium green, coarse-grained, red in irregular patches, beds poorly defined, 2 to 6 inches thick; weathers medium greenish grey, platy to flaggy	7.0	389.0
32	Quartzite, white, in part streaked red and light green, coarse-grained, zones of quartzitic sandstone and thin green argillitic partings, crossbedding locally, beds 3 to 18 inches thick; weathers light grey to white, blocky	12.0	382.0
31	Argillite, light green, rubbly, irregular channeled upper surface with quartzite fill	1.5	370.0
30	Quartzite, white, coarse-grained; weathers white, blocky	2.0	368.5
29	Argillite, light green with red patches; weathers recessive, rubbly, light green and red	2.5	366.5
28	Quartzite, white and very light green, coarse-grained, beds 4 to 10 inches thick; weathers white and light green, blocky	4.0	364.0
27	Quartzite, hematitic, red, streaked with white, coarse-grained, scattered red argillite pebbles; beds 4 to 8 inches thick; weathers red, flaggy, prominent	2.5	360.0
26	Covered (red quartzite and red argillite float)	15.0	357.5
25	Quartzite, white and very light green, coarse-grained, beds 1 inch to 4 inches thick; weathers white, flaggy	1.5	342.5
24	Argillite, bright red, platy, locally with mud-cracked bedding surfaces, interbedded in 2- to 12-inch beds with quartzite, white, coarse-grained, ripple-marked and crossbedded, contains flat pebbles of red argillite	16.5	341.0
23	Argillite, bright red, platy, with occasional 1-inch to 3-inch interbeds of coarse-grained, white quartzite; weathers red, recessive	13.0	324.5
22	Siltstone, bright red, quartzitic and argillaceous, platy to massive	1.5	311.5
21	Argillite, bright red, platy to rubbly, recessive	4.5	310.0

Unit No.		Thickness (feet)	Height above base (feet)
	GRINNELL FORMATION—*Continued*		
20	Quartzite, white, streaked with bright red, coarse-grained, beds 2 to 6 inches thick; crossbedded; weathers white and red, flaggy, prominent	2.0	305.5
19	Argillite, bright red, platy to rubbly, recessive	4.0	303.5
18	Quartzite, white, coarse-grained, beds 1 inch to 3 inches thick, interbeds of red quartzitic sandstone, thin red argillite partings	2.0	299.5
17	Argillite, bright red, platy, with a few 6-inch interbeds of red siltstone, and 1- to 2-inch interbeds of coarse-grained, white quartzite; weathers red, rubbly to platy, recessive	18.0	297.5
16	Quartzite, white, coarse-grained, beds ½ inch to 2 inches thick, interbeds of red quartzitic sandstone; weathers light grey to white, prominent	1.0	279.5
15	Argillite, bright red, platy; weathers bright red, platy to rubbly	10.0	278.5
14	Quartzite, white and very light green, coarse-grained, beds 2 to 8 inches thick, red argillite pebbles on bedding surfaces, ripple-marked surfaces in part; weathers white and light green, flaggy, prominent	4.0	268.5
13	Argillite, bright red, platy, interbeds 2 to 8 inches thick of red siltstones and reddish grey, fine-grained, quartzitic sandstone with red argillite pebbles, interbeds 1 inch to 3 inches thick of coarse-grained, white quartzite with red argillite pebbles increasing in abundance toward base; weathers red, recessive	72.0	264.5
12	Quartzite, white, coarse-grained, with numerous flat pebbles of red argillite; red argillite interbeds throughout	5.0	192.5
11	Argillite, bright red, platy, with interbeds 1 inch to 3 inches thick of medium- to coarse-grained, white quartzite; weathers red, recessive	21.5	187.5
10	Quartzite, white, coarse-grained, with zones of red, hematitic, quartzitic sandstone at base; weathers white, blocky, prominent	1.0	166.0
9	Covered (red argillite float)	18.0	165.0
8	Argillite, bright red, platy, with interbeds 1 inch to 2 inches thick of medium-grained, white quartzite	2.0	147.0
7	Covered (red argillite float)	80.0	145.0
6	Argillite, bright red, with patches of light green, interbeds 4 to 12 inches thick of coarse-grained, white, quartzitic sandstone with numerous green and red argillite pebbles	15.0	65.0
5	Quartzite, white, coarse-grained, crossbedded, beds 2 to 6 inches thick, scattered red argillite pebbles in quartzite locally	2.0	50.0
4	Argillite, mottled, bright red and light green, platy	4.5	48.0
	Total thickness of Grinnell Formation	351.5	
	APPEKUNNY FORMATION		
3	Quartzite, light green with white patches and interbeds, coarse-grained, beds 3 to 12 inches thick, green and red argillite flat pebbles on bedding surfaces, mud-crack casts on some bedding surfaces; weathers light green, blocky to flaggy, prominent	7.0	43.5
2	Argillite, bright red, streaked and banded with light green, platy	3.5	36.5
1	Quartzite, light green and white, coarse-grained, with zones of coarse-grained quartzitic sandstone, crossbedded, beds 2 to 18 inches thick, zones of red and green argillite flat pebbles in quartzite; thin partings and interbeds of red argillite, locally streaked with green	33.0	33.0
	Measured thickness of Appekunny Formation	43.5	

Section 3

This section was measured on Hollebeke Mountain along the provincial boundary between the headwaters of Pollock Creek and Macdonald Creek. It is 1¼ miles southeast of North Kootenay Pass and can be reached from the British Columbia Forest Service road at Flathead townsite by way of the access road to the Forest Service 'Pollock Lookout'. From there it is 1¼ miles to the section.

Unit No.		Thickness (feet)	Height above base (feet)
	PURCELL LAVA		
56	Andesite, dark green, medium-grained, amygdules up to ½ inch in diameter of quartz and calcite	10.0	1,189.5
55	Pillow andesite (?), ellipsoidal- and spherical-weathering masses of light green, aphanitic, porphyritic (plagioclase) andesite, associated with volcanic breccia containing Siyeh argillite fragments and shard-like 'tachylyte' fragments; 'pillow structure' discernible only in weathered loose rock	25.0	1,179.5
	(Purcell descriptions based on examination of additional exposures 100 yards south of line of section along ridge.)		
	SIYEH FORMATION		
	Upper Part		
54	Argillite, bright red, papery, with mud-cracked bedding surfaces locally, a few thin red siltstone interbeds	21.0	1,154.5
53	Argillite, light green, platy, locally with ripple-marked bedding surfaces	16.0	1,133.5
52	Argillite, dolomitic, light green, beds platy and up to 2 inches thick; weathers light green, in part with brownish yellow patches	30.0	1,117.5
51	Argillite, green, bright red in irregular patches and bands, platy, abundant asymmetrical ripple-marks	8.5	1,087.5
50	Dolomite, argillaceous, and argillite, dolomitic, light green, platy; weathers light green	29.0	1,079.0
	Total thickness of Upper Part	104.5	
	Middle Part		
49	Dolomite, medium to light grey, fine-crystalline, beds platy, up to 4 inches thick; local delicate wisp-like laminations preserved in chert; weathers light brownish yellow, platy, with cherty laminations in relief locally	155.5	1,050.0
48	Dolomite, medium grey, very fine-crystalline, with discontinuous wisp-like arenaceous (coarse-grained, well-rounded quartz) bands up to 2 inches thick, beds poorly defined, 2 feet thick; weathers light brownish yellow, blocky	15.0	894.5
47	Dolomite, medium grey, fine-crystalline, platy to papery; weathers light yellow, platy	9.5	879.5
46	Dolomite, dark grey to black, fine-crystalline; beds poorly defined, 4 to 18 inches thick; weathers light brownish yellow, platy to blocky, with faint delicate surface lamination in relief	53.0	870.0
45	Dolomite, medium to dark grey, platy to papery, fine colour lamination; weathers light brownish yellow, platy	35.5	817.0
44	Covered	30.0	781.5

Unit No.		Thickness (feet)	Height above base (feet)
	MIDDLE PART OF SIYEH FORMATION—*Continued*		
43	Dolomite, black to dark grey, fine-crystalline, poorly defined beds 10 to 36 inches thick; weathers light brownish yellow, blocky to rubbly, with faint surface laminations in relief	66.0	751.5
42	Dolomite, black to dark grey, fine-crystalline, nodular and platy, beds poorly defined; a few 6- to 12-inch beds of non-platy dolomite; weathers light brownish yellow, rubbly	140.0	685.5
41	Dolomite, black to dark grey, fine-crystalline, poorly defined beds 6 to 18 inches thick form alternating zones of platy-weathering and blocky-weathering dolomite; weathers light brownish yellow, rubbly and platy to blocky, with faint surface lamination in relief	137.0	545.5
40	Dolomite, black to dark grey, very fine-crystalline, poorly defined beds 6 to 18 inches thick; weathers light brownish yellow, platy and rubbly	54.0	408.5
39	Dolomite, medium grey, fine-crystalline, beds 3 to 8 inches thick; a few black argillite partings less than 2 inches thick; weathers light brownish yellow; platy to blocky	22.0	354.5
38	Covered	14.5	332.5
37	Dolomite, light grey, fine-crystalline, beds 3 to 8 inches thick; weathers very light brownish yellow, platy to blocky	11.0	318.0
36	Covered (probably a diorite sill; fine-grained chloritized diorite abundant in float)	14.0	307.0
35	Limestone, dark grey, very fine-crystalline, mottled with ellipsoidal patches (parallel with bedding) of medium grey, fine-crystalline dolomite, beds poorly defined ¼ to 1 inch thick; weathers to blue-grey with light brownish yellow mottling, platy	10.0	293.0
34	Dolomite, dark grey, fine-crystalline, platy ¼- to 2-inch beds with a few beds 1 foot to 2 feet thick; weathers light brownish yellow	24.5	283.0
33	Dolomite, dark grey, fine-crystalline, finely laminated with carbonaceous matter; weathers light brownish yellow with distinct lamination on weathered surface	2.0	258.0
32	Dolomite, dark grey, fine-crystalline, beds ¼ to 1 inch thick; weathers light brownish yellow, platy	14.5	256.5
31	Dolomite, light grey, fine-crystalline; weathers light brownish yellow with faint surface lamination	2.0	242.0
30	Dolomite, medium to dark grey, very fine-crystalline, beds ½ inch to 2 inches thick; weathers light brown-yellow, platy	19.0	240.0
29	Sandstone, dolomitic, quartzose, coarse-grained with numerous flat pebbles of light grey, very fine-crystalline dolomite generally parallel with bedding	0.5	221.0
28	Dolomite, light grey, very fine-crystalline, beds ⅛ to ½ inch thick; weathers light yellow, platy	0.5	220.5
27	Dolomite, light grey, very fine-crystalline; weathers light brownish yellow, blocky	0.7	220.0
26	Argillite, silty, dark grey, finely laminated; weathers medium grey	0.3	219.3
25	Dolomite, light to medium grey, very fine-crystalline, beds ¼ to 1 inch thick; weathers light brownish yellow, platy	27.0	219.0
24	Dolomite, argillaceous, light grey, very fine-crystalline, beds ¼ inch thick; weathers light brownish yellow, platy	1.5	192.0
23	Argillite, dolomitic, light grey, platy; weathers light brownish yellow, rubbly, recessive	7.0	190.5

Unit No.		Thickness (feet)	Height above base (feet)
	MIDDLE PART OF SIYEH FORMATION—*Continued*		
22	Quartzite, dolomitic, light grey, coarse-grained, interbedded with 2-inch bands of light grey, fine-crystalline, arenaceous dolomite; crossbedding evident on weathered surface of dolomite; weathers light yellowish brown	1.0	183.5
21	Covered	12.0	182.5
20	Dolomite, light to medium grey, fine-crystalline, intraformational flat pebble conglomerate zones alternate with zones of arenaceous (coarse-grained quartz) dolomite; weathers light yellowish brown, massive	6.5	170.5
19	Dolomite, argillaceous, light grey, fine-crystalline beds ½ inch to 2 inches thick; weathers light brownish yellow, platy; zones of light grey argillite, weathering light grey	11.5	164.0
18	Covered	15.0	152.5
17	Dolomite, light grey, very fine-crystalline, beds ¼ inch to 3 inches thick; weathers light yellowish brown, thicker beds show faint lamination in relief on surface, platy; a few 3- to 6-inch interbeds of dark grey chert and dark grey siliceous, dense quartzite	42.0	137.5
16	Argillite, light greenish grey, dolomitic, fine colour lamination, platy; a few 6-inch interbeds of light grey, very fine-crystalline dolomite; argillite weathers greenish grey, platy; dolomite weathers light brownish yellow, blocky	8.0	95.5
15	Dolomite, dark grey, fine-crystalline, scattered irregular blebs of milky chert (less than 1 inch long), massive; weathers light brown	5.0	87.5
14	Dolomite, medium grey, very fine-crystalline, platy; weathers light yellowish brown, platy, recessive	11.0	82.5
13	Dolomite, dark grey, fine-crystalline, with irregular small lace-like blebs of white and milky chert, no bedding apparent; weathers light brown, chert in relief, with faint wavy concentric lamination etched into relief (stromatolitic)	10.0	71.5
12	Dolomite, light grey, very fine-crystalline, beds ½ to 1 inch thick; weathers light yellowish brown, platy	6.5	61.5
	Thickness of Middle Part	995.0	
	Lower Part		
11	Argillite, black, finely laminated with grey, platy	1.0	55.0
10	Dolomite, flat pebble, intraformational conglomerate; plates less than ½ inch thick of light grey, fine-crystalline dolomite, in medium grey, fine-crystalline dolomite matrix	1.0	54.0
9	Dolomite, light green, very fine-crystalline, beds ½ inch to 3 inches thick; weathers light yellowish brown, platy	9.0	53.0
8	Argillite, black, finely laminated with grey, platy	2.0	44.0
7	Dolomite, argillaceous, light green, very fine-crystalline, beds ½ inch to 3 inches thick; weathers light yellowish brown, platy, recessive; gradational in zones into green and black platy argillite	10.0	42.0
6	Dolomite, arenaceous (quartz sand), silty, light grey beds ½ inch to 2 inches thick with irregular bedding surfaces; weathers light yellowish brown, platy	3.0	32.0
5	Argillite, black, platy	1.0	29.0
	(Cross shallow syncline and anticline, and small fault.)		
4	Argillite, light green, no well-defined beds; weathers light green, platy to rubbly, recessive	4.0	28.0
	Thickness of Lower Part	31.0	
	Total thickness of Siyeh Formation	1,130.5	

Unit No.		Thickness (feet)	Height above base (feet)
	GRINNELL FORMATION		
3	Quartzite, white, medium- to coarse-grained, dense, siliceous, beds 24 inches thick; weathers white, blocky, prominent..................	5.0	24.0
	Grades upward into sandstone, quartzitic and calcareous, white, coarse-grained; weathers light brownish grey, blocky		
2	Covered (float consists primarily of medium- and coarse-grained white and light green quartzite)..	16.0	19.0
1	Quartzite, dark red mottled with white, coarse-grained, contains rounded ellipsoidal pebbles of red argillite up to 1 inch long, bedding surfaces irregular; beds 3 to 6 inches thick; weathers dark red, flaggy..	3.0	3.0
	Measured thickness of Grinnell Formation............................	24.0	

Section 5

Section was measured along the provincial boundary south from North Kootenay Pass. It is accessible by way of the North Kootenay Pass trail from roads at Flathead in British Columbia (2 miles) and along the Carbondale River in Alberta (4 miles). Overlain by Kintla Formation of Section 6 (*see* p. 152).

Unit No.		Thickness (feet)	Height above base (feet)
	SHEPPARD FORMATION		
24	Argillite, dull red, sandy, ½-inch layers interbedded with yellow-weathering dolomite; transitional to red sandy argillite at top and light grey dolomite at base..	4.0	155.0
23	Dolomite, light grey, fine-crystalline, beds well defined by ½-inch partings of argillaceous dolomite and argillite; weathers yellowish brown, platy...	10.0	151.0
22	Dolomite, alternating argillaceous and arenaceous, medium green, fine- to medium-crystalline, 6- to 18-inch units; weathers dull brownish green, shaly..	13.5	141.0
21	Dolomite, medium grey, fine-crystalline, beds 1 foot thick; weathers light yellowish brown, blocky.......................................	8.5	127.5
20	Argillite, dolomitic, dark grey, beds ¼ inch thick; weathers very dark reddish brown, shaly..	5.0	119.0
19	Dolomite, 4-inch layers of stromatolite-fragment conglomerate and 1-inch layers of argillite, medium to dark grey, beds locally laminated (stromatolitic?); weathers medium yellowish brown, shaly..	7.0	114.0
18	Dolomite, stromatolitic at base, gradational to fragmental at top, medium grey, medium-crystalline; weathers medium yellowish brown, blocky..	2.0	107.0
17	Sill, andesite?, medium green, medium-grained; small thin plagioclase laths; many calcite-filled vugs, some also containing chalcopyrite; disseminated chalcopyrite and some galena in part of overlying dolomite..	4.0	105.0
16	Argillite, slightly dolomitic, locally sandy, light green, beds 1 inch thick; weathers dull brownish green, blocky................................	6.0	101.0

Unit No.		Thickness (feet)	Height above base (feet)
	SHEPPARD FORMATION—*Continued*		
15	Shale, medium green, slightly calcareous, beds ¼ inch thick; weathers light green, shaly	3.0	95.0
14	Quartzite, and lithic granule conglomerate, slightly calcareous; andesite (?) fragments up to ¼ inch in diameter; light green, graded bedding in 4- to 6-inch beds; unit thickens and thins by 50 per cent within 50 feet; chalcopyrite in masses up to ½-inch in diameter; weathers medium brown, blocky	1.0	92.0
13	Argillite, slightly calcareous, medium green, beds ½ to 1 inch thick, laminated in part; weathers light to medium green, shaly	4.0	91.0
12	Quartzite, slightly calcareous, medium dull red with greenish interbands, fine-grained, locally ripple-marked, beds 4 to 8 inches thick; weathers dull red, platy to blocky	14.5	87.0
11	Quartzite, dolomitic, yellow, medium-grained, massive, sharply defined over stromatolitic dolomite, truncates stromatolites, contains dolomite fragments; weathers bright orange-yellow, rubbly	2.0	72.5
10	Dolomite, stromatolitic, medium grey with brownish and pinkish tinges, fine-crystalline, *Collenia*-type structures 12 to 18 inches long and 6 inches high; weathers bright yellowish brown, blocky	3.5	70.5
9	Quartzite, slightly dolomitic, white to very light brown, fine-grained, beds massive and faintly crossbedded; weathers medium yellowish brown, blocky	4.0	67.0
8	Siltstone, micaceous and arenaceous, dull red with some medium green interbeds, beds 1 inch to 2 inches thick, with some delicate crossbedding; weathers dull red, shaly	4.0	63.0
7	Quartzite, locally dolomitic, gradational in part to dolomite, pink to red, locally crossbedded and ripple-marked, beds 2 feet thick; weathers light to medium yellowish brown, blocky	13.5	59.0
6	Quartzite, slightly calcareous, white, fine-grained, massive, cross-bedded, faint lamination discernible on weathered surfaces; weathers medium yellowish brown, blocky	3.0	45.5
5	Quartzite, locally calcareous, pink to red, fine-grained beds 3 to 4 feet thick, laminated and crossbedded; weathers dull red, blocky	18.0	42.5
4	Argillite, slightly dolomitic, medium green, beds ¼ inch thick; weathers dull brownish green, shaly	8.0	24.5
3	Limestone, light to medium green, medium-crystalline, laminations on weathered surface; weathers medium yellowish brown	1.5	16.5
2	Siltstone, micaceous and calcareous, medium green, very thin bedded; weathers dark brown, shaly	8.5	15.0
1	Quartzite, calcareous, red at bottom, grading through white to light green at top, fine-grained, massive bed with faint lamination on weathered surface; weathers medium grey, blocky	6.5	6.5
	Total thickness of Sheppard Formation	155.0	
	PURCELL LAVA		
	Andesite, green, medium-grained, "chloritized", non-vesicular.		

Section 6

Unit No.		Thickness (feet)	Height above base (feet)
	Overlies Section 5		
	FLATHEAD FORMATION		
	Quartzite, dark grey at base grading into very light brown within 3 feet, coarse-grained, well-rounded grains, beds 2 feet thick; weathers medium brown, blocky; unconformable at base, 2-foot weathered zone in diorite sill below lowest quartzite bed.		
	KINTLA FORMATION		
	Member C		
24	Sill, diorite, coarse-grained, pink feldspar, dark green mafic minerals	32.0	1,786.5
23	Quartzite, micaceous, locally silty, deep reddish purple, fine-grained, beds 1 inch to 4 inches thick; weathers dark purple, platy	43.0	1,754.5
22	Quartzite, pink to medium red, interbedded with less resistant, more thinly bedded, light greenish brown-weathering units 3 feet thick; weathers to a banded red and greenish brown	203.0	1,711.5
21	Quartzite, pink to medium red, fine- to medium-grained, cross-bedded locally, beds 3 to 4 inches thick; weathers dull red, platy	121.0	1,508.5
	Thickness of Member C	399.0	
	Member B		
20	Covered (in part argillite, medium green, beds 1 inch thick; weathers medium brown, platy)	36.0	1,387.5
19	Sill, diorite, dark greenish grey, medium-grained	14.0	1,351.5
18	Siltstone, argillaceous, dolomitic, light to medium green, beds ½ to 1 inch thick; weathers dull medium green, locally brownish, platy	80.0	1,337.5
17	Dolomite, sandy, light grey with greenish tinge, fine-crystalline, beds ½ to 1 inch thick; weathers light yellowish brown, platy	10.0	1,257.5
16	Dolomite, and dolomitic siltstone, grading from light grey at bottom to medium green at top, fine- to medium-crystalline, beds ½ inch to 2 inches thick; weathers yellowish brown with greenish patches locally, platy	24.0	1,247.5
15	Covered (scree and a few isolated exposures of brown-weathering, argillaceous, platy, dolomite)	126.0	1,223.5
14	Dolomite, medium green, fine-crystalline, beds ¼ to ½ inch thick; weathers medium greenish brown, platy	7.0	1,097.5
13	Covered (yellowish brown, calcareous, siltstone, scree)	194.0	1,090.5
12	Siltstone, sandy, dull red, beds ½ to 1 inch thick; interbedded with dolomite, argillaceous, medium greyish green, fine-crystalline, beds ½ inch thick; includes eight dolomite beds between 2 and 3 feet thick; dolomite weathers medium brown	79.0	896.5
	Thickness of Member B	570.0	

Unit No.		Thickness (feet)	Height above base (feet)
	Member A		
11	Siltstone, and fine-grained sandstone, dull red, beds about 1 inch thick; weathers medium red, platy	144.0	817.5
10	Covered (float as in unit below)	31.0	673.5
9	Siltstone, in part micaceous, dull red, beds ½ inch thick; weathers dull red, platy	70.0	642.5
8	Argillite, medium green, beds ½ inch thick; weathers light green, platy	10.0	572.5
7	Siltstone, micaceous, dull red, fine-grained, beds ¼ to ½ inch thick; weathers dull red, shaly	73.0	562.5
6	Dolomite, light green, fine-crystalline, beds 2 to 4 inches thick; weathers light yellowish brown, platy	5.0	489.5
5	Siltstone, micaceous, deep red, beds ½ to ¼ inch thick; weathers dull red, platy	14.0	484.5
4	Argillite, dolomitic, light green, platy, beds ½ to 1 inch thick; weathers light yellowish brown, platy	10.0	470.5
3	Siltstone, micaceous and slightly arenaceous, very deep red, beds ¾ inch thick; weathers deep red, platy; many salt-crystal casts on bedding surfaces	60.5	460.5
2	Argillite, somewhat sandy, medium green, with some 4- to 6-inch reddish interbands; weathers to a dull green with some reddish interbands, platy, prominent	22.0	400.0
1	Siltstone, grades locally to sandy siltstone and to argillite, dull brownish red, commonly alternating with grey to light green interbeds 1 inch to 3 inches thick (less than 20 per cent), beds average 2 inches but range from $\frac{1}{16}$ inch to 12 inches thick; salt-crystal casts and ripple-marks common; weathers dull red, shaly to platy	223.0	378.0
	Thickness of Member A	662.5	
	Total thickness of Kintla Formation	1,631.5	
	Overlies Sheppard Formation of Section 5.		

