GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

PAPER 61-24

FERNIE MAP-AREA, EAST HALF, ALBERTA AND BRITISH COLUMBIA

82 G E½

(Report and Map 35-1961)

R. A. Price

Price 50 cents

1962

CANADA

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Illustration

FERNIE MAP-AREA, EAST HALF, ALBERTA AND BRITISH COLUMBIA

INTRODUCTION

Fernie map-area (east half) extends across the Rocky Mountains, at the latitude of Crowsnest Pass, from the Porcupine Hills of the Interior Plains in Alberta almost as far southwest as the Rocky Mountain Trench in British Columbia. It is bounded by latitudes 49 and 50° and longitudes 114 and 115°, and includes parts or all of Clark, Livingstone, Blairmore, Flathead, High Rock, Wisukitsak, MacDonald, and Galton Ranges.

This preliminary report is concerned mainly with the western and southern parts of the map-area. It integrates and supplements data from published accounts and maps based on more detailed studies in the eastern part of the map-area (Hage, 1943 and 1945; Douglas, 1950; Norris, 1955 and 1959a; and Price, 1959)[1].

Considerable interest in the area by the petroleum and natural gas and the coal industries is reflected by the amount of geological mapping and seismic and drilling activity, the discovery of the Waterton gas field, and increased exploration of the coal deposits.

Field work was done during the summers of 1958, 1959 and 1960. G.C. Taylor and D.L. Scott contributed field data in 1959 and 1960 respectively. Assistance in the field in 1958 was provided by K.P. Cole, G.F. Shillington, and D.W. Sykes; in 1959 by H. Ganter and J.K. Oswald; and in 1960 by G.A. Jelinski and R.C. Latimer.

ACCESS

Most of the Alberta part of the map-area is accessible from secondary roads, logging and forestry roads, and seismic trails which connect with Alberta Highways No. 2 and No. 3. Pack trails follow most valleys in Waterton Lakes National Park in the southeastern part of the map-area and these can be reached from the National Park roads to Cameron Lake and Red Rock Canyon. Roads to wells in the Waterton gas field enter Clark Range along Yarrow and Spionkop Creeks. A seismic trail that follows south Drywood Creek to Bovin Lake near the Continental Divide was passable to motor vehicles in 1960. Seismic trails extend from a forestry road on Castle River to the National Park boundary and from a logging road on West Castle River to Middle

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[1]Names and dates in parentheses refer to publications listed in the References.

Kootenay Pass. The latter trail continues down Middle Pass Creek to the Flathead River valley in British Columbia. Logging roads give access to Syncline Brook, upper Carbondale River, North and South Lost Creek, Goat Creek, and York Creek. A seismic trail extends from the road on upper Carbondale River to North Kootenay Pass.

In the north-central part of the map-area the 'Kananaskis Road' extends northward from Coleman and gives access to the west side of Livingstone Range north of Racehorse Creek. A forestry road on Dutch Creek connects it with a seismic trail to Tornado Pass. Seismic trails extend from the Kananaskis road up both branches of Racehorse Creek to the foot of High Rock Range. A logging road extends from Alberta Highway No. 3 up Allison Creek to the headwaters of Racehorse Creek and a seismic trail connects this road with a logging road along Alexander Creek in British Columbia, via Deadman Pass.

The northwestern part may be reached via a road up the west side of Elk River valley from Natal, British Columbia. Logging roads follow most of the principal tributaries of Elk River. Private roads extend along the east side of Elk River valley to Fording Mountain and up the valleys of Grave and Line Creeks to the west slope of High Rock Range. Pack trails give access to Tornado Pass and Northfork Pass east of Elk River and to the headwaters of Brûlé Creek west of Elk River. An abandoned logging road up Alexander Creek was passable to conventional motor vehicles for approximately 8 miles in 1960.

The west-central part is accessible from the British Columbia Forest Service Flathead road up Michel Creek, thence down the Flathead River drainage to Montana, and via pack and seismic trails that follow Ptolemy, Andy Good, Leach, Marten, McEvoy, Coal, Morrissey, and McLatchie Creeks and upper Flathead River.

The Flathead road in the south-central part of the map-area was passable south of Coal Mountain in July and August of 1958 and 1960. Seismic trails extend from this road up most of the tributaries entering Flathead River from Clark Range. The North Kootenay, Middle Kootenay, Sage, South Kootenay, and Akamina Passes may be reached with pack horses from Flathead River valley. Pack and seismic trails extend up Harvey, Howell and Twentynine Mile Creeks and provide access between Flathead River and Lodgepole Creek. Cabin Pass may be reached from the Flathead road via a trail along Cabin Creek. A branch road from the Flathead road extends approximately 8 miles up Sage Creek to the Sage Creek hunting lodge between Commerce and Langemarck Mountains. A logging road extends up Couldrey Creek to the region between Horseshoe Ridge and Inverted Ridge.

In the southwestern part of the map-area logging roads extend up Phillips Creek to the summit of Galton Range from British Columbia Highway No. 93 in the Rocky Mountain Trench, and up Bighorn (Ram) Creek from British Columbia Highway No. 3 near Morrissey. A forestry road up Lodgepole Creek connects with seismic and pack trails that can be followed to Flathead River valley via McLatchie, Harvey and Howell Creeks. Wigwam River valley and Desolation Creek valley are passable with pack horses during low water.

STRATIGRAPHY

PURCELL

Waterton Formation

The Waterton Formation occurs only within Clark Range, where it is exposed immediately above the Lewis thrust fault between Castle River and Carbondale River and around fensters at Cate Creek and Haig Brook. It was penetrated by Pacific-Atlantic Flathead No. 1 well in the western part of Clark Range along Sage Creek, between Commerce Peak and Langemarck Mountain. Typical rock types are medium grey, very fine crystalline limestone, banded and streaked with lighter grey, very fine crystalline dolomite; medium to light green dolomite, argillaceous dolomite and argillite; brownish red dolomite and argillaceous dolomite, commonly laminated with medium to light green; and white cryptocrystalline limestone. In the vicinity of the fensters and Carbondale River, imbricate faulting, tight folding and limited exposures obscure details of the stratigraphic succession and thickness of the Waterton Formation. The maximum thickness of Waterton strata occurring above the Lewis thrust in the northwestern part of Clark Range is in the order of 500 feet. Norris (1959a) reported a thickness of 440 feet on Barnaby Ridge in the northern part of Clark Range, and Douglas (1952, Section D-E) indicated a maximum thickness of approximately 1,500 feet in Waterton map-area adjacent to the southeast corner of the Fernie map-area. An apparently unfaulted succession of Waterton strata was penetrated over an interval of approximately 1,500 feet in Pacific-Atlantic Flathead No. 1 well.

Altyn Formation

Altyn strata occur in the northern and western parts of Clark Range and lie with transitional contact above the Waterton Formation.

The lower part of the Altyn Formation comprises medium to dark grey and black, fine-crystalline, argillaceous limestone and dolomite interbedded with black fissile shale and argillite. It characteristically forms relatively gentle slopes in contrast to overlying and underlying beds. The amount and proportion of black argillite increase toward the southwest.

The more resistant upper part of the Altyn consists of light to dark grey dolomitic argillite and argillaceous dolomite. It grades eastward and northeastward into sandy and gritty dolomite with stromatolitic dolomite and black argillite interbeds. This change in lithofacies corresponds with a marked change in thickness of the Altyn Formation. Thus, in the vicinity of Sage Creek, where graphic calculations involving the log of the Pacific-Atlantic Flathead No. 1 well indicate a thickness of 4,000 feet for the Altyn Formation, no gritty or sandy beds were observed. The upper part of the Altyn Formation comprises dark to light grey, colour-laminated, dolomitic argillite and argillite that commonly weathers to dark grey, rusty, platy or flaggy fragments. In northwestern Clark Range, where the Altyn Formation is approximately 1,500 feet thick, silty and sandy dolomite interbedded with black argillite occur toward the base of the upper part,

TABLE OF FORMATIONS

ERA	PERIOD OR EPOCH	FORMATION OR GROUP	LITHOLOGY	THICKNESS (FEET)
CENOZOIC	Eocene and/or Oligocene	Kishenehn	Non-marine conglomerate, breccia, sandstone, mudstone, marl and lignite	0-6,600(?)
CENOZOIC	Angular unconformity			
CENOZOIC	Paleocene	Porcupine Hills	Non-marine sandstone and shale	4,000+
CENOZOIC	Erosional unconformity			
CENOZOIC / MESOZOIC	Paleocene and Upper Cretaceous	Willow Creek	Non-marine sandstone and shale	4,100
MESOZOIC	Upper Cretaceous	St. Mary River	Non-marine and brackish sandstone, shale, limestone, and coal	2,500-3,200
MESOZOIC	Upper Cretaceous	Bearpaw	Marine shale, concretionary shale, and sandstone	0-600
MESOZOIC	Upper Cretaceous	Belly River	Non-marine and brackish sandstone, shale, argillaceous limestone, and coal	2,500-4,000+
MESOZOIC	Upper Cretaceous	Alberta: Wapiabi	Marine shale, concretionary shale, siltstone, and sandstone	1,000-2,000(?)
MESOZOIC	Upper Cretaceous	Alberta: Cardium	Marine sandstone, siltstone, and shale; non-marine and brackish conglomeratic sandstone, siltstone, shale and coal	10-300+
MESOZOIC	Upper Cretaceous	Alberta: Blackstone	Marine shale, concretionary shale, siltstone, and sandstone	250-450
MESOZOIC	Disconformity (?)			
MESOZOIC	Upper Cretaceous(?)	Crowsnest	Volcanic breccia, conglomerate, sandstone, tuff	0-1,400
MESOZOIC	Lower Cretaceous and/or Younger		Trachyte, latite, syenite, felsite, and intrusion breccia	
MESOZOIC	Intrusive contact			
MESOZOIC	Lower Cretaceous	Blairmore	Non-marine sandstone, mudstone, conglomerate, and shale	1,200-6,500
MESOZOIC	Erosional unconformity			
MESOZOIC	Lower Cretaceous and Jurassic	Kootenay	Non-marine and brackish sandstone, siltstone, shale, conglomerate, and coal	75-3,530
MESOZOIC	Jurassic	Fernie	Marine shale, siltstone, sandstone, and limestone	600-1,000(?)
MESOZOIC	Disconformity			
MESOZOIC	Triassic	Spray River	Marine shale, siltstone, and dolomitic siltstone	0-1,500(?)
	Erosional unconformity			
PALAEOZOIC	Pennsylvanian and Permian	Rocky Mountain	Marine sandstone, cherty and arenaceous dolomite, chert, shale, and siltstone	0-1,500

PALAEOZOIC	Mississippian	Rundle	Etherington	Marine limestone, dolomite, shale, siltstone, and anhydrite	200-860
			Mount Head	Marine limestone, dolomite, argillaceous dolomite, silty dolomite and limestone, and dolomite and limestone breccias	400-1,000
			Livingstone	Marine limestone, cherty limestone, and dolomite	800-1,400
			Banff	Marine limestone, cherty limestone, argillaceous limestone, shale, and chert	600-1,050
			Exshaw	Marine shale	5-40(?)
	Disconformity				
	Devonian		Palliser	Marine limestone, dolomitic limestone, and dolomite	650-720
			Alexo	Marine limestone, dolomite, silty limestone and dolomite, siltstone, and sandstone	20-490
				Erosional unconformity	
			Fairholme	Marine limestone, argillaceous limestone, shale, dolomite, dolomitized reefs	950-1,500
				Erosional unconformity	
	Cambrian		Elko	Marine dolomite and dolomitic limestone	285-700
				Marine shale, siltstone, limestone	150-275
			Flathead	Marine sandstone, conglomeratic sandstone	25-150
Erosional unconformity					
PRECAMBRIAN	Purcell		Roosville	Green argillite, siltstone, sandstone, stromatolitic dolomite	3,500+
			Phillips	Red sandstone, siltstone, argillite	500-700
			Gateway (upper member)	Argillite, argillaceous siltstone, dolomite, dolomitic argillite and sandstone	1,150-3,000
			Sheppard (lower member of Gateway)	Quartzitic and dolomitic sandstone, dolomite, oolitic dolomite, argillite, siltstone, pillowed andesite	150-900
		Erosional unconformity in part			
			Purcell	Chloritized andesite and amygdaloidal andesite flows; pillowed andesite	0-600
			Siyeh	Limestone, dolomite, argillaceous and sandy limestone and dolomite, argillite, stromatolitic limestone	1,130-3,000
			Grinnell	Red argillite, sandstone, and siltstone	350-1,700
			Appekunny	Argillite, sandstone and siltstone	1,500-2,000
			Altyn	Argillaceous limestone and dolomite, sandy dolomite, argillite, and stromatolitic dolomite	500-4,000
			Waterton	Limestone and dolomite, argillite, and argillaceous dolomite	1,500+

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and overlying beds comprise light to medium grey argillaceous dolomite and limestone. In the northeastern and southeastern parts of Clark Range (Norris, 1961, personal communication; Douglas, 1952) where the Altyn Formation attains its minimum observed thickness of approximately 500 feet, gritty and sandy dolomite beds occur throughout the upper part of the formation and are interbedded with black argillite.

Appekunny Formation

The Appekunny Formation outcrops around the periphery of Clark Range. The characteristic rock types are light green and greenish grey argillite, and white, grey, and green quartzose sandstone and quartzite. The base of the formation in the western part of Clark Range is transitional into the underlying Altyn Formation, and has been placed at the change from light green or greenish grey argillite and dolomitic argillite to the light or medium grey dolomitic argillite and argillaceous dolomite of the upper part of the Altyn Formation. Beds of light greenish grey, green and white quartzitic sandstone generally occur near the base of the Appekunny Formation. Two resistant white quartzite beds, approximately 175 and 300 feet above the base of the formation, form distinctive marker horizons in the vicinity of Sage Creek. Mud-cracks, ripple-marks, and zones of intraformational conglomerate, comprising argillite pebbles in a quartz-sandstone matrix, are common in the Appekunny Formation. The top of the Appekunny is gradational over a few feet or a few tens of feet into the red argillites and siltstones of the Grinnell Formation. The thickness varies between approximately 2, 000 feet and 1, 500 feet in Fernie map-area.

Grinnell Formation

In contrast with the Appekunny, the Grinnell Formation consists mainly of red rather than green argillite. Bright red argillites are dominant in the lower part and are mottled and banded with subordinate light green argillite and interbedded with minor amounts of white coarse-grained quartzitic sandstone and red fine-grained sandstone. Mud-cracks are common, and cut-and-fill structures, current-bedding, ripple-marks, and argillite-pebble intraformational conglomerates are associated with the sandstone interbeds. White quartzitic sandstone interbeds become more common and thicker toward the top of the formation. The Grinnell thins from approximately 1, 700 feet in southwestern Clark Range adjacent to Sage and Kishinena Creeks to 1, 100 feet in the southeast, east of Mount Blakiston (Douglas, 1952); to 750 feet in northeastern Clark Range on Pincher Ridge (Hage, 1943); and to 350 feet in northwestern Clark Range near Hollebeke Mountain (Price, 1959).

Siyeh Formation

The Siyeh Formation, mainly of yellowish-brown-weathering resistant carbonate strata, is exposed in both Clark and Galton Ranges. Three subordinate units are distinguishable within it. The upper and lower of these are relatively thin. Green or green and grey argillite are interbedded with dolomite, silty dolomite, and quartz sandstone in the lower part of the Siyeh. The middle part comprises fine-crystalline dolomite and limestone with interbeds or partings of dark grey argillite, and the upper part consists mainly of green argillite.

In Galton Range, Siyeh strata occur in the vicinity of Phillips and Rabbit Creeks but exposures are poor and reliable data on details of the stratigraphic succession and thicknesses are lacking. The upper green argillite unit is present but appears to be less than 100 feet thick. The thick middle part of the Siyeh consists of yellowish and orange-brown, argillaceous, fine-crystalline limestone, dolomite, and dolomitic limestone that commonly exhibits 'molar-tooth' structure and is, in part, interbedded with dark grey or black argillite. Silty dolomite, dolomitic siltstone, and fine-grained sandstone become abundant toward the base, and in the lower part are interbedded with green dolomitic argillite. The oldest beds observed occur between two branches of Rabbit Creek near Wigwam Pass. They consist of green argillite, laminated and banded in part with red, and white and light green coarse-grained quartz sandstone, and are similar to the upper part of the Grinnell Formation except that the argillite is dominantly green rather than red. These rocks probably comprise the same lithostratigraphic unit as those that occur beneath the Siyeh Formation in the western part of Galton Range (Leech, 1960).