Section 10

The entire Cambrian succession occurs along the east slope of the Flathead Range at Mount Darrah. The following section was examined along the crest of the ridge between North Lost Creek and Goat Creek, east of the summit of Mount Darrah. Exposures are incomplete, especially in the middle part of the sequence. The cirque immediately to the north of the section is accessible from Blairmore, Alberta, via a logging road up Lyons Creek, across Willoughby Ridge, and down Lynx Creek to the mouth of Goat Creek. From there the section is about 4 miles by pack-trail along Goat Creek.

	Overlying beds—Fairholme Group of Section 16		
	ELKO FORMATION		
22	Dolomite, medium to light grey, fine- to medium-crystalline, bedding obscure; weathers light grey with faint mottling, massive, prominent	178.0	624.0

Unit No.		Thickness (feet)	Height above base (feet)
	ELKO FORMATION—*Continued*		
21	Dolomite, dark grey, medium-crystalline, bedding poorly defined by stylolites, beds 4 inches to 4 feet thick; weathers light brownish grey, with faint mottling, massive, prominent	40.0	446.0
20	Limestone, dark grey, fine-crystalline, mottled with medium grey, medium-crystalline dolomite, poorly defined beds 4 to 24 inches thick; weathers light grey with yellowish grey mottling, blocky to massive, prominent	48.0	406.0
19	Limestone, dark grey, fine-crystalline, mottled with orange-yellow, medium-crystalline dolomite, bedding obscure; weathers medium grey with orange-yellow mottling	19.0	358.0
	Total thickness of Elko Formation	285.0	
	SHALE UNIT		
18	Covered (shale?)	21.0	339.0
17	Limestone, dark grey, fine-crystalline, mottled with orange-yellow, medium-crystalline dolomite; weathers medium grey with orange-yellow mottling	1.0	318.0
16	Covered (shale?)	6.0	317.0
15	Limestone, dark grey, very fine-crystalline, mottled with orange-yellow, medium-crystalline dolomite, beds 3 to 6 inches thick; weathers medium grey with orange-yellow mottling, flaggy	3.0	311.0
14	Covered (green shale rubble)	44.0	308.0
13	Shale, grey green, waxy, platy to rubbly	38.0	264.0
12	Covered (green shale and dark grey, fine-crystalline, rusty weathering limestone rubble)	69.0	226.0
11	Covered (quartzite rubble)	17.0	157.0
	Total thickness of Shale Unit	199.0	
	FLATHEAD FORMATION		
10	Quartzite, light brown, very coarse grained, indistinct laminations, beds 1 foot thick; weathers rust-brown, blocky	2.0	140.0
9	Covered (blocky quartzite rubble)	15.0	138.0
8	Quartzite, light brown, coarse-grained faint colour lamination. Weathers rust-brown, blocky	1.0	123.0
7	Covered (blocky quartzite rubble)	20.5	122.0
6	Quartzite, light brown, coarse-grained, beds ½ foot to 1½ feet thick; weathers rust-brown, blocky	16.0	101.5
5	Covered (blocky quartzite rubble)	15.5	85.5
4	Quartzite, dark grey, very fine grained, argillaceous, with sparse rounded quartz granules; massive with shaly partings; weathers to very dark grey, markedly recessive	25.5	70.0
3	Quartzite, light grey, very coarse grained, faint colour lamination 1-foot beds; weathers light grey to rust-brown, blocky	6.5	44.5
2	Quartzite, hematitic, dull red, medium-grained, well-rounded grains; hematitic staining throughout ¼-inch laminations in 3-foot massive beds; weathers deep red, blocky	3.0	38.0

Unit No.		Thickness (feet)	Height above base (feet)
	FLATHEAD FORMATION—*Continued*		
1	Quartzite, white to light yellow-brown, medium to very coarse grained, up to 5% granule and pebble conglomerate, grains clear and well rounded; beds 1 foot to 3 feet thick, with fine lamination defined by grain size variations; weathers light brown to white, blocky, prominent	35.0	35.0
	Base of Flathead Formation—quartzite overlies red shale of Kintla Formation along very sharply defined bedding surface with no apparent discordance of bedding.		
	Total thickness of Flathead Formation	140.0	

Section 11

This section was examined along the ridge between North Lost Creek and South Lost Creek, along the east slope of Flathead Range, in Alberta. It is accessible from the town of Hillcrest in the Crowsnest Pass, via a road along Byron and Webb Creeks and Carbondale River to Lost Creek. Logging access roads extend along South Lost Creek to within 2 miles of the section and a pack-trail to within ½ mile of it.

	ELKO FORMATION		
18	Limestone, medium grey, fine-crystalline, mottled with orange-yellow, medium-crystalline dolomite; bedding obscure; weathers dark grey with orange mottling, massive, prominent	10.0	234.0
	Measured thickness of Elko Formation	10.0	
	SHALE UNIT		
17	Limestone, medium grey, fine-crystalline, mottled with orange-yellow, medium-crystalline dolomite, beds 1 foot to 3 feet thick; interbedded with limestone, medium grey, fine-crystalline, shaly and nodular, beds 1 foot to 3 feet thick	14.0	224.0
16	Shale, medium green-grey, rubbly, gradational to nodular limestone toward top and base. Small fragments of trilobites (spines) locally; weathers to recessive slope	6.5	210.0
15	Limestone, medium grey to dark grey, fine-crystalline, mottled with orange-grey, medium-crystalline dolomite; weathers dark grey with orange mottling, prominent	2.0	203.5
14	Shale, green-grey, waxy, platy to rubbly, with nodules, lenses and thin bands of yellow-grey, medium-crystalline limestone; trilobite fragments throughout shale; at 10 feet above the base: *Albertella* cf. *limbata* Raschi, *Albertella* sp., *Vanuxemella* cf. *nortia* Walcott, *Vanuxemella* sp., ?*Zacanthoides* sp., indet. brachiopods, indet. 'coral-like' markings (GSC loc. 31260)	14.0	201.5
13	Limestone, medium grey and medium yellowish grey, alternating 4-foot zones of dolomitic mottled limestone and nodular shaly limestone	15.0	187.5
	(cross small anticline and syncline)		
12	Shale, grey-green, platy, nodules and thin (less than 4-inch) beds of light yellow-grey, medium-crystalline limestone increase in abundance toward top	17.0	172.5

Unit No.		Thickness (feet)	Height above base (feet)
	SHALE UNIT—*Continued*		
11	Limestone, light yellowish grey, fine-crystalline, flaggy to nodular; weathers brownish yellow	1.0	155.5
10	Shale, grey-green, platy to rubbly	4.0	154.5
9	Limestone, light yellowish grey, fine-crystalline, nodular; weathers light brownish yellow	1.0	150.5
8	Shale, green-grey, platy, with a few thin (less than 2-inch) interbeds of light yellowish grey, fine-crystalline limestone	28.0	149.5
7	Shale, greenish grey, papery, with numerous thin (less than 2-inch) interbeds of yellow, limonitic, medium- to coarse-crystalline limestone; trilobite fragments in shale; at 6 feet above base: *Albertella* sp., cf. *Kochina* sp., ?*Vanuxemella* sp., *Zacanthoides* sp., indet. trilobite fragments, linguloid brachiopods, *Hyolithes* sp., indet. 'coral-like' markings (GSC loc. 31259)	14.0	121.5
6	Limestone, light grey, fine-crystalline with disseminated glauconitic trilobite fragments and minute glauconite pellets; weathers limonitic yellow, flaggy	0.5	107.5
5	Shale, grey-green, platy and papery, numerous thin interbeds of limestone, medium grey, fine-crystalline limonitic and glauconitic occ ur near top of stratum, and weather limonitic yellow	62.0	107.0
4	Limestone, medium grey, fine-crystalline, beds 2 to 6 inches thick; weathers limonitic yellow, flaggy	4.0	45.0
3	Shale, grey-green, maroon in patches near top of stratum, platy to papery	24.0	41.0
2	Covered	12.0	17.0
	Total thickness of Shale Unit	219.0	
	FLATHEAD FORMATION		
1	Sandstone, limonitic and quartzitic, light yellowish grey, coarse-grained, beds 6 to 18 inches thick; weathers rust-yellow, blocky, prominent	5.0	5.0

Section 12

Strata of the upper part of the Cambrian succession were examined on the south slope of Flathead Range in the first prominent gully west of the provincial boundary. The lowest beds are poorly exposed and structurally disturbed, and, therefore, measurements were commenced above them. The top of the Elko Formation was traced for about 150 yards to the provincial boundary, where it is overlain by Fairholme Group strata of Section 14. The section is accessible via the North Kootenay Pass pack-trail either from the British Columbia Forest Service road near Flathead (2 miles) or from logging roads along Carbondale River in Alberta (4 miles).

Overlying beds—Fairholme Group, Section 14
Contact sharply defined and apparently concordant

	ELKO FORMATION		
27	Dolomite, light to medium grey, medium-crystalline, faintly mottled, weathers light grey with faintly mottled, pock-marked surface, massive	114.0	470.0

Unit No.		Thickness (feet)	Height above base (feet)
	ELKO FORMATION—*Continued*		
26	Limestone, dolomitic, mottled light orange-brown and dark grey; distinct light orange-brown and light grey mottling on weathered surface	7.0	356.0
25	Dolomite, calcareous, light to medium grey, medium-crystalline, sacchroidal, discontinuous vuggy (less than 2 mm) and inter-crystalline porosity; porosity well developed locally in zones parallel with bedding; weathers light grey, massive to blocky	84.0	349.0
24	Limestone, dolomitic, medium grey, faint mottling, fine-crystalline; weathers light grey with yellow-grey dolomitic mottling in poorly defined bands	30.0	265.0
23	Limestone, light to medium grey, very fine-crystalline, mottled with light yellowish brown sacchroidal, fine- to medium-crystalline dolomite; weathers light grey, slabby to blocky, prominent, with distinct yellowish mottling	102.0	235.0
22	Limestone, medium grey with light brownish grey dolomitic mottling, very fine-crystalline; weathers light grey with light orange-brown mottling, slabby to blocky	8.0	133.0
21	Limestone, shaly, light grey, fine-crystalline, nodular	4.0	125.0
20	Limestone, medium grey, very fine-crystalline, with fine-crystalline, light brownish grey dolomitic mottling; weathers medium grey with orange mottling	2.0	121.0
	Total thickness of Elko Formation	351.0	
	SHALE UNIT		
19	Limestone, dark grey, fine-crystalline, nodular, and dark green-grey shale	5.0	119.0
18	Shale, dark green-grey; at 5 feet above base, trilobite fragments: *Albertella* sp., *Kochina* sp., *Ptarmigania* sp., *Zacanthoides* sp. (GSC loc. 28122)	6.0	114.0
17	Limestone, medium grey, fine-crystalline, weathers light brownish grey with limonitic orange mottling	2.0	108.0
16	Shale, dark green-grey, platy to rubbly; at 8 feet above base, trilobites and brachiopods: *Albertella* sp., *Glossopleura*? sp., *Kochina* cf., *americana* (Walcott), *Kochina*? sp., *Ptarmigania* cf. *rossensis* (Walcott), *Zacanthoides* sp., *Micromitra* sp., *Iphidella* sp., indet. organic markings (GSC loc. 28124)	9.0	106.0
15	Limestone, medium grey, fine-crystalline, platy and flaggy, skeletal in part	1.0	97.0
14	Limestone, shaly, medium grey, fine-crystalline, nodular	8.0	96.0
13	Limestone, shaly, medium grey, fine-crystalline, nodular at top and base, skeletal in part	1.5	88.0
12	Shale, grey-green, platy, waxy, with subordinate (less than 10%) thin (less than 2 inches) interbeds of medium-crystalline yellowish grey limestone	14.0	86.5
11	Limestone, silty, dark grey, fine-crystalline, nodular, disseminated trilobite fragments	1.5	72.5
10	Shale, grey-green, platy to rubbly, waxy, with thin (less than 1 inch) lenses of nodular dolomitic limestone (less than 10%)	4.0	71.0
9	Limestone, dark grey, fine-crystalline, becomes shaly, nodular toward top and base, disseminated skeletal fragments	1.0	67.0

Unit No.		Thickness (feet)	Height above base (feet)
	SHALE UNIT—*Continued*		
8	Shale, grey-green, platy to rubbly, with rare thin (½- to 4-inch) beds of very fine-crystalline, medium grey, light yellowish brown weathering dolomitic limestone	21.0	66.0
7	Limestone, medium grey, medium-crystalline, nodular at top and base; weathers light orange-brown	0.5	45.0
6	Shale, green-grey, waxy, gradational to distinct green toward top	22.0	44.5
5	Shale, medium grey, platy to rubbly, interbedded with limestone, dolomitic, medium grey, medium-crystalline, platy to nodular	2.0	22.5
4	Shale, medium grey, platy to rubbly, with rare thin (less than 7 inches) lenses of shaly limestone	7.0	20.5
3	Shale, green-grey, waxy, with 4- to 8-inch interbeds of medium grey, medium-crystalline dolomite, nodular at top and base; at base linguloid brachiopods and trilobite fragments: cf. *Albertella* sp., *Micromitra*? sp *Iphidella* sp., *Hyolithes*? sp. (GSC loc. 28123)	3.0	13.5
2	Shale, green-grey, platy to rubbly, with thin lenses of nodular yellowish grey and limonitic yellow dolomite	6.0	10.5
1	Dolomite, shaly and nodular in part, dark grey, medium-crystalline, intensely fractured; weathers rust-orange, blocky to rubbly, becomes shaly and nodular toward the top	4.5	4.5
	Measured thickness of Shale Unit	119.0	

Section 13

This section was measured at the south end of Flathead Range along a prominent gully about 1,100 yards west of North Kootenay Pass. The base of the section is accessible from the British Columbia Forest Service road at Flathead via the North Kootenay Pass pack-trail, which crosses the gully at its lower end.

	FAIRHOLME GROUP		
	MOUNT HAWK FORMATION		
41	Limestone, shaly, black, fine-crystalline, slightly nodular; weathers to fine, medium grey rubble; at top: small *Gypidula* sp., *Leptostrophia*? sp., small *Productella* sp., *Atrypa* cf. *A. varicostata* Stainbrook, small *Cyrtospirifer* sp. (GSC loc. 28155)	6.0	715.0
	Measured thickness of Mount Hawk Formation	6.0	
	BORSATO FORMATION		
40	Dolomite, black, medium-crystalline, sugary, vague-bedded appearance; weathers light brownish grey, blocky	8.0	709.0
39	Limestone, black, fine-crystalline, beds 4 inches thick; weathers light grey, rubbly; contains: *Atrypa* cf. *A. varicostata* Stainbrook (GSC loc. 28330)	4.0	701.0
38	Dolomite, black, and dark brownish grey, medium-crystalline, sugary, vaguely bedded in units 18 inches thick; cavernous vugs up to 4 inches long occur locally and are abundant toward top of unit; weathers light brownish grey, blocky	20.5	697.0
37	Dolomite, dark grey, fine-crystalline, beds 2 to 4 inches thick; weathers light brownish grey to light grey, platy	8.0	676.5

Unit No.		Thickness (feet)	Height above base (feet)
	BORSATO FORMATION—*Continued*		
36	Dolomite, black and dark brownish grey, medium-crystalline to coarse-crystalline, sugary, vague 1- to 3-foot beds; cavernous vuggy porosity locally, vugs in part filled with white calcite; weathers light brownish grey, massive to blocky; at 39 feet above base irregular nodules of light grey chert occur along a bedding surface	53.0	668.5
35	Dolomite, medium brownish grey, coarse-crystalline, sugary, small vugs filled with white calcite	3.0	615.5
34	Dolomite, black and dark brownish grey, medium-crystalline, sugary; vague 18-inch beds; vuggy porosity locally; weathers light brownish grey, massive to blocky	10.5	612.5
33	Dolomite, medium brownish grey, coarse-crystalline, sugary, inter-crystalline porosity, laminated in texture; weathers light brownish grey with lamination etched into relief	4.0	602.0
32	Breccia, angular fragments of coarse-crystalline, sugary, medium brown-grey dolomite up to 3 inches long cemented with coarse-crystalline white calcite	5.0	598.0
31	Dolomite, medium brownish grey, coarse-crystalline, sugary, intergranular porosity, laminated in texture; weathers light brownish grey with lamination etched into relief on surface	3.0	593.0
30	Breccia, angular fragments of coarse-crystalline, sugary, medium brownish grey dolomite up to 3 inches long cemented with coarse-crystalline white calcite; boundaries of unit parallel lamination in underlying unit but obliquely transect lamination in overlying unit	5.0	590.0
29	Dolomite, medium brownish grey, coarse-crystalline, intergranular porosity, laminated in texture; weathers light brownish grey with lamination etched into relief on surface	5.0	585.0
28	Breccia, angular fragments of coarse-crystalline, medium brownish grey dolomite up to 3 inches long cemented with coarse-crystalline white calcite	4.5	580.0
27	Dolomite, dark grey, fine-crystalline, sugary, bedding obscure; numerous minute tubular vugs filled with white calcite (*Amphipora*?); weathers light brownish grey	12.0	575.5
26	Dolomite, light grey, fine-crystalline, sugary, beds 6 inches thick; weathers very light grey, platy	3.5	563.5
25	Dolomite, medium brownish grey, medium-crystalline, sugary, beds 6 inches thick; weathers light brownish grey with faint lamination etched into relief on weathered surfaces, blocky	6.0	560.0
24	Shale, dark brown, nodular, grades upward through mottled dolomitic limestone with shale partings to dolomite; weathers medium brownish grey, platy	7.0	554.0
	Total thickness of Borsato Formation	162.0	
	HOLLEBEKE FORMATION		
	Upper Member		
23	Limestone, dark grey, very fine-crystalline, bedding obscure; weathers light grey, massive to rubbly	27.5	547.0
22	Breccia, angular fragments of limestone and dolomite up to 6 inches long cemented with coarse-crystalline, white calcite; casts of numerous angular fragments in calcite	10.0	519.5

Unit No.		Thickness (feet)	Height above base (feet)
	UPPER MEMBER OF HOLLEBEKE FORMATION—*Continued*		
21	Limestone, dark grey, very fine-crystalline, bedding obscure; weathers light grey, massive to rubbly	30.0	509.5
20	Limestone, dark grey, fine-crystalline, beds 6 to 18 inches thick; weathers light grey with lamination etched into relief	16.0	479.5
19	Limestone, dark grey, very fine-crystalline, mottled with dark brownish grey, vague bedding, beds 6 to 18 inches thick; weathers light grey, mottled with light brownish grey, massive to rubbly	67.5	463.5
18	Covered	12.0	396.0
17	Limestone, dark grey, very fine-crystalline, bedding obscure; weathers light grey, massive to rubbly	36.0	384.0
16	Limestone, very fine-crystalline, dark grey, vague bedding, beds 6 to 18 inches thick; weathers light grey with faint lamination etched into relief	9.5	348.0
	Thickness of Upper Member	208.5	
	Lower Member		
15	Limestone, silty and argillaceous, dark grey, fine-crystalline, beds 2 to 6 inches thick; weathers light brownish grey with gritty surface and with lamination etched into relief	6.0	338.5
14	Limestone, dark grey, very fine-crystalline, bedding obscure; weathers light grey, massive to rubbly	8.0	332.5
13	Limestone, silty to argillaceous, dark grey, fine-crystalline, beds 6 to 18 inches thick; weathers light brownish grey with faint lamination etched into relief on weathered surfaces	7.0	324.5
12	Limestone, silty, medium grey, fine-crystalline, bedding obscure; weathers light greyish brown with faint lamination etched into relief	31.0	317.5
11	Limestone, dark grey, very fine-crystalline, bedding obscure; weathers light grey, massive	6.0	286.5
10	Limestone, silty to argillaceous, medium grey, fine-crystalline with faint lamination etched into relief on weathered, light brownish grey surface; several zones up to 6 inches thick of very fine-crystalline dark grey limestone; basal 12 inches show fine concentric lamination in limestone (stromatolites?)	8.5	280.5
9	Limestone, silty, dark grey, fine-crystalline, beds 2 to 6 inches thick; weathers light brown-grey with lamination etched into relief; at top: stromatoporoid indet., *Atrypa* cf. *A. multicostellata* Kottlowski (GSC loc. 28328)	14.5	272.0
8	Limestone, dark grey, very fine-crystalline, beds 4 to 12 inches thick; weathers light grey with lamination etched into relief in part	8.0	257.5
7	Limestone, dark grey, fine-crystalline, mottled with medium-crystalline, dark brownish grey dolomitic limestone; weathers light grey with light brown mottling: gradational upward into fine-crystalline limestone	1.5	249.5
6	Limestone, silty, light yellowish grey, fine-crystalline; weathers light yellowish grey, platy	1.0	248.0

Unit No.		Thickness (feet)	Height above base (feet)
	LOWER MEMBER OF HOLLEBEKE FORMATION—*Continued*		
5	Limestone, light grey, fine- to medium-crystalline, platy; weathers light grey with lamination etched into relief	2.0	247.0
4	Breccia, fragments of limestone and dolomite scattered through a matrix of fine-grained light yellowish grey, silty limestone	2.0	245.0
3	Covered	37.0	243.0
	Thickness of Lower Member	132.5	
	Total thickness of Hollebeke Formation	341.0	
	Measured thickness of Fairholme Group	509.0	
	ELKO FORMATION		
2	Dolomite, light to medium grey, fine-crystalline; weathers white to light grey and brownish grey with gritty surface, massive	204.0	206.0
1	Limestone, black, fine-crystalline, mottled with brownish grey dolomite; weathers light grey with brownish grey mottling	2.0	2.0
	Measured thickness of Elko Formation	206.0	

Section 14

The following stratigraphic sequence was examined along the provincial boundary at the south end of Flathead Range on Mount Borsato. These strata overlie the Elko Formation of Section 12. They are accessible via the North Kootenay Pass pack-trail from roads at Flathead, British Columbia, and along Carbondale River in Alberta.

	PALLISER FORMATION		
99	Limestone, medium grey, fine-crystalline, no apparent bedding; weathers medium grey, massive, prominent	20.0	1,387.5
98	Dolomite, medium grey, medium- to coarse-crystalline, bedding obscure; weathers medium to light grey, massive, prominent	42.0	1,367.5
	Measured thickness of Palliser Formation	62.0	
	ALEXO FORMATION		
97	Covered (recessive zone below Palliser Formation cliff)	23.5	1,325.5
96	Limestone, silty, light yellow-grey, fine-crystalline, very finely laminated, platy, contorted bedding	9.5	1,302.0
95	Dolomite, medium grey, medium- to coarse-crystalline; massive to blocky weathering	10.0	1,292.5
94	Covered	18.0	1,282.5
93	Dolomite, light grey with faint colour laminations, fine-crystalline; weathers light grey, platy to blocky	6.0	1,264.5
92	Dolomite, argillaceous and silty, greyish yellow, fine-crystalline, finely laminated; thin zones of 'collapse breccia', interbeds 3 feet thick approximately 10 feet apart of dolomite, silty, light grey, fine-crystalline	36.0	1,258.5
	Total thickness of Alexo Formation	103.0	

Unit No.		Thickness (feet)	Height above base (feet)
	FAIRHOLME GROUP		
	SOUTHESK FORMATION		
	Arcs Member		
91	Dolomite, light grey, coarse-crystalline; weathers light grey	1.0	1,222.5
90	Dolomite, light grey with faint colour laminations, fine-crystalline; weathers light grey	1.0	1,221.5
89	Dolomite, light grey, coarse-crystalline; thick bedded to massive; weathers light grey	32.0	1,220.5
88	Dolomite, light grey, coarse-crystalline; intergranular porosity and vugs, porous zones that parallel bedding give faint laminated and crossbedded appearance	8.0	1,188.5
87	Dolomite, yellow-green, medium-crystalline, flaggy	0.5	1,180.5
86	Dolomite, light grey, coarse-crystalline; weathers light grey	2.5	1,180.0
85	Dolomite, yellow, medium-crystalline, flaggy to blocky	1.5	1,177.5
84	Dolomite, light grey, coarse-crystalline; bedding obscure; weathers light grey, massive to blocky	54.5	1,176.0
	Thickness of Arcs Member	101.0	
	Grotto Member		
83	Dolomite, slightly silty, medium brownish grey, fine- to medium-crystalline, beds average 12 inches thick; weathers light brownish grey	84.0	1,121.5
82	Dolomite, silty, dark grey, medium-crystalline; beds 6 to 36 inches thick; weathers light yellow-grey	25.5	1,037.5
	Thickness of Grotto Member	109.5	
	Total thickness of Southesk Formation	210.5	
	MOUNT HAWK FORMATION		
81	Limestone, shaly, dark grey, fine-crystalline, platy to nodular	37.5	1,012.0
80	Dolomite, finely arenaceous and silty (quartz), medium to light grey, medium-crystalline	5.0	974.5
79	Limestone, silty, dark grey, fine-crystalline, slightly nodular; beds 8 to 12 inches thick	13.5	969.5
78	Dolomite, silty and arenaceous (quartz), calcareous, light grey, fine-crystalline; beds 6 to 12 inches thick; weathers light yellowish brown with a gritty surface	9.0	956.0
77	Limestone, medium grey, medium-crystalline	3.5	947.0
76	Limestone, argillaceous, dark grey, platy	1.0	943.5
75	Limestone, slightly silty, medium grey, medium-crystalline	3.0	942.5
74	Limestone, argillaceous, dark brownish grey, platy; weathers black	4.0	939.5
73	Limestone, silty, medium grey, medium-crystalline; beds 8 to 24 inches thick; weathers medium to light grey	10.0	935.5
72	Limestone, silty, calcareous, light yellowish grey, medium-crystalline; beds 6 to 24 inches thick; weathers light yellowish brown with gritty surface	4.0	925.5
71	Limestone, slightly silty, dark grey, fine-crystalline; weathers platy and nodular to massive; at 12 feet above base; *Gypidula* cf. *G. munda* Calvin, *Grunewaldtia americana* Stainbrook (GSC loc. 28155)	21.0	921.5

Unit No.		Thickness (feet)	Height above base (feet)
	MOUNT HAWK FORMATION—*Continued*		
70	Limestone, silty, dark grey, fine-crystalline, platy to nodular; weathers medium to dark grey	12.5	900.5
69	Limestone, dolomitic, silty and finely arenaceous, dark grey, medium-crystalline; worm-tube-like carbonaceous markings on bedding surfaces; weathers distinct light yellowish brown with gritty surface	5.5	888.0
68	Limestone, argillaceous and shaly, dark grey, fine-crystalline, platy; interbedded with limestone, silty, dark grey, fine-crystalline, beds 3 to 4 feet thick	46.0	882.5
67	Limestone, silty, dark grey, medium-crystalline, with scattered crinoid columnals and brachiopod fragments; weathers medium grey, platy to massive with faint laminations	40.0	836.5
66	Limestone, argillaceous, dark grey, fine-crystalline, platy; interbedded with limestone, black, fine-crystalline, dense; in beds 3 feet thick	40.0	796.5
65	Limestone, shaly, dark grey, fine-crystalline, nodular, with occasional platy argillaceous and non-argillaceous beds at top: *Disphyllum* cf. *D. colemanense* Warren, *Gypidula* sp., productellid indet., *Atrypa* cf. *A. varicostata* Stainbrook, *Atrypa* sp. (GSC loc. 28154)	24.0	756.5
64	Limestone, argillaceous, dark grey, fine-crystalline, platy, interbedded with limestone, black, fine-crystalline, with scattered crinoid columnals and brachiopod fragments; in beds 4 to 36 inches thick	117.5	732.5
63	Limestone, dark grey, fine-crystalline, enclosing a coral framework	2.0	615.0
62	Limestone, black, very fine-crystalline, dense; weathers a dark grey	4.0	613.0
61	Limestone, silty, dark grey, platy	0.5	609.0
60	Limestone, black, fine-crystalline; beds 4 to 24 inches thick; weathers dark grey	7.0	608.5
59	Limestone, silty, medium grey-brown, calcareous siltstone, in part, platy; weathers light yellowish brown	5.0	601.5
58	Limestone, black, very fine-crystalline, dense, in beds 6 to 18 inches thick; weathers medium grey	9.0	596.5
57	Limestone, silty, dolomitic, argillaceous, slightly nodular at top, fine-crystalline; weathers light yellowish brown	2.0	587.5
56	Limestone, black, very fine-crystalline, dense, in beds 4 to 8 inches thick; weathers medium grey	8.5	585.5
55	Shale, calcareous, black	0.5	577.0
54	Limestone, somewhat shaly, black, very fine-crystalline, dense, nodular; weathers rubbly, medium grey	16.0	576.5
53	Limestone, dolomitic, silty, light brownish grey, fine-crystalline; weathers buff, platy	5.0	560.5
52	Limestone, silty, black and dark grey, platy; interbedded with limestone, black, very fine-crystalline, dense, in 8-inch beds	10.0	555.5
51	Shale, silty, calcareous, brownish black, grades upward into platy, silty limestone, and black fine-crystalline limestone with brachiopod fragments	2.5	545.5
50	Limestone, black, fine-crystalline, slightly fetid, in beds 6 inches thick: *Leptostrophia* sp., *Calvinaria albertensis* (Warren), small *Atrypa* sp., *Warrenella nevadensis* (Walcott), fish fragments (GSC loc. 28153)	3.5	543.0
	Total thickness of Mount Hawk Formation	472.5	

Unit No.		Thickness (feet)	Height above base (feet)
	BORSATO FORMATION (type section)		
49	Dolomite, calcareous, medium brownish grey, coarse-crystalline, in beds 6 inches thick; weathers light grey	6.0	539.5
48	Dolomite, dark grey, fine- to medium-crystalline, sacchroidal, in beds 10 inches thick; weathers medium brownish grey	16.0	533.5
47	Dolomite, slightly silty, black, fine-crystalline, platy	1.0	517.5
46	Shale, slightly dolomitic, silty, brown	0.5	516.5
45	Dolomite, black, fine-crystalline; weathers medium brownish grey	1.0	516.0
44	Dolomite, slightly bituminous, medium to dark brownish grey, medium-crystalline, sacchroidal, cavernous druzy vugs up to 3 inches long; beds 4 to 36 inches thick, average 12 inches	31.0	515.0
43	Dolomite, black, fine-crystalline; weathers medium brownish grey with faint lamination in part	4.5	484.0
42	Dolomite, calcareous, bituminous, medium brownish grey, coarse-crystalline, sacchroidal, fetid, in part with vugs up to 1 inch in diameter, beds 4 to 20 inches thick, become laminated and thin toward the top	42.5	479.5
41	Limestone, dolomitic, silty, light yellowish grey, platy, laminated; weathers light buff	1.0	437.0
40	Dolomite, calcareous, bituminous, medium brownish grey, coarse-crystalline, fetid, in beds 8 to 36 inches thick, laminated in part	12.5	436.0
39	Limestone, dolomitic, light grey, medium- to coarse-crystalline, sacchroidal, with numerous vugs up to 2 inches in diameter; a few thin interbeds of medium grey, medium-crystalline limestone; weathers light grey, blocky	9.0	423.5
38	Limestone, dark grey to black, fine-crystalline, platy; weathers medium grey	4.0	414.5
37	Dolomite, medium brownish grey, medium-crystalline, sacchroidal; weathers light grey, flaggy to blocky	7.0	410.5
36	Dolomite, medium to light grey, medium-crystalline, sacchroidal; at 1 foot above the base: *Amphipora* sp., stromatoporoid, *Alveolites* sp., *Thamnopora* sp. (GSC loc. 28157)	2.0	403.5
35	Dolomite, slightly silty, dark grey, fine-crystalline; weathers light buff-grey, flaggy to platy	4.5	401.5
	Total thickness of Borsato Formation	142.5	
	HOLLEBEKE FORMATION (type section)		
	Upper Member		
34	Limestone, black, very fine-crystalline, dense, in beds 4 to 10 inches thick; weathers medium grey, fine rubbly	13.5	397.0
33	Limestone, medium grey, medium- to fine-crystalline, badly fractured with calcite druse on fractures	15.5	383.5
32	Limestone, black, fine-crystalline, dense; weathers medium grey with faint lamination locally	14.5	368.0
31	Limestone, medium grey laminated, fine-crystalline; weathers platy	15.0	353.5
30	Breccia, laminated limestone fragments in a calcareous matrix	3.0	338.5
29	Dolomite, calcareous, silty, yellow-grey, platy; weathers light yellowish brown	1.0	335.5
28	Limestone, medium grey, fine- to medium-crystalline, thinly bedded; weathers light grey, platy to flaggy	7.0	334.5

Unit No.		Thickness (feet)	Height above base (feet)
	UPPER MEMBER OF HOLLEBEKE FORMATION—*Continued*		
27	Limestone, dark grey, fine-crystalline, in beds 3 to 8 inches thick; weathers flaggy with medium grey mottled appearance....	30.0	327.5
26	Limestone, shaly and nodular, dark grey to black, very fine-crystalline, brachiopod fragments abundant locally; weathers medium grey, flaggy to rubbly, with distinct mottled appearance; at 5 feet above base; large fragmentary *Schizophoria* sp., stropheodontids, *Eostrophalosia* sp. H, *Atrypa* ex gr. *A. independensis* Webster, *Atrypa* cf. *A. multicostellata* Kottlowski, small "*Spirifer*" indet. (GSC loc. 28156)..	48.0	297.5
25	Limestone, black, fine-crystalline, with numerous pinpoint vugs lined with light brown druse, bedding obscure...........................	14.0	249.5
24	Limestone, medium grey, fine-crystalline, in beds 4 to 24 inches thick, platy in part; weathers light grey with mottled appearance	24.0	235.5
23	Limestone, black, very fine-crystalline, dense, bedding obscure; weathers light grey with faint lamination locally........................	5.0	211.5
22	Limestone, dark grey to black, fine-crystalline, bedding obscure; weathers medium grey, rubbly to blocky....................................	40.0	206.5
	Thickness of Upper Member..	230.5	
	Lower Member		
21	Limestone, medium grey, medium-crystalline, faintly laminated, in beds 4 to 24 inches thick; weathers medium brownish grey....	39.0	166.5
20	Breccia, platy fragments up to 24 inches long of laminated limestone, silty dolomite and fine-crystalline dolomite; calcareous matrix..	6.0	127.5
19	Dolomite, silty, light yellowish grey, fine- to medium-crystalline; weathers light yellowish brown with fine lamination..................	45.0	121.5
18	Limestone, dolomitic, medium brownish grey, medium-crystalline, sacchroidal, with intercrystalline porosity locally; weathers medium brownish grey with faint lamination on surface...........	4.0	76.5
17	Breccia, large platy fragments of laminated and non-laminated dolomitic limestone, limestone and dolomite in a matrix of silty dolomite..	0.5	72.5
16	Limestone, medium brownish grey, medium-crystalline, sacchroidal, in beds 6 to 24 inches thick; weathers brown-grey with faint lamination on surface..	11.0	72.0
15	Limestone, dolomitic, light grey, medium- to coarse-crystalline, faintly laminated, in beds 6 to 18 inches thick; weathers light grey, blocky...	6.0	61.0
14	Breccia, platy fragments of dolomite and silty dolomite up to 36 inches long in a matrix of silty dolomite......................................	8.0	55.0
13	Dolomite, medium grey, medium-crystalline, faintly laminated, in beds 4 to 12 inches thick, lenses of breccia with dolomitic matrix at base..	9.0	47.0
12	Dolomite, silty, light yellowish grey, fine- to medium-crystalline; weathers light yellowish brown..	1.0	38.0
11	Dolomite, slightly bituminous, dark grey, medium-crystalline, finely laminated, in beds 6 to 18 inches thick; weathers dark brown..	6.0	37.0
10	Dolomite, calcareous, silty, medium grey, platy and finely laminated..	3.0	31.0

Unit No.		Thickness (feet)	Height above base (feet)
	LOWER MEMBER OF HOLLEBEKE FORMATION—*Continued*		
9	Dolomite, silty, medium grey, medium- to coarse-crystalline, sacchroidal, in beds 8 to 12 inches thick; weathers light yellowish brown	5.0	28.0
8	Dolomite, dark grey, medium-crystalline, slightly fetid, vuggy, faint crude lamination locally; weathers dark brown	4.5	23.0
7	Dolomite, silty, medium to dark grey, medium-crystalline, in beds 6 to 8 inches thick; weathers light brownish grey; interbeds less than 6 inches thick of platy, laminated, silty dolomite	1.5	18.5
6	Dolomite, medium grey, medium-crystalline, faintly mottled	0.5	17.0
5	Dolomite, silty, dark grey, medium-crystalline, in beds 6 to 8 inches thick; weathers light brownish grey; two interbeds less than 6 inches thick of dark grey, platy, silty shale	2.5	16.5
4	Dolomite, slightly bituminous, dark grey, medium-crystalline; weathers brown	1.0	14.0
3	Dolomite, medium grey, medium-crystalline, faintly mottled, beds 6 to 12 inches thick; weathers light grey, blocky, mottled with yellowish brown	4.0	13.0
2	Dolomite, silty, medium to dark grey, medium-crystalline; weathers light brownish grey, blocky	7.0	9.0
1	Dolomite, distinctly mottled dark grey and light orange-brown, medium-crystalline	2.0	2.0
	Thickness of Lower Member	166.5	
	Total thickness of Hollebeke Formation	397.0	
	Total thickness of Fairholme Group	1,222.5	
	Underlain by Section 12.		

Section 15

This section was examined on the ridge between North Lost Creek and South Lost Creek on the east slope of Flathead Range in Alberta. It is accessible from Hillcrest, Alberta, via a road along Byron and Webb Creeks and Carbondale River to Lost Creek. Logging roads extend along South Lost Creek to within 2½ miles of the section and pack-trail extends beyond that point to within a mile of the section.

Unit No.		Thickness (feet)	Height above base (feet)
	PALLISER FORMATION		
62	Dolomite, medium to dark grey, medium-crystalline, poorly defined beds 1 foot to 6 feet thick; weathers light grey, massive, prominent, with irregular pock-marked surface	57.5	1,179.5
61	Dolomite, dark grey to black, medium- to coarse-crystalline, fetid, zones with large irregular patches of white calcite; weathers light brownish grey, calcite patches white, with faint surface laminations in colour, massive, prominent; brecciated in patches in lower 3 feet (angular fragments less than an inch long)	27.0	1,122.0
	Measured thickness of Palliser Formation	84.5	
	ALEXO FORMATION		
60	Dolomite, medium grey, fine-crystalline, beds 2 to 18 inches thick; weathers very light grey, flaggy to blocky, with faint surface lamination in relief	47.0	1,095.0

Unit No.		Thickness (feet)	Height above base (feet)
	ALEXO FORMATION—*Continued*		
59	Dolomite, yellow-grey, fine-crystalline, silty, lenses of breccia (silty dolomite fragments in dolomite matrix) thin silt layers in part give fine compositional banding; weathers yellow, platy to blocky, with surface lamination, recessive	14.0	1,048.0
	Total thickness of Alexo Formation	61.0	
	FAIRHOLME GROUP		
	SOUTHESK FORMATION		
	Arcs Member		
58	Dolomite, very light grey, coarse-crystalline, beds 2 to 3 feet thick, poorly defined; weathers very light grey, massive, in part with brecciated appearance on surface; in part with surface lamination in relief	29.0	1,034.0
	(Thrust fault repeats 40 feet of section)		
57	Dolomite, medium grey, medium- to fine-crystalline, beds 4 to 18 inches thick, not well defined; weathers light grey, massive prominent	26.0	1,005.0
56	Dolomite, light grey, very coarse, to coarse-crystalline, beds 1 foot to 5 feet thick, intercrystalline and vuggy porosity; vugs up to 2 inches long elongated parallel with bedding; weathers very light grey, massive, with pock-marked surface, faint banding	36.0	979.0
55	Dolomite, silty, light yellowish grey, fine-crystalline, beds 2 to 18 inches thick; weathers light yellowish grey and light yellow, platy to blocky, recessive with faint surface lamination in relief	37.0	943.0
54	Dolomite, white, very coarse-crystalline to coarse-crystalline, no apparent bedding, network of interconnecting vugs throughout; weathers very light grey, massive, prominent, with highly irregular surface	5.0	906.0
53	Dolomite, light to medium grey, medium- to coarse-crystalline, beds 6 to 17 inches thick; weathers very light grey, blocky, with pock-marked surface	22.0	901.0
	Thickness of Arcs Member	155.0	
	Grotto Member		
52	Dolomite, dark grey, medium-crystalline, fetid, poorly preserved coral fragments, vugs up to 1 inch long, beds 1 foot to 3 feet thick; weathers light brownish grey, blocky, prominent, with pock-marked surface	16.5	879.0
51	Dolomite, dark to medium grey, medium-crystalline, beds 6 to 10 inches thick; silicified colonial corals; weathers light brownish grey, blocky	22.5	862.5
50	Dolomite, dark grey, medium- to fine-crystalline, fetid, black chert as nodules and bands parallel with bedding decreases toward base, abundant silicified colonial corals, silicified brachiopods, beds 2 to 8 inches thick; weathers light greyish brown, flaggy to blocky, prominent; at 43 feet above base: small *Phacellophyllum* indet., *Atrypa* sp., *Spinatrypa* sp. (GSC loc. 31243)	52.0	840.0
	Thickness of Grotto Member	91.0	
	Total thickness of Southesk Formation	246.0	

Unit No.		Thickness (feet)	Height above base (feet)
	MOUNT HAWK FORMATION		
49	Dolomite, silty and arenaceous (quartz), medium grey, fine-crystalline, grades to very fine-grained quartzite in bands in middle of unit; gradational top and base; beds 4 to 18 inches thick; weathers light yellowish grey, flaggy to blocky	44.5	788.0
48	Limestone, dark grey, fine-crystalline, with silicified brachiopods and corals, beds 2 to 6 inches thick, in part shaly or nodular; contains: disphyllid coral indet., *Schizophoria* cf. *S. amanaensis* Stainbrook, *Atrypa* sp. (GSC loc. 31241)	6.0	743.5
47	Dolomite, dark grey, medium-crystalline, beds poorly defined, 1 inch to 6 inches thick; weathers medium yellowish grey, platy	5.0	737.5
46	Limestone, dark grey, fine-crystalline, silicified coral fragments, beds poorly defined, platy; weathers dark grey, platy, recessive	14.0	732.5
45	Sandstone, dolomitic, dark grey, very fine-grained; beds not well defined, platy, gradational top and base; weathers yellow, platy	4.0	718.5
44	Limestone, dark grey, fine-crystalline, platy beds up to 4 inches thick; weathers dark grey, recessive	9.5	714.5
43	Siltstone, and very fine-grained sandstone, dolomitic, dark grey, beds 10 inches thick to thin and platy; weathers yellowish grey	8.0	705.0
42	Limestone, dark grey, fine-crystalline, beds 10 inches thick to thin and platy; weathers dark grey	9.5	697.0
41	Siltstone and very fine-grained sandstone, dolomitic, dark grey, beds 6 to 10 inches thick; weathers light greyish yellow	4.0	687.5
40	Limestone, dark grey, fine-crystalline, beds 6 inches thick to thin and platy; weathers dark grey, recessive; at 13 feet above base: *Atrypa* sp., *Grunewaldtia* cf. *G. americana* Stainbrook, *Spinatrypa* sp. C (GSC loc. 31249)	26.0	683.5
39	Sandstone, dark grey, dolomitic, very fine-grained, with carbonaceous films throughout, bedding not apparent; weathers greyish yellow, platy, massive	12.5	657.5
38	Limestone, silty, dark grey, fine-crystalline, beds thin and platy but up to 8 inches thick; weathers dark grey, platy, recessive	35.0	645.0
37	Dolomite, silty, dark grey, fine-grained, bedding obscure; weathers yellow, platy	5.0	610.0
36	Limestone, dark grey, very fine-crystalline, interbedded thin platy zones and 1- to 3-foot beds; weathers dark grey, platy to rubbly, recessive	64.0	605.0
35	Limestone, dark grey, very fine-crystalline, beds thin and platy or shaly, a few 6-inch interbeds of dark grey, very fine-crystalline limestone	68.0	541.0
34	Limestone, dark grey, fine-crystalline, bedding obscure; weathers medium grey, blocky to rubbly; at base: *Atrypa* sp., *Spinatrypa* sp. C, bellerophon gastropod (GSC loc. 31250)	8.0	473.0
33	Limestone, argillaceous (?), dark grey, fine-crystalline, beds thin and platy; weathers dark grey, rubbly, recessive	30.5	465.0
32	Limestone, dark grey, fine-crystalline, bedding obscure; weathers light yellowish orange, blocky to rubbly, prominent	7.0	434.5
31	Limestone, dark grey, very fine-crystalline, alternating thin, platy, recessive and non-platy 3-foot beds; weathers dark grey, rubbly to platy, recessive	16.5	427.5
30	Limestone, silty, dark grey, fine-crystalline, bedding not apparent; weathers light yellowish grey, with faint surface lamination, prominent	4.0	411.0

Unit No.		Thickness (feet)	Height above base (feet)
	MOUNT HAWK FORMATION—*Continued*		
29	Limestone, dark grey, fine-crystalline, beds 6 to 18 inches thick, with thin, 2- to 3-inch, brown-black argillaceous limestone partings increasing in abundance toward base; weathers dark grey, rubbly to platy, recessive	21.0	407.0
	Total thickness of Mount Hawk Formation	402.0	
	BORSATO FORMATION		
28	Limestone, dark grey, fine-crystalline, mottled with dark brownish grey, medium-crystalline, fetid dolomite; beds 1 foot to 4 feet thick; weathers dark brownish grey, blocky, prominent	15.0	386.0
27	Dolomite, dark brownish grey, medium- to coarse-crystalline, fetid, beds 4 to 24 inches thick; weathers dark brownish grey, blocky	15.0	371.0
26	Dolomite, dark brownish grey, medium-crystalline, fetid; weathers brownish black; interbedded with dolomite, argillaceous (?), dark grey to black, very fine-crystalline; weathers light yellowish grey	12.5	356.0
25	Dolomite, dark brownish grey, medium-crystalline, fetid; weathers dark brownish grey, in part with brecciated appearance on surface	18.5	343.5
	Total thickness of Borsato Formation	61.0	
	HOLLEBEKE FORMATION		
	Upper Member		
24	Limestone, dark grey to black, very fine-crystalline; no bedding discernible; weathers light grey, massive, with fine surface lamination toward base	53.0	325.0
23	Limestone, argillaceous, light yellowish grey, beds thin and platy; weathers yellow, platy, recessive; lenses of breccia with fragments of laminated limestone at top; gradational base	7.5	272.0
22	Limestone, dark grey, fine-crystalline, bedding not apparent; weathers medium grey, massive with nodular surface, prominent	57.0	264.5
21	Limestone, dark grey, very fine-crystalline, no apparent bedding; weathers light grey, massive, prominent, with fine surface lamination	18.5	207.5
20	Limestone, dark grey, fine-crystalline, in beds 2 to 3 feet thick; with a few interbeds of light greyish yellow, argillaceous dolomite 3 feet thick	16.5	189.0
	(Cross thrust fault with 20 feet of stratigraphic separation.)		
19	Limestone, dark grey, very fine-crystalline, no apparent bedding; weathers light grey, massive, prominent	9.0	172.5
18	Limestone, dark grey, fine-crystalline, beds 6 to 24 inches thick; weathers light grey and light brownish grey, blocky, with surface lamination in relief	20.5	163.5
17	Limestone, dark grey, fine-crystalline, no bedding apparent; weathers light grey, massive, prominent	17.0	143.0
16	Limestone, dark grey, fine-crystalline, poorly defined beds 4 to 10 inches thick; weathers light brownish grey with fine surface lamination, massive to blocky, prominent	7.0	126.0
	Thickness of Upper Member	206.0	