In Clark Range all three units in the Siyeh Formation thin toward the northwest from the vicinity of the International Boundary to North Kootenay Pass. The thickness of the Siyeh varies from between 2,500 and 3,000 feet at Mount Lineham in southeastern Clark Range to 2,500 feet at Kishinena Creek in southwestern Clark Range; to 1,650 feet between Whistler and Windsor Mountains in northeastern Clark Range; and to 1,130 feet at Hollebeke Mountain in northwestern Clark Range.

The lower part of the Siyeh grades upwards through interbedded green argillite, dolomitic argillite and silty dolomite into the dolomite and limestone of the middle part. At the base it is gradational over a few feet or a few tens of feet into interbedded red argillite and white quartzitic sandstone of the Grinnell Formation. Interbedded green argillite and coarse-grained white quartzitic sandstone occur in this transitional interval and have been included in the Siyeh Formation. The lower part of the Siyeh comprises several hundred feet of beds in southeastern Clark Range, approximately 100 feet of beds in southwestern Clark Range, and 30 feet of beds in northwestern Clark Range.

The middle part of the Siyeh Formation is a conspicuous cliff-forming sequence of resistant carbonate strata throughout most of Clark Range. In the southern and eastern parts of the range it is 1,500 to 2,000 feet thick and consists mainly of dolomitic limestone, limestone, and dolomite. Partings and thin interbeds of dark grey and black argillite and calcareous argillite are common. Beds of intraformational conglomerate, commonly consisting of rounded plates of limestone or dolomite in a matrix of dolomitic, quartzose sandstone, occur sporadically throughout the unit. The dolomitic limestone characteristically occurs in thick massive beds which weather to yellowish and orange-brown and exhibit 'molar-tooth' structure (Daly, 1912, p. 74) on weathered surfaces. The 'molar-tooth' structure typically comprises irregular laminae, veinlets, blebs, and anastomosing masses of medium grey to black, very fine crystalline limestone in a matrix of medium grey to black, very fine crystalline dolomitic limestone or dolomite. On weathered surfaces the dolomitic parts of the rock are yellowish or orange-brown and etched into relief, whereas the limestone is dark grey. The dolomite beds commonly show a faint textural lamination that has been etched into relief on weathered surfaces, and they are commonly platy or flaggy weathering. Oolitic limestone occurs at several horizons in the middle part but is rare.

In northwestern Clark Range the middle part of the Siyeh is 1,000 feet thick and consists mainly of medium to dark grey, fine-crystalline dolomite, argillaceous dolomite and silty dolomite that weathers light yellowish brown and is platy or flaggy. Thin interbeds or partings of grey and black argillite are common but 'molar-tooth' structure is rare or absent. Intraformational limestone conglomerates and sandstone interbeds are more common than elsewhere. Many of the latter are quartzitic.

A conspicuous bed of stromatolitic limestone occurs in the middle part of the Siyeh Formation throughout most of Clark Range and serves as a useful stratigraphic marker. It is generally 50 to 75 feet thick and occurs 715 feet below the top of the Siyeh at South Drywood Creek; 335 feet below the top between Whistler and Windsor Mountains (Norris, 1959a); approximately 800 feet below the top at Lineham Lakes; and 530 feet below the top at Sunkist Mountain.

The upper part of the Siyeh Formation is gradational over a few tens of feet through interbedded green argillite and dolomitic argillite and light grey fine-crystalline dolomite into the dolomite and limestone of the middle part. Within the upper part, beds of siltstone and fine-grained sandstone are intercalated with the green argillites. Beds of red argillite and siltstone also occur, especially toward the top of the unit, but are much less common than the green rocks. Mud-cracks, beds of flat-pebble intraformational conglomerate and ripple-marks are common. The upper part of the Siyeh is 460 feet thick at South Drywood Creek, 340 feet thick at Sunkist Mountain, and 100 feet thick at Hollebeke Mountain.

Purcell Lava

The Purcell lava, comprising chloritized andesite and pillowed andesite, overlies the Siyeh Formation and serves as a reliable stratigraphic marker in Clark Range, southern Flathead Range, and southwestern Galton Range. It is absent in part of southeastern Galton Range.

In southern Galton Range the Purcell lava thins conspicuously from west to east. Along Phillips Creek adjacent to longitude 115°, approximately 600 feet of lava occurs beneath the Sheppard Formation and the base is not exposed. At least 400 feet of lava occurs beneath the Sheppard 1 1/2 miles to the east. About 2 1/2 miles to the east the Sheppard rests on the upper part of the Siyeh, and 3 1/2 miles to the east it rests on the middle part of the Siyeh.

This local marked thinning of the lava appears to be a consequence of erosion prior to deposition of the Sheppard. This interpretation is supported by the occurrence of sandstone and pebble-conglomerate, comprising detritus derived from the lava, in the basal beds of the Sheppard Formation along Phillips Creek. The lava is exposed again northeast of Wigwam Pass. There it is in the order of 100 feet thick and overlies green argillite of the upper part of the Siyeh.

In Clark Range the Purcell lava thins toward the east and, less conspicuously, toward the northwest. In southwestern Clark Range, at Sunkist Mountain, the lava is 485 feet thick. It thins eastward to approximately 225 feet along Bauerman Creek; northeastward to 280 feet along South Drywood Creek and to 350 feet on Pincher Ridge (Hage, 1943); northward to 295 feet between Whistler and Windsor Mountains (Norris, 1959a); and northwestward to 320 feet in the southern part of Flathead Range. A zone of pillowed andesite up to 70 feet thick commonly occurs at the base and is characterized by a matrix comprising shard-like, light green, chloritized, aphanitic andesite fragments enclosed in a dark green cryptocrystalline groundmass. A series of andesite flows 5 to 15 feet thick commonly occupies an interval up to 150 feet thick above the pillowed andesite. The overlying andesite seldom shows well-defined flow-layering. In general the lava is dark green and reddish or purplish. Amygdules of quartz, chlorite, and calcite are common. Stellate aggregates of tabular plagioclase phenocrysts up to 3 inches long occur locally in porphyritic andesite.

Sheppard Formation (Lower Member of Gateway Formation)

The Sheppard Formation can be traced around the periphery of Clark Range, through the southwestern part of Flathead Range, and through southern Galton Range. In the latter region it is equivalent to Daly's (1912, p. 107) lower member of the Gateway Formation. In southern Galton Range, along Phillips Creek, the Sheppard is estimated to be 150 feet thick. Its relationships with the Purcell have been considered in the discussion of that unit. In the lower part of the Sheppard beds, succeeding the feldspathic and chloritic, basal sandstone and conglomerate consist mainly of light-coloured, dolomitic and quartzitic, fine- or medium-grained quartz sandstone, dolomite and oolitic dolomite. The upper part comprises light-coloured very fine crystalline dolomite, sandy and silty dolomite, and stromatolitic dolomite with minor amounts of dolomitic sandstone. Ripple-marks are common on sandstone beds throughout the formation.

In Clark Range the Sheppard Formation comprises light-coloured dolomite, light yellow and grey and dark red sandstone and siltstone, light green dolomitic sandstone, dolomitic argillite, and argillite, and locally, a relatively thin andesite flow. The formation thins from an estimated maximum thickness of 900 feet at Wall Lake in south-central Clark Range to approximately 500 feet at Bauerman Creek; to 580 feet at South Drywood Creek; to 470 feet at Pincher Ridge (Hage, 1943); 400 feet at Sunkist Mountain; and to 160 feet at North Kootenay Pass (Price, 1959). In the eastern part of Clark Range two distinctive subdivisions are discernible. The lower part consists of light green and greenish grey, fine-crystalline dolomite and argillaceous dolomite interbedded with silty and sandy dolomite, coarse-grained dolomitic quartz sandstone, and light green argillite. Dark green and purplish green amygdaloidal andesite occurs near the top of the lower part. At Wall Lake it is approximately 50 feet thick and in part shows pillow structure. It thins to 35 feet at Sunkist Mountain and to 8 feet at the headwaters of West Castle River. The lava is absent in the eastern and northern parts of Clark Range.

The upper part of the Sheppard contains much dark red micaceous mudstone, siltstone, and fine-grained sandstone in the eastern and northeastern parts of Clark Range. This occurs interbedded with light grey fine-crystalline dolomite, silty dolomite, stromatolitic dolomite, and light grey dolomitic sandstone, and grades upward into light greenish grey argillaceous dolomite and white sandstone which mark the top of the Sheppard Formation. The distinctive red rocks of the upper Sheppard appear to grade laterally to lighter-coloured mudstones, siltstones, and sandstones which occupy an equivalent stratigraphic position in western and northwestern Clark Range. In northeastern Clark Range these red beds appear to have been assigned to the Kintla Formation by Hage (1943). They comprise the lower part of Member A of the Kintla Formation as mapped by Norris (1959a).

Gateway Formation — Upper Member

(Members A and B of Kintla Formation)

The upper member of the Gateway Formation in the southern part of Galton Range, as defined by Daly (1912, p. 107), is equivalent to Member A plus Member B of the Kintla Formation (Hume, 1933; Hage, 1943) in Clark Range.

In Clark Range the lower part of this unit consists of dark red and purplish red argillaceous and micaceous siltstone and argillite, and constitutes Member A of the Kintla Formation. Grey siltstone interbeds occur within these red rocks in the southwestern part of Clark Range. In Galton Range greenish grey and grey argillaceous siltstones are dominant and occur in thin beds with partings of dark red and purplish red argillite. Abundant casts of cubic salt crystals occur in these rocks throughout the map-area and are characteristic of this particular part of the stratigraphic succession. Mud-cracks, ripple-marks, and intraformational conglomerates comprising argillite fragments in a siltstone matrix are abundant locally in both Clark and Galton Ranges. The red and grey siltstones and argillites are gradational upward into green micaceous argillite, dolomitic argillite, dolomite, and dolomitic sandstone comprising Member B of the Kintla Formation. It is generally difficult to distinguish an unequivocal boundary between these two groups of beds, particularly in Galton Range, and accordingly they have not been differentiated on the map. The lower part of the upper member of the Gateway (Member A of the Kintla) appears to thin toward the northwest, north, and east from between 1,500 and 2,000 feet at Kishinena and Sage Creeks to 650 feet at North Kootenay Pass (Price, 1959); to 720 feet near Windsor Mountain (Norris, 1959a); to 800 feet on Pincher Ridge (Hage, 1943); to 1,000 feet at Loaf Mountain; and to 1,000 feet at Akamina Pass. It is probably about 1,500 feet thick in southern Galton Range.

The upper part of the upper member of the Gateway Formation consists of green and greenish grey micaceous argillite, dolomitic argillite, and coarse-grained dolomitic sandstone with interbeds of light grey dolomite and sandy dolomite. Ripple-marks are common and mud-cracks and stromatolites occur locally. Sandstone is most common in the upper part of the sequence and in part reflects a transition into the overlying Phillips Formation. This sequence of beds comprises Member B of the Kintla Formation. In Clark Range it thins from 750 feet in the vicinity of Sage and Kishinena Creeks to 500 feet in the northern and eastern parts of the range. It is probably about 1,000 feet thick in southern Galton Range.

Phillips Formation

(Member C of Kintla Formation)

The Phillips Formation consists of red and purplish red, fine- to coarse-grained quartz sandstone and red siltstone. Argillite and micaceous argillite occur as partings and thin interbeds and these commonly grade laterally into intraformational conglomerate consisting of chips and flat pebbles of argillite in a sandstone matrix. Ripple-marked bedding surfaces occur in the sandstones, and the argillite interbeds are commonly mud-cracked. The sandstones are commonly mottled with light pink spots.

Rocks comprising Member C of the Kintla Formation in Clark Range (Hume, 1933; Hage, 1943) are similar to, and occupy the same stratigraphic position as those of Daly's (1912, p. 108) Phillips Formation, and the two names are synonymous. The Phillips Formation also embraces rocks that formed the basis for Daly's (1912, p. 100) definition of the Hefty Formation, and, in part at least, rocks which he named the Wigwam Formation.

The Phillips Formation is approximately 700 feet thick in MacDonald and Galton Ranges, and 500 to 700 feet thick in Clark Range. It is absent northward from the vicinity of North Kootenay Pass due to pre-Palaeozoic erosion. Its base is marked by a transition over a few feet or a few tens of feet into sandstones and argillites of the Gateway Formation.

Roosville Formation

(Member D of Kintla Formation)

The Roosville Formation comprises green and greenish grey argillite, dolomitic argillite, siltstone, and sandstone with subordinate white and grey quartz sandstone and light-coloured argillaceous and stromatolitic dolomite. It is exposed in Clark, MacDonald and Galton Ranges and in each of these is overlain unconformably by Palaeozoic rocks. In Clark Range it is equivalent to Member D of the Kintla Formation.

The thickness of the Roosville varies from zero to approximately 3,500 feet as a consequence of variations in the depth of pre-Palaeozoic erosion. It is absent at North Kootenay Pass and thickens toward the south and west, from zero at the north end of Windsor Mountain (Hage, 1943) to 1,500 feet at Font Mountain and to 2,000 feet at Flanders Brook in Clark Range; to 1,800 feet south of Twentynine Mile Creek in MacDonald Range; to approximately 3,500 feet in northeastern Galton Range; and to more than 3,500 feet in southwestern MacDonald Range. At the latter locality it embraces the MacDonald Formation as defined by Daly (1912, p. 101).

The lower 1,000 feet of the Roosville Formation is mainly light green argillite and dolomitic argillite with subordinate silty argillite and rare stromatolitic dolomite. Interbeds of red argillite occur locally and are as much as 75 feet thick. The base is gradational into the Phillips Formation. In the middle part the argillite is interbedded with siltstone and fine-grained quartzitic sandstone. Micaceous partings commonly occur in the siltstone and sandstone. The upper part is characterized by much dark green argillite and micaceous siltstone and includes thin beds of red siltstone, argillaceous dolomite, and stromatolitic dolomite. Mud-cracks and ripple-marks occur throughout the formation.

The strata of the Roosville Formation are similar to those of the Appekunny Formation and the upper part of the Gateway Formation, and it is commonly difficult to distinguish between these three units on the basis of lithology alone.

CAMBRIAN

Flathead Formation

The Flathead Formation consists of light yellowish brown and light grey coarse-grained quartz sandstone and quartzite. Quartz-pebble conglomerate and conglomeratic sandstone are common in the lower part of the formation especially in Clark and MacDonald Ranges. Crossbedding is a characteristic feature of the sandstones.

The Flathead lies unconformably on Purcell strata. Progressively older beds occur beneath the Flathead sandstones from west to east and from south to north across the map-area. Between Desolation Creek in southwestern MacDonald Range and Mount Darrah in Flathead Range, approximately 5,000 feet of beds comprising the Roosville Formation and the upper member of the Gateway Formation are truncated against the unconformity. At Windsor Mountain, where the contact between the Flathead and Roosville Formations is exposed in a cliff on the southwest slope, the angular discordance is in the order of 10 feet per 100 yards or approximately 2 degrees. Elsewhere, where exposures are less extensive, the Flathead Formation is apparently concordant with underlying beds. Locally the uppermost Purcell strata show evidence of pre-Flathead weathering.

The Flathead Formation thins from 150 feet in Flathead Range to 85 feet at Windsor Mountain (Norris, 1959a); to approximately 50 feet at Font and Citadel Mountains in Clark Range and Outlier Ridge in MacDonald Range; and to less than 25 feet at Mount Broadwood.