Unit No.		Thickness (feet)	Height above base (feet)
	Lower Member		
15	Limestone, dark grey, fine-crystalline, beds 3 feet thick; weathers light grey, blocky, stromatolites discernible as lamination on weathered surface	9.0	119.0
14	Limestone, dark grey, fine-crystalline, beds 6 to 10 inches thick; weathers medium grey, with faint surface lamination; interbedded with dolomite, light greyish, platy, yellow weathering	10.5	110.0
13	Limestone, dark grey, fine- to medium-crystalline, no bedding apparent; weathers light grey, with fine surface lamination	3.0	99.5
12	Breccia, fragments of laminated limestone as above, up to 10 inches long and 3 inches thick and a heterogeneous assemblage of other angular carbonate rock fragments in medium-crystalline limestone matrix; interbedded with medium grey, medium-crystalline limestone that weathers with fine surface lamination	10.0	96.9
11	Dolomite, yellow, argillaceous, nodular, weathers yellow, recessive	3.5	86.5
10	Limestone, medium grey and light yellowish grey, beds 4 to 18 inches thick; weathers brownish grey and yellowish grey in alternating bands, flaggy, recessive	14.0	83.0
9	Covered	15.0	69.0
8	Limestone, medium grey, fine-crystalline, nodular; weathers light grey, rubbly	5.0	54.0
7	Dolomite, argillaceous, yellow, platy; weathers yellow, platy, recessive	12.0	49.0
6	Dolomite, dark grey, fine- to medium-crystalline, beds 6 inches thick; weathers dark brownish grey, blocky, with surface lamination	7.0	37.0
5	Dolomite, argillaceous (?), light yellowish grey, platy with lenses of breccia at top–dolomite fragments in argillaceous dolomite matrix	3.0	30.0
4	Dolomite, argillaceous (?), light yellowish grey; weathers yellow, with fine surface lamination	3.5	27.0
3	Dolomite, dark grey to black, fine-crystalline, beds 6 to 17 inches thick; weathers light yellowish brown, blocky	5.0	23.5
2	Dolomite, silty, light yellowish grey, alternating 3-foot platy zones, and 6- to 24-inch beds; weathers yellow, recessive	12.5	18.5
1	Shale, silty, brownish black, rubbly, interbedded with light yellowish grey, silty dolomite	6.0	6.0
	Thickness of Lower Member	119.0	
	Total thickness of Hollebeke Formation	325.0	
	Total thickness of Fairholme Group	1,034.0	

ELKO FORMATION

Regolith?, reddish orange and yellow mudstone penetrates into Elko Formation dolomite along fracture zones both perpendicular and oblique to bedding; dolomite shows extensive staining (red and orange) along these zones; staining extends to depth of more than 30 feet below top of Cambrian dolomite unit; apparent relief of more than 10 feet on upper surface of Elko Formation.

Dolomite, medium grey, medium-crystalline, no well-defined bedding; weathers light grey with colour-mottled surface.

Section 16

Section 16 is in Flathead Range on the east slope of Mount Darrah, along the crest of the ridge between North Lost Creek and Goat Creek. It is accessible from Blairmore, Alberta, via a logging road along Lyons Creek, across Willoughby Ridge, and down Lynx Creek to the mouth of Goat Creek. From there it is about 4 miles by pack-trail along Goat Creek to the section.

Unit No.		Thickness (feet)	Height above base (feet)
	PALLISER FORMATION		
73	Limestone, dark grey, very fine-crystalline, mottled with medium grey, medium-crystalline dolomite, a few isolated echinoderm columnals, bedding obscure; weathers light grey, mottled light brown, massive, prominent	9.5	1,135.0
72	Dolomite, medium grey, medium- to coarse-crystalline, pinpoint vugs become larger and more numerous toward base, bedding obscure; weathers light brownish grey with faint mottling and pock-marked surface, massive, prominent	43.0	1,125.5
71	Breccia, fragments of medium- to coarse-crystalline dolomite, as above, and light brownish grey, calcareous dolomite with stromatolite-like concentric lamination, fragments from 1-inch angular chips to 12-inch long rectangular blocks, a few continuous bands of "stromatolitic" calcareous dolomite persist through the zone	8.0	1,082.5
	Measured thickness of Palliser Formation	60.5	
	ALEXO FORMATION		
70	Covered	8.5	1,074.5
69	Limestone, silty, light grey, fine- to medium-crystalline, beds less than 1 inch thick, mud-cracked on surface in part; weathers light grey, platy, recessive	20.0	1,066.0
68	Dolomite, silty (quartz), light yellowish grey, fine-crystalline, beds ½ inch to 2 inches thick, finely laminated (colour); weathers light yellowish grey, platy, recessive	16.0	1,046.0
67	Covered (rubble is breccia with fragments less than 2 inches in diameter of silty dolomite and silty limestone)	17.0	1,030.0
	Total thickness of Alexo Formation	61.5	
	FAIRHOLME GROUP		
	SOUTHESK FORMATION		
	Arcs Member		
66	Dolomite, light grey to white, very coarse-crystalline, faint coarse cross-lamination discernible locally, beds 2 to 5 feet thick; weathers very light grey, massive, prominent	75.0	1,013.0
	Total thickness of Arcs Member	75.0	

Unit No.		Thickness (feet)	Height above base (feet)
	Grotto Member		
65	Dolomite, dark grey to black, medium-crystalline, fetid, discontinuous vuggy porosity locally in zones parallel with bedding (vugs up to 2 inches long), black chert as thin (less than 2 inches) bands and lenses in lower 9.5 feet, beds not well defined, numerous stylolites along bedding; weathers light brownish grey, massive, prominent	25.5	938.0
64	Dolomite, dark grey to black, medium-crystalline, fetid, discontinuous vuggy porosity (vugs less than 3 inches long), beds 4 inches to 6 inches thick; weathers light brownish grey, blocky, prominent	11.5	912.5
63	Dolomite, dark grey to black, medium-crystalline, fetid, discontinuous vuggy porosity (vugs less than 2 inches long), poorly defined beds 2 to 4 feet thick; weathers light yellowish grey, massive and prominent; at 1 foot above base: small *Phacellophyllum* indet., *Atrypa* fragments (GSC loc. 31246)	13.0	901.0
62	Dolomite, dark grey, medium-crystalline, fetid, black chert as lenses and bands less than 2 inches thick parallel with bedding, beds 4 to 6 inches thick; weathers light brownish grey, blocky	7.5	888.0
61	Dolomite, dark grey, medium- to fine-crystalline, fetid, beds 6 to 8 inches thick; weathers light brownish grey, blocky	12.5	880.5
	Thickness of Grotto Member	70.0	
	Total thickness of Southesk Formation	145.0	
	MOUNT HAWK FORMATION		
60	Limestone, argillaceous, black to dark grey, medium- to fine-crystalline, silicified corals and brachiopods, beds 6 to 18 inches thick; weathers light yellowish grey, flaggy, with fine surface lamination in relief; at 1.5 feet above base: *Coenites* sp., *Syringopora* sp., *Tabulophyllum* sp. A, *Devonoproductus* cf. *D. vulgaris* Stainbrook, *Atrypa* sp. (GSC loc. 31242)	7.5	868.0
59	Dolomite, dark grey, fine-crystalline, fetid, lenses of black chert less than an inch thick parallel with bedding, beds 4 to 6 inches thick; weathers light yellowish grey, flaggy	6.0	860.5
58	Limestone, argillaceous, dark grey, fine-crystalline, brachiopod and coral fragments common, bedding obscure throughout; weathers medium grey, platy to rubbly, toward the base mottled medium and dark grey, less platy; at 65.5 feet above base: *Nervostrophia* sp., *Devonoproductus* sp. indet., *Atrypa* sp., *Spinatrypa* sp. C (GSC loc. 31248)	94.0	854.5
57	Limestone, dolomitic, medium grey, medium-crystalline, bedding obscure; weathers light yellowish grey, blocky	5.0	760.5
56	Limestone, dark grey, fine-crystalline, fetid, bedding poorly defined, beds 2 to 6 feet thick; weathers dark grey, rubbly, recessive; at 33.5 feet above base: *Phacellophyllum* sp. A (GSC loc. 31247)	91.0	755.5
55	Limestone, medium grey, medium- to very coarse-crystalline, fetid, bedding obscure, faint lamination on weathered surface; weathers light grey, prominent	5.0	664.5
54	Limestone, dark grey, fine-crystalline, fetid, bedding poorly defined; weathers dark grey, rubbly, recessive	4.0	659.5
53	Limestone, light to medium grey, very coarse- to medium- crystalline, fetid; weathers light grey, prominent	2.0	655.5

Unit No.		Thickness (feet)	Height above base (feet)
	MOUNT HAWK FORMATION—*Continued*		
52	Limestone, argillaceous, dark grey to black, fine-crystalline, fetid, bedding obscure; weathers dark grey, rubbly, recessive	40.5	653.5
51	Limestone, dark grey, fine-crystalline, fetid, beds poorly defined, 2 to 4 feet thick; weathers dark grey, in part mottled dark grey and medium grey, rubbly, recessive	47.0	613.0
50	Limestone, dolomitic, medium grey, medium-crystalline; weathers light brownish grey, prominent	3.5	566.0
49	Limestone, dark grey to black, fine-crystalline, fetid, beds poorly defined, 2 to 4 feet thick; weathers dark grey, rubbly, in part with mottled surface	28.0	562.5
48	Dolomite, dark grey, medium-crystalline, fetid, numerous druse-lined vugs up to 3½ inches in diameter; weather light brownish grey	1.5	534.5
47	Dolomite, black to dark grey, fine-crystalline, beds 5 to 18 inches thick; weathers light brownish grey with faint lamination in relief on weathered surface, blocky	4.0	533.0
46	Limestone, argillaceous, dark grey, fine-crystalline; weathers black, shaly	2.5	529.0
45	Limestone, argillaceous, dark grey, fine-crystalline, beds 6 to 18 inches thick; weathers dark grey, blocky to shaly, in part with faint laminations on surface; at 11 feet above base: *Lingula* sp. and *Calvinaria albertensis* (Warren) (GSC loc. 31255)	21.0	526.5
44	Limestone, argillaceous, dark grey, fine-crystalline, beds 2 to 3 feet thick; weathers dark grey, alternate beds shaly and rubbly	20.0	505.5
43	Limestone, dark grey, medium-crystalline, fetid, beds 1 foot to 2 feet thick; weathers light brownish grey, blocky with surface lamination, prominent	9.0	405.5
42	Limestone, argillaceous, dark grey, fine-crystalline; weathers dark grey, platy, recessive	1.0	476.5
41	Limestone, dark grey to black, fine-crystalline, fetid, bedding obscure; weathers dark grey, rubbly with mottled surface	12.5	475.5
40	Limestone, argillaceous, dark grey, fine-crystalline, nodular; weathers dark grey, rubbly	7.5	463.0
39	Covered (shale?)	13.0	455.5
38	Limestone, dark grey, medium-crystalline, fetid; weathers medium grey, blocky	2.0	442.5
37	Shale, calcareous, black, platy with interbeds of limestone (argillaceous, dark grey to black, platy)	8.0	440.5
	Total thickness of Mount Hawk Formation	435.5	
	BORSATO FORMATION		
36	Dolomite, dark grey, coarse-crystalline, fetid, minor discontinuous vuggy porosity, beds 6 to 18 inches thick; weathers light brownish grey with surface laminations in relief, blocky, prominent	19.0	432.5
35	Dolomite, dark grey to black, medium- to coarse-crystalline, fetid, zones of vugs up to 3 inches in diameter parallel with bedding, beds 4 inches thick; weathers medium brownish grey, massive, prominent	46.0	413.5
34	Dolomite, dark grey, coarse-crystalline, fetid, beds 4 to 18 inches thick; weathers medium brownish grey with surface laminations, some crossbedding, prominent	37.5	367.5
	Total thickness of Borsato Formation	102.5	

Unit No.		Thickness (feet)	Height above base (feet)
	HOLLEBEKE FORMATION		
	Upper Member		
33	Dolomite, calcareous, light grey, medium-crystalline; weathers light yellowish grey, platy	4.5	330.0
32	Limestone, dark grey, fine- to medium-crystalline, beds 4 to 8 inches thick; weathers medium grey, blocky, with surface lamination in part, prominent	7.0	325.5
31	Limestone, medium grey, medium-crystalline, almost exclusively stromatoporoids (?) and corals, grades down into shaly dark grey limestone; at 3 feet above base; stromatoporoid, *Alveolites* sp. C, *Thamnopora* sp. A, *Phacellophyllum* sp. B, *Tabulophyllum* cf. *T. magnum* Fenton and Fenton (GSC loc. 31251)	4.5	318.5
30	Limestone, medium grey, medium-crystalline, a few isolated stromatoporoids (?); weathers light grey, blocky	2.0	314.0
29	Limestone, argillaceous, medium brownish grey, fine-crystalline, nodular to platy; weathers light yellowish grey, platy, recessive	5.0	312.0
28	Limestone, dark grey, very fine- to fine-crystalline, argillaceous, beds 4 to 18 inches thick; weathers light to medium grey, blocky, with faint surface lamination	14.0	307.0
27	Limestone, medium grey, medium-crystalline, bedding obscure, grades through shattered limestone into breccia, medium grey limestone fragments, tightly packed, with interstitial white calcite	8.0	293.0
26	Limestone, dark grey to black, very fine-crystalline, beds 2 to 3 feet thick; weathers dark grey, rubbly, recessive	13.5	285.0
25	Limestone, dark grey, fine-crystalline, beds 4 to 8 inches thick; weathers medium grey, blocky, with surface lamination	11.5	271.5
24	Breccia, fragments of dark grey, medium-crystalline, laminated limestone, in matrix of light grey fine-crystalline limestone; at least one unbroken 6-inch bed of dark laminated limestone is interbedded with the light grey limestone matrix material	2.5	260.0
23	Limestone, silty and argillaceous, light yellow-grey, beds less than 2 inches thick, laminated; weathers yellow-grey, platy, recessive; at base: *Spinatrypa* sp., *Athyris* sp. (GSC loc. 31245)	11.5	257.5
22	Limestone, dark grey, fine-crystalline, bedding poorly defined; weathers medium grey with surface lamination at top, nodular at base; at 5 feet above base: *Schizophoria* fragments, *Stropheodonta* fragments indet., *Eostrophalosia* sp. H ("*Productella* cf. *belanskii*" of Warren and Stelck 1956), *Atrypa* sp., *Eleutherokomma jasperensis* (Warren) (GSC loc. 31244); at base: *Schizophoria* sp. indet., *Eostrophalosia* sp., *Productella* sp., *Atrypa* sp., *Eosyringothyris*? cf. *E. anchiasper* (J. S. Williams) (GSC loc. 31240)	46.0	246.0
21	Limestone, dark grey, fine-crystalline, beds 6 to 24 inches thick; weathers medium grey, blocky	6.0	200.0
20	Limestone, medium grey, very fine-crystalline, beds 6 inches thick; weathers light yellowish grey with surface lamination	2.5	194.0
19	Limestone, dark grey, very fine-crystalline, beds 6 to 18 inches thick; weathers medium grey, blocky to rubbly	10.5	191.5
18	Covered	8.0	181.0
17	Limestone, medium grey, medium-crystalline, with abundant stromatoporoids (?)	1.0	173.0

Unit No.		Thickness (feet)	Height above base (feet)
	UPPER MEMBER OF HOLLEBEKE FORMATION—*Continued*		
16	Limestone, dolomitic, dark grey, fine- to medium-crystalline, beds 4 to 18 inches thick; weathers light yellowish grey with surface lamination, blocky, prominent	6.0	172.0
15	Limestone, dark grey, very fine-crystalline, beds 2 to 4 inches thick; weathers medium grey, rubbly, surface lamination in relief	13.0	166.0
14	Limestone, dark grey, fine-crystalline, beds 18 to 20 inches thick; weathers light greyish brown with surface lamination, blocky, prominent	5.5	153.0
13	Limestone, dark grey, fine- to very fine-crystalline, isolated stromatoporoids and brachiopods, beds poorly defined 2 to 3 feet thick; weathers light grey, massive, prominent; at 12 feet above base: a crushed coquina, *Atrypa multicostellata* Kottlowski, small spiriferid indet. (GSC loc. 31253)	12.5	147.5
12	Limestone, dark grey, medium-crystalline, stromatoporoids and brachiopods in lower part, beds 6 to 10 inches thick; weathers light brownish grey with surface lamination; at 1 foot above base: stromatoporoid, spiriferid indet., *Atrypa multicostellata* Kottlowski (GSC loc. 31252)	29.0	135.0
	Thickness of Upper Member	224.0	
	Lower Member		
11	Breccia, angular fragments of light grey limestone, dark grey limestone and yellow-grey silty limestone in matrix of medium grey fine-crystalline limestone, gradational top and bottom	1.0	106.0
10	Limestone, light brownish grey, fine-crystalline, finely colour-laminated; weathers light brownish grey, platy, recessive	2.5	105.0
9	Dolomite, light brown, fine- to medium-crystalline, beds 2 feet thick; weathers light brown with surface lamination	9.0	102.5
8	Breccia, angular fragments less than 2 inches long of light yellow silty limestone, medium grey, medium-crystalline limestone, and dark grey fine-crystalline limestone in matrix of medium grey fine-crystalline limestone	5.0	93.5
7	Covered	8.5	88.5
6	Breccia, fragments of brownish grey, medium-crystalline limestone; medium grey, fine-crystalline and light brown laminated dolomite in matrix of medium grey, very fine-crystalline limestone; grades down into laminated, medium-crystalline, brown dolomite	4.0	80.0
5	Covered	4.0	76.0
4	Limestone, light brown, medium-crystalline, finely laminated; weathers brown, flaggy	2.0	72.0
3	Limestone, dark grey, fine-crystalline, fine surface lamination, zones of breccia less than 6 inches thick, fragments of dark grey, fine-crystalline, laminated limestone in non-laminated matrix	2.0	70.0
2	Covered	52.0	68.0
1	Dolomite, dark grey, fine- to medium-crystalline, beds 6 to 8 inches thick; weathers light yellow-grey and light brownish grey with surface lamination, rubbly, recessive; base of bed sharply defined without apparent discordance	16.0	16.0
	Thickness of Lower Member	106.0	
	Total thickness of Hollebeke Formation	330.0	
	Total thickness of Fairholme Group	1,013.0	
	Overlies Elko Formation of Section 10.		

Section 17

Section 17 is a mile north of Section 16, on the east slope of Flathead Range between the middle and south forks of Goat Creek. The grey dolomite lithofacies comprising the Peechee Member of the Southesk Formation at this locality is essentially devoid of bedding. Measurements of its thickness are based on a tape and compass traverse and are subject to a higher margin of error than those in other parts of the section. No evidence of significant thickening of this unit due to repetition along thrust faults was discernible in the exposures, but thrust faults have resulted in thickening of the Fairholme sequence ½ mile to the north and the available data do not preclude their presence here. The cirque lying immediately south of the section is accessible from Blairmore via a logging road along Lyons Creek, across Willoughby Ridge, and down Lynx Creek to the mouth of Goat Creek. From there it is about 4 miles by pack-trail along Goat Creek to the section.

Unit No.		Thickness (feet)	Height above base (feet)
	PALLISER FORMATION		
35	Limestone, dark grey, fine-crystalline, mottled with medium grey, medium-crystalline dolomite, bedding obscure; weathers light grey with light yellowish grey mottling, massive, prominent	5.0	1,481.0
34	Dolomite, light brownish grey, medium-crystalline, fetid, beds poorly defined, 2 to 4 feet thick; weathers light brownish grey with faint mottling, massive prominent	20.0	1,476.0
33	Dolomite, light brownish grey, medium-crystalline, fetid, beds 4 to 18 inches thick; weathers light brownish grey with faint surface lamination, blocky, prominent	4.5	1,456.0
32	Breccia, angular fragments of brownish grey, colour-laminated dolomite, dark grey limestone, and white medium-crystalline dolomite in matrix of light brownish grey, medium-crystalline dolomite; fragments up to 18 inches long; size highly variable over short distance	4.5	1,447.0
	Measured thickness of Palliser Formation	34.0	
	ALEXO FORMATION		
31	Dolomite, silty, light yellowish grey, fine-crystalline, colour banding in beds 3 to 6 inches thick; weathers light yellowish grey, rubbly to flaggy	11.5	1,442.5
30	Dolomite, silty, light yellowish grey, fine-crystalline, fine colour lamination, beds less than 2 inches thick, in part dolomitic siltstone with mud-cracked surfaces; weathers yellowish grey, platy, recessive	11.5	1,431.0
	Total thickness of Alexo Formation	23.0	

Unit No.		Thickness (feet)	Height above base (feet)
	FAIRHOLME GROUP		
	SOUTHESK FORMATION		
	Peechee Member		
29	Dolomite, light grey, coarse-crystalline to very coarse-crystalline, sugary; irregular interlocking vugs lined with coarse-crystalline white calcite druse, in part completely filled with coarse-crystalline white calcite; no apparent bedding; weathers very light grey, massive, prominent, with irregular cavities in surface up to several feet in diameter	146.0	1,419.5
28	Dolomite, light grey, medium- to fine-crystalline, network of interlocking vugs filled with medium- to coarse-crystalline white calcite; locally has appearance of breccia with dolomite fragments in white calcite matrix; no bedding apparent; weathers very light grey, massive, prominent	32.0	1,273.5
27	Dolomite, very light grey, medium- to coarse-crystalline, numerous small vugs lined with dolomite druse; bedding not discernible; weathers very light grey, massive, prominent	277.0	1,241.5
26	Dolomite, white and very light grey, coarse-crystalline, numerous large irregular vugs filled with medium- to coarse-crystalline white calcite; no bedding discernible; weathers very light grey, massive, in part with brecciated appearance on weathered surface (dolomite fragments in calcite matrix)	25.5	964.0
25	Dolomite, light grey, medium-crystalline, numerous vugs, lined with white calcite druse or filled with white calcite, permeate the rock; no apparent bedding discernible; weathers very light grey, massive, prominent	172.0	939.0
24	Dolomite, very light grey, coarse- to medium-crystalline, sugary, discontinuous druse-lined vugs, show faint planar orientation; weathers very light grey, massive, with faint thick-bedded appearance, prominent	59.0	767.0
23	Dolomite, very light grey, medium- to coarse-crystalline, little or no vuggy porosity; bedding not discernible; weathers very light grey, massive, prominent	128.0	708.0
22	Dolomite, medium to light grey, medium-crystalline; zones of dolomite, dark grey, medium-crystalline, fetid; faint bedding discernible as thick colour-banding on weathered surface; medium to light grey dolomite weathers light grey; dark grey dolomite weathers light brownish grey; massive, prominent; faint bedding and dark grey dolomite zones grade laterally into non-bedded medium grey, medium-crystalline dolomite	50.0	580.0
21	Dolomite, medium grey, medium-crystalline, vugs filled with white medium-crystalline calcite occur locally; toward base grades into dolomite breccia with angular fragments of medium grey, fine- to medium-crystalline dolomite set in matrix of light pink-grey, coarse-crystalline dolomite; vuggy with white calcite filling vugs; weathers light grey, massive, prominent	93.0	530.0
20	Dolomite, dark grey, medium-crystalline, fetid, vugs up to 3 inches in diameter filled with coarse-crystalline white calcite; weathers light brownish grey, massive, with faint colour banding	12.0	437.0
19	Dolomite, light grey, medium-crystalline, pinpoint vugs throughout; no well-defined bedding; weathers very light grey, massive with faint surface banding in patches, prominent	77.0	425.0
18	Dolomite, dark grey, medium-crystalline, slightly fetid, no distinct bedding; weathers light brownish grey with faint surface lamination, massive, prominent, gradational into units above and below	12.0	348.0

Unit No.		Thickness (feet)	Height above base (feet)
	PEECHEE MEMBER—*Continued*		
17	Dolomite, dark grey, medium-crystalline, slightly fetid, contains a few silicified coral fragments, black chert lenses and bands less than 2 inches thick locally, beds 3 to 6 inches thick; weathers light brownish grey, flaggy	7.5	336.0
	Total thickness of Peechee Member and of Southesk Formation	1,051.0	
	MOUNT HAWK FORMATION		
16	Limestone, brownish black, fine-crystalline, silicified brachiopods and corals abundant locally, beds 6 to 24 inches thick; weathers light brown-grey with dark grey mottling, blocky; at 21 feet above base: *Phacellophyllum* sp., *Schizophoria* sp., *Atrypa* cf. *A. devoniana* Webster, *Spinatrypa* sp. C, *Cyrtina* small sp. (GSC loc. 31254)	24.0	328.5
	Total thickness of Mount Hawk Formation	24.0	
	BORSATO FORMATION		
15	Dolomite, dark grey, medium-crystalline, beds 8 to 18 inches thick; weathers light brownish grey, blocky	10.0	304.5
14	Dolomite, dark grey to black, medium-crystalline, fetid, black chert lenses locally, poorly defined beds 2 to 4 feet thick; zones with abundant *Amphipora*; weathers medium brownish grey, massive, prominent	51.0	294.5
	Total thickness of Borsato Formation	61.0	
	HOLLEBEKE FORMATION		
	Upper Member		
13	Limestone, dark grey to black, fine- to medium-crystalline, beds 4 feet thick; weathers medium grey, in part with surface lamination, blocky	20.0	243.5
12	Limestone, medium grey, very fine-crystalline, beds 6 to 18 inches thick; weathers medium grey, blocky	9.0	223.5
11	Limestone, brownish black, fine-crystalline, abundant spherical and elliptical stromatolites; medium grey	2.0	214.5
10	Limestone, dark grey, fine-crystalline, beds 2 inches to 3 feet thick; weathers medium grey, blocky, with surface lamination in a few beds	20.0	212.5
9	Limestone, brownish black, fine-crystalline, abundant spherical and elliptical stromatolites; weathers light brownish grey, stromatolites medium grey	3.0	192.5
8	Limestone, medium grey, very fine-crystalline, beds 2 to 3 feet thick; weathers medium grey, blocky	10.0	189.5
7	Limestone, dark grey, very fine-crystalline, beds poorly defined, ½ foot to 4 feet thick; weathers medium grey, massive, with surface laminations; near base a lens of breccia 6 feet thick and 15 feet long grades into unbroken limestone laterally; rectangular blocks up to 3 feet long and 1 foot thick occur in matrix of medium grey, medium-crystalline limestone; at base a bed of brecciated, platy limestone 3 feet thick extends for 50 feet along strike grading into non-brecciated limestone	39.0	179.5

Unit No.		Thickness (feet)	Height above base (feet)
	UPPER MEMBER OF HOLLEBEKE FORMATION—*Continued*		
6	Limestone, medium grey to dark grey, very fine-crystalline, slightly nodular, bedding poorly defined, bedding surfaces wavy and irregular; weathers light yellowish grey, flaggy to rubbly...........	50.0	140.5
5	Limestone, dark grey, very fine-crystalline, beds poorly defined 4 to 18 inches thick; weathers medium grey, massive to rubbly with faint surface lamination in relief..	25.0	90.5
4	Limestone, medium grey, fine-crystalline, isolated spherical stromatolites; weathers light yellow-grey, stromatolites medium grey..	1.0	65.5
3	Limestone, light brownish grey, fine-crystalline, beds 6 to 12 inches thick; weathers light yellowish grey, blocky................................	5.5	64.5
2	Limestone, dark grey, fine-crystalline, beds not well defined; weathers light grey, rubbly with faint surface lamination in relief..	49.0	59.0
1	Limestone, dark grey, fine-crystalline, faint colour lamination, beds not well defined; weathers light brownish grey with surface lamination in relief..	10.0	10.0
	Measured thickness of Hollebeke Formation...........................	243.5	
	Measured thickness of Fairholme Group................................	1,419.5	

Section 18

The following section is on the southwest slope of Mount Darrah, at the headwaters of North Lost Creek. The section may be reached from Blairmore by way of the road along Lyons Creek, across Willoughby Ridge and down Lynx Creek to the mouth of Goat Creek. A pack-trail follows Goat Creek to the headwaters of the south fork and the section is about a mile to the south. An alternate route is by way of the road from Hillcrest along Byron and Webb Creeks and the Carbondale River valley to Lost Creek where logging roads extend along North Lost Creek to within 2 miles of the section.

	EXSHAW FORMATION		
	Shale, black		
	PALLISER FORMATION		
	Costigan Member		
11	Limestone, dark grey, very fine-crystalline, local vuggy porosity (¼-inch), fetid, poorly defined nodular 1-inch beds which are components of more clearly defined 6- to 12-inch units; weathers medium grey, rubbly, mildly recessive..	42.0	718.0
10	Limestone, dark grey, very fine-crystalline, fetid, nodular 2- to 6-inch beds; weathers medium grey, rubbly, mildly recessive........	78.0	676.0
9	Limestone, dark grey, very fine-crystalline, fetid, distinctly bedded in 3- to 6-inch units; weathers medium grey, blocky, locally nodular...	39.0	598.0
	Thickness of Costigan Member..	159.0	

95894—13

Unit No.		Thickness (feet)	Height above base (feet)
	Morro Member		
8	Limestone, dark brownish grey, cryptocrystalline, massive, becomes brecciated and mottled with dolomite in lower 12 feet; weathers medium grey, blocky, prominent	56.0	559.0
7	Limestone, dark brownish grey, medium-crystalline, mottled with a dolomite boxwork, fetid, massive; weathers dark brown, blocky, mildly recessive	20.0	503.0
6	Limestone, medium grey, fine-crystalline, fetid, slightly dolomitic in mottles near top, a few 1-inch black chert nodules near top; weathers medium grey, blocky, prominent	55.0	483.0
5	Limestone, dark grey, fine- to medium-crystalline, fetid, beds 1 foot to 3 feet thick; weathers light grey, blocky, prominent	48.0	428.0
4	Limestone, dark grey, fine-crystalline, fetid, mottled with irregular patches of dark brown, medium-crystalline dolomite (20 to 30% of rock), poorly defined beds 6 to 24 inches thick; weathers light to medium grey with medium brown mottling, blocky, prominent	287.0	380.0
3	Dolomite, medium brown, medium-crystalline, fetid, vuggy porosity (½- to 1-inch), massive with poorly defined 1- to 2-inch colour laminations; weathers light brown, blocky	36.0	93.0
	Thickness of Morro Member	502.0	
	Total thickness of Palliser Formation	661.0	
	ALEXO FORMATION		
2	Covered (some brown weathering limestone in scree)	47.0	57.0
	Total thickness of Alexo Formation	47.0	
	FAIRHOLME GROUP		
	SOUTHESK FORMATION		
	Arcs Member		
1	Dolomite, white to light grey, coarse-crystalline, poorly defined beds 2 to 4 feet thick; weathers light grey, massive	10.0	10.0
	Measured thickness of Fairholme Group	10.0	

Section 19

The following section was examined along the provincial boundary 6,500 feet south of Mount Darrah. It is accessible from the 'Corbin road' in the valley of Corbin Creek. The basal part of the Banff Formation and the Exshaw Formation (?) are covered and exposures are only fair within the lower part of the Banff Formation.

	BANFF FORMATION		
	Upper Part		
18	Limestone, medium grey, medium- to coarse-crystalline, crinoidal, with irregular lenticular blebs of medium grey chert parallel with bedding	5.0	385.0
	Measured thickness of upper part of Banff Formation	5.0	

Unit No.		Thickness (feet)	Height above base (feet)
	Middle Part		
17	Limestone, dark grey, fine- to medium-crystalline, with irregular and lenticular blebs of black chert parallel with bedding; weathers light brownish grey, blocky	8.0	380.0
16	Limestone, argillaceous, black, fine-crystalline, dense; weathers brownish grey with faint colour lamination locally, platy; at 20 feet above base: *Cleiothyridina* sp., *Proetus* sp. (GSC loc. 28148)	42.0	372.0
15	Limestone, argillaceous, black, fine-crystalline, dense, finely colour laminated, with thin bands and lenticular blebs of black chert and cherty limestone parallel with bedding; weathers medium grey, platy	62.0	330.0
14	Limestone, argillaceous, black, fine-crystalline, dense; zones with bands and lenticular blebs of black cherty limestone; beds 4 to 12 inches thick; weathers light brown with fine colour lamination	78.0	268.0
13	Limestone, argillaceous, black, fine-crystalline, dense with thin bands and small nodules of black chert; beds less than 4 inches thick; weathers light brown with fine colour lamination	21.0	190.0
12	Limestone, argillaceous, black, fine-crystalline, dense; beds 4 to 12 inches thick, finely laminated; weathers light brown	21.0	169.0
	Thickness of middle part	232.0	
	Lower Part		
11	Covered	20.0	148.0
10	Shale, silty, black; finely colour laminated; fissile to platy; weathers brown	7.0	128.0
9	Siltstone, calcareous, dark grey to black; finely colour laminated; platy; weathers light brown	18.0	121.0
8	Chert, black, finely colour laminated, beds less than 4 inches thick	12.0	103.0
7	Limestone, argillaceous, cherty, black, fine-crystalline, dense; finely colour laminated; beds 6 inches thick; weathers platy to rubbly	14.0	91.0
6	Chert, calcareous, black, finely colour laminated; beds less than 4 inches thick; weathers to fine rubble	10.0	77.0
5	Shale, silty, calcareous, brownish black, fissile; interbedded with black chert and with limestone, black with faint fine colour laminations, fine-crystalline, dense, beds under 12 inches thick	12.0	67.0
4	Shale, silty, calcareous, brownish black, fissile	5.0	55.0
3	Shale, silty, cherty, black, finely colour laminated; bands of black chert 2 to 4 inches thick; weathers to fine rubble	9.5	50.0
2	Limestone, argillaceous, black, fine-crystalline, dense	1.5	40.5
	Thickness of lower part	109.0	
	Measured thickness of Banff Formation	341.0	
	EXSHAW FORMATION (?)		
1	Covered (scree of black, fissile, silty shale; minor amounts of black chert and dense argillaceous limestone)	39.0	39.0
	Total thickness of Exshaw Formation (?)	39.0	
	PALLISER FORMATION		
	Limestone, dark grey, fine- to medium-crystalline; weathers light grey, massive	—	—

Section 20

Section was measured along the north slope of Centre Mountain in the southern part of Flathead Range; measurements commence below a thrust fault in the Carnarvon Member of the Mount Head Formation. The precise stratigraphic separation across the fault is unknown. The section terminates in the middle part of the Banff Formation above a thrust fault that cuts out part of this stratigraphic unit. Exposures of the steeply dipping beds are excellent along the steep cliff that forms the north face of Centre Mountain. The section is accessible from the British Columbia Forest Service Flathead road in the valley of Squaw Creek.

Unit No.		Thickness (feet)	Height above base (feet)
	RUNDLE GROUP		
	MOUNT HEAD FORMATION		
	Carnarvon Member		
135	Limestone, black, very fine-crystalline, beds 1 foot to 3 feet thick; weathers light grey and light brownish grey, blocky; at 11 feet above base: *Dictyoclostus* sp. possibly *D. tenuicostatus* (Hall), *Reticularia* sp., *Punctospirifer* sp. (GSC loc. 28147)	15.0	2,299.5
134	Limestone, skeletal (echinoderm) calcarenite, black, coarse-grained, with small brachiopods and bryozoa, beds 1 foot to 3 feet thick; weathers light grey, blocky; at 6 feet above base: *Spirifer* sp., cf. *S. pellaensis* Weller, *Girtyella*? sp., small pelecypods, fenestellid bryozoan fragments (GSC loc. 28143)	17.0	2,284.5
133	Limestone, dark grey, fine-crystalline, with scattered brachiopod, bryozoan, and echinoderm fragments; fragments very abundant at base	31.0	2,267.5
	Measured thickness of Carnarvon Member	63.0	
	Marston Member		
132	Dolomite, silty, dark grey, fine-crystalline, beds 1 foot to 3 feet thick; weathers light greyish brown with fine lamination, blocky, recessive	22.0	2,236.5
131	Limestone, dark grey, very fine-crystalline, with lenses of black chert	1.0	2,214.5
130	Dolomite, slightly silty, dark grey, fine-crystalline, beds 4 to 6 inches thick, weathers light greyish brown with fine lamination, platy	3.0	2,213.5
129	Limestone, dark grey, fine-crystalline, pelletoidal and oolitic (medium-grained) calcarenite in part, beds 1 foot to 2 feet thick, a few bands and lenses (less than 3 inches thick) of black chert near top; weathers light grey	3.0	2,210.5
128	Limestone, dolomitic, silty, dark grey, fine-crystalline, beds 1 inch to 6 inches thick; weathers light yellowish brown, with fine surface lamination, platy to blocky, recessive	6.5	2,207.5
127	Limestone, dark grey to black, very fine-crystalline and cryptocrystalline, beds 4 to 8 inches thick, bands up to 6 inches thick of medium grey chert; weathers light grey with fine lamination in upper part, recessive	4.5	2,201.0

Unit No.		Thickness (feet)	Height above base (feet)
	MARSTON MEMBER—*Continued*		
126	Dolomite, silty and argillaceous, yellow-grey, fine-crystalline; weathers light yellowish brown, blocky, recessive	5.0	2,196.5
125	Limestone, dark grey, fine- to medium-crystalline, beds 6 to 8 inches thick, cherty limestone bands; weathers light blue-grey with fine surface lamination, blocky	7.0	2,191.5
124	Limestone, medium grey, medium-crystalline, beds 6 to 18 inches thick; weathers light grey, blocky, prominent	10.0	2,184.5
123	Dolomite, slightly silty, light grey, fine-crystalline, with bands of light grey chert increasing in abundance towards top, beds 6 to 18 inches thick; weathers light grey, blocky, prominent	13.0	2,174.5
122	Limestone, medium grey, medium-crystalline, blebs of light grey chert up to 12 inches in diameter, scattered echinoderm fragments and silicified corals, beds 6 to 36 inches thick; weathers light grey, blocky, prominent; at 26 feet above base: *Ekvasophyllum*? sp., *Lithostrotion banffense* Warren, *Syringopora* sp. (GSC loc. 28136)	27.0	2,161.5
121	Dolomite, silty, light grey, fine-crystalline, beds 3 to 12 inches thick; weathers very light yellow-grey, recessive; at top: *Ekvasophyllum*? sp., fossil fragments (GSC loc. 28149)	4.0	2,134.5
	Thickness of Marston Member	106.0	
	Loomis Member		
120	Limestone, light grey, medium-crystalline, bedding obscure; weathers light grey, massive, prominent; at 5 feet above base: *Koninckophyllum arizelum*? Crickmay (GSC loc. 28139)	15.0	2,130.5
119	Limestone, skeletal (echinoderm) calcarenite, medium grey, coarse-grained, scattered bryozoa and brachiopod fragments; weathers light grey, massive, prominent	30.0	2,115.5
118	Dolomite, light grey, fine-crystalline, small (less than ½ inch) vugs filled with white calcite; weathers light brownish grey, massive	4.0	2,085.5
117	Limestone, fine-crystalline, light grey, poorly defined beds 2 to 4 feet thick, disseminated skeletal fragments (echinoderms, brachiopods, and bryozoa); weathers light grey, massive, prominent; at 2.5 feet above base: *Spirifer* sp. aff. *S. keokuk* Hall, fenestellid bryozoa (GSC loc. 28134)	7.0	2,081.5
116	Dolomite, calcareous, light grey, fine-crystalline; weathers light grey, massive, prominent	11.0	2,074.5
115	Limestone, crinoidal calcarenite, light grey, coarse-grained, bedding obscure; weathers very light grey, massive, prominent	19.0	2,063.5
114	Dolomite, medium grey, medium-crystalline, scattered vugs (less than 1 inch) filled with coarse-crystalline white calcite, bedding obscure; weathers light brownish grey, blocky, recessive	7.0	2,044.5
113	Limestone, skeletal (echinoderm), light grey, coarse-crystalline; weathers very light grey, massive, prominent	32.0	2,037.5
112	Limestone, dolomitic, light grey, coarse-grained, echinoderm fragments in a fine-crystalline dolomite matrix; weathers light grey, massive, prominent	15.0	2,005.5
111	Limestone, skeletal (echinoderm) calcarenite, oolitic in part, light grey, coarse-grained; weathers light grey, massive, prominent	30.0	1,990.5
110	Dolomite, medium grey, medium-crystalline, with small (less than ½ inch) vugs filled with white calcite; weathers light brownish grey, recessive	15.0	1,960.5

Unit No.		Thickness (feet)	Height above base (feet)
	LOOMIS MEMBER—*Continued*		
109	Dolomite, slightly silty, medium to dark grey, fine-crystalline, beds 6 to 18 inches thick; weathers light brownish grey with faint lamination, blocky to flaggy, recessive	13.0	1,945.5
108	Limestone, skeletal (echinoderm-brachiopod) calcarenite, medium grey, very coarse grained; weathers light grey	2.0	1,932.5
107	Limestone, skeletal (echinoderm) and oolitic calcarenite, light to medium grey, coarse-grained, bedding obscure; weathers very light grey, massive, prominent	83.0	1,930.5
106	Limestone, slightly dolomitic, medium grey, medium- to coarse-crystalline, scattered relict echinoderm fragments; weathers light brownish grey, massive, prominent	13.5	1,847.5
	Thickness of Loomis Member	296.5	
	Salter Member		
105	Dolomite, dark grey, very fine-crystalline; weathers light yellowish grey, blocky	1.5	1,834.0
104	Dolomite, silty, light yellow-grey, medium-crystalline; weathers light yellowish brown, flaggy, with faint lamination and delicate crossbedding etched into relief on weathered surface	20.0	1,832.5
103	Dolomite, light grey, fine-crystalline, beds 2 to 4 feet thick; weathers light greyish brown, blocky, prominent	2.0	1,812.5
102	Dolomite, arenaceous (very fine-grained quartz sand), light grey, fine-crystalline, beds 2 to 4 feet thick; weathers light grey with delicate lamination and crossbedding etched into relief on gritty surface, blocky, prominent	18.0	1,810.5
101	Dolomite, light grey, medium- to fine-crystalline, with irregular bands of white chert parallel with bedding and occasional large (2- to 6-inch) vugs filled with white calcite, bedding obscure; weathers light brownish grey, massive, prominent	17.0	1,792.5
100	Dolomite, silty, light grey, medium-crystalline, with irregular lacy patches of cherty dolomite and with vugs filled with coarse white calcite, beds 4 to 6 feet thick; weathers light brownish grey, prominent	33.0	1,775.5
99	Dolomite, very light grey, medium-crystalline, sugary; weathers white	2.0	1,742.5
98	Dolomite, light grey, fine-crystalline, with irregular blebs of medium grey chert, small vugs filled with coarse white calcite, beds 1 foot to 4 feet thick; weathers light grey, prominent	31.0	1,740.5
97	Limestone, skeletal (echinoderm) calcarenite, medium grey, coarse-grained; weathers light grey, massive, prominent	10.0	1,709.5
96	Limestone, medium grey, medium-crystalline, with irregular blebs of medium grey chert aligned parallel with bedding, beds 2 to 4 feet thick; weathers light brownish grey, prominent	14.0	1,699.5
95	Dolomite, slightly silty, light grey, fine-crystalline, with nodules ¼ inch in diameter of milky chert scattered throughout, beds 6 to 24 inches thick; weathers light greyish brown, blocky with gritty surface, recessive	13.0	1,685.5
	Thickness of Salter Member	161.5	
	Measured thickness of Mount Head Formation	627.0	

Unit No.		Thickness (feet)	Height above base (feet)
	LIVINGSTONE FORMATION		
	Upper Part		
94	Limestone, light grey, medium-crystalline, with occasional echinoderm fragments, large irregular blebs of medium grey chert parallel with bedding; weathers light grey, massive, prominent	8.0	1,672.5
93	Limestone, skeletal (echinoderm) calcarenite, medium grey, coarse-grained, fetid; weathers light grey, massive, prominent.............	6.0	1,664.5
92	Limestone, light grey, medium-crystalline, with irregular blebs of medium grey chert; weathers light grey, massive, prominent......	8.0	1,658.5
91	Limestone, skeletal (echinoderm), light grey, coarse-crystalline; weathers light grey, massive, prominent......................................	75.0	1,650.5
90	Limestone, dolomitic, light to medium grey, coarse-grained echinoderm fragments embedded in a matrix of fine-crystalline dolomite; weathers light grey, massive, prominent............................	5.0	1,575.5
89	Dolomite, calcareous, light grey, fine-crystalline, scattered irregular blebs of medium grey chert..	4.5	1,570.5
88	Limestone, skeletal (echinoderm) calcarenite, light grey, coarse-grained; weathers light grey, massive, prominent.......................	4.0	1,566.0
87	Limestone, light grey, medium-crystalline, scattered echinoderm and bryozoan fragments, irregular blebs of medium grey chert in upper part, beds 1 foot to 4 feet thick; weathers light grey, slightly recessive..	13.5	1,562.0
86	Limestone, oolitic and skeletal (echinoderm) calcarenite, light to medium grey, coarse-grained; weathers very light grey, massive, prominent..	24.0	1,548.5
85	Limestone, light grey, medium-crystalline, beds 1 foot to 3 feet thick; weathers light grey, blocky..	10.0	1,524.5
84	Limestone, slightly dolomitic, medium grey, fine-crystalline, with large (2- to 6-inch) irregular blebs of medium grey calcareous chert; weathers light brownish grey, massive, prominent...........	13.0	1,514.5
83	Limestone, skeletal (echinoderm) calcarenite, light grey, coarse-grained, with scattered very coarse grains; weathers light grey, massive, prominent..	9.0	1,501.5
82	Dolomite, argillaceous, calcareous, slightly silty, light grey, fine-crystalline, sugary, beds 2 to 3 feet thick; weathers light brownish grey, blocky, recessive...	10.0	1,482.5
81	Limestone, skeletal (echinoderm) calcarenite, very coarse-grained, light grey; in part, light grey, coarse-crystalline; weathers light grey, massive, prominent..	117.0	1,482.5
80	Dolomite, slightly silty, light grey, fine-crystalline, with small (less than $\frac{1}{2}$ inch) calcite filled vugs; weathers light grey, massive, prominent..	6.5	1,365.5
79	Limestone, skeletal (echinoderm) calcarenite, light grey, coarse-grained, poorly defined 2- to 8-foot beds; weathers light grey with faint coarse lamination etched into relief on weathered surface..	13.5	1,359.0
78	Limestone, light grey, fine-crystalline, beds 1 foot thick, irregular blebs of light grey chert..	7.5	1,345.5
77	Limestone, skeletal (echinoderm) calcarenite, light grey, coarse-grained; weathers light grey, massive, prominent.......................	1.5	1,338.0