Shale Unit

The Cambrian shale unit consists of light green and greenish grey fissile shale with interbeds of yellow sandstone and siltstone in the lower part and lenses and interbeds of argillaceous limestone and limestone in the upper part. Interbeds of dark red shale occur in the lower part in Clark Range. Because of its lack of resistance to erosion the formation is seldom well exposed. In MacDonald Range and at Mount Broadwood it appears to be approximately 150 feet thick. In southern Flathead Range it is 210 feet thick (Price, 1959) and in northeastern Clark Range approximately 275 feet thick (Norris, 1959a; Hage, 1943).

Fossils collected from the upper half of the unit in Flathead and Clark Ranges have been identified by A.W. Norris and B.S. Norford and are reported to be of early Middle Cambrian age. They include: Albertella, Zacanthoides, Kochina, Ptarmigania, Vanuxemella, Glossopleura(?), Hyolithes, Iphidella, Micromitra, and Cambrotrypa.

The Cambrian shale unit is gradational at the base into the Flathead Formation. Interbedded green shale and fine-grained quartzose sandstone occur in the transition zone. Higher beds of sandstone are generally argillaceous and glauconitic or calcareous. They commonly contain comminuted trilobites.

Elko Formation

The Elko Formation consists mainly of grey, fine- to medium-crystalline dolomite that weathers to a mottled light grey or brownish grey and commonly forms prominent cliffs. Black, very fine crystalline limestone, mottled with light brown and orange-brown, fine- or medium-crystalline dolomite, occurs at the base and is similar to that occurring as interbeds in green shale at the top of the underlying Cambrian shale unit. The contact with the Cambrian shale unit is transitional and has been designated as the top of the highest bed of green shale. The dolomite occurs in beds 1/2 foot to 6 feet thick or, more commonly, as massive cliffs. The mottling in the dolomite can be related to variations in crystal size and intercrystalline porosity. Faint relict structures resembling intraformational conglomerate fragments and pisolites, and texturally laminated dolomites occur locally but are rare.

The Elko Formation thickens toward the south or southeast from 285 feet at Mount Darrah in Flathead Range (Price, 1959) to 350 feet at North Kootenay Pass; to approximately 500 feet at Windsor Mountain in Clark Range; and to an estimated 700 feet at Citadel Mountain. It appears to be approximately 300 feet thick at Mount Broadwood. No fossils have been found in the Elko Formation. Hume (1933, p. 7B) reported an occurrence of "many poor corals" in strata that seem to constitute part of the Elko Formation in the Palaeozoic outlier immediately north of Sage Creek in Clark Range. He stated that they indicate a Silurian age. B.S. Norford re-examined material from Hume's collection (1961, personal communication) and reported that the material can now be confidently described as inorganic. Hume (1933, p. 7B) also reported that Devonian fossils occur in the lowest bed of the limestone-shale sequence above the trilobite-bearing Gordon shales at North Kootenay Pass. The Elko Formation occurs at this locality but no fossils were recovered from it by the writer. Devonian fossils were collected from the lower part of the overlying Fairholme Group.

The Elko Formation is unconformably overlain by the basal beds of the Fairholme Group sequence. The contact is generally sharp and apparently concordant, however at a few localities channelling is evident at the base of the Fairholme Group and locally a paleosol is preserved. On the ridge between North and South Lost Creek, orange and yellow mudstone, presumably representing a paleosol, fills irregularities on the weathered upper surface of the Elko Formation. At Citadel Mountain in Clark Range a basal sandstone unit 10 to 30 feet thick fills depressions up to 15 feet deep on the upper surface of the Elko. Mudstone occurring at the bottom of some of the depressions may represent a regolith. Elsewhere the base of the Fairholme Group is marked by dolomitic sandstone or yellow-weathering argillaceous dolomite, and no channelling or weathering is evident.

On the basis of its relationships to the Cambrian shale unit and the Fairholme Group and its apparent lateral equivalence to the Jubilee Formation (Leech, 1958), the Elko Formation is presumably Middle and/or Upper Cambrian.

DEVONIAN

Fairholme Group and Alexo Formation

The sequence of strata constituting the Fairholme Group and the Alexo Formation consists mainly of limestone and dolomite, and changes conspicuously from one locality to another within the map-area. On a regional scale the most pronounced change in the character of this stratigraphic interval occurs across the MacDonald thrust. Consequently exposures lying northeast of and beneath the thrust will be considered first and those lying southwest of the thrust later.

In Flathead and Clark Ranges and north-central MacDonald Range the Fairholme Group consists of four principal stratigraphic units, two of which are laterally contiguous. Abrupt lateral changes in the character of the Fairholme Group are due to the intertonguing of the contrasting lithofacies of these latter two units.

The lowest principal unit in the Fairholme Group consists mainly of dark grey, very fine crystalline limestone and argillaceous limestone and is characteristically massive or nodular and light grey weathering. It is gradational toward the base into a heterogeneous sequence of medium- and fine-crystalline dolomites and limestones that are commonly silty, sandy, and argillaceous and are thin bedded and light yellow weathering. Zones of sedimentary breccia up to 10 feet thick comprising fragments of limestone and dolomite in matrix of limestone or dolomite occur throughout the unit but are most common in the lower part. Quartzose sandy dolomites or dolomitic sandstones mark the base of the unit locally, but are not common at higher levels. The thickness varies from between 325 and 400 feet in various localities in Flathead Range to 500 feet at Windsor Mountain in Clark Range and an estimated 350 feet at Twentynine Mile Creek in north-central MacDonald Range.

Fossils collected from the unit, mainly in the upper two thirds, have been identified by D.J. McLaren and include the following: *Spongophyllum imperfectum* Smith, *Schizophoria* sp., *Eostrophalosia* sp. H. ("Productella cf. belanskii" of Warren and Stelk), Productella sp., Atrypa multicostellata Kottlowski, Eleutherokomma jasperensis (Warren), Eleutherokomma reidfordi (Crickmay), Athyris sp. McLaren reported that the faunas submitted to him may be correlated with those of the Flume, Maligne, and Cairn Formations of the Fairholme Group of the Alberta Rocky Mountains and with those of the upper Waterways Formation and possibly with lower horizons of the Waterways Formation of northeastern Alberta. Stromatoporoids, Amphipora, and stromatolites occur locally and are most abundant where the unit is thickest. The yellow-weathering limestones and dolomites of the lower part of the unit represent the basal phase of the Devonian sequence and are similar to Leech's (1958) "basal Devonian unit".

The middle principal unit in the Fairholme Group is mainly dark grey and brownish black, fine- to coarse-crystalline, fetid dolomite. It is generally thickly bedded or massive and commonly vuggy. Lamination is commonly etched into relief on weathered surfaces, and locally defines crossbedding. Partings and interbeds of brownish black shale occur in the southern part of Flathead Range and at Twentynine Mile Creek in MacDonald Range. At Howell Creek in MacDonald Range the unit appears to consist mainly of black shale. The thickness varies from between 60 and 160 feet at different localities in Flathead Range, to 185 feet at Windsor Mountain; and to 135 feet at Twentynine Mile Creek. The base is conformable and apparently gradational into the lower unit of the Fairholme Group. The fauna recovered to date is not diagnostic and consists of stromatoporoids, tabulate corals, and Amphipora.

The Mount Hawk Formation overlies the brownish black dolomites of the middle part of the Fairholme Group. It consists predominantly of dark grey, fine-crystalline, argillaceous and silty limestones. Dark shale, silty dolomite and siltstone are less abundant. These rocks are less resistant to weathering and typically form gentle, scree-covered slopes between cliffs formed by the overlying and underlying units. The lower half and possibly all of the formation intertongues laterally with the dolomites of the Peechee Member of the Southesk Formation. The formation is between 400 and 475 feet thick at various localities in southern Flathead Range and at Twentynine Mile Creek in MacDonald Range. Silty dolomite and limestone beds occur in the upper half and apparently increase in abundance toward the southwest.

McLaren has identified the following fossils in collections from the Mount Hawk Formation: Coenites sp. E., Disphyllum cf. D. colemanense Warren, Tabulophyllum sp. A., Phacellophyllum sp. A., Thamnophyllum cf. T. tructense (McLaren), Schizophoria cf. S. amanaensis Stainbrook, Gypidula cf. G. munda Calvin, Devonoproductus cf. D. vulgaris Stainbrook, Calvinaria albertensis (Warren), Atrypa cf. A. devoniana Webster, Atrypa cf. A. varicostata Stainbrook, Spinatrypa sp. C., Grunewaldtia americana Stainbrook, Warrenella nevadensis (Walcott). He reported that these fossils, in collections made from various horizons in the formation, represented comparable horizons in the Mount Hawk Formation farther north.

The Southesk Formation consists mainly of medium- to very-coarse-crystalline dolomite. Three members are distinguishable within it. The lower of these, the Peechee Member, forms discrete reef-like masses that intertongue with the lower part and possibly all of the Mount Hawk Formation. The upper two, the Grotto and Arcs Members, form tabular or sheet-like masses that extend beyond the limits of the Peechee Member and overlie the limestones of the Mount Hawk Formation.

The Peechee Member consists mainly of massive, coarse-crystalline, white and light grey dolomite reef masses. It occurs at Windsor Mountain in Clark Range, and in Flathead Range at the head of South Lost Creek and Goat Creek and between Mount Ptolemy and Mount Pengelly. It appears to be present also southwest of Mount Hollebeke in the vicinity of Flathead Valley and at Phillips Pass in High Rock Range. The dolomite is typically saccharoidal and devoid of any recognizable organic structures. Locally it shows a relict very coarse breccia fabric in which blocks of dolomite are outlined by calcite-filled vugs. At the head of Goat Creek the blocks are as much as several feet long but their peripheries are seldom well defined. Elsewhere vugs in the dolomite show a preferred orientation along certain zones that is suggestive of bedding. Along the margins of the Southesk reef masses, coarse-crystalline white dolomite is interbedded with coarse-crystalline brown dolomite, and the dolomites intertongue abruptly with the limestones of the Mount Hawk Formation. The brown dolomite constitutes a lithofacies intermediate between that of the Peechee white dolomite and the Mount Hawk limestone. It also occurs interbedded with white dolomite at the base of some of the reef masses.

Although individual tongues of Peechee dolomite can be traced into the lower part of the Mount Hawk Formation, it is uncertain whether succeeding beds forming the upper part of the Mount Hawk Formation are intertongued with the Peechee Member or whether they onlap everywhere over the steep flanks of the reef masses. The latter relationship occurs at the head of South Lost Creek. There the uppermost beds of a Peechee reef mass intertongue with the lower part of the Mount Hawk Formation. Higher beds in the Mount Hawk onlap over the flank of the reef mass and the geometric relationships are indicative of at least 100 feet of relief on a former depositional interface extending from the top of the reef to the lower part of the Mount Hawk Formation. Cross-sections of reef masses exposed in the cliffs of the eastern slope of Flathead Range show that individual reef masses may either taper toward the top as at South Lost Creek or flare out upward as at Goat Creek and between Mounts Ptolemy and Pengelly.

The Grotto Member of the Southesk Formation comprises dark grey and grey-brown, medium- and fine-crystalline fetid dolomite. Bedding is commonly discernible but rarely well defined. Beds vary in thickness from a few inches to several feet. Vuggy porosity is common locally in zones parallel to the bedding. Poorly preserved corals occur within the dolomites at some localities. The Grotto Member varies in thickness from 65 feet at Twentynine Mile Creek in MacDonald Range to between 70 and 110 feet at various localities in southern Flathead Range. It passes laterally into argillaceous limestone of the Mount Hawk Formation and is absent on Mount Coulthard in northern Flathead Range and at the head of Howell Creek in MacDonald Range. At both localities the Arcs Member overlies the Mount Hawk Formation. The Grotto Member overlies the Peechee reef and surrounding beds of the Mount Hawk Formation at South Lost Creek.

Between Mount Ptolemy and Mount Pengelly, the Grotto Member and the overlying Arcs Member are truncated and overlapped by the Alexo Formation on the flank of a Peechee reef mass. The Southesk reef at Goat Creek overlies approximately 25 feet of dark limestone with interbedded dolomite that marks a lithofacies transitional from the Mount Hawk to the Peechee. At the top the reef is overlain by the Alexo Formation and both the Grotto and overlying Arcs Members are absent. The marginal zone is not well exposed but presumably the absence of the Arcs and Grotto Members is due to erosional truncation and overlap by the Alexo Formation, as is the case between Mount Ptolemy and Mount Pengelly.

The Arcs Member of the Southesk Formation marks the top of the Fairholme Group throughout the area northeast of the MacDonald thrust, except above the two Peechee reef masses described previously. It consists of white and light grey, coarse-crystalline dolomite. Beds, where discernible, are generally several feet thick. The base is gradational over a few feet into the Grotto Member. The top is generally sharply marked by the base of the Alexo Formation. Lamination and cross-lamination are occasionally etched into relief on weathered surfaces of the dolomite, and vuggy and intercrystalline porosity occurs in some beds. The dolomite typically forms prominent white cliffs. No fauna has been obtained from the Arcs Member in Fernie map-area. The thickness of this member varies between 75 and 155 feet.

The Alexo Formation in north-central MacDonald Range and in Flathead Range consists of platy, laminated, silty, fine-crystalline limestone and dolomite with local intercalations of breccia and light coarse-crystalline dolomite. This sequence of beds typically forms a distinctive yellowish-weathering recessive zone beneath the resistant limestones of the Palliser Formation. Mud-cracks are common in the dolomite and limestone. The lenses of breccia that occur here and there appear to represent both intraformational flat-pebble 'conglomerate' and solution breccia. Contorted bedding indicative of slumping penecontemporaneous with deposition occurs but is not common. Light coarse-crystalline dolomite occurs only in the thickest sections. The contact of the Alexo with underlying beds is sharp, and on the basis of observed truncation, is presumed to be everywhere unconformable. The formation is 100 feet thick at Mount Borsato but thins northward in Flathead Range to a minimum of 25 feet over the reef masses at Goat Creek and northeast of Mount Pengelly. The thinning over the reefs is due, in part at least, to transgressive overlap by the Alexo. At Twentynine Mile Creek in north-central MacDonald Range the Alexo is 65 feet thick.

Southwest of the MacDonald thrust, on Inverted Ridge and at Mount Broadwood, the lower two principal stratigraphic units in the Fairholme Group are essentially the same as in Flathead Range. The dark grey, very fine crystalline limestone unit is approximately 575 feet thick at Mount Broadwood. Fossils collected from it have been identified by D.J. McLaren as: Eleutherokomma cf. E. reidfordi Crickmay, Atrypa multicostellata Kottlowski(?), and Thamnopora sp. The lower part contains thin-bedded, yellowish-weathering dolomite, and dolomitic quartzose sandstone marks the base. The overlying middle part of the Fairholme comprises brownish black, saccharoidal, fetid dolomite and is 135 feet thick on Inverted Ridge at Desolation Creek.

Succeeding beds, occupying the position of the Mount Hawk and Southesk Formations in Flathead, Clark, and north-central MacDonald Ranges, differ markedly from those northeast of the MacDonald thrust. The Southesk Formation is absent. Approximately 150 feet of dark grey, argillaceous and shaly limestone and calcareous shale, representing the Mount Hawk Formation, overlie the brownish black fetid dolomite. These appear to grade upward into dark grey, silty, argillaceous limestone and dolomite. Fossils collected from these silty beds were identified by McLaren as: *Athyris* small sp., *Cyrtiopsis mimetes* Crickmay, and "*Pugnoides*" sp. McLaren stated that this fauna is characteristic of the lower Alexo in the Jasper region and is the earliest Famennian faunal zone of Western Canada. He stated that it is later than any occurrence of corals, *Atrypa*, etc. in the region. This implies that it is older than the upper part of the Mount Hawk Formation or the Grotto Member of the Southesk Formation in the region northeast of the MacDonald thrust, and that these beds are absent on Inverted Ridge and at Mount Broadwood as a result of non-deposition or of erosion which pre-dates this Alexo fauna.

The silty, argillaceous limestones and dolomites with an early Famennian fauna grade upward into dolomitic and quartzitic siltstone which is in turn succeeded by fine-grained quartzite and dolomitic quartzite. These latter beds constitute the Broadwood quartzite member of the Alexo Formation as defined by Crabb (1957). They are overlain by platy, laminated, silty, fine-crystalline limestone and dolomite with intercalated breccia that is in every respect similar to the Alexo Formation of Flathead Range and north-central MacDonald Range. Thus, the quartzites, siltstones, and silty carbonates with a Famennian fauna, overlying a thinned Mount Hawk Formation on Inverted Ridge at Mount Broadwood, occur in place of the upper part of the Mount Hawk Formation and the Grotto and Arcs Members of the Southesk Formation of north-central MacDonald Range and Flathead Range.