Unit No.		Thickness (feet)	Height above base (feet)
	UPPER PART OF LIVINGSTONE FORMATION—*Continued*		
76	Dolomite, slightly silty, calcareous, light grey, fine-crystalline, beds 8 to 18 inches thick; weathers light yellow-grey, recessive	8.0	1,336.5
75	Limestone, skeletal (echinoderm) calcarenite, light grey, coarse-grained; weathers light grey, massive, prominent	15.0	1,328.5
74	Limestone, slightly dolomitic, skeletal (echinoderm), light grey to white, medium- to coarse-crystalline, slightly sugary; weathers very light grey, massive, recessive	3.0	1,313.5
73	Limestone, skeletal (echinoderm) calcarenite, light grey, very coarse-grained; weathers very light grey, massive and prominent	9.0	1,310.5
72	Limestone, dolomitic, light grey to white, medium- to coarse-crystalline, echinoderm fragments discernible in zones, slightly sugary; weathers light grey, massive, slightly recessive	17.0	1,301.5
71	Limestone, slightly dolomitic, skeletal (echinoderm), light grey, medium- to coarse-crystalline, beds 4 feet thick; weathers light grey, partly recessive	8.0	1,284.5
70	Limestone, skeletal (echinoderm) calcarenite, light grey, very coarse-grained; weathers light grey, massive to slabby, prominent	11.0	1,276.5
69	Dolomite, calcareous, slightly silty, light grey, fine-crystalline; weathers very light grey, recessive	1.0	1,265.5
68	Limestone, skeletal (echinoderm) calcarenite, light grey, coarse-grained, with scattered bryozoan fragments; weathers light grey, massive	9.0	1,264.5
67	Dolomite, calcareous, light grey, fine-crystalline; weathers light grey to white, recessive	4.0	1,255.5
66	Limestone, skeletal (echinoderm-bryozoa) calcarenite, light grey, very coarse-grained; weathers very light grey, massive, prominent	28.0	1,251.5
65	Limestone, medium grey, fine-crystalline, with coarse calcite grains; weathers light grey, massive, prominent	9.0	1,223.5
64	Limestone, skeletal (echinoderm) calcarenite, light grey, coarse-grained; weathers light grey, massive, slightly recessive	10.0	1,214.5
63	Dolomite, light grey, medium-crystalline, slightly sugary with intercrystalline porosity; weathers white, blocky, recessive	4.0	1,204.5
62	Limestone, skeletal (echinoderm) calcarenite, light grey, coarse-grained; weathers very light grey, massive, prominent	3.0	1,200.5
61	Dolomite, slightly silty, light grey, fine-crystalline; weathers light grey, gritty surface, recessive	3.0	1,197.5
60	Limestone, skeletal (echinoderm-bryozoa) calcarenite, light grey, coarse-grained, weathers very light grey, massive	17.0	1,194.5
59	Dolomite, slightly calcareous, light grey, fine-crystalline, with irregular lacy blebs of light grey chert; weathers light grey, recessive, blocky	3.0	1,177.5
58	Limestone, skeletal (echinoderm) calcarenite, light grey, coarse-grained; weathers very light grey, massive	4.0	1,174.5
57	Dolomite, slightly calcareous, light grey, fine-crystalline, with irregular lacy blebs of light grey chert; weathers light grey, blocky, recessive	8.0	1,170.5
56	Limestone, skeletal (echinoderm) calcarenite, light grey, very coarse-grained with scattered bryozoan fragments; weathers light grey, massive	3.0	1,162.5

Unit No.		Thickness (feet)	Height above base (feet)
	UPPER PART OF LIVINGSTONE FORMATION—*Continued*		
55	Dolomite, calcareous, very light grey, fine-crystalline, sugary, with scattered small (less than ¼ inch) limonitic nodules; weathers white, recessive	4.0	1,159.5
54	Limestone, skeletal (echinoderm) calcarenite, light grey, very coarse-grained; weathers light grey, massive	6.0	1,155.5
53	Covered	6.0	1,149.5
52	Limestone, skeletal (echinoderm) calcarenite, light grey, very coarse-grained; weathers very light grey, massive, prominent, with faint coarse lamination etched into relief on weathered surface	16.0	1,143.5
51	Limestone, skeletal (echinoderm), slightly dolomitic, light grey, medium-crystalline; weathers very light grey, blocky to massive	8.0	1,127.5
50	Dolomite, light grey, fine-crystalline, with small (less than ¼ inch) nodules of limonite, bedding obscure; weathers white, blocky..	8.0	1,119.5
49	Limestone, skeletal (echinoderm) calcarenite, light grey, very coarse-grained, scattered bryozoan fragments; weathers light grey, massive	5.0	1,111.5
48	Dolomite, calcareous, very light grey, medium-crystalline, slightly sugary, bedding obscure; weathers white, blocky	7.0	1,106.5
47	Breccia, very angular blocks of light grey, very coarse-grained, crinoidal calcarenite, medium-crystalline limestone and fine-crystalline limestone up to 3 feet in diameter, loosely packed; interstices open and lined with very coarse calcite druse or filled with a mixture of very coarse skeletal (echinoderm) sand and fine calcite silt; all gradations in fragment size along strike to coarse-grained skeletal calcarenite; coarse breccia lenses; coarse-grained calcarenite becomes dominant upward and is sole component toward top of unit	46.0	1,099.5
46	Dolomite, light grey, medium-crystalline, scattered echinoderm columnals locally; weathers white, recessive	8.0	1,053.5
45	Limestone, medium to light grey, fine-crystalline, with nodular and irregular wisp-like patches of medium grey calcareous chert; weathers light grey, massive, with faint wisp-like lamination	56.0	1,045.5
44	Limestone, dolomitic, light grey, fine-crystalline, with pea-size nodules of 'marcasite' largely altered to limonite; weathers yellow-grey, blocky	4.0	989.5
43	Limestone, silicified in part, light grey, very coarse-grained, with scattered bryozoa fragments, corals; limestone vuggy with hematite-limonite vug coatings; cherty in part; contains: *Syringopora* sp., *Productus*? sp., fenestellid bryozoa (GSC loc. 28142)	1.5	985.5
42	Dolomite, slightly silty, calcareous, light to medium grey, fine-crystalline, marcasite nodules up to 1 inch in diameter; weathers blocky to platy yellow-grey	2.5	984.0
	Thickness of upper part	691.0	
	Lower Part		
41	Limestone, skeletal (echinoderm-bryozoa) calcarenite, light grey, coarse-grained, very coarse-grained in lenses, silicified crinoid and fenestellid bryozoan fragments locally; weathers light grey, massive	4.0	981.5
40	Limestone, light to medium grey, fine-crystalline; weathers light grey	2.0	97.75

Unit No.		Thickness (feet)	Height above base (feet)
	LOWER PART OF LIVINGSTONE FORMATION—*Continued*		
39	Limestone, skeletal (echinoderm) calcarenite, light grey, very coarse-grained; weathers light grey, massive	9.0	975.5
38	Limestone, slightly dolomitic (?), light grey, fine-crystalline, with irregular lace-like patches of light grey chert	6.0	966.5
37	Limestone, skeletal, light grey, coarse-crystalline; weathers light grey, massive	5.0	960.5
36	Limestone, medium grey, medium- to fine-crystalline, with cherty limestone zones parallel with bedding; weathers light grey, cherty zones yellow-grey	3.0	955.5
35	Limestone, skeletal (echinoderm) calcarenite, light grey, coarse-grained; weathers light grey, massive	8.0	952.5
34	Limestone, light grey, medium-crystalline, with wisp-like stringers and nodular patches of medium grey calcareous chert, parallel with bedding	31.5	944.5
33	Limestone, light grey, fine-crystalline, with wisp-like blebs of calcareous chert parallel with bedding	4.0	913.0
32	Limestone, skeletal (echinoderm) calcarenite, white, very coarse-grained; weathers very light grey, massive	6.5	909.0
31	Limestone, light grey, fine- to medium-crystalline, faint wisp-like cherty limestone zones parallel with bedding	4.0	902.5
30	Limestone, skeletal (echinoderm) calcarenite, light grey, coarse-grained; weathers light grey, massive	21.0	898.5
29	Limestone, light grey, medium-crystalline, with irregular wisp-like blebs of medium grey calcareous chert parallel with bedding; weathers light grey, massive	39.0	877.5
28	Limestone, skeletal (echinoderm) calcarenite, light grey, coarse-grained, with zones up to 4 feet thick of very coarse grained skeletal calcarenite; weathers light grey, massive; in very coarse grained zones, slabby	39.0	838.5
27	Limestone, medium grey, fine- to medium-crystalline, with irregular blebs of calcareous medium grey chert; at 4 feet above base; *Echinoconchus* sp. cf. *E. biseriatus* (Hall), fenestellid bryozoa (GSC loc. 28138)	7.0	799.5
26	Limestone, skeletal (echinoderm) calcarenite, light grey, very coarse-grained; weathers very light grey, massive	12.0	792.5
25	Limestone, medium grey, fine- to medium-crystalline, with irregular blebs up to 6 inches across of medium grey cherty limestone; weathers light grey, massive	8.0	780.5
24	Limestone, skeletal (echinoderm) calcarenite, light grey, very coarse-grained, friable in part, a few scattered horn corals; weathers very light grey, massive	80.0	772.5
23	Limestone, medium grey, fine-crystalline, with fine lamination; weathers light grey, platy	3.0	692.5
22	Limestone, skeletal (echinoderm) calcarenite, light grey, very coarse-grained, fetid and bituminous; weathers light grey, massive; at 8 feet above base: coarse-ribbed zaphrentoid corals, indet. (GSC loc. 28165)	22.0	689.5
21	Limestone, medium grey, medium-crystalline, scattered crinoid (?) fragments, thin wispy cherty stringers locally	17.0	667.5
20	Limestone, medium grey, medium- to fine-crystalline, with scattered crinoid fragments and irregular calcareous chert lenses, beds 4 feet thick, poorly defined, weathers light grey, massive	30.0	650.0

Unit No.		Thickness (feet)	Height above base (feet)
	LOWER PART OF LIVINGSTONE FORMATION—*Continued*		
19	Limestone, medium grey, fine-crystalline, numerous scattered large (up to ½ inch) echinoderm fragments, interbeds less than 2 feet thick of light grey, fine-crystalline limestone	22.0	600.5
18	Limestone, medium grey, fine- to medium-crystalline, scattered large calcite grains, wisp-like bands of cherty limestone parallel with bedding; weathers light grey, massive, cherty bands in relief	66.0	598.5
17	Limestone, skeletal (echinoderm) calcarenite, light grey, coarse-grained, very coarse-grained lenses locally; weathers light grey, massive, with faint surface lamination	49.0	532.5
16	Limestone, skeletal (crinoidal?), light grey, coarse-crystalline, with thin (less than ¼ inch) elongate cherty lenses parallel with bedding; weathers light grey, massive, with faint surface lamination in zones	95.0	483.5
15	Limestone, interbanded medium to light grey, medium-crystalline and medium grey, coarse-crystalline, skeletal, beds 6 inches thick; weathers light grey, with laminated surface in part	2.0	388.5
14	Limestone, skeletal (echinoderm) calcarenite, light grey, very coarse-grained, bedding obscure, occasional nodular chert patches and thin cherty stringers; weathers very light grey with crossbedding in surface lamination; in basal 6 inches: *Schellwienella*? sp., *Chonetes*? sp., crinoid fragments (GSC loc. 28141)	81.0	386.5
	Thickness of lower part	676.0	
	Total thickness of Livingstone Formation	1,367.0	
	BANFF FORMATION		
	Upper Part		
13	Limestone, medium grey, medium- to fine-crystalline, with wisp-like bands, lenses, and patches of medium grey calcareous chert, beds 1 foot thick; weathers light to medium grey, blocky	23.5	305.0
12	Limestone, medium grey, medium-crystalline, with scattered skeletal (echinoderm?) fragments, wisp-like bands and lenses of medium grey calcareous chert parallel with bedding, beds 4 feet thick, not distinct; weathers light to medium grey, massive to blocky	21.5	281.5
11	Limestone, dark grey, fine- to medium-crystalline, with abundant dark grey and black chert as irregular bands, blebs and lenses roughly parallel with bedding (30% chert); weathers light to medium grey, platy to blocky	29.0	260.0
10	Limestone, medium grey, medium-crystalline, with occasional wisp-like lenses and bands of medium grey calcareous chert less than 2 inches thick (up to 50% calcareous chert)	32.0	231.0
9	Limestone, medium grey, medium-crystalline; weathers light grey, massive	58.0	199.0
8	Limestone, medium grey, fine- to medium-crystalline, with irregular bands and lenses of medium grey calcareous chert parallel with bedding, poorly defined beds 4 feet thick; weathers medium grey, massive	38.0	141.0
7	Limestone, argillaceous, medium to dark grey, fine- to medium-crystalline, argillaceous partings give platy appearance; weathers medium grey, platy, with wisp-like lamination	30.0	103.0

Unit No.		Thickness (feet)	Height above base (feet)
	UPPER PART OF BANFF FORMATION—*Continued*		
6	Limestone, medium to light grey, medium-crystalline; weathers light grey, massive, with faint wisp-like lamination	15.0	73.0
5	Limestone, medium grey, medium-crystalline, with wisp-like stringers of medium grey cherty limestone parallel with bedding; weathers light grey with wisp-like lamination, blocky to platy; gradational downward through approximately 3 feet into middle part of Banff Formation	15.5	58.0
	Thickness of upper part	262.5	
	Middle Part		
4	Limestone, slightly silty and argillaceous, dark grey, fine-crystalline, finely laminated, with bands, lenses and irregular patches of black chert (30% chert)	26.5	42.5
3	Limestone, black, fine-crystalline, with thin (less than 1 inch) irregular bands and lenses of black chert and cherty limestone; weathers light brown grey with 'honeycombed' to banded surface, platy	11.0	16.0
2	Limestone, black, fine-crystalline, with fine colour lamination; weathers medium grey	1.0	5.0
1	Limestone, argillaceous, black, fine-crystalline, with elongate lenses and bands less than 2 inches thick of black chert throughout (40% chert); weathers light brownish grey, blocky to platy	4.0	4.0
	Base of Banff faulted		
	Thickness of middle part	42.5	
	Measured thickness of Banff Formation	305.0	

Section 21

The Etherington Formation and the upper part of the Mount Head Formation are relatively well exposed along the crest of a prominent east-west ridge immediately east of the summit of the British Columbia Forest Service Flathead road at Flathead Pass. The section was measured along the crest of this ridge which lies 2 miles north of Centre Mountain. The upper part of the Etherington Formation is not completely exposed. The description of this part of the section is based on the examination of exposures along the south side of the ridge a few hundred feet below the crest. The section terminates at the base against a fault on which the precise stratigraphic separation is unknown. The exposures are easily accessible from the British Columbia Forest Service Flathead road, a mile to the west.

	ROCKY MOUNTAIN FORMATION		
117	Sandstone, dolomitic, white, medium-grained, bands and blebs of light grey chert; weathers light grey with pink patches	2.0	783.0
116	Dolomite, very silty, dark grey, fine-crystalline, medium grey chert blebs; weathers light grey with pink patches	4.0	781.0
115	Sandstone, dolomitic, medium grey, fine-grained, irregular bands and blebs of medium grey chert (50% chert); weathers light yellow-grey with pink patches	6.0	777.0
	Measured thickness	12.0	

Unit No.		Thickness (feet)	Height above base (feet)
	ETHERINGTON FORMATION		
	Upper Part		
114	Covered	10.0	771.0
113	Dolomite, silty, calcareous, dark grey, fine-crystalline; weathers very light grey, blocky	4.0	761.0
112	Covered	5.0	757.0
111	Limestone, skeletal (echinoderm in part) calcarenite, dark grey, coarse-grained; weathers light grey, blocky	13.0	752.0
110	Covered	7.0	739.0
109	Limestone, silty, dark grey, fine-crystalline; weathers light grey and light brownish grey, blocky	3.0	732.0
108	Limestone, dark grey, medium-crystalline; weathers light grey, blocky	12.0	729.0
107	Limestone, arenaceous (fine-grained quartz), light grey, fine-crystalline, laminated; weathers light grey, blocky, with pronounced surface lamination	8.0	717.0
106	Dolomite, arenaceous (fine-grained quartz), light grey, fine- to medium-crystalline, with irregular cherty dolomite wisps and blebs; weathers light grey, blocky, recessive	6.0	709.0
105	Covered	8.0	703.0
104	Sandstone, quartzose, white, fine-grained, friable; weathers light yellow, recessive	2.0	695.0
	Total thickness of upper part	78.0	
	Middle Part		
103	Limestone, medium grey, medium-crystalline, beds 2 feet thick; weathers light grey, blocky	6.0	693.0
102	Limestone, silty, slightly dolomitic, light grey, fine-crystalline, scattered medium-grained fragmental calcite grains; weathers light yellow-grey, blocky, recessive	11.0	687.0
101	Limestone, dark grey, medium-crystalline, disseminated medium-grained fragmental calcite grains, beds 1 foot to 3 feet thick; weathers light grey, blocky, prominent	12.0	676.0
100	Limestone, dolomitic, slightly silty, light grey, fine-crystalline; weathers light brownish grey, blocky, recessive	3.0	664.0
99	Limestone, skeletal (echinoderm), very coarse-grained calcarenite in part, light grey, coarse-crystalline; weathers light grey, massive	9.0	661.0
98	Dolomite, slightly silty, light grey, fine-crystalline; weathers light brownish grey, recessive, platy	6.0	652.0
97	Limestone, light grey, medium-crystalline, disseminated coarse fragmental calcite grains, fine-crystalline and dolomitic in part, beds 2 to 3 feet thick; weathers grey, blocky	11.0	646.0
96	Dolomite, slightly calcareous and silty, light grey, fine-crystalline; weathers very light grey, blocky, recessive	3.0	635.0
95	Limestone, dark grey, coarse-crystalline, beds 2 to 4 feet thick; weathers light grey, blocky, massive, prominent	12.0	632.0
94	Dolomite, slightly calcareous, silty, light grey, fine-crystalline, platy, recessive	1.5	620.0
93	Limestone, dark grey, medium-crystalline, isolated irregular patches of medium grey calcareous chert, bedding obscure; weathers light grey, massive, prominent	10.0	618.5

Unit No.		Thickness (feet)	Height above base (feet)
	MIDDLE PART OF ETHERINGTON FORMATION—*Continued*		
92	Limestone, medium grey, fine-crystalline, bands and lenses of medium grey, calcareous grey chert, platy; weathers light grey, platy, recessive	5.0	608.5
91	Limestone, dark grey, medium-crystalline, beds 2 to 4 feet thick; weathers light grey, blocky to massive, prominent	12.0	603.5
90	Limestone, dolomitic, silty, light grey, fine-crystalline, platy; weathers light buff, recessive; at base: *Orthotetes* sp., *Chonetes* sp. aff. *C. chesterensis* Weller, *Punctospirifer* sp., *Cleiothyridina* sp., *Dielasma* sp.? fenestellid bryozoa (GSC loc. 28160)	2.5	591.5
89	Limestone, light grey, fine-crystalline, coarse calcite fragments abundant locally; weathers light grey, blocky	6.0	589.0
88	Limestone, light grey, cryptocrystalline and fine-crystalline, beds 2 feet thick; weathers light grey, blocky	4.0	583.0
87	Limestone, medium grey, fine-crystalline, scattered brachiopods; at top: Productid fragments similar to 28137 (below), *Spirifer* sp. possibly *S. bifurcatus* Hall, *Punctospirifer* sp., *Composita* sp. (GSC loc. 28146); at 1 foot above base: *Orthotetes*? sp., fragments of small *Dictyoclostus*, *Girtyella* sp. possibly aff. *G. indianensis* Weller (GSC loc. 28137)	2.0	579.0
86	Limestone, light grey, fine-crystalline, irregular blebs of light grey chert, beds 6 inches thick; weathers light grey, blocky	3.0	577.0
85	Dolomite, light grey, fine-crystalline; weathers light grey	1.0	574.0
84	Limestone, calcarenite, light grey, medium-grained and coarse-grained, oolitic in part; weathers light grey, blocky	3.0	573.0
83	Limestone, medium grey, fine-crystalline, beds 4 to 6 inches thick; weathers light grey, flaggy	3.5	570.0
82	Siltstone, calcareous, light grey, platy; weathers light grey	3.0	566.5
81	Limestone, medium grey, fine-crystalline, beds 6 to 12 inches thick; weathers light grey, blocky	4.5	563.5
80	Limestone, light grey, medium-crystalline, irregular bands and blebs of light grey chert and calcareous chert, beds 6 inches thick; weathers light grey, flaggy, with surface lamination and banding	15.0	559.0
79	Limestone, oolitic calcarenite, light grey, coarse-grained and medium-grained, beds 2 feet thick; weathers light grey, blocky	8.0	544.0
78	Limestone, calcarenite, medium grey, coarse-grained, isolated rounded granules of medium grey, very fine crystalline limestone, light grey chert blebs at base, beds 18 inches thick	3.0	?
77	Shale, calcareous; and limestone, argillaceous, rubbly, yellow-grey and greenish grey, isolated oolites and pelletoidal grains, recessive	1.5	533.0
76	Limestone, skeletal (echinoderm) in part, light grey, coarse-crystalline, beds 2 feet thick; weathers light grey, blocky	8.0	531.5
75	Limestone, rudaceous calcarenite, light grey and medium grey, coarse-grained, scattered rounded granules and pebbles of medium grey, very fine crystalline limestone, beds 18 inches thick	5.0	523.5
74	Limestone, light grey, very fine crystalline, lenticular blebs of light and medium grey chert, beds 4 inches thick; weathers light grey, flaggy, with surface lamination	8.5	518.5
73	Limestone, light grey, very fine crystalline and cryptocrystalline, with patches, lenses and irregular wisps of medium-grained oolitic calcarenite, beds 1 foot to 3 feet thick; weathers light grey, blocky	9.0	510.0

Unit No.		Thickness (feet)	Height above base (feet)
	MIDDLE PART OF ETHERINGTON FORMATION—*Continued*		
72	Limestone, silty, yellow-grey, fine-crystalline, platy, with isolated ½-inch pebbles of fine-crystalline, medium grey limestone	0.5	501.0
71	Limestone, light grey, fine-crystalline, isolated coarse fragmental calcite grains, beds 6 to 24 inches thick; weathers light grey, blocky	14.0	500.5
70	Dolomite, calcareous, argillaceous, light grey, fine-crystalline; weathers light greyish brown	1.5	486.5
69	Limestone, light grey, fine- to medium-crystalline; weathers light grey, blocky	2.0	485.0
68	Limestone, silty, light grey and light yellow-grey, fine-crystalline, beds 2 to 6 inches thick; abundant spiriferoid brachiopods; weathers buff, platy to flaggy	5.0	483.0
67	Limestone, light grey, fine-crystalline, bands and blebs of light blue-grey chert, beds 4 to 6 inches thick; weathers light grey, flaggy	4.0	478.0
66	Limestone, oolitic in part, light grey, coarse-crystalline, flecked with limonite, beds 18 inches thick; weathers light grey, blocky	5.0	474.0
65	Limestone, light grey, fine-crystalline, beds 3 to 6 inches thick; weathers light grey, flaggy	4.0	469.0
64	Limestone, slightly silty, dark grey to medium grey, fine-crystalline, platy; weathers light greenish brown at top: small *Linoproductus*, *Spirifer increbescens* Hall, *Spirifer* cf. *S. leidyi* Norwood and Pratten (GSC loc. 28129)	2.0	465.0
63	Limestone, light grey, medium-crystalline, platy to flaggy, finely laminated in part, bands and blebs of dark grey chert; basal 6 inches shaly and fossiliferous: *Echinoconchus* sp. cf. *E. biseriatus* (Hall), fenestellid bryozoa (GSC loc. 28138)	7.5	463.0
62	Dolomite, light yellow-grey, fine-crystalline; weathers light greyish brown, recessive, blocky to rubbly	5.5	455.5
61	Limestone, light grey, fine- to medium-crystalline, beds 1 foot to 3 feet thick; weathers light grey	11.0	450.0
60	Limestone, light grey, medium-crystalline; weathers light grey, grades to dolomite at top and base; light yellow-grey, fine-crystalline dolomite zone at top; highly variable in thickness over short distances	7.5	439.0
	Thickness of middle part	261.5	
	(Cross west-dipping thrust fault with stratigraphic separation of about 30 feet)		
	Lower Part		
59	Dolomite, light grey, fine-crystalline; weathers white, blocky	5.0	431.5
58	Dolomite, argillaceous, light grey, fine-crystalline; weathers buff, blocky	3.5	426.5
57	Limestone, dark grey, fine-crystalline; weathers light grey, blocky	3.5	423.0
56	Covered	10.0	419.5
55	Shale, green, soft, rubbly	0.5	409.5
54	Limestone, cryptocrystalline, medium grey, becomes dolomitic, fine-crystalline toward top	2.0	409.0
53	Shale, green, rubbly	0.5	407.0
52	Covered	6.0	406.0
51	Limestone, crinoidal, light grey, medium- to coarse-crystalline, dolomitic and fine-crystalline in part; weathers light grey, flaggy	4.5	400.5

Unit No.		Thickness (feet)	Height above base (feet)
	LOWER PART OF ETHERINGTON FORMATION—*Continued*		
50	Limestone, light grey, medium- to coarse-crystalline, bedding obscure; weathers light grey, massive, prominent	22.0	396.0
49	Limestone, light grey, fine-crystalline, beds 4 to 6 inches thick; bands of light grey chert 2 to 4 inches thick	6.5	374.0
48	Shale, light green, rubbly	0.5	367.5
47	Limestone, light grey, fine-crystalline, isolated brachiopods; weathers light grey; contains *Gigantoproductus brazerianus* (Girty) (GSC loc. 28151)	3.0	367.0
46	Limestone, shaly, light grey, fine-crystalline, platy	1.0	364.0
45	Limestone, light grey, medium-crystalline, shot through and interbanded with light grey chert (50% chert), weathers light grey	1.5	363.0
44	Shale, light green-grey, rubbly	0.5	361.5
43	Limestone, light grey, medium-crystalline, irregular bands and patches of light grey calcareous chert (50% chert); limestone weathers light grey; chert, light greyish brown	5.5	361.0
42	Limestone, dark grey, fine-crystalline, isolated crinoid columnals; weathers light grey, blocky	2.5	355.5
41	Shale, light green-grey, rubbly	0.5	353.0
40	Dolomite, silty, yellow-grey, fine-crystalline, numerous irregular blebs of light grey chert, irregular patches of very coarse-crystalline, light grey, porous, bituminous and fetid, calcite up to 12 inches in diameter	5.0	352.5
39	Limestone, light grey, fine-crystalline, beds 1 foot to 3 feet thick; weathers light grey, blocky	5.5	347.5
38	Limestone, light grey, fine- to medium-crystalline, irregular blebs of light grey and white chert; weathers light brownish grey, blocky; at 0.5 foot above base: Rugose coral, possibly a new species of *Dibunophyllum* (GSC loc. 28167)	4.0	342.0
	Thickness of lower part	93.5	
	Total thickness of Etherington Formation	433.0	
	MOUNT HEAD FORMATION		
	Carnarvon Member		
37	Limestone, black, fine-crystalline, shot through with irregular blebs of black chert	2.0	338.0
36	Limestone, skeletal (echinoderm) calcarenite, dark grey, coarse-grained, with fine-crystalline limestone matrix; small brachiopods, pelecypods and possibly some ostracod fragments; bryozoa (GSC loc. 28133)	2.5	336.0
35	Limestone, dark grey to black, fine-crystalline, beds 2 to 4 feet thick, numerous large ellipical blebs of dark grey, slightly calcareous chert	10.0	333.5
34	Limestone, dark grey, fine- to medium-crystalline, beds 1 foot to 4 feet thick, isolated coarse-grained echinoderm and bryozoan skeletal fragments throughout, occasional lenses where fragmental material is dominant have gradational boundaries; prominent beds; at 0.5 foot below top: Rugose coral fragments, *Dictyoclostus* sp. possibly *D. tenuicostatus* (Hall), *Spirifer* sp. indet. *Composita* sp. (GSC loc. 28128)	44.5	323.5
33	Limestone, skeletal calcarenite, medium grey, coarse-grained, black echinoderm fragments in calcareous silt matrix	5.0	279.0

Unit No.		Thickness (feet)	Height above base (feet)
	CARNARVON MEMBER—*Continued*		
32	Limestone, shaly, black, fine-crystalline, platy	0.5	274.0
31	Limestone, black, cryptocrystalline; weathers light grey	2.5	273.5
30	Limestone, black, fine-crystalline, beds 2 feet thick; weathers light grey, blocky; 6 feet above base a 1-foot zone with irregular blebs of black calcareous chert	23.5	271.0
29	Limestone, argillaceous, black, fine-crystalline, platy, becomes less argillaceous and less platy toward top, isolated echinoderm fragments; weathers medium grey	8.0	?
28	Limestone, dark grey, fine-crystalline, beds 1 foot thick; weathers light grey, blocky	16.0	239.5
27	Limestone, silty, dark grey, fine- to medium-crystalline, beds 1 foot thick; weathers light grey-brown, blocky; at base: *Faberophyllum*? sp. (fragments) (GSC loc. 28127)	12.0	223.5
26	Shale, calcareous, black, papery	0.5	211.5
25	Limestone, dark grey to black, fine-crystalline, beds 1 foot to 3 feet thick; weathers light grey, blocky	18.0	211.0
24	Limestone, medium to dark grey, cryptocrystalline, isolated coarse fragmental grains locally, beds 6 to 18 inches thick; weathers light grey, blocky	29.0	193.0
23	Limestone, slightly silty, black, fine-crystalline, fetid, beds 8 to 12 inches thick; weathers light brown-grey, blocky	4.0	164.0
22	Limestone, black, cryptocrystalline, numerous small (less than ½ inch long) vugs filled with white calcite, beds 1 foot thick; weathers light grey, blocky	6.0	160.0
21	Limestone, silty, especially in lower part, black, fine-crystalline, fetid, beds 6 to 18 inches thick; weathers medium brown, blocky; becomes less silty and light brownish grey weathering toward top; at 1 foot above base: *Linoproductus* sp. (GSC loc. 28159)	21.0	154.0
20	Limestone, medium to dark grey, cryptocrystalline, beds 1 foot to 4 feet thick; weathers light grey, blocky	6.0	133.0
19	Limestone, black, fine-crystalline, beds 18 inches thick; weathers light grey, blocky	4.0	127.0
	Cross west-dipping thrust fault with a stratigraphic separation of about 10 feet.		
18	Limestone, black, fine-crystalline, beds 18 to 36 inches thick; weathers light brown-black, blocky	25.0	123.0
17	Limestone, medium to dark grey, cryptocrystalline, beds 18 inches thick; weathers light grey, blocky	19.0	98.0
16	Limestone, black, fine-crystalline; weathers light brownish grey	2.0	79.0
15	Limestone, light to medium grey, becomes darker toward top, cryptocrystalline, beds 2 feet thick; vuggy porosity, vugs up to 2 inches in diameter; weathers light grey, blocky	33.5	77.0
	Total thickness of Carnarvon Member	294.5	
	Marston Member		
14	Dolomite, silty near base, gradational upward through interbedded calcareous zones into limestone, medium yellow-grey, fine-crystalline, beds 2 feet thick; weathers light brownish grey	9.5	43.5
13	Shale, carbonaceous, silty near top, non-calcareous, black, some poorly preserved coalified plant fragments	1.5	34.0
12	Limestone, dark grey, fine-crystalline, isolated crinoid columnals; weathers light grey	3.5	32.5

Unit No.		Thickness (feet)	Height above base (feet)
	MARSTON MEMBER—*Continued*		
11	Limestone, slightly dolomitic, slightly silty, dark grey, fine-crystalline; weathers light greyish brown with faint surface lamination	1.5	29.0
10	Limestone, black, fine-crystalline; weathers light grey....................	1.0	27.5
9	Dolomite, silty, dark brown-grey, fine-crystalline; weathers light greyish brown with gritty surface..	3.0	26.5
8	Limestone, black, fine-crystalline; weathers light grey....................	1.5	23.5
7	Dolomite, silty, gradational into silty limestone and limestone at top and base, dark grey, fine-crystalline; weathers light greyish brown with gritty surface...	4.0	22.0
6	Limestone, black, fine-crystalline, isolated crinoid fragments in zones, a 6-inch band with vuggy porosity 12 inches below top..	3.0	18.0
5	Shale, silty, non-calcareous, carbonaceous, black with coalified plant fragments; the predominance of lycopod structures indicates the presence of: *Lepidodendron* sp., *Lepidophyllum* sp. and possibly *Sigillaria* sp., in addition there are fragments of cordaitean leaves and a suggestion of calamitean stems (GSC loc. 4929)....	0.5	15.0
4	Limestone, dark grey, cryptocrystalline, dense; weathers light grey, blocky..	4.0	14.5
3	Limestone, silty, black, fine-crystalline, scattered echinoderm fragments; weathers light greyish brown, gritty, blocky...................	3.0	10.5
2	Limestone, dark grey to black, fine-crystalline beds 18 inches thick; weathers light grey, blocky with fine lamination etched into relief in part..	3.5	7.5
1	Limestone, silty, slightly dolomitic, medium grey, fine-crystalline, beds 18 inches thick; weathers light brown, blocky, fine gritty surface..	4.0	4.0
	(Steep east-dipping normal fault)		
	Measured thickness of Marston Member.................................	43.5	

Section 22

Section was examined along the steep banks of the headwaters of Michel Creek, about 1,100 yards east of the British Columbia Forest Service Flathead road. The section is on the west slope of Flathead Range, 2 miles on a bearing of N35°W from the peak of Centre Mountain.

The upper part of the Rocky Mountain Formation is not exposed but strata of the upper part of the Spray River Formation occur about 200 feet stratigraphically above the highest exposed Rocky Mountain beds.

	ROCKY MOUNTAIN FORMATION		
	Lower Part		
34	Sandstone, light grey to white, medium-grained, quartzitic, dolomitic at base with faint surface lamination; more quartzitic at top, beds 4 feet thick..	46.0	674.0
33	Dolomite, silty with faint lamination, light grey, fine-crystalline, irregular patches of cherty dolomite; weathers light grey............	17.0	628.0
32	Sandstone, quartzitic and dolomitic, fine-grained; weathers light grey, blocky, with lamination in relief..	22.0	611.0

Unit No.		Thickness (feet)	Height above base (feet)
	LOWER PART OF ROCKY MOUNTAIN FORMATION—*Continued*		
31	Quartzite, light grey and white, medium-grained, beds 4 to 6 feet thick; weathers light grey, blocky to massive	49.0	589.0
30	Covered	26.0	540.0
29	Quartzite, light grey, medium-grained, beds 2 to 4 feet thick; weathers light grey, blocky	100.0	514.0
28	Sandstone, quartzitic, light grey, coarse-grained; weathers light grey with pink patches; coarse surface lamination and cross-bedding in part, sharp contact with underlying unit grades imperceptibly into overlying unit	10.0	414.0
27	Sandstone, quartzitic, light grey to white, coarse-grained, beds 4 feet thick, not distinct; weathers light grey, massive	61.0	404.0
26	Sandstone, quartzitic, light grey to light yellow-grey, slightly dolomitic, fine- to medium-grained, beds 2 to 4 feet thick; weathers light grey	20.0	343.0
25	Quartzite, light grey, medium-grained, beds 2 to 4 feet thick; weathers light grey	10.0	323.0
24	Sandstone, dolomitic to quartzitic, light grey, medium-grained, a few thin bands of light grey chert; at base: *Orbiculoidea arenaria* Shimer, *Productus* sp. indet., *Schizophoria* sp. possibly *S. texana* Girty (GSC loc. 28150)	6.0	313.0
23	Sandstone, slightly dolomitic, light grey, fine- to medium-grained, beds 6 to 24 inches thick; weathers light grey, blocky, faintly laminated in part	50.0	307.0
22	Sandstone, slightly dolomitic, light grey, fine-grained, distinct banded appearance	3.0	257.0
21	Quartzite, light grey to light yellow-grey, medium- to fine-grained, beds 2 feet thick; weathers light grey	23.0	254.0
20	Sandstone, quartzitic and dolomitic, light to medium grey, fine-grained, beds 2 feet thick; weathers grey to brown with surface lamination, coarsely crossbedded	8.0	231.0
19	Quartzite, dolomitic, light grey to light yellow-grey, fine-grained, beds 2 to 3 feet thick; weathers light grey	14.0	223.0
18	Quartzite, light grey to medium grey, fine-grained, in beds 2 feet thick; weathers light grey	6.0	209.0
17	Sandstone, quartzitic and dolomitic, light grey to yellow-grey, beds 2 to 4 feet thick; weathers light grey	7.0	209.0
16	Quartzite, white and light grey, fine-grained; weathers light grey	2.0	196.0
15	Sandstone, quartzitic and dolomitic, light to medium grey and yellow-grey, very fine-grained, beds 2 to 4 feet thick; weathers light grey, blocky	37.0	194.0
14	Sandstone, dolomitic, light grey, fine-grained, faintly laminated in part; weathers light brownish grey	4.0	157.0
13	Dolomite, arenaceous (quartz), medium grey, medium-crystalline; weathers light grey	2.5	153.0
12	Sandstone, dolomitic, light grey, very fine grained, faint lamination in part; weathers light brownish grey	4.0	150.5
11	Quartzite, slightly dolomitic, light grey to white, fine-grained, beds 18 inches thick; weathers light grey, blocky	31.5	146.5
10	Dolomite, arenaceous (quartz), light grey, medium-crystalline, beds 1 foot to 3 feet thick; weathers light grey, blocky	10.0	115.0
9	Dolomite, silty, light grey, fine- to medium-crystalline, with occasional bands and lenses of light grey chert, beds 2 feet thick; weathers very light grey, blocky	25.0	105.0

Unit No.		Thickness (feet)	Height above base (feet)
	LOWER PART OF ROCKY MOUNTAIN FORMATION—*Continued*		
8	Dolomite, argillaceous, light grey, very fine-crystalline, with irregular blebs of light grey chert, beds 2 to 3 feet thick; weathers light brownish grey to grey, blocky	5.0	80.0
7	Sandstone, quartzitic and dolomitic, light greenish grey, fine-grained, some scattered pyritic nodules up to 2 inches in diameter, beds 1 foot to 2 feet thick; weathers light yellowish grey, blocky	4.0	75.0
6	Sandstone, dolomitic, light yellow-grey and orange-grey, very fine-grained, beds 3 to 6 feet thick; weathers light grey with rust splashes	16.0	71.0
5	Sandstone, slightly dolomitic, light grey and light yellowish grey, medium- to fine-grained, banded and laminated; weathers light grey, flaggy to blocky with lamination and crossbedding on surface locally	9.0	55.0
4	Sandstone, dolomitic, and calcareous, light grey, medium-grained, bands and blebs of light grey chert at base (50% chert); weathers light grey, blocky, with distinct lamination in relief	3.0	46.0
	Measured thickness of lower part of Rocky Mountain Formation	631.0	
	ETHERINGTON FORMATION		
3	Dolomite, slightly silty in part, light grey, fine-crystalline, contains a few light grey chert nodules 3 inches long; weathers light grey, blocky	9.0	43.0
2	Dolomite, calcareous, medium grey, fine-crystalline, beds 6 to 18 inches thick, occasional vugs lined with coarse, white calcite and bituminous matter; weathers light grey, blocky	33.0	34.0
1	Dolomite, calcareous, light grey, very fine-crystalline; weathers white, blocky	1.0	1.0
	Measured thickness of Etherington Formation	43.0	

Section 23

Section was examined at the east side of the Fernie basin between the headwaters of Michel and McEvoy Creeks. The strata are exposed on the headwall of a cirque immediately west of Barnes Lake at the head of a tributary of Michel Creek. The base of the section is 5.68 miles on a bearing of S72°W from Mount Darrah. Section is accessible by way of the tributary stream from where it enters Michel Creek valley at an abandoned logging campsite, 1½ miles south of the north boundary of the map-area, and 2½ miles south of the mouth of Corbin Creek.

	SPRAY RIVER FORMATION		
	Lower Part		
63	Shale, medium rust-brown, faintly colour-laminated, rubbly	4.5	865.5
62	Shale, slightly silty, medium rust-brown, colour-laminated, platy	1.5	861.0
61	Shale, medium rust-brown, faintly colour-laminated, rubbly	4.0	859.5
60	Shale, slightly silty, medium rust-brown, colour-laminated, platy	6.5	855.5
59	Siltstone, shaly, medium rust-brown, platy	2.5	849.0

Unit No.		Thickness (feet)	Height above base (feet)
	LOWER PART OF SPRAY RIVER FORMATION—*Continued*		
58	Shale, silty in part, medium rust-brown, faintly colour-laminated, rubbly	42.5	846.5
57	Siltstone, shaly, medium rust-brown, colour-laminated, papery	1.5	804.0
56	Shale, medium to light rust-brown, rubbly	20.5	802.5
55	Siltstone, calcareous, medium rust-brown, platy	1.5	782.0
54	Covered (loose rubbly rust-brown shale and slightly silty shale)	43.5	737.0
53	Sandstone, phosphatic, calcareous, dark grey, medium-grained, small nodules of black chert; weathers light grey on exterior and medium rust-brown in interior, blocky	11.0	737.0
	Measured thickness of Spray River Formation	139.5	
	ROCKY MOUNTAIN FORMATION		
	Upper Part		
52	Dolomite, light grey, fine-crystalline, patchy discontinuous vuggy porosity, vugs 0.5 to 1 mm in diameter lined with bituminous matter, lacy networks of milky white chert, bedding obscure; weathers white, blocky to massive	10.0	726.0
	No apparent discordance at base of Spray River Formation.		
51	Dolomite, silty, medium to light grey, very fine-crystalline, nodular blebs of medium grey chert, beds 3 feet thick; weathers white, blocky; at top: fossil fragments including some silicified corals of *Caninia* type (GSC loc. 28327)	8.0	716.0
50	Chert, light yellow-grey, scattered quartz pebbles up to 3 mm in diameter	0.3	708.0
49	Dolomite, silty, medium to light grey, very fine-crystalline; weathers white	0.7	707.7
48	Conglomerate, quartz pebbles and very coarse quartz sand, medium grey, cemented with medium grey chert	0.3	707.0
47	Dolomite, silty, medium to light grey, very fine-crystalline; weathers white	0.6	706.7
46	Shale, light brownish grey, rubbly	0.3	706.1
45	Chert, dolomitic, medium grey, gradational up through dolomitic shale to shale	0.3	705.8
44	Dolomite, silty, medium grey, fine-crystalline, irregular blebs of medium grey chert; weathers very light yellow-grey	2.0	705.5
43	Sandstone, quartzitic and dolomitic, medium grey, fine-grained, 2-inch lenses of quartzitic quartz-pebble conglomerate at base	0.5	703.5
42	Dolomite, silty, dark grey, fine-crystalline; weathers very light grey	1.0	703.0
41	Shale, light yellowish brown, rubbly	0.1	702.0
40	Dolomite, silty, dark grey, fine-crystalline, with irregular patches of vuggy, colloform, medium grey chert; weathers light yellowish grey	4.9	701.9
39	Dolomite, silty, light grey, fine-crystalline, with irregular patches of medium and dark grey chert and of silicified crinoid and brachiopod fragments, beds 3 feet thick; weathers very light grey, blocky; at 12 feet above base: brachiopod fragments, crinoid ossicles, bryozoa cf. *Tabulipora* (GSC loc. 28326)	10.0	697.0
38	Sandstone, dolomitic, fine- to medium-grained; dolomite, quartzose, fine-crystalline; and quartzite, fine-grained; patchy, rounded coarse quartz sand and granules and angular chert fragments scattered throughout	3.0	684.0

Unit No.		Thickness (feet)	Height above base (feet)
	UPPER PART OF ROCKY MOUNTAIN FORMATION—*Continued*		
37	Dolomite, medium grey, very fine-crystalline, gradational upward into quartzose dolomite and quartzite; weathers white	0.5	681.0
36	Sandstone, dolomitic, light grey, coarse-grained, crossbedded, grades downward to quartzose fine-crystalline light grey dolomite at base	3.0	680.5
	Total thickness of upper part of Rocky Mountain Formation	48.5	
	Lower Part		
35	Sandstone, dolomitic, light grey, coarse- to medium-grained, thin quartzitic bands, coarsely crossbedded; weathers light grey, massive, with quartzitic bands as surface ribs	13.0	677.5
34	Quartzite, slightly dolomitic, very light grey, medium-grained; weathers light yellow-grey with 'honeycombed' surface	6.0	664.5
33	Quartzite, light grey, medium-grained, crossbedded; weathers light yellowish grey, massive, with ribbed surface	5.0	658.5
32	Chert, light reddish grey, in large irregular and elliptical patches with concentric colour banding, occasional lenses of fine-crystalline, light grey dolomite	0.5	653.5
31	Sandstone, slightly dolomitic, light grey, medium-grained; weathers light yellowish grey with 'honeycombed' surface	2.0	653.0
30	Sandstone, slightly dolomitic, light grey, medium-grained, thin dense quartzite bands, crossbedded; weathers light grey, massive, with fine surface ribbing in relief	15.0	651.0
29	Sandstone, slightly dolomitic, light grey, fine-grained, beds 1 foot to 3 feet thick; weathers light grey in part, with surface ribbing in relief, blocky	12.0	636.0
28	Quartzite, dolomitic, light grey, fine-grained; weathers very light grey, massive	6.0	624.0
27	Quartzite, light grey, fine-grained, beds 2 to 4 feet thick; weathers light grey, massive to blocky	14.0	618.0
26	Quartzite, light grey, fine-grained, numerous irregular patches of white chert	6.0	604.0
25	Quartzite, dolomitic, light grey, fine-grained; weathers very light grey	3.0	598.0
24	Quartzite, slightly dolomitic, light grey, fine-grained, numerous bands and lenses of light grey chert	4.0	595.0
23	Quartzite, slightly dolomitic, light grey, fine- to medium-grained, occasional lens and band of white chert; weathers light grey, massive, in part with surface ribbing in relief	17.0	591.0
22	Quartzite, light grey, fine-grained, dense; weathers white	2.0	574.0
21	Quartzite, slightly dolomitic, light grey, fine-grained, beds 3 feet thick; weathers light grey, blocky, in part with surface relief ribbing	14.0	572.0
20	Dolomite, silty, medium grey, fine-crystalline, numerous lenses and nodules of medium and dark grey chert (50% chert)	6.0	558.0
19	Dolomite, light grey, fine-crystalline, zones with scattered grains of quartz and chert of coarse sand grade and quartzitic lenses of coarse quartz sand; weathers light grey with surface ribbing in relief	3.0	552.0
18	Quartzite, slightly dolomitic, light grey, fine-grained, beds 1 foot to 4 feet thick; weathers light grey, blocky	31.0	549.0
17	Dolomite, silty, medium grey, fine-crystalline, lenses and bands of dark grey chert	1.5	518.0