Palliser Formation

Palliser strata are exposed above the Lewis thrust fault in High Rock, Flathead, and MacDonald Ranges. They also occur along Inverted Ridge and in the vicinity of Mount Broadwood. As in other parts of the Canadian Rockies the Palliser Formation is a conspicuous cliff-former. It consists mainly of dark grey, fine-crystalline limestone that is commonly mottled with brownish grey, medium-crystalline dolomite. Calcarenitic (skeletal and pelletoidal) limestone occurs also but is not common. The dolomitic mottling resembles that in the basal part of the Elko Formation. The thickness varies from 650 to 720 feet.

The Morro Member forms the lower part of the formation. It is thickly bedded to massive and characteristically forms prominent cliffs. Brownish grey, medium-crystalline dolomite generally occurs at the base and locally it contains lenses of dolomite breccia. Dolomite or dolomite breccia is typically in sharp contact above the Alexo Formation, and grades upward into the dolomite-mottled limestone. The Morro Member is about 600 feet thick. *Cyrtiopsis* sp. and *Athyris* sp. have been identified by McLaren in collections made from it.

The upper part of the Palliser Formation comprises the dark grey, thin-bedded and nodular, fine-crystalline limestone and argillaceous limestone of the Costigan Member. It is 100 to 150 feet thick and much less resistant to erosion than the Morro Member. Dolomitic mottling occurs in some of the limestone beds and some contain abundant pelletoidal or skeletal ('crinoid') grains. Fossils collected from the member are reported by McLaren to comprise faunas of Palliser age. They include: nautiloid cf. Ryticeras sp., Camarotoechia cf. C. banffensis Warren, Camarotoechia nordeggi Kindle, Cyrtiopsis glenfoxi (Crickmay), and Cyrtiopsis cf. C. monticola Haynes.

MISSISSIPPIAN

Exshaw Formation

The Exshaw Formation consists of platy, black, non-calcareous shale that weathers black and brownish black with rust and yellow staining. It varies in thickness from a few feet to a few tens of feet. The basal contact is sharp and marked by a pronounced contrast in lithology from the Palliser Formation. A hard bed commonly marks the top. At different localities this bed consists of silty limestone or of glauconitic or calcareous siltstone. It is generally in the order of 1 foot or 2 feet thick but may locally be as much as 10 feet thick. Shale interbeds occurring within the lower part of the Banff Formation are similar to the Exshaw shale, and the Exshaw Formation is apparently transitional upward into the lower part of the Banff Formation, marking a basal phase of the Banff-Rundle depositional sequence.

Banff Formation

Banff strata are well exposed in Livingstone, Blairmore, High Rock, Flathead, and MacDonald Ranges. At the first two localities Banff strata are the oldest rocks exposed and the basal part of the formation is absent due to faulting. Representative thicknesses for the Banff Formation are: 800 feet in Livingstone Range, 6 miles south of the Gap, with the lower part absent due to faulting (Douglas, 1950); more than 400 feet in Blairmore Range, with the lower part absent due to faulting (Norris, 1955); 1, 050 feet at Tornado Pass in High Rock Range; 600 feet in southern Flathead Range (Price, 1959); and 900 feet on Inverted Ridge, at Cabin Pass, in MacDonald Range.

The lower part of the Banff Formation consists of black and brownish black shale and calcareous shale, interbedded with black cherty limestone, platy and cherty siltstone, and black, banded chert. Textural and compositional lamination is common, and thin bedding is typical. The thickness of this unit varies from 110 to 270 feet, and it is less resistant to erosion than overlying beds.

The middle part of the Banff Formation, 250 to 450 feet thick, comprises dark grey and black, dense, cherty, argillaceous limestone in beds from a few inches to a foot thick. The chert is calcareous and dark grey. It occurs as discontinuous bands and streaks from a fraction of an inch to a few inches thick and produces a ribbed appearance on weathered surfaces. Compositional and textural lamination is common in the lower part of the unit but becomes less conspicuous toward the top. This unit marks a transition from the shaly beds of the lower part of the formation to the lighter and more coarsely crystalline limestones of the upper part.

A sequence of beds 265 to 400 feet thick occurring in the upper part of the Banff Formation consists mainly of medium and dark grey, fine- to medium-crystalline limestone with disseminated skeletal (mainly echinoderm) fragments and with wisp-like bands, lenses, and patches of medium and dark grey calcareous chert. The beds are generally 1 foot to 4 feet thick. This sequence of beds generally forms relatively prominent topographic features and weathers to a lighter grey than lower parts of the Banff Formation but to a darker grey than the lower part of the overlying Livingstone Formation.

Rundle Group

Livingstone Formation

The Livingstone Formation lies with gradational contact above the Banff Formation. It consists mainly of light grey skeletal (echinoderm-bryozoa) calcarenites and calcarenitic fine-crystalline limestones. Cherty-limestone interbeds are common in the lower part of the formation and interbeds of light grey, fine-crystalline dolomite, commonly silty, occur within the upper half. The base has been designated as the base of the lowest bed of coarse-grained skeletal calcarenite. Beds are generally several feet thick and individual beds of massive skeletal calcarenite up to 25 feet thick are not uncommon. The Livingstone Formation characteristically forms prominent ribbed cliffs.

The upper part in Livingstone and Blairmore Ranges contains many beds of porous calcarenite. In general the calcarenites appear to be more tightly cemented in High Rock, Flathead, and MacDonald Ranges. Beds of porous sugary dolomite within the Livingstone Formation appear to be the dolomitized equivalents of calcarenites, and their areal distribution is similar to that of the porous calcarenites.

The thickness of the Livingstone Formation in Livingstone Range varies from between 800 and 900 feet in Gap map-area (Douglas, 1950) to 1,100 feet at Green Creek in Blairmore map-area (Norris, 1955). The formation is 1,370 feet thick in southern Flathead Range (Price, 1959), 1,120 feet thick at Mount Broadwood, and 1,170 feet thick at Tornado Pass in High Rock Range. It was penetrated by the Pacific-Atlantic Flathead well, and there, the lithofacies and thickness are most similar to those in southern Flathead Range.

Mount Head Formation

Strata of the Mount Head Formation appear to be conformable over those of the Livingstone Formation in Livingstone, Blairmore, High Rock, Flathead, Wisukitsak, Taylor, and MacDonald Ranges and at Erickson Ridge and Mount Broadwood. The thickness of the Mount Head Formation varies from approximately 700 feet in

Livingstone Range (Douglas, 1950; Norris, 1955) to 860 feet in southern Flathead Range (Price, 1959); to 900 feet in western MacDonald Range; and to 1,000 feet in High Rock Range at Tornado Pass and at the headwaters of Alexander Creek, 3 miles south of Mount Erris.

In Livingstone Range the Mount Head Formation comprises six members (Douglas, 1950 and 1953; Norris, 1955). The lowest of these, the Wileman Member, consists of fine-crystalline, brown, argillaceous dolomite and is approximately 75 feet thick. The overlying Baril Member, about 95 feet thick, consists mainly of medium-crystalline limestone and is not easily distinguishable from the Wileman Member. The Salter Member comprises between 100 and 150 feet of brownish grey, fine-crystalline argillaceous dolomites with interbedded dolomite breccias overlying the Baril Member. It forms a yellowish brown platy and recessive interval between the limestone members above and below. The Loomis Member overlies it, is approximately 150 feet thick, and consists mainly of medium to dark grey, fine- and medium-crystalline limestone. It is blocky and forms a light grey rib between adjacent dolomite units. The overlying Marston Member, 85 to 100 feet thick, is mainly platy, brown-weathering, fine-crystalline, argillaceous dolomite with interbeds of limestone and of solution breccia. The Carnarvon Member marks the top of the Mount Head Formation. It is a dark grey, fine-crystalline and cryptocrystalline limestone with a few thin interbeds of black calcareous shale, and forms a conspicuous marker unit. The thickness and lithofacies of Mount Head strata encountered in Pacific-Atlantic Flathead well at Sage Creek are comparable with those of Livingstone Range.

The westward thickening of the Mount Head Formation from Livingstone Range to Flathead, High Rock, and MacDonald Ranges is accompanied by significant changes in the details of the stratigraphic succession. The Baril and Wileman Members have not been recognized in the west. Presumably, a westward increase in the amount of skeletal calcarenite in this interval has made it indistinguishable from the upper part of the Livingstone Formation, and it has been included in the Livingstone Formation. As in Livingstone Range, the Salter Member is between 100 and 150 feet thick. However, in this western region, the breccias are absent and interbeds of limestone and calcarenitic limestone are not uncommon. The yellowish-brown-weathering and recessive nature of the member are still characteristic and therefore it serves as a conspicuous marker for the base of the Mount Head Formation. The overlying Loomis Member is 300 to 400 feet thick, more than twice the thickness in Livingstone Range, and consists mainly of coarse-grained skeletal calcarenites rather than fine- and medium-crystalline limestone. This change in lithofacies makes it difficult to distinguish the Loomis Member from the Livingstone Formation in isolated exposures. The Marston Member is between 100 and 110 feet thick in southern Flathead Range and MacDonald Range but thickens northward to 225 feet at Tornado Pass. As in Livingstone Range it consists mainly of fine-crystalline argillaceous dolomite, but solution breccias are absent, the dolomites are less platy and limestone interbeds are more common. The Marston Member is gradational upward into the Carnarvon Member and the designation of a contact between the two is arbitrary. The Carnarvon Member is 275 to 325 feet thick, somewhat thicker than in Livingstone Range. However, as in Livingstone Range, it comprises dark grey fine-crystalline and cryptocrystalline limestone and is a conspicuous marker at the top of the Mount Head Formation. Like the Marston Member, it is thickest in the vicinity of Tornado Pass.

Etherington Formation

The Etherington Formation is exposed in Livingstone, Blairmore, High Rock, Flathead, Wisukitsak, Taylor, and MacDonald Ranges, on Erickson Ridge and Mount Broadwood, and in the area west of Elk River.

Beneath the Lewis thrust fault in Livingstone and Blairmore Ranges and in Pacific-Atlantic Flathead No. 1 well, the Etherington Formation consists mainly of cherty and silty, fine-crystalline limestone and dolomite with interbeds of green and red shale and either solution breccia or anhydrite. The thickness varies from 200 to 375 feet (Douglas, 1950; Norris, 1955), and increases from east to west. Anhydrite occurs in the upper part of the formation in fault slices encountered beneath the Lewis thrust fault in the Pacific-Atlantic Flathead No. 1 well. Breccias, presumably indicating the former presence of anhydrite, have been reported from the southern part of Livingstone Range (Norris, 1955) but not from the more northerly parts (Douglas, 1950). Green shale is common in the lower part of the formation, and in southern Livingstone Range is mottled and banded with red shale (Douglas, 1950; Norris, 1955). In the Pacific-Atlantic Flathead well the lower part of the Etherington consists mainly of red shaly siltstone with interbeds of dense dolomite and green shale.

The Etherington Formation thickens westward across the Lewis thrust fault. It is 400 to 500 feet thick at Flathead Pass in southern Flathead Range, and approximately 550 feet thick at Mount Broadwood. It thickens northward within the Lewis thrust sheet to approximately 600 feet at Crowsnest, British Columbia, to 625 feet at the headwaters of Alexander Creek 3 miles south of Mount Erris, and to 860 feet at Beehive Pass 5 miles north of Fernie map-area (Norris, 1957). A section of Etherington strata 1,000 feet thick was measured along the north side of Tornado Creek adjacent to the north boundary of the map-area, but silty beds forming the upper part of the formation are somewhat thicker here than elsewhere, and 100 feet or more of strata near the top of the formation may be repeated by an unrecognized thrust fault. The thicknesses given above include beds which Norris (1957) named the "Todhunter Member" and assigned to the Rocky Mountain Formation. These beds become less silty southward and are not always distinguishable from the remainder of the Etherington Formation; on the other hand, they are distinct from the monotonous succession of light grey sandstones which forms the bulk of the Rocky Mountain Formation. Therefore it was considered expedient, in this study, to designate the base of this sandstone succession as the top of the Etherington Formation.

Changes in lithofacies occur in conjunction with the westward thickening of the Etherington Formation. In British Columbia, above the Lewis thrust fault, the Etherington Formation is divisible into three parts. The lowest of these, 100 to 200 feet thick, consists mainly of medium grey, fine-crystalline to cryptocrystalline limestone with variable amounts of skeletal calcarenite, mainly as disseminated echinoderm fragments in the dense limestone matrix. Nodules and bands of medium grey chert are abundant and silicified brachiopods are common. Thin interbeds of green and greenish grey shale are characteristic. The limestone is typically thinly bedded and commonly has faint lamination etched into relief on weathered surfaces. These beds appear to be gradational over a fraction of a foot or a few feet into those of the Carnarvon Member of the Mount Head Formation.

The middle part of the Etherington Formation, 200 to 350 feet thick, consists mainly of medium and light grey skeletal calcarenites. Medium- to very-coarse-grained echinoderm fragments occur in association with foraminifera, and less commonly with pellets and oolites, in a dense limestone matrix. The calcarenites are generally thickly bedded or massive and commonly contain lenses and nodules of medium grey chert. They are interbedded with fine-crystalline limestone and silty and argillaceous limestone and dolomite.

The upper part of the Etherington is generally 100 to 250 feet thick and is characterized by silty and sandy fine-crystalline dolomite. The dolomites are dark grey, cherty, and interbedded with limestone toward the base, but become lighter and more silty upward and grade into dolomitic siltstone and sandstone at the top of the Etherington Formation. The beds are typically platy or flaggy and yellowish or brownish grey weathering. Delicate lamination is commonly etched into relief, especially in the uppermost beds. Norris' (1957) Todhunter Member was recognized with certainty only at Tornado Pass in High Rock Range. There it comprises 100 feet of red, orange, and yellow, very fine grained dolomitic sandstone and siltstone lying below a thick sequence of light yellowish grey, dolomitic and quartzitic sandstone which forms the lower part of the Rocky Mountain Formation. In Taylor Range, 8 feet of red and orange silty dolomite, overlain by 46 feet of light grey and yellowish grey cherty and silty dolomite, occurs at the top of the Etherington Formation and may represent the lateral equivalent of the Todhunter Member.

PENNSYLVANIAN AND PERMIAN

Rocky Mountain Formation

Rocky Mountain strata within the map-area have a distribution similar to that of the Etherington Formation. Variations in the thickness of the Rocky Mountain Formation, in general, parallel those of the Etherington Formation.

Beneath the Lewis thrust sheet in Livingstone and Blairmore Ranges and in the Pacific-Atlantic Flathead No. 1 well the thickness of the Rocky Mountain Formation varies from a few tens of feet to almost 300 feet. It consists mainly of light grey quartz sandstone and sandy, cherty dolomite. Overlying beds in Livingstone and Blairmore Ranges consist of 25 to 50 feet of dark siltstone, sandstone, limestone, and dolomite, with a chert-pebble conglomerate at the base. These beds may constitute the Spray River Formation but have been grouped with the Rocky Mountain Formation for mapping purposes. In the Pacific-Atlantic Flathead well the Rocky Mountain strata are overlain by 20 to 30 feet of black shale and shaly siltstone that resembles the lower part of the Spray River Formation as developed in the western half of the map-area.

Above the Lewis thrust fault, in British Columbia, the Rocky Mountain Formation varies in thickness from 650 feet in southern Flathead Range and Taylor Range to approximately 1,000 feet at Tornado Pass in High Rock Range, and to approximately 1,500 feet immediately west of Elk River along Wilson Creek.

In High Rock, Flathead, Wisukitsak, Taylor, and MacDonald Ranges, the lower and by far the greater part of the formation consists of a monotonous succession of light-coloured, quartzitic, dolomitic or calcareous, fine-grained, quartz sandstone. Silicified productids commonly occur within dolomitic sandstones in the lower few hundred feet in Taylor, Flathead, and High Rock Ranges. Several of the collections made from this interval have been examined by P. Harker of the Geological Survey. Harker identified the brachiopods as Dictyoclostus sp. cf. D. portlockianus Norwood and Pratten and reported that the fauna is of Pennsylvanian age. The sandstone succession is overlain by approximately 50 feet of grey, fine-crystalline dolomite, silty dolomite, and cherty dolomite with interbeds of yellow and brown shale, grey chert, cherty quartz-pebble conglomerate, and conglomeratic sandstone. The dolomites are most abundant and they occasionally contain silicified corals, pelecypods, scaphopods, gastropods, and brachiopods. The other lithologic components are only sporadically present. Fossils collected from these beds in Taylor and MacDonald Ranges have been identified by Harker as: Plagioglypta canna White, 'Caninia' sp., Bakewellia sp., and Spirifer sp. Collections from other parts of the area have yet to be studied.

West of Elk River the Rocky Mountain succession differs somewhat from that in other parts of the map-area. A section of the Rocky Mountain Formation exposed along Wilson Creek, adjacent to the valley of Elk River, is summarized as follows from a description by D.L. Scott:

	Thickness (feet)
Overlying beds are grey, platy, brown-weathering, argillaceous siltstone of the middle part of the Spray River Formation.	
Rocky Mountain Formation	
Covered. (An estimated 50 feet of a 250-foot covered interval probably constitutes the uppermost part of the Rocky Mountain Formation)....	50
Sandstone, calcareous, light grey, fine-grained, quartzitic in part, lamination etched into relief on weathered surfaces..............................	215
Sandstone, calcareous, dark grey, very fine grained, blebs and geodes of chert.........................	18
Sandstone, calcareous, light grey, fine-grained, nodules and bands of chert, lamination etched into relief on weathered surfaces......................	68

	Thickness (feet)
Sandstone, very fine grained, and siltstone, dark to medium grey, calcareous and dolomitic, cherty in part, thin interbeds of dense silty limestone, and medium-grained, light grey, skeletal (echinoderm) limestone	287
Sandstone, calcareous, light to medium grey, very-fine- to medium-grained, cherty in part, thin interbeds of coarse-grained skeletal (echinoderm) calcarenite, lamination etched into relief on weathered surfaces....	134
Sandstone, quartzitic, and quartzite, light grey, fine-grained, hard, brittle	422
Sandstone, dolomitic and quartzitic, light grey, fine-grained	300
Thickness of Rocky Mountain Formation, approximately.	1,500
Covered (probably recessive beds of the upper part of the Etherington Formation)........................	120
Underlying beds are dark grey silty and cherty limestones and dolomites of the Etherington Formation.	

This section appears to be representative for the area west of Elk River. A general twofold subdivision is distinguishable within it. The lower part, comprising approximately 750 feet of beds, is characterized by light-coloured quartzitic and dolomitic sandstone and is more resistant to erosion. It is similar to the monotonous sandstone succession forming most of the Rocky Mountain Formation in High Rock, Flathead, Taylor, and MacDonald Ranges. The upper part contains a higher proportion of carbonate, is less resistant to erosion, and in general is darker. Dark grey and black siltstones, and silty dolomites and limestones occur within the lower half of this sequence of beds. Adjacent to Nordstrum Creek, thin interbeds of black chert and pelletoidal or oolitic phosphate rock occur in association with them.

TRIASSIC

Spray River Formation

In Livingstone and Blairmore Ranges, Douglas (1950) and Norris (1955 and 1959a) have tentatively assigned a sequence of grey siltstones, fine-grained sandstones and fine-crystalline limestones and dolomites, ranging from 20 to 65 feet in thickness, to the Spray River Formation. A distinctive conglomerate containing pebbles of black chert marks the base of this sequence.

Above the Lewis thrust fault, in British Columbia, the Spray River Formation is divisible into two parts. The lower part consists mainly of platy siltstone, calcareous siltstone, and silty shale.

These rocks are dark grey and weather to a deep brown; but are seldom well exposed. Dark sandstones with black chert pebbles and phosphatic(?) nodules commonly mark the base of the formation. The upper part of the formation consists of light grey dolomitic or sideritic, argillaceous siltstone. It characteristically weathers to a light yellowish brown on exposed surfaces but to a dark reddish brown beneath a thin outer crust. The lower beds are platy but higher beds are a foot thick or more.

The Spray River Formation thickens northwestward from approximately 300 feet in southeastern MacDonald Range, Flathead Range, and Taylor Range, to approximately 650 feet at Tornado Pass in High Rock Range; and perhaps to as much as 1,500 feet west of the Elk River.

JURASSIC

Fernie Group

Strata of the Fernie Group are relatively incompetent and much structural deformation is localized within this part of the stratigraphic succession. Exposures are generally relatively poor. No complete, unfaulted sections of the group have been described. Frebold (1957) has provided detailed descriptions of Fernie strata from a number of localities in this region and has integrated these in a regional synthesis of the Fernie Group. Some of his descriptions are summarized in the discussion that follows.

Strata of the Fernie Group can be separated into three broad subdivisions for mapping purposes. The lowest of these comprises dark grey, brownish grey, and black, shale, limestone and fine-grained sandstone. The Grey beds form the middle subdivision. The upper subdivision embraces the Green beds and Passage beds.

In Alberta, beneath the Lewis thrust fault, the base of the Fernie Group is marked by a pelecypod coquina and pebble-conglomerate generally a foot or less in thickness. Succeeding beds vary from place to place from dark fissile shale and calcareous shale to dark fine-grained sandstone or sandstone and shale, and have been dated as Toarcian by Frebold. These beds are 50 to 100 feet thick and are in turn overlain by 50 to 125 feet of dark grey to black, rusty-weathering shale with bands and large concretions of argillaceous limestone and beds of calcareous sandstone. These younger beds constitute the Rock Creek Member of the Fernie and they have yielded ammonites that are representative of the Middle Bajocian according to Frebold.

In British Columbia, above the Lewis thrust fault, the base of the Fernie Group is marked by a few feet of black pelletoidal and nodular phosphate rock and phosphatic shale. Overlying these basal beds is at least 100 feet of dark grey and black, massive, hard shale that has yielded ammonites indicative of the Sinemurian (Frebold, 1957, p. 7) and is thus in part at least older than homotaxial beds beneath the Lewis thrust fault in Alberta. Frebold reported that higher dark shales at Fernie contain ammonites indicative of the Toarcian. These dark shales are succeeded by the Rock Creek Member, comprising dark brownish grey and brownish black, fissile, silty shale with concretions and thin beds of black limestone. Frebold (1957, p. 71) has reported ammonites indicative of the Middle Bajocian from these beds along Fording River. Pelecypods and ammonite fragments collected from limestone concretions in the shales 1 mile east of Grave Lake were identified by Frebold as fragments of Stephanoceratids (indet.) and Inoceramus ferniensis Warren, and reported to be of Middle Bajocian age. In southern MacDonald Range in the vicinity of Cabin and Couldrey Creeks, part of the lowest subdivision of the Fernie is apparently represented by black argillaceous limestone overlain by about 75 feet of brownish black shale and approximately 50 feet of dark grey and black, very fine grained quartzitic sandstone. The sandstone may represent the Rock Creek Member but has not yielded fossils.

The Grey beds form a distinctive lighter-coloured lithologic unit in the middle of the Fernie Group. They are more resistant than overlying and underlying beds and hence are more commonly exposed. The Grey beds characteristically consist of medium to light grey shale and calcareous shale with variable amounts of silty shale, fine-grained calcareous sandstone and sandy limestone.

Frebold reported that in the vicinity of Blairmore and Livingstone Ranges the Grey beds are in the order of 300 feet thick and consist of medium brownish grey shale with bands of silty and sandy calcareous shale. They embrace a distinctive group of beds that have been named the facies of the Corbula munda and Gryphaea beds. This facies consists of grey shales intercalated with bands and lenses of calcareous sandstone containing abundant pelecypods, and is marked at the top by a coquina consisting largely of Gryphaea. Ammonites from these beds have been dated as Upper Callovian, and two ammonite zones of the European standard sequence are represented.

In British Columbia, above the Lewis thrust fault, the facies of the Grey beds differs somewhat from that in the vicinity of Blairmore and Livingstone Ranges. Calcareous sandstone, and sandy, silty, and shaly limestone are more abundant and lighter coloured. The beds are more resistant and generally form a conspicuous light-coloured rib or cliff. They are gradational at the base through yellowish brown shale into fissile brownish black shale which probably represents the Rock Creek Member. Structural complications generally obscure the true stratigraphic thickness of the Grey beds but it appears to be in the order of 200 to 300 feet (Frebold, 1957, Fig. 3). Frebold has reported an ammonite fauna from along Fording River that is representative of the lower of the two Lower Callovian zones in the vicinity of the Blairmore region. In a fauna collected by the writer from the Grey beds along the north side of Lodgepole Creek at longitude 114°50', Frebold has identified the following: Procerites cf. engleri Frebold (fragments), Belemnites sp., Oxytoma blairmorensis McLearn, Gervillia ferrieri McLearn, Gryphaea impressimarginata McLearn, Trigonia(?) sp. indet., Lima sp. indet., Pleuromya obtusiprorata McLearn. He reported that this fauna is characteristic of the Gryphaea bed which contains the fauna of the upper of the two Lower Callovian faunal zones in the vicinity of Blairmore Range.

The Green beds and Passage beds together form a distinctive unit some 200 to 300 feet thick at the top of the Fernie

Group. The Green beds mark the base of this unit at most localities. They consist of up to 65 feet of glauconite sandstone and glauconitic shale, and commonly grade upward into black shale with lenses or concretions of colloform limonite. Frebold (1957, pp. 73-79) has reported that at several localities in the vicinity of Livingstone and Blairmore Ranges they overlie dark grey shales and occur between 30 and 100 feet above the Gryphaea bed. At Alexander Creek (Frebold, 1957, p. 71) and on Coal Mountain, southeast of Corbin, the Green beds lie with sharp contact on light grey calcareous sandstone and shale marking the top of the Grey beds. On the west side of Limestone Ridge, in Taylor Range, glauconitic beds are absent and black shale of the lower part of the Passage beds lies in sharp contact on the Grey beds. Elsewhere the Green beds apparently grade upward into the black shale of the lower part of the Passage beds. The basal part of the Passage beds comprises black shale and micaceous shale. Spherical sideritic concretions are common in this shale, as for example, at Tent Mountain (Frebold, 1957, p. 73), Coal Mountain, and Limestone Ridge. Higher beds mark a transition from the black shale to carbonaceous sandstone at the base of the Kootenay Formation. They consist of interbedded shale and platy siltstone that grade upward into thin-bedded sandstone and silty shale and finally, into brown quartz-chert sandstone that marks the top of the Fernie Group.

JURASSIC AND CRETACEOUS

Kootenay Formation

Kootenay strata are exposed along the flanks of Blairmore and Livingstone Ranges, along the hanging-wall of the Coleman fault and the Livingstone thrust, and along the hanging-walls of several intervening faults. They occur around the periphery of the Fernie basin, a structural depression bounded by MacDonald Range, Flathead Range, Erickson Ridge, and the valley of Elk River. Outliers of the Kootenay Formation occur in the vicinity of Cabin and Storm Creeks in MacDonald Range, and between High Rock Range and Erickson Ridge. Kootenay strata are also exposed along Flathead River near Shepp Creek and Squaw Creek, and in the southern end of the Fording River basin, between High Rock Range and Wisukitsak Range.

The Kootenay Formation comprises grey and black, carbonaceous sandstones, siltstones, mudstones, and shales with interbeds of coal and quartz-chert pebble-conglomerate and conglomeratic sandstone. In Alberta, beneath the Lewis thrust fault, the thickness of the Kootenay varies from approximately 400 feet at Grassy Mountain and York Creek, to 260 feet at Hastings Ridge (Norris, 1959b). It may be as much as 600 feet thick in fault slices occurring beneath the Lewis thrust at the headwaters of Carbondale River (Price, 1959). Above the Lewis thrust fault, in British Columbia, the Kootenay thickens markedly towards the west from approximately 1,600 feet at Mount Taylor (Price, 1959) to 1,800 feet at the south end of the Fernie basin 7 1/2 miles northeast of the mouth of Lodgepole Creek; and to 3,530 feet at the western edge of the Fernie basin along the north side of Coal Creek.

Norris (1959b) has proposed a type section for the Kootenay Formation at Grassy Mountain, and has described three members. The lowest of these, the Moose Mountain Member, appears to be the most persistent laterally. 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 63 feet thick in the type section and 45 feet thick at Hastings Ridge in the vicinity of the Adanac strip mine (Norris, 1959b). In British Columbia it is 41 feet thick at Mount Taylor, 47 feet thick at Lodgepole Creek, and 81 feet thick at Coal Creek. Throughout most or all of this region the Moose Mountain Member is overlain by a coal seam which marks the base of the succeeding Adanac Member. The occurrence of a large ammonite in the upper part of the Moose Mountain Member adjacent to Coal Creek (Newmarch, 1953) indicates that the sandstones of the Moose Mountain Member are of marine origin. They presumably represent littoral deposits that accumulated between neritic deposits—characterized by the upper part of the underlying Passage beds—and deposits of a paralic swamp—represented by the overlying coaly beds of the Adanac Member.

The Adanac Member (Norris, 1959b) consists of grey and black mudstone, shale, siltstone, and fine-grained sandstone with a widespread coal bed at the base and, locally, one or more coal beds at higher levels. It is less resistant than the sandstone members above and below and less commonly well exposed. Norris (1959b) has reported thicknesses of between 67 and 100 feet for the Adanac Member in the area east of the Lewis thrust fault. West of this area its thickness varies from 44 feet at Mount Taylor to 93 feet at Lodgepole Creek, and to 68 feet at Coal Creek. The coal seam at the base is seldom well exposed. It is less than 29 feet thick at Mount Taylor, less than 19 feet thick at Lodgepole Creek, and 11 feet thick at Coal Creek.

The Hillcrest Member (Norris, 1959b) comprises a sequence of resistant, grey, fine- to coarse-grained, carbonaceous sandstones with lesser amounts of mudstone and siltstone. The resistance to erosion of this member sets it apart from adjacent beds. It is between 90 and 165 feet thick at various localities east of the Lewis thrust fault (Norris, 1959b), 190 feet thick at Mount Taylor, 150 feet thick at Lodgepole Creek, and 100 feet thick at Coal Creek. In the more westerly exposures, lying above the Lewis thrust fault, lenses and thin beds of dark, chert-quartz pebble-conglomerate occur sporadically in this sequence of beds, and moulds and coalified films of large plant fragments are common in the sandstones.

At the localities in Alberta described by Norris (1959b) the Mutz Member embraces that part of the Kootenay Formation between the Hillcrest Member and the unconformity at the base of the Blairmore Group. It consists mainly of recessive siltstones, shales, mudstones, and fine-grained sandstones, and includes a thick coal seam at the base and one or more thinner coal seams above this. In Alberta the Mutz Member thins from 187 feet at Grassy Mountain to 95 feet at York Creek and 27 feet at Hastings Ridge, mainly because of pre-Blairmore erosion (Norris, 1959b). In British Columbia the stratigraphic interval between the Hillcrest Member and the base of the Blairmore Group is represented by a sequence of carbonaceous strata varying in thickness from approximately 1,200 feet at Mount Taylor to 1,500 feet at Lodgepole Creek and 3,300 feet at Coal Creek.

No reliable stratigraphic markers are evident within this interval on the basis of data available at present, and consequently, it is uncertain as to what part of this sequence should be correlated with the Mutz Member.

Beds of chert-, quartz-, and quartzite-pebble and cobble conglomerate occur throughout the upper part of the Kootenay Formation in the western and northern parts of the Fernie basin. They are interbedded with dark carbonaceous sandstones, siltstones, and mudstones, and with thin coal seams—an assemblage of rocks typical of the Kootenay elsewhere. This sequence of beds constitutes most or all of the Elk conglomerates of McEvoy (1902) and later writers, and the Elk Formation of Newmarch (1953). It has been examined in relative detail on the ridge along the north side of Coal Creek where it embraces the upper 1,440 feet of a total thickness of 3,530 feet of Kootenay strata. At this locality the upper part of the Kootenay contains 11 beds of conglomerate and conglomeratic sandstone, between 7 and 45 feet thick, with an aggregate thickness of 220 feet. Individual beds of conglomerate grade laterally within relatively short distances through conglomeratic sandstone to dark grey, carbonaceous, quartz-chert sandstone that is apparently indistinguishable from that in other parts of the Kootenay Formation. These upper beds of the Kootenay have not been mapped separately because individual beds of conglomerate do not persist laterally, even over short distances, and data available at present do not afford a reliable basis for tracing individual beds of sandstone over any appreciable distance. The conglomerates are most abundant, and occupy the thickest interval, in the vicinity of Coal Creek, where the Kootenay Formation attains its maximum thickness. They are present in the vicinity of Morrissey Ridge, Fernie Ridge, Sparwood Ridge, Natal Ridge, Michel Creek between Natal and the mouth of Leach Creek, and the north end of Mount Taylor. Conglomerates are lacking in the upper part of the Kootenay Formation adjacent to Lodgepole Creek, McLatchie Creek, and McEvoy Creek and at the south end of Mount Taylor.

Conglomerates occurring in the upper part of the Kootenay Formation are similar to those that characterize the lower part of the overlying Blairmore Group. However, the conglomerates in the Kootenay Formation occur as intercalations in a sequence of rocks consisting mainly of much finer clastics that are easily distinguished on the basis of their dark carbonaceous character, whereas overlying conglomerates forming part of the Blairmore Group are interbedded with red, green, and light grey, non-carbonaceous mudstones, siltstones, and sandstones. The basal bed of conglomerate and sandstone of the Blairmore Group is typically thicker and more resistant than others occurring within this general interval and can be mapped without difficulty.

Plant fossils collected from the Kootenay Formation have been dated by Bell (1956) as Lower Cretaceous, and more specifically as representing the interval embracing the Neocomian and Barremian stages. Most collections appear to have come from the Mutz Member and younger beds although at least one collection has been made from the Adanac Member (Bell, 1956). Collections made by the writer from the Kootenay Formation have been identified by W.A. Bell and D.C. McGregor. They are reported to include a number of species which have been collected from the Kootenay previously. Rouse (1959) has reported that plant microfossils collected from the Kootenay Formation in the Fernie basin suggest a closer age relationship to the Upper Jurassic than to the Lower Cretaceous. The large ammonite discovered in the upper part of the Moose Mountain Member near Coal Creek (Newmarch, 1953) is reported by Frebold (1957) to be Jurassic in age and representative of the upper part of the Portlandian stage.

CRETACEOUS

Blairmore Group

Blairmore strata occur in the Foothills above the Livingstone thrust, the Coleman fault, and several intervening faults. They are also known from several fault slices below the Lewis thrust sheet in the vicinity of Carbondale and Castle Rivers, and from the core of an anticline above the Mill Creek fault in the vicinity of Mill Creek. West of the Foothills, in British Columbia, exposures of Blairmore strata are restricted to the central part of the Fernie basin, to small downthrown fault blocks along the valley of Flathead River near Shepp and Squaw Creeks, and to an outlier adjacent to Flathead River at Cabin Creek.

The Blairmore Group is characterized by green, yellow, grey, and red mudstones, siltstones, sandstones, and conglomerates. Its thickness increases from approximately 1,200 feet along Mill Creek in the eastern part of the area (Hage, 1943) to a maximum of 6,500 feet along Flathead River in the McEvoy syncline in the western part of the area. The westward thickening is accompanied by an overall increase in the abundance of coarse clastics and a divergence of distinctive stratigraphic markers. It is mainly, if not entirely, independent of post-Blairmore erosion.

The lower part of the Blairmore Group comprises non-carbonaceous and non-feldspathic, quartz-chert-quartzite conglomerate, sandstone, and siltstone, mudstone, and minor argillaceous limestone and calcareous shale. It forms a distinctive stratigraphic unit within the group and can be recognized throughout the area. Conglomerates and conglomeratic sandstones occur at the base and are unconformable on the Kootenay Formation in the Foothills (Norris, 1959b) and probably throughout the area. They are overlain by grey quartz-chert sandstones and siltstones and varicoloured mudstones and shales. In the Foothills, the lower part of the Blairmore is 200 to 300 feet thick; the conglomerates and conglomeratic sandstones at the base are generally less than 50 feet thick; and argillaceous limestone and calcareous shale occur near the top (Hage, 1943 and 1945; Douglas, 1950). Along the east limb of the McEvoy syncline, near Flathead River, conglomerate and conglomeratic sandstone occur throughout the lower 450 to 550 feet of the Blairmore Group and are interbedded with sandstone, siltstone, and varicoloured mudstone. The total thickness of the non-feldspathic lower part of the group is in the order of 1,000 feet. Farther west, in the vicinity of Coal Creek, the total thickness is approximately 2,000 feet, and conglomerates occur throughout the lower 1,000 feet. These non-feldspathic beds have been mapped separately in the Fernie basin but have not been differentiated from the rest of the Blairmore Group in other parts of the area.

Younger beds forming the middle part of the Blairmore Group consist mainly of green, yellow, and grey feldspathic sandstones, arkoses, siltstones and mudstones with a few beds of pebble- or cobble-conglomerate and red mudstone. The sandstones are characteristically poorly sorted and commonly exhibit very coarse crossbedding. They are conglomeratic locally, and the pebbles comprise igneous rocks as well as quartz and chert. A cliff- and ridge-forming sandstone unit occurs near the base of this sequence of beds in the Fernie basin and is useful as a stratigraphic marker. A distinctive pebble-and-cobble conglomerate occurs approximately 1,000 feet below the top of the Blairmore Group west of Livingstone Range (Douglas, 1950), in the vicinity of Blairmore Range (Norris, 1955), and in Blairmore strata exposed above the Coleman fault north of Vicary Creek. The pebbles and cobbles are well rounded and average a few inches in diameter, although locally some cobbles are as much as 6 inches in diameter. The coarse fraction consists of quartz, quartzite, chert, cherty siltstone and shale, and a variety of leucocratic alkaline igneous rocks, and occurs in a coarse-grained feldspathic sandstone matrix. The conglomerate is gradational into sandstone similar to that of the matrix and is not persistent along strike. It is probably a lateral equivalent of a conglomerate that occurs about 300 feet below the top of the Blairmore Group in the vicinity of Mill Creek (Hage, 1943). A similar conglomerate occurs approximately 1,000 feet below the top of the Blairmore Group along Flathead River in the McEvoy syncline. It consists mainly of well-rounded cobbles in a feldspathic sandstone matrix and contains a few boulders up to 11 inches long. Approximately 10 per cent of these cobbles are leucocratic, alkaline igneous rocks and the remainder are resistant siliceous rocks that include distinctive banded black chert characteristic of the Banff Formation, light quartzitic sandstone similar to that of the Rocky Mountain Formation, greenish grey and red quartzitic siltstones comparable to those occurring at several horizons in the Purcell sequence, and chertified skeletal and pelletoidal limestone similar to that in parts of the Rundle Group.

Strata of the upper part of the Blairmore Group can be distinguished from those of the middle part on the basis of their higher content of quartz and chert fragments. Coarse-grained quartz-chert sandstones and granule conglomerates occur at the base of this sequence of beds and lie above the feldspathic sandstones, arkoses and mudstones of the middle part. In the vicinity of Livingstone Range they occur at progressively greater depths below the top of the Blairmore Group toward the west, ranging from a few feet below the base of the Blackstone Formation to 150 feet below the base of the Crowsnest Formation (Douglas, 1950). At Ma Butte on McGillivray Ridge, 3 feet of quartz-chert pebble-conglomerate overlies feldspathic sandstones of the Middle Blairmore, and is in turn overlain by 240 feet of quartz-chert sandstones interbedded with varicoloured mudstones and siltstones. Higher beds forming the upper 150 feet of the Blairmore Group comprise feldspathic quartz-chert sandstones, interbedded with varicoloured mudstones and siltstones. They are overlain by orthoclase tuff and trachyte cobble-conglomerate with an orthoclase tuff matrix that forms the base of the Crowsnest Formation. A granule-conglomerate of quartz-chert sandstone also occurs approximately 500 feet below the top of the Blairmore Group in the McEvoy syncline. In this region, overlying beds comprise green and grey calcareous quartz-chert sandstones and green and grey mudstones and siltstones, and are overlain by the Blackstone rather than the Crowsnest Formation.

Two floras occur in the Blairmore Group. The lower of these has been assigned to the Aptian stage of the Lower Cretaceous (Bell, 1956). The upper flora has been assigned to the Albian stage. Collections of plant fossils made from the Blairmore Group in the course of the present investigation have been examined by W.A. Bell and D.C. McGregor. Only one collection contained identifiable plant remains. This collection was from the upper part of the Blairmore Group, approximately 100 feet below the base of the Blackstone Formation, in the east limb of the McEvoy syncline immediately north of Flathead River. Bell identified the material as *Sapindopsis angusta* (Heer) forma *magnifolia* Fontaine and remarked that it denotes a probable correlation with Upper Blairmore or an Albian age.

Crowsnest Formation

The Crowsnest Formation, an alkaline volcanic unit comprising trachyte and phonolite detritus, is restricted to a belt extending along the centre of the Foothills in the east half of Fernie map-area. It attains its maximum thickness in the Coleman fault plate near Crowsnest River and is known to thin markedly to the north, south and east from this locality. It is absent in the Coleman fault plate in the vicinity of Dutch Creek, in the Livingstone thrust sheet adjacent to and northeast of Oldman River (Douglas, 1950), in the southeastern part of the Foothills east of Fernie map-area (Douglas, 1951), and in the McEvoy syncline adjacent to Flathead River. Its absence at the last locality indicates that it must also thin markedly toward the west.

The alkaline volcanic rocks of the Crowsnest Formation consist mainly of poorly sorted detritus derived from various types of previously solidified trachyte. Fragments of analcite phonolite are abundant locally. Sedimentary rock fragments also occur here and there but are rare. Glassy detritus appears to be entirely lacking. The thicker sections of the formation show least evidence of sorting and contain the largest fragments. The petrography of the fragments has been described in some detail by MacKenzie (1914). Where the formation is thinner, arkose, volcanic sandstone, and volcanic mudstone are common, bedding is distinct, and crossbedding occurs locally.

The thickest known section of the Crowsnest Formation is exposed in highway-cuts and railway-cuts west of the town of Coleman. A summary description of this section, based on a plane survey, is as follows:

	Thickness (feet)
Overlying beds are dark grey fissile shales of the Blackstone Formation.	
Covered. (Dark grey shale scree occurs 35 feet above the base.)	148
Crowsnest Formation	
Volcanic (pyroclastic?) breccia, subangular fragments of trachyte (tabular pink orthoclase in a dense green matrix) and angular fragments of sanidine(?) and orthoclase in a dense dark green matrix	5

	Thickness (feet)
Tuff(?), dense, light yellowish grey with interbeds 2 to 10 inches thick containing medium-grained feldspar fragments..................................	7
Tuff, coarse angular pink and white feldspar fragments and rounded trachyte lapilli in a dense light greenish yellow matrix	21
Covered	57
Volcanic (pyroclastic?) conglomerate, well-rounded fragments of very coarse grained trachyte 2 to 18 inches long in a dense light green matrix.............	21
Crystal tuff(?), coarse-grained analcite and orthoclase in a dark green fine-grained matrix.................	2
Tuff, very coarse grained orthoclase fragments (50%), and rounded trachyte lapilli (10%) in a dense light green matrix......................................	18
Volcanic (pyroclastic?) breccia, a massive unsorted aggregate of angular to subrounded fragments of trachyte, sedimentary rock and feldspar up to 12 inches long (average 1/4 inch), in a dense dark greenish grey matrix............................	357
Covered	74
Volcanic (pyroclastic?) breccia, a massive unsorted aggregate of angular and subangular fragments of trachyte, sedimentary rock, and orthoclase up to 18 inches long (average 1/2 inch), in a dark green dense matrix, massive..............................	340
Tuff, coarse-grained orthoclase and black garnet, and trachyte lapilli up to 2 inches long in a dense light green matrix......................................	66
Covered	215
Tuff, pink and green, fragments of orthoclase, sanidine, and black garnet, trachyte lapilli and a few rounded cobbles of coarse-grained trachyte occur in a dense green, grey and pink matrix	205
Covered	164

Underlying beds are dark greenish grey mudstones, medium to light grey siltstones, and light grey coarse-grained quartz-chert sandstones of the upper part of the Blairmore Group.

The thickness of the exposed part of the Crowsnest Formation is approximately 1,400 feet. The actual thickness of the formation is probably about 1,600 feet. About 2 1/2 miles east of this locality, on the opposite side of the Coleman fault, the Crowsnest Formation is reported to be 490 feet thick and to include trachyte flows (Norris, 1955).

Alberta Group

Blackstone Formation

Exposures of Blackstone strata are widespread, though generally incomplete, in the Foothills of Alberta. In contrast, the Blackstone Formation has been positively identified in British Columbia only within the core of the McEvoy syncline in the Lewis thrust sheet, although it may also be present in the hanging-wall of the Howell thrust, beneath the Lewis thrust sheet, along Howell Creek.

The Blackstone Formation consists of dark grey shale and silty shale that weathers light grey, dark rusty-weathering shale, dark grey, very fine grained sandstone and siltstone, and brown-weathering shale containing brown sideritic concretions. Pebble-and-granule conglomerate comprising chert fragments in a sandstone or shale matrix generally marks the base of the formation. In the northeastern part of the area the Blackstone is in the order of 400 to 450 feet thick (Douglas, 1950). Stott (in press) has reported a thickness of 262 feet for the formation on lower Link Creek near Carbondale River, and his account of the Blackstone Formation includes a discussion of the pelecypod and ammonite fauna which forms the basis for assigning it to the Turonian stage and the upper part of the Cenomanian stage of the Upper Cretaceous.

In the McEvoy syncline adjacent to Flathead River the Blackstone Formation overlies the upper part of the Blairmore Group. A pelecypod coquina with an argillaceous limestone matrix occurs at or near the base. Fossils collected from this bed have been identified as Exogyra suborbiculata Lamarck (? = E. columbella Meek) by J.A. Jeletzky. Jeletzky reported that the fauna appears to be diagnostic of a narrow zone of the early Upper Cretaceous (late Cenomanian) throughout the western interior of North America and has been collected previously from several localities in the Carbondale area, east of the Lewis thrust sheet. Succeeding beds in the McEvoy syncline are poorly exposed but include at least 100 feet of dark grey shale that contains ironstone concretions. The shale is gradational upward into a 30-foot-thick sequence of light yellowish grey coarse-grained sandstone that may represent the Cardium Formation.

Cardium Formation

The Cardium Formation is exposed at numerous localities throughout the Foothills. It occurs in the lower part of the sequence of beds lying between the Howell thrust and the Lewis thrust in the vicinity of Howell Creek, and may also be represented by the youngest beds exposed in the core of the McEvoy syncline.

The Cardium Formation is characterized by a pronounced thickening from east to west across the area and this thickening occurs in conjunction with an increase in its content of coarse clastic detritus. East of Livingstone Range it comprises 30 to 50 feet of fine-grained sandstones and silty shales (Douglas, 1950); and above the Mill Creek thrust on Castle River it is represented by 10 feet of sandy shale and sandstone with a bed of chert pebbles at the top (Hage, 1945). In the western part of the Foothills the Cardium Formation comprises three sandstone units separated by dark silty shale and is in the order of 300 feet thick (Douglas, 1950). Fossils collected from what appears to be the uppermost sandstone unit, in a road-cut 5 miles south of Crowsnest Mountain, were identified by J.A. Jeletzky as: Inoceramus deformis Meek (giant form), Inoceramus deformis Meek cf. var. schloenbachi Boehm, and Inoceramus nov. sp. aff. deformis. Jeletzky reported that these fossils are diagnostic of the Scaphites preventricosus and Inoceramus deformis zone which he places in the uppermost part of the Turonian stage of the Upper Cretaceous. Farther west, between the Howell thrust and the Lewis thrust, along Howell Creek, dark grey chert-pebble conglomerates and conglomeratic sandstones with thin interbeds of coal occur above black laminated pyritic shale and probably represent the basal unit of the Cardium Formation. Higher beds comprise dark grey concretionary siltstone and silty shale intercalated with one or more grey, fine-grained, quartz-chert sandstone and conglomeratic sandstone units, and probably represent the remainder of the Cardium Formation.

Wapiabi Formation

The Wapiabi Formation is widely distributed throughout the Foothills and also occurs in fensters in the Lewis thrust sheet at Cate Creek and Haig Brook in Clark Range, and at Howell Creek in MacDonald Range. It is characteristically poorly exposed and reliable data relating to its thickness and details of the stratigraphic succession within it are lacking. It consists of dark grey shale, concretionary shale, siltstone, and fine-grained sandstone. The thickness varies from approximately 1,000 feet in the eastern part of the area (Douglas, 1950) to as much as 2,000 feet in the western part of the Foothills. The Wapiabi Formation is gradational at the top into the basal sandstone unit of the Belly River Formation.

In the Howell Creek fenster, between Howell and Harvey Creeks, a nodular and flaggy, dark grey, fine-grained sandstone unit, at least 50 feet thick, occurs in the upper part of the Wapiabi Formation. It is succeeded by approximately 330 feet of dark grey silty shale which grades upward through an interval of 45 feet into the light yellowish grey quartz-chert sandstones of the base of the Belly River Formation. Fossils collected from a relatively low horizon in the Wapiabi Formation along Howell Creek were identified by J.A. Jeletzky as Scaphites ventricosus Meek and Hayden s. lato and Inoceramus sp. Jeletzky reported that they are characteristic of the generalized zone of Scaphites ventricosus which he places in the Coniacian and Santonian stages of the Upper Cretaceous. Fossils collected from approximately 700 feet below the top of the formation in a road-cut 1,500 feet southeast of Crowsnest Lake were identified as Scaphites cf. S. vermiformis Meek and Hayden, Scaphites cf. S. saxitonianus McLearn, Baculites asper Morton, Baculites sp. indet., and indeterminable pelecypods. Jeletzky made the identifications and reported that Scaphites (Clioscaphites) vermiformis Meek and Hayden is diagnostic of a zone in the lower part of the Wapiabi which is of late Lower Santonian age in terms of the international standard stages of the Cretaceous.

Belly River Formation

The Belly River Formation underlies much of the eastern and western parts of the Foothills and is exposed in fensters in the Lewis thrust sheet at Cate Creek and Howell Creek. It is probably also present in the fenster in the Lewis thrust sheet at Haig Brook.

The formation consists of light yellowish grey to green sandstones, grey to green silty shales and shales, minor argillaceous limestone and carbonaceous shale and a few coal seams. Its thickness varies across the Foothills from approximately 2,500 feet in the east (Hage, 1943 and 1945) to more than 4,000 feet in the west (Hage, 1943; Norris, 1959a). A conspicuous ridge-forming sandstone unit occurs at the base and most of the remainder of the formation consists of interbedded sandstone and shale. Coal seams occur in the upper part, both in the eastern part of the Foothills and to the west, adjacent to the Lewis thrust fault. In the eastern part of the Foothills the Belly River Formation is overlain by the marine shales of the Bearpaw Formation. In the western part of the Foothills, beneath the Lewis thrust fault at Tornado Mountain, dark grey shale occurs within a sequence of yellowish grey sandstones. These are the youngest beds exposed beneath the Lewis thrust fault and may represent lateral equivalents of the Bearpaw Formation. Limestone-chert-quartzite pebble and cobble conglomerate and conglomeratic sandstone occur below. Norris (1958) has reported a fauna that E.T. Tozer of the Geological Survey considers to be characteristic of the basal member of the St. Mary River Formation from beds in an equivalent structural position north of the map-area. A similar fauna has been reported to occur immediately beneath the Lewis thrust fault south of Beaver Mines Lake (Clow and Crockford, 1951; Norris, 1959a).

Bearpaw Formation

Exposures of Bearpaw strata are limited to a narrow belt in the eastern part of the Foothills. They have not been studied in the course of the present investigation but have been mapped and described by Douglas (1950) and Hage (1943 and 1945). The Bearpaw Formation consists of dark grey shale and concretionary shale with interbeds of brown-weathering, coarse-grained grey sandstone, and is approximately 600 feet thick. Douglas (1950) has reported a fauna that indicates correlation with the lower part of the Maestrichtian stage of the Upper Cretaceous.

St. Mary River Formation

Exposures of St. Mary River strata are also restricted to a narrow belt in the eastern part of the Foothills. They have been described in considerable detail by Douglas (1950) and Tozer (1956).

Douglas has reported a thickness of more than 3, 200 feet along Oldman River. The lower 580 feet comprises grey, coarse- to medium-grained sandstone that weathers reddish brown and is intercalated with grey and green shales, coal seams, ironstone bands, and oyster coquinas. These brackish-water beds mark a transition between the upper part of the formation and underlying marine shales of the Bearpaw Formation. The upper part of the St. Mary River Formation is composed of a series of interbedded lenticular sandstones, shales, and fresh-water limestones or 'ironstones'. Hage (1945) has reported that the formation is approximately 2, 500 feet thick along Oldman River.

CRETACEOUS AND TERTIARY

Willow Creek Formation

The Willow Creek Formation underlies a belt along the eastern margin of the Foothills and occurs in an elongate outlier a short distance west of this belt (Douglas, 1950). Tozer (1956) has described typical sediments of the Willow Creek Formation as comprising soft, grey, medium-grained sandstones, and friable or clayey shales of grey, green and pink colour. He has reported a thickness of 4, 135 feet for the Willow Creek Formation on Castle River, and has described two molluscan faunas from the formation. The first of these was obtained from the lower part of the Willow Creek Formation and has been dated as Upper Cretaceous. The second occurs in the upper part of the formation and has been dated as Paleocene.

TERTIARY

Porcupine Hills Formation

The Porcupine Hills Formation underlies the Porcupine Hills of the Interior Plains adjacent to the eastern margin of the Foothills. Douglas (1950) has reported that about 4, 000 feet of Porcupine Hills beds are preserved in the eastern part of Fernie map-area. He has described the formation as comprising fine- to coarse-grained, crossbedded, yellowish brown to brown-weathering, grey and green sandstones and massive rubbly, grey and brown shales, and has reported that it is unconformable on the Willow Creek Formation, lying on progressively older zones in the Willow Creek Formation northward.

Kishenehn Formation

The Kishenehn Formation occurs within the valley of Flathead River, along the downthrown side of the Flathead fault. It is overlain unconformably by a thick and widespread mantle of drift and fluvial sands, gravels, and silts, and is exposed only in cutbanks on the major streams and on low ridges along the east side of the valley between Commerce and Packhorse Creeks. Individual exposures generally involve only a few tens of feet of the succession although locally they embrace an interval several hundred feet thick.

The formation consists of a series of distinctive, soft and friable, light greenish and yellowish grey mudstones, marls, siltstones, sandstones, conglomerates and breccias, and thin lignite seams. The coarser clastic fraction consists of fragments derived from stratigraphic units in the lower part of the Mesozoic succession, most or all of the Palaeozoic succession, and much of the Purcell succession, as well as fragments of trachyte and syenite. The finer sediments occur in distinct, relatively thin beds whereas the conglomerates and breccias occur in beds 75 feet or more thick, and they commonly grade imperceptibly into mudstone or sandstone. Bedding in the Kishenehn Formation consistently dips eastward or northeastward, toward the Flathead fault, at between 14 and 45 degrees.

Two main facies are recognized in the formation (MacKenzie, 1916). A border facies outcrops on ridges along the eastern side of the valley adjacent to the Flathead fault. It consists almost exclusively of conglomerates and breccias. These are composed of pebbles, cobbles, boulders, and blocks of Palaeozoic limestones, dolomites and sandstones that are up to 4 feet in diameter and occur in a matrix of sandy calcareous mudstone or, less commonly, of sandstone. At several localities the lowest exposures are characterized by fragments derived from the Rocky Mountain Formation and the upper part of the Rundle Group, whereas higher beds contain Livingstone and Banff fragments and the highest beds contain fragments derived mainly from the Fairholme Group and the Palliser Formation—a relationship indicative of progressive denudation of a local area of relatively high relief. The conglomerates are only locally well sorted and it is only where there is appreciable sorting that bedding is discernible. Breccias occur only in the exposures closest to the Flathead fault, and all gradations exist between well-sorted conglomerate and massive breccias. The border facies appears to be in fault contact with Palaeozoic and Purcell rocks in the Flathead fault zone, although an actual fault contact between the Kishenehn Formation and these older rocks has not been observed. In the area adjacent to the Flathead fault, individual masses of conglomerate and breccia themselves are cut by steep southwest-dipping faults.

The marls, mudstones, siltstones, sandstones, and lignite seams characterize a basinal facies that underlies the central and western parts of the valley. Mudstone and marl are the dominant components of this facies. They commonly contain coalified plant fragments or fresh-water molluscs (e.g. see Russell, 1955). Conglomerate, conglomeratic mudstone, and coarse-grained sandstone occur locally in beds from a few feet to as much as 75 feet thick. The conglomerates typically have cut-and-fill structure at the base and are lenticular. The composition of pebbles, cobbles, and boulders varies from one bed to another. Some consist exclusively of Palaeozoic rocks, others of both Purcell and Palaeozoic rocks. Trachyte and syenite fragments are common in conglomerate beds along Commerce Creek, and presumably were derived from intrusives that cut the Purcell rocks in the west-central part of Clark Range.

A thick and apparently unfaulted section of Kishenehn strata occurs along Couldrey Creek immediately west of Flathead River. It is exposed in intermittent outcrops in cutbanks along the creek. The thickness of this section, as scaled from a structure-section drawn along a line south of the creek, is 6,600 feet. The lowest exposure is of conglomerate in beds 15 feet thick, interbedded with greenish grey, non-calcareous sandstone (lithic arenite). The conglomerate contains cobbles, up to 12 inches in diameter, of Purcell, Palaeozoic, and Lower Mesozoic rocks. A covered interval separates the Kishenehn Formation from underlying Fernie beds and the relationships across this interval are apparently those of an angular unconformity. Higher beds comprise sandstone, mudstone, and marl with thin seams of lignite.

Although the actual base of the Kishenehn Formation has not been observed it is apparent from the distribution of the formation and the structural discordance between it and the older rocks that its base is marked by an angular unconformity. MacKenzie (1916) has described a local angular unconformity within the Kishenehn Formation along Flathead River south of Commerce Creek. The facies, provenence, and present structure of the Kishenehn Formation clearly indicate that it has been deposited in a structural basin along the downthrown southwest side of the Flathead fault, and that tilting along the fault occurred during and after deposition of the formation. Palaeontological evidence relating to the age of the Kishenehn Formation is particularly significant because it dates this faulting and establishes an upper limit for the age of other deformation that preceded it. Russell (1954) has described a mammalian fauna collected from the Kishenehn Formation at several localities in the valley of Flathead River, and has concluded that this fauna is latest Eocene or earliest Oligocene in age.

INTRUSIVE ROCKS

PURCELL OR (?) WINDERMERE

Moyie Intrusions

Purcell strata in the east half of Fernie map-area are cut by chloritized diorite sills and dykes that vary in thickness from a few feet to 75 feet. These rocks are petrographically similar to the Moyie intrusions of the Purcell Mountains and exhibit the same structural relationships as the Moyie intrusions. They have been observed in contact with all stratigraphic units in the Purcell sequence except the Waterton Formation and the Purcell lava. They appear to be most common in the vicinity of North Kootenay Pass. There they cut the Gateway and Phillips Formations. At North Kootenay Pass, a sill in the Phillips Formation is overlain unconformably by the Cambrian quartzites of the Flathead Formation—a relationship that indicates the Moyie intrusions are pre-Palaeozoic in age. The most conspicuous of the sills occurs toward the base of the middle part of the Siyeh Formation in the southern and eastern parts of Clark Range. It is as much as 75 feet thick and only very rarely transects the bedding. In cliff-face exposures it forms a conspicuous black band with bleached white bands on either side of it.

CRETACEOUS AND/OR (?) TERTIARY

Leucocratic Alkalic Intrusives

Leucocratic alkalic igneous rocks occur in the Lewis thrust sheet in the vicinity of Crowsnest Pass, in western Clark Range in the vicinity of Sage and Commerce Creeks, and in east-central MacDonald Range. They are most common in the latter area, particularly on Trachyte Ridge and along the headwaters of Twentynine Mile Creek and Howell Creek. They occur in bodies ranging in form from narrow dykes to irregular and anastomosing stock-like masses. The most common rock type is trachyte, consisting of tabular feldspar phenocrysts in a dense light-coloured matrix. Other rock types include aegerine-augite and aegerine trachytes and syenites, latites, felsites and intrusion breccia. Several types commonly occur together in an individual stock-like mass. The breccias comprise a variety of sedimentary rock fragments with fragments of trachyte in a dense light-coloured matrix. Contact effects in the wall-rocks of some bodies are negligible whereas haloes of marble or calc-silicate marble occur around others. The largest intrusive bodies occur in MacDonald Range and are about 1 1/2 miles long. The only intrusives observed in the vicinity of Crowsnest Pass are narrow dykes that cut the Palaeozoic succession on Crowsnest Mountain and at the head of Star Creek in Flathead Range.

Available structural and stratigraphic data do not provide an adequate basis for dating the intrusion of these alkalic rocks accurately. The relationships between the alkalic intrusives and the faults have not been clearly established. The fault surfaces are seldom well exposed and observation of actual truncation or offset of the intrusives are lacking. Shearing, brecciation, and the development of slickensides in intrusive bodies in the vicinity of Howell Creek and Crowsnest Pass may be related to the proximity of these bodies to the Lewis thrust fault, a relationship which would indicate that the intrusives were emplaced prior to displacement on the fault. A trachyte mass occurring on the ridge between Howell Creek and Twentynine Mile Creek is at least partly ringed by exposures of Alberta Group and Belly River Formation strata. Its contact is not exposed. On the map it has been inferred that this mass of trachyte forms a fault slice that has been brought into juxtaposition with Upper Cretaceous sediments during deformation. It could equally well represent an intrusive body that cuts the Upper Cretaceous rocks. The youngest unequivocal host rock for the intrusives is the basal conglomerate unit of the Blairmore Group at the mutual headwaters of McLatchie, Foisey, and Lodgepole Creeks. The first appearance of alkalic igneous detritus in the local stratigraphic succession is in the middle part of the Blairmore Group. The most abundant alkalic igneous detritus in the local succession occurs in the Crowsnest Formation, and this material is petrographically similar to the intrusive rocks except for the fact that it includes feldspathoids locally, and these are lacking in the intrusives. Pebbles, cobbles, and boulders of trachyte and syenite that are petrographically indistinguishable from that of the intrusives occur in association with both Palaeozoic and Purcell detritus in the Kishenehn Formation along Commerce Creek, indicating that the intrusives are older than the Kishenehn Formation. It would appear that the alkalic intrusives were emplaced during the time of deposition of the Blairmore Group and Crowsnest Formation, but the available data do not preclude the possibility that they were emplaced as recently as the beginning of the Tertiary period or subsequent to displacement along the Lewis thrust fault.

STRUCTURAL GEOLOGY

Two distinct groups of structures are superimposed within the east half of Fernie map-area. An older group is characterized by thrust faults that are generally subparallel to the bedding and by folds that are concordant with these thrust faults. The faults delimit individual thrust plates or sheets, each of which has been displaced toward the east or northeast relative to underlying structural units. These structures express a horizontal contraction and vertical thickening of the tabular mass of sedimentary rocks that was deposited within this region. They are truncated and offset by a younger group of normal faults that generally dip toward the southwest or west. These normal faults outline blocks that have been tilted toward the northeast and east. They express a horizontal extension and complementary thinning of the previously thickened layered rock mass.

The Lewis thrust is the most prominent component of the older group of structures. It forms the boundary between two principal structural subdivisions of the Rocky Mountains. The Foothills subdivision lies between the Lewis thrust and the Alberta syncline of the Interior Plains. The Front Ranges subdivision embraces the remainder of the Rocky Mountains at this latitude and extends from the Lewis thrust, southwestward, a few miles beyond the southwestern part of the map-area, to the Rocky Mountain Trench. Several less prominent thrust faults divide these principal structural subdivisions into smaller structural units, most of which comprise individual thrust sheets or plates.

Two major structural salients within the Rocky Mountains meet along a re-entrant that extends across the east half of Fernie map-area from the vicinity of the town of Cowley, southwestward via North Kootenay Pass, to the vicinity of Mount Broadwood. This re-entrant is expressed as a rather abrupt change in the orientation of both the folds and thrust faults and the normal faults across the entire width of the area. Structures lying northwest of the re-entrant form part of a more northerly regional structural salient and strike north-south. Structures lying southeast of the re-entrant form part of a more southerly salient and strike northwest-southeast. The re-entrant is also marked by unusually steep plunges of fold axes in the Alberta syncline, the Foothills, and the Front Ranges. The direction of plunge reverses between adjacent structural subdivisions. The axis of the Alberta syncline plunges toward the northwest along the re-entrant and lies at greater depth in the more northerly salient than in the more southerly salient. On the other hand, structures in the Foothills plunge toward the south in the vicinity of the re-entrant and lie at greater depth within the more southerly salient. Finally, folds in the Front Ranges consistently plunge abruptly toward the northwest along the re-entrant and are in sharp contrast with the south-plunging structures east of the Lewis thrust fault in the Foothills. The zone of northwestward-plunging structures in the Front Ranges lies along a prominent northwest-facing monocline developed in the strata of the Lewis thrust sheet.

ALBERTA SYNCLINE

Only the western limb of the Alberta syncline lies within Fernie map-area. At the surface it comprises an east- and northeast-dipping homocline in strata of the Porcupine Hills, Willow Creek, and St. Mary River Formations. The continuity of the homocline in the latter two formations is disrupted locally by folds and steeply dipping thrust faults that mark the eastern boundary of the Foothills subdivision of the Rocky Mountains. Little is known about the structural geometry in the subsurface beneath this homocline. Wells drilled through it approximately 25 miles north of the area are reported to have encountered faults that do not reach the surface to the east. The presence of these faults indicates that structures characteristic of the Foothills extend under the western limb of the Alberta syncline (Fox, 1959), and that the easterly dipping homocline forming the western limb of the syncline results from tilting due to differential tectonic thickening of the Mesozoic strata beneath it. These relationships form the basis for inferring the gross structural pattern shown beneath the western limb of the Alberta syncline in Sections A-B and G-H.

FOOTHILLS

The Foothills subdivision is characterized by a series of subparallel thrust faults, most of which dip toward the west. These faults delimit a series of thrust sheets or plates and the bedding in these also generally dips toward the west, but less steeply than the thrust faults. Various structural levels are exposed in different parts of the Foothills and it is apparent that, in general, the thrust faults dip more steeply and intersect the stratigraphic layering more obliquely where they transect the upper part of the Mesozoic sequence than where they transect the lower part. As Douglas (1950) has indicated there is a tendency for faults to follow the Kootenay Formation and Fernie Group for great distances. This relationship is substantiated, particularly with regard to the Kootenay Formation, by data from the many wells drilled in the southern part of the Foothills. These relations imply that many of the thrust-fault surfaces are concave upward in cross-section and that many of the fault plates have been rotated about near-horizontal axes during translation up curved fault surfaces.

There is a progressive increase in structural level across the Foothills from the eastern margin to a structural culmination that trends along the central part of the Foothills approximately midway between the Alberta syncline and the Lewis thrust fault. This structural culmination is related to several of the more important thrust faults in the Foothills. From east to west respectively, these are: the Mill Creek thrust, the Todd Creek fault, the Livingstone thrust, the Turtle Mountain fault, the Mutz fault, and the Coleman fault. These faults divide the central and western parts of the Foothills into a series of relatively large thrust sheets and set them apart from the smaller structures which make up the eastern part of the Foothills and the Carbondale River structure in the western part.

Eastern Part

Most of the eastern part of the Foothills is underlain by strata of the Belly River Formation and the Alberta Group. The beds dip steeply, mainly toward the west, and are repeated by steeply dipping and closely spaced thrust faults. Folds occur here and there, mainly along strike from or above thrust faults. These folds are not persistent over great distances. For the most part they appear to represent the surface manifestations of thrust faults that terminate at depth, or drag-folds that formed adjacent to thrust faults. Many of the individual structures in the eastern part of the Foothills have been discussed in considerable detail by Douglas (1950), whose account contains data beyond the scope of this report.

Few data are available relating to the behaviour of the thrust faults beneath the eastern part of the Foothills. Although most of the faults are characterized by small stratigraphic separation, and presumably by small displacement, two or more faults commonly merge at depth to form a single fault with larger stratigraphic separation and larger displacement. Whether these faults involve the Palaeozoic succession at depth is a question of considerable economic importance. It is inferred in Sections A-B and G-H that they do not, but rather that they extend downward into zones of bedding-thrusting in the Kootenay Formation and the Fernie Group. This interpretation involves less tectonic thickening of the stratigraphic sequence and makes it unnecessary to assume a maximum depth in excess of 10,000 feet below sea-level to the top of the Palaeozoic succession beneath the eastern part of the Foothills. The possibility exists however, that, as in the regions to the north and south of Fernie map-area at Turner Valley and Pincher Creek respectively, the Palaeozoic succession beneath the eastern Foothills is repeated by thrust faults.

Mill Creek Thrust Sheet

At the surface the Mill Creek thrust brings Wapiabi strata and older Belly River strata over younger parts of the Belly River Formation. The beds above the thrust, in part, form a west-dipping homocline and, in part, are folded. The most conspicuous of the folds occurs adjacent to the thrust in the vicinity of Mill Creek and is a faulted anticline with Blairmore strata exposed in the core. These folds occur above thrust faults which do not reach the surface or along zones in which the Mill Creek thrust cuts downward rather abruptly in the stratigraphic sequence along its hanging-wall.

In the subsurface, the Mill Creek thrust was encountered by several of the wells drilled in the vicinity of the Waterton gas field. Along the line of Section G-H it can be followed via two wells to a position beneath the Palaeozoic reservoir rocks of the eastern part of the Waterton field. The reservoir in this part of the field occurs in a drag-like fold in Palaeozoic rocks along the hanging-wall of the thrust. It is probable that a similar structure also occurs above the thrust beneath Livingstone Range to the north and the eastern edge of Clark Range to south as inferred in Sections A-B and I-J respectively.

Todd Creek Fault Sheet

The Todd Creek fault repeats Cretaceous strata lying west of the Mill Creek thrust in the region between Mill Creek and Oldman River. Near Mill Creek the fault passes into the core of an anticline that forms part of the Mill Creek thrust sheet. The fault was encountered in the Alliance well on the west flank of the anticline but has not been recognized to the northeast of the well at the surface. Displacement along the fault at depth appears to have been accommodated by folding of Blairmore strata in the core of the anticline at higher levels. North of Oldman River the Todd Creek fault is overlapped by the Livingstone thrust sheet and appears to merge upward with the Livingstone thrust.

The reservoir structure in the northern part of the Waterton gas field comprises at least two fault slices of Palaeozoic rocks. As has been indicated, the Mill Creek thrust underlies the more easterly fault slice. A higher slice, lying immediately to the west, appears to form part of the Todd Creek fault sheet as shown in Section G-H. Correlation of the Todd Creek fault from the surface to a position beneath this fault slice is based on anomalous thickness of the Blairmore and Kootenay-Fernie intervals encountered in wells to the northeast rather than on distinct repetition of stratigraphic units as in the case of the Mill Creek thrust. This structure appears to extend northward beneath the Livingstone Range where Palaeozoic rocks were encountered in the Shell Calalta Coleman well between the Livingstone thrust and the Todd Creek fault, as shown in Section A-B. It probably does not persist southward from Mill Creek but equivalent structures appear to occur en échelon from it to the southwest above an unnamed fault between the Mill Creek thrust and the Harland Lakes thrust (Douglas, 1951) and finally above the Harland Lakes thrust itself.

Livingstone Thrust Sheet

The Livingstone thrust sheet has been displaced more than 6 miles to the east relative to underlying structures and is the most conspicuous structure within the Foothills at this latitude. That part of the sheet lying in the northern part of the area has been discussed in detail by Douglas (1950). A number of prominent folds occur within the sheet and in several of these the thrust fault itself is folded. Douglas has shown that the fault alternately follows certain stratigraphic units and cuts abruptly across others, and that folds in the thrust sheet and in the fault itself can be related to this step-like character of the path of the fault through the stratigraphic succession.

In the northern half of the area the eastern limit of Palaeozoic rocks in the Livingstone thrust sheet lies at or just east of the eastern margin of Livingstone Range, and overlaps the eastern limit of Palaeozoic rocks in the underlying Todd Creek fault sheet and Mill Creek thrust sheet (see Section A-B). In contrast, in the southern part of the area, Palaeozoic rocks were not encountered above the Livingstone thrust in the Shell Calalta Carbondale well but extend east of the well in both the Todd Creek fault sheet and the Mill Creek thrust sheet beneath it (see Section G-H). The Livingstone thrust sheet overlaps the underlying sheets en échelon toward the north. Whereas most of the relative eastward displacement of the Palaeozoic rocks in the Foothills is concentrated on the Livingstone thrust in the northern part of the area, there appears to be a progressive transfer of displacement to underlying faults toward the south; and in the southeastern part of the area these underlying faults assume a more prominent structural role than the Livingstone thrust.

The stratigraphic separation across the Livingstone thrust decreases to the north and south along the tectonic strike from a maximum value in the central part of Livingstone Range. The decrease in stratigraphic separation is probably associated in part with the northerly and southerly plunges of the Palaeozoic strata in the northern and southern parts of Livingstone Range. South of Crowsnest River, across the zone of southerly plunge, the Palaeozoic strata in the Livingstone thrust sheet are progressively overlapped by the overlying Turtle Mountain fault sheet. In the southeastern part of the area, between Mill Creek and Pincher Creek, the Livingstone thrust itself is overlapped by the Turtle Mountain fault sheet. The complex structural relationships among several faults in this area were mapped by Hage (1943). These relationships imply that the Turtle Mountain fault not only overlaps the Livingstone thrust but is equivalent to the Harland Lakes thrust and the group of fault splays lying between the Harland Lakes thrust and the Twin Butte thrust southeast of Pincher Creek, in Pincher Creek map-area (Douglas, 1951). Furthermore, they imply that the displacement on the Twin Butte thrust is at least partly equivalent to the displacement on an unnamed fault which underlies and offsets the Turtle Mountain - Harland Lakes thrust along Pincher Creek. However, the latter relationship does not preclude the possibility that the Twin Butte thrust is fundamentally a splay from the Turtle Mountain - Harland Lakes thrust and that the displacement on it is mainly equivalent to part of the displacement on the Turtle Mountain fault.

Turtle Mountain Fault Sheet

The Turtle Mountain fault underlies the Palaeozoic sequence of Blairmore Range, and along it these Palaeozoic rocks have overridden an anticline in the Livingstone thrust sheet. The Palaeozoic rocks in Blairmore Range form two anticlines that are en échelon and plunge to the north and south. The southerly plunge is a feature that characterizes most of the structures in the Foothills along the structural re-entrant that passes immediately south of Blairmore Range. The northerly plunge on the other hand is a feature that is restricted to the Turtle Mountain fault sheet. The group of northerly plunging structures in the sheet mark an east-west-trending transverse 'step' in the path of the Turtle Mountain fault, and along this 'step' the fault rises abruptly toward the north in the stratigraphic sequence of its hanging-wall. The transverse structure is genetically related to the change in stratigraphic level of the fault and is similar to the conspicuous northwest-facing monocline in the Lewis thrust sheet at North Kootenay Pass (Price, 1959).

The stratigraphic separation across the Turtle Mountain fault decreases rapidly northward. In the Shell Calalta Coleman well it is in the order of 500 feet and involves a repetition of part of the Fernie Group. Five or six miles north of Blairmore Range no stratigraphic separation has been recognized and the fault presumably terminates. However, an unnamed fault that is marked by repetition of Kootenay beds on the west slope of Grassy Mountain appears to link the Turtle Mountain fault to the McConnell thrust by merging at depth with both faults at its south and north ends respectively.

Kootenay and Blairmore strata in the western part of the Turtle Mountain fault sheet are repeated along the Mutz fault southward from the area west of Bluff Mountain. Southeast of Hastings Ridge, along the south side of Carbondale River, the Mutz fault is offset along an unnamed fault that rises out of the Fernie strata on the east side of Blairmore Range. Southeast of the offset it converges with the Turtle Mountain fault and the two faults merge between Beaver Mines Creek and Gladstone Creek. Palaeozoic rocks occurring above the Turtle Mountain - Harland Lakes thrust beneath Clark Range probably occupy a structural position west of the Mutz fault and therefore, west of Blairmore Range.

Coleman Fault Sheet

The Coleman fault sheet is a prominent structural feature from the vicinity of Castle River northward beyond the north boundary of the area. It comprises a sequence of beds ranging from the Kootenay Formation to the Belly River Formation and has been displaced eastward at least 6 miles onto Belly River and Alberta Group rocks. Two broad folds—the Crowsnest syncline and the Allison anticline—occur in the western part of the sheet between Crowsnest River and the north boundary of the area.

The Coleman fault follows the stratigraphic interval embracing the Kootenay Formation and the Fernie Group for at least 4 miles across the tectonic strike in the vicinity of Crowsnest Pass (see Section A-B). Along strike it follows the Kootenay Formation for at least 38 miles from the vicinity of Carbondale River to the north boundary of the area. Over most of the area beneath which the Coleman fault lies near parallel to the bedding in the Kootenay Formation and the Fernie Group, the fault sheet is a west-dipping homocline. The Crowsnest syncline and Allison anticline lie west of this homocline and involve the Lewis thrust fault as well as the Coleman fault sheet beneath it. The Allison anticline probably marks the zone along which the Coleman fault passes from the Kootenay-Fernie interval into the underlying Palaeozoic succession (see Section A-B).

Carbondale River Structure

The Carbondale River structure lies immediately beneath the Lewis thrust sheet between Mount Coulthard in Flathead Range and Table Mountain in Clark Range. It involves the interval from the Fernie Group to the Belly River Formation and comprises two tight synclines and an intervening faulted isoclinal anticline. The folds are overturned toward the northeast, and southwest-dipping faults occur in the limbs. Over most of their length these faults are characterized by an omission rather than a repetition of part of the stratigraphic succession. This characteristic is common to both the upright and overturned fold-limbs.

The Carbondale River structure straddles the regional structural re-entrant that crosses the Rocky Mountains in the vicinity of North Kootenay Pass. North of the re-entrant the faults and the axial surfaces of the folds strike north-northwest and are overlapped by a north-striking segment of the Lewis thrust sheet. In the vicinity of the re-entrant the entire structure is folded about a southwest-plunging axis and is essentially conformable with the geometry of the base of the Lewis thrust sheet. To the southeast it strikes east-southeast, almost parallel to the Lewis thrust fault, but is progressively overlapped by a southeast-striking segment of the Lewis thrust sheet. Overlapping relationships are also apparent between fault slices within the structure. A fault slice comprising overturned Kootenay and Blairmore strata in the west limb of the more westerly syncline overlaps the intervening upright limb south of Carbondale River and lies in contact with overturned Kootenay strata of the more easterly syncline in the vicinity of Mount McCarty.

FRONT RANGES

The structure of the Front Ranges subdivision is dominated by the Lewis thrust sheet and the Flathead fault and other normal faults related to it. The Lewis thrust sheet embraces essentially all of that part of the Front Ranges lying east of the MacDonald and Hosmer thrusts. It has been offset along the normal faults, and different structural levels in the sheet commonly occur in juxtaposition across them. The more important of the normal faults are the Flathead fault, the Loop and Erickson faults, en échelon to the north, the Harvey fault which is probably a branch