Unit No.		Thickness (feet)	Height above base (feet)
	LOWER PART OF ROCKY MOUNTAIN FORMATION—*Continued*		
16	Quartzite, slightly dolomitic, light grey, fine-grained, scattered grains of quartz and chert of coarse sand grade; weathers light grey, massive, with surface ribbing in relief	4.0	516.5
15	Quartzite, slightly dolomitic, light grey, fine- to medium-grained, beds 2 to 4 feet thick; weathers light grey and light yellowish grey, blocky	45.5	512.5
14	Quartzite, light grey to white, fine-grained, dense, bedding obscure; weathers light grey with rust patches, massive, prominent	117.0	467.0
13	Sandstone, quartzitic, light grey, medium-grained; and quartzite, light grey, medium-grained; flecked with limonite in zones; bedding obscure; weathers light grey, massive	40.0	350.0
12	Quartzite, light grey, fine-grained, dense, beds 2 to 4 feet thick, bedding not well defined; weathers light grey and light yellowish grey	83.0	310.0
11	Quartzite, slightly dolomitic, light grey, fine-grained, bedding obscure; weathers light grey, massive, with faint surface lamination in relief	12.0	227.0
10	Quartzite, light grey, fine-grained, dense, beds 1 foot to 4 feet thick; weathers light yellowish grey, massive to blocky	79.0	215.0
9	Quartzite, dolomitic, light grey, fine-grained; weathers light grey, with 'honeycombed' surface	4.0	136.0
8	Dolomite, silty and arenaceous (quartz), light grey, fine-crystalline, beds 2 to 4 feet thick; weathers light grey, blocky	12.0	132.0
7	Quartzite, light grey, fine-grained, dense, bedding obscure; weathers light grey, massive to blocky	12.0	120.0
6	Sandstone, quartzitic and dolomitic, light yellowish grey, fine-grained, irregular bands and lenses of light grey chert, beds 3 to 5 feet thick; weathers light yellowish grey, massive to blocky with 'honeycombed' surface; at 26 feet above base: *Productus* fragments (GSC loc. 28325)	40.0	108.0
	Thickness of lower part	609.5	
	Total thickness of Rocky Mountain Formation	658.0	
	RUNDLE GROUP		
	ETHERINGTON FORMATION		
5	Dolomite, silty, light yellowish grey, fine-crystalline, nodules and irregular patches of white and light grey chert, beds 1 foot to 3 feet thick, scattered angular chert fragments of coarse sand grade; weathers very light grey, blocky; at 13 feet above base: *Spirifer* sp. possibly *S. increbescens* Hall, *Composita* sp. (GSC loc. 28324)	14.0	68.0
4	Dolomite, light yellowish grey, fine-crystalline, lenses of white chert; weathers light yellowish grey, platy to blocky	8.0	54.0
3	Dolomite, silty, light grey, fine-crystalline, lenses and irregular patches of white chert, beds 3 to 4 feet thick; weathers very light grey, blocky	23.0	46.0
2	Siltstone, dolomitic, rust-red to orange-yellow, colour variable and patchy	8.0	23.0
1	Dolomite, silty, light grey, very fine-crystalline, beds 1 foot to 3 feet thick; weathers very light grey, blocky	15.0	15.0
	Measured thickness of Etherington Formation	68.0	

APPENDIX B

Palaeontology

PALAEONTOLOGY

Fossils collected from Flathead map-area during the present investigation have been examined by stratigraphic palaeontologists of the Geological Survey of Canada and the following lists and comments are from their office reports. Collections from the sections described in Appendix A are designated by section and stratigraphic unit number; location and approximate stratigraphic position of other collections are as indicated.

Cambrian

by A. W. Norris

Shale Unit

Section 11

Unit 7 26.5 feet below top of formation. GSC loc. 31259

Albertella sp.
cf. *Kochina* sp.
?*Vanuxemella* sp.
Zacanthoides sp.
trilobite fragments indet.
linguloid brachiopods
Hyolithes sp.
'coral-like' markings indet.

Unit 14 114 feet below top of formation. GSC loc. 31260

Albertella cf. *A. limbata* Raschi
Albertella sp.
Vanuxemella cf. *nortia* Walcott
Vanuxemella sp.
?*Zacanthoides* sp.
brachiopods indet.
'coral-like' markings indet.

Both lots contain relatively abundant trilobite remains. The brachiopods are few and are too poorly preserved for identification. The indeterminate 'coral-like' markings are groups of polygonal tubes with very thin walls, somewhat resembling a *Favosites*-like coral, but lacking tabulae. Similar markings were noted in a Middle Cambrian collection from unit 16 of Section 12.

The presence of numerous incomplete specimens of the trilobite genus *Albertella* definitely dates the enclosing beds as low Middle Cambrian. *Albertella* is the diagnostic fossil of the *Albertella* zone of the Middle Cambrian of western North America. The beds are therefore correlated with the Ross Lake shale member of the Cathedral Formation of the Rocky Mountains, and with the Gordon shale of Montana.

Section 12

Unit 3 108 feet below top of formation. GSC loc. 28123

cf. *Albertella* sp.
Micromitra? sp.
Iphidella sp.
Hyolithes? sp.

Unit 16 14 feet below top of formation. GSC loc. 28124

Albertella sp.
Glossopleura? sp.
Kochina cf. *K. americana* (Walcott)
Kochina? sp.
Ptarmigania cf. *P. rossensis* (Walcott)
Zacanthoides sp.
Micromitra sp.
Iphidella sp.
indeterminate organic markings

Unit 18 6 feet below top of formation. GSC loc. 28122

Albertella sp.
Kochina sp.
Ptarmigania sp.
Zacanthoides sp.

The brachiopod genera *Micromitra*? and *Iphidella* are present in lots from units 3 and 16. *Iphidella* here refers to those brachiopods having a *Micromitra*-like form and a peculiar pitted surface ornamentation produced by the oblique intersection of narrow ridges. Brachiopods of this type range in age from Lower to Upper Cambrian. The most abundant trilobite genus *Albertella* is well represented in lots from units 16 and 18, and may also occur in unit 3. Next in abundance are representatives of *Zacanthoides*.

The presence of specimens of *Albertella* in units 16 and 18 date the beds as low Middle Cambrian. This is the diagnostic fossil of the *Albertella* zone . . . The fauna from unit 3 is also assigned to this zone because of the close similarity of the brachiopods in units 3 and 16, along with a trilobite form that closely resembles *Albertella*.

Devonian

by D. J. McLaren

Fairholme Group

HOLLEBEKE FORMATION—*Lower Member*

Section 13

Unit 9 66 feet above base of formation. GSC loc. 28328

stromatoporoid indet.

Atrypa cf. *A. multicostellata* Kottlowski

This fauna may be of Flume age, but the fragmentary nature of the material allows only the most tentative suggestion.

HOLLEBEKE FORMATION—*Upper Member*

Section 14

Unit 26 254.5 feet above the base of the formation. GSC loc. 28165

large fragmentary *Schizophoria* sp.

stropheodontids

Eostrophalosia sp. H

Atrypa ex gr. *A. independensis* Webster

Atrypa cf. *A. multicostellata* Kottlowski

small *"Spirifer"* indet.

This appears to be a Flume fauna, although there is little to go on as the material is largely fragmentary. *Eostrophalosia* sp. H . . . occurs in the Waterways Formation of northeastern Alberta, and . . . is commonly referred to *Productella belanskii,* although incorrectly. The age, therefore, is possibly earliest Upper Devonian.

Section 16

Unit 12 107 feet above the base of the formation. GSC loc. 31252

stromatoporoid

spiriferid indet.

Atrypa multicostellata Kottlowski

Unit 13 147 feet above the base of the lower part. GSC loc. 31253

crushed coquina containing

Atrypa multicostellata Kottlowski

small spiriferid indet.

Atrypa multicostellata occurs throughout the Flume Formation.

Unit 22 200 feet above the base of the formation. GSC loc. 31240

Schizophoria sp. indet.

Eostrophalosia sp.

Productella sp.

Atrypa sp.

Eosyringothyris? cf. *E. anchiasper* (J. S. Williams)

Unit 22 205 feet above the base of the formation. GSC loc. 31244

Schizophoria fragments
Stropheodonta fragments indet.
Eostrophalosia sp. H ("*Productella* cf. *belanskii*" of Warren and Stelck)
Atrypa sp.
Eleutherokomma jasperensis (Warren)

Eostrophalosia sp. H occurs in the Upper Waterways of northeastern Alberta (Crickmay's Moberly Member) . . . *Eleutherokomma jasperensis* suggests correlation with the Upper Flume but is by no means positive; it could hardly be younger. The possible *Eosyringothyris* suggests a lower horizon in the Waterways but there is little to justify a positive conclusion.

Unit 23 256 feet above base of formation. GSC loc. 31245

Spinatrypa sp.
Athyris sp.

Athyris is unknown above the Flume in this region.

Unit 31 317 feet above the base of the formation. GSC loc. 31251

stromatoporoid
Alveolites sp. C
Thamnopora sp. A
Phacellophyllum sp. B
Tabulophyllum cf. *T. magnum* Fenton and Fenton

This coral fauna is presumably Cairn or Lower Fairholme but I cannot be more precise. Locally it may correlate with the horizon of GSC loc. 28157 in unit 36 of Section 14.

BORSATO FORMATION

Section 13

Unit 39 154 feet above the base of the formation. GSC loc. 28330

Atrypa cf. *A. varicostata* Stainbrook

This fauna may be correlated with those from units 65 and 71 of Section 14, and is of comparable age.

Section 14

Unit 36 4.5 feet above the base of the formation. GSC loc. 28157

Amphipora sp.
stromatoporoid
Alveolites sp.
Thamnopora sp.

This stromatoporoid-tabulate coral facies . . . could occur at any horizon within the Fairholme Group.

Section 13

Unit 41 at base of the formation. GSC loc. 28155

small *Gypidula* sp.
Leptostrophia? sp.
small *Productella* sp.
Atrypa cf. *A. varicostata* Stainbrook
small *Cyrtospirifer* sp.

This fauna may be correlated with that from units 65 and 71 of Section 14—GSC locs. 28154 and 28155—and is of comparable age.

Section 14

Unit 50 3.5 feet above the base of the formation. GSC loc. 28153

Leptostrophia sp.
Calvinaria albertensis (Warren)
small *Atrypa* sp.
Warrenella nevadensis (Walcott)
fish fragments

This fauna is typical of the lower part of the Mount Hawk or the upper part of the Perdrix Formation. *Calvinaria albertensis,* the zone fossil, occurs throughout the Mount Hawk but *Warrenella nevadensis* is confined to the lower part of the zone, which overlaps the topmost beds of the Perdrix in some areas.

Unit 65 207 feet above the base of the formation. GSC loc. 28154

Disphyllum cf. *D. colemanense* Warren
Gypidula sp.
productellid indet.
Atrypa cf. *A. varicostata* Stainbrook
Atrypa sp.

Unit 71 373 feet above the base of the formation. GSC loc. 28155

Gypidula cf. *G. munda* Calvin
Grunewaldtia americana Stainbrook

Both of these collections are typical of the Mount Hawk Formation of the Front Ranges farther north. It is difficult to say what horizon is represented but it could be the middle or upper part of the formation. These fossils are all known to occur within my zone of *Nudirostra albertensis, Grunewaldtia americana, Gypidula munda,* and *Atrypa varicostata* occur in the Independence Formation of Iowa and correlation is indicated.

Section 15

Unit 34 79 feet above the base of the formation. GSC loc. 31250

Atrypa sp. (very fine ribbed form)
Spinatrypa sp. C
bellerophontid gastropod

Unit 40 284.5 feet above the base of the formation. GSC loc. 31249

Atrypa sp.
Grunewaldtia cf. *G. americana* Stainbrook
Spinatrypa sp. C

Unit 48 357 feet above the base of the formation. GSC loc. 31241

disphyllid coral indet.
Schizophoria cf. *S. amanaensis* Stainbrook
Atrypa sp.

All these faunules suggest a general Mount Hawk age. The *Schizophoria* species is similar to a form from the Hay River shale. *Grunewaldtia* is normally found fairly low in both Mount Hawk and Hay River Groups, but has been found just below the Grumbler Formation in the Mackenzie region.

Section 16

Unit 45 84 feet above the base of the formation. GSC 31255

Lingula sp.
Calvinaria albertensis (Warren)

Unit 56 265.5 feet above the base of the formation. GSC loc. 31247

Phacellophyllum sp. A

The species of *Phacellophyllum* is new to me. The presence of *C. albertensis* at locality 31255 suggests a horizon still equivalent to the Mount Hawk or high Perdrix. This may correlate locally with the horizon of locality 28153 in unit 50 of Section 14.

Unit 58 394 feet above the base of the formation. GSC loc. 31248

Nervostrophia sp.
Devonoproductus sp. indet.
Atrypa sp.
Spinatrypa sp. C

Unit 60 430 feet above the base of the formation. GSC loc. 31242

Coenites sp.
Syringopora sp.
Tabulophyllum sp. A
Devonoproductus cf. *D. vulgaris* Stainbrook
Atrypa sp.

These faunules probably represent a horizon fairly high in the Mount Hawk Formation although, as far as I am aware, *Tabulophyllum* does not occur in the highest beds of this formation.

Section 17

Unit 16 21 feet above the base of the formation. GSC loc. 31254

Phacellophyllum sp.
Schizophoria sp.
Atrypa cf. *A. devoniana* Webster
Spinatrypa sp. C
Cyrtina small sp.

The *Spinatrypa* species appears to be a fairly long ranging form and occurs in several of the other collections. The *Phacellophyllum* is probably similar to those from unit 50 of Section 15 and unit 63 of Section 16 and correlation is indicated.

SOUTHESK FORMATION

Grotto Member

Section 15

Unit 50 43 feet above the base of the member. GSC loc. 31243
small *Phacellophyllum* indet.
Atrypa sp.
Spinatrypa sp.

. . . this faunule suggests a general Mount Hawk age.

Section 16

Unit 63 21 feet above the base of the member. GSC loc. 31246
small *Phacellophyllum* indet.
Atrypa fragments

The *Phacellophyllum* is too poorly preserved to allow specific identification but is probably the same species as the specimens from unit 50 of Section 15 and unit 16 of Section 17.

Mississippian

Invertebrates *by P. Harker*
Plants *by W. L. Fry*

BANFF FORMATION

Section 19

Unit 16 353 feet above base of formation. GSC loc. 28148
Cleiothyridina sp.
Proetus sp.

Typical Banff occurrence, not relatable to any particular horizon.

RUNDLE GROUP

LIVINGSTONE FORMATION

Section 20

Unit 14 1 foot above base of formation. GSC loc. 28141
Schellwienella? sp.
Chonetes sp.
crinoid fragments

Unit 22 370.5 feet above base of formation. GSC loc. 28165
Coarse ribbed zaphrentoid corals indet.

Unit 27 491.5 feet above base of formation. GSC loc. 28138
Echinoconchus sp. cf. *E. biseriatus* (Hall)
fenestellid bryozoa

95894—15

Unit 43 680.5 feet above base of formation. GSC loc. 28142

rugose coral fragments
Syringopora sp.
Productus? sp.
fenestellid bryozoa

With the exception of the small *Echinoconchus,* tentatively compared with *E. biseriatus,* there are no identifiable fossils in these collections from the Livingstone Formation. *E. biseriatus* occurs low in the Meramec of the mid-continent Mississippian.

MOUNT HEAD FORMATION

Loomis Member

Section 20

Unit 117 405.5 feet above base of formation. GSC loc. 28134

Spirifer sp. aff. *S. keokuk* Hall
fenestellid bryozoa

Unit 120 448 feet above base of formation. GSC loc. 28139

Koninckophyllum arizelum Crickmay

K. arizelum was described by Crickmay from Shimer's Lake Minnewanka section where it occurs in Shimer's bed 14 (Section 2). These beds at Lake Minnewanka are probably correlatives of the Loomis.

Uppermost beds of the Loomis Member: 7,800 feet on a bearing of 260° from Mount Darrah summit. GSC loc. 28131

Ekvasophyllum sp.
Lithostrotionella sp. possibly *L. pennsylvanica* Shimer
Syringopora sp.

External preservation good but some of the cut sections show extensive recrystallization which makes accurate determination difficult.

Marston Member

Section 20

Unit 121 462 feet above base of Mount Head Formation. GSC loc. 28149

Ekvasophyllum? sp.
fossil fragments

Unit 122 488 feet above base of formation. GSC loc. 28136

Ekvasophyllum? sp.
Lithostrotion banffense Warren
Syringopora sp.

A similar faunal association occurs 300 feet below the top of the thick unit in the Fording River area which D. K. Norris correlates with the Carnarvon.

Section 21

Unit 5 29 feet below the top of the Marston Member. GSC plant loc. 4924

This collection contains a mass of broken plant remains, all of which are coalified. There is a predominance of lycopod structures indicating the presence of *Lepidodendron* sp., *Lepidophyllum* sp., and possibly *Sigillaria* sp. In addition there are fragments of cordaitean leaves and suggestions of calamitean stems.

The accumulation does not indicate a precise horizon but merely gives evidence for a Carboniferous dating . . .

Carnarvon Member

Section 21

Unit 134 571 feet above base of Mount Head Formation. GSC loc. 28143
Spirifer sp. cf. *S. pellaensis* Weller
Girtyella? sp.
small pelecypods
fenestellid bryozoa fragments

Unit 135 623 feet above base of formation. GSC loc. 28147
Dictyoclostus sp. possibly *D. tenuicostatus* (Hall)
Reticularia sp.
Punctospirifer sp.

Spirifer pellaensis occurs in the Marston and lower part of the Carnarvon Members at Mount Head. *Girtyella* is also found in the Carnarvon.

Section 21

Unit 21 90.5 feet above base of Carnarvon Member. GSC loc. 28159
Linoproductus sp.

Unit 27 168 feet above base of Carnarvon Member. GSC loc. 28127
Faberophyllum? sp. (fragments)

Unit 34 279.5 feet above base of Carnarvon Member. GSC loc. 28128
rugose coral fragments
Dictyoclostus sp. possibly *D. tenuicostatus* (Hall)
Spirifer sp. indet.
Composita sp.

The collection from locality 28159 contains some medium sized linoproductids. Shells of this type are very characteristic of the Carnarvon Member at Mount Head, where they form part of a morphological series that appears to culminate, in the upper beds, with the appearance of large, transverse shells identified as *Gigantoproductus brazerianus* (Girty). With the exception of the form somewhat doubtfully referred to *D. tenuicostatus* (loc. 28128), the other Carnarvon collections have no particular affinities with the Carnarvon at Mount Head.

Approximately 10 feet below the top of the Carnarvon Member; 12,800 feet on a bearing of 226° from Mount Darrah summit. GSC loc. 28164
small transverse productids of the '*Linoproductus*' type

Fairly typical of Carnarvon faunas elsewhere. Approximately 50 feet below the top of the Carnarvon Member; 12,000 feet on a bearing of 225° from Mount Darrah summit. GSC loc. 28158

Faberophyllum sp. cf. *F. occultum* Parks
Orthotetes sp.
Gigantoproductus brazerianus Girty
Linoproductus sp.

Fairly typical of the fauna from the higher beds of the Carnarvon Member.

ETHERINGTON FORMATION

Section 21

Unit 38 0.5 feet above the base of formation. GSC loc. 28167
Rugose coral. Possibly a new species of *Dibunophyllum*

Unit 47 27 feet above the base of the Etherington Formation. GSC loc. 28151
Gigantoproductus brazerianus Girty

Unit 63 117.5 feet above base of formation. GSC loc. 28130
Spirifer sp. cf. *S. leidyi* Norwood and Pratten
Spirifer increbescens Hall
Composita sp.

Unit 64 127 feet above base of formation. GSC loc. 28129
small *Linoproductus*
Spirifer increbescens Hall
Spirifer cf. *S. leidyi* Norwood and Pratten

Unit 87 240 feet above base of Etherington Formation. GSC loc. 28137
Orthotetes? sp.
fragments of small *Dictyoclostus*
Girtyella sp. possibly aff. *G. indianensis* Weller

Unit 87 241 feet above base of formation. GSC loc. 28146
productid fragments similar to 28137
Spirifer sp. possibly *S. bifurcatus* Hall
Punctospirifer sp.
Composita sp.

Unit 90 251 feet above base of Formation. GSC loc. 28160
Orthotetes sp.
Chonetes sp. aff. *C. chesterensis* Weller
Punctospirifer sp.
Cleiothyridina sp.
Dielasma sp. ?
fenestellid bryozoa

Most of these (Etherington Formation) collections suggest a correlation with the Etherington Formation of the Mount Head sections. The large productid from unit 10, however, occurs in the upper part of the Carnarvon at Mount Head. On faunal grounds these beds would be included in the Carnarvon in the Mount Head sense.

Section 23

Unit 5 1 foot below top of Etherington Formation. GSC loc. 28324

Spirifer sp. possibly *S. increbescens* Hall
Composita sp.

All rather poorly preserved. No comment.

Pennsylvanian

by P. Harker

ROCKY MOUNTAIN FORMATION—*Lower part*

Section 22

Unit 24 264 feet above base of Rocky Mountain Formation. GSC loc. 28150

Orbiculoidea arenaria Shimer
Productus sp. indet.
Schizophoria sp. possibly *S. texana* Girty

This fauna is almost certainly of Pennsylvanian age.

Section 23

Unit 6 26 feet above base of the Rocky Mountain Formation. GSC loc. 28325

productus fragments similar to those in 28166

Though not easily identified in this collection, the productids from loc. 28325 are similar to other from lower beds of Rocky Mountain Formation. Pennsylvanian.

Approximately 100 feet above the base of the Rocky Mountain Formation; 6,200 yards on a bearing of 285° from the summit of Centre Mountain. GSC loc. 28166

Dictyoclostus sp. cf. *D. portlockianus* Norwood and Pratten

This collection is of Pennsylvanian age.

Approximately 50 feet above the base of the Rocky Mountain Formation; 3,300 yards on a bearing of 238° from the summit of Mount Darrah. GSC loc. 28161

Dictyoclostus sp. cf. *D. portlockianus* Norwood and Pratten
'Productus' sp.
Spirifer sp. possibly *S. opimus* Hall
Squamularia?
Composita sp.

This fauna is of Pennsylvanian age.

Permian?

by P. Harker

ROCKY MOUNTAIN FORMATION—*Upper part*

Section 23

Unit 39 18.5 feet above the base of the Upper part, 628 feet above the base of the Rocky Mountain Formation. GSC loc. 28326

brachiopod fragments
crinoid ossicles
bryozoa cf. *Tabulipora*

Unit 51 38.5 feet above the base of the Upper part, 648 feet above the base of the Rocky Mountain Formation. GSC loc. 28327

fossil fragments including some silicified corals of the *Caninia* type

Less than 50 feet below the top of the Rocky Mountain Formation; 6,800 yards on a bearing of 288° from the summit of Centre Mountain. GSC loc. 28144

Plagioglypta canna White
'Caninia' sp. and other coral fragments

Plagioglypta canna occurs near the top of Shimer's section of the Rocky Mountain Formation at Lake Minnewanka. It lies within the Norquay Member in the sense of Warren (not Raasch). The beds in which it occurs at Lake Minnewanka are believe to be equivalent to those immediately underlying the big chert unit at Tunnel Mountain. *Plagioglypta* associated with a small *Euphemites* (as at Lake Minnewanka) occurs in the Phosphoria Formation in Wyoming in beds of undoubted Permian age. The Norquay Member (Upper part of the Rocky Mountain Formation) is probably of Permian age.

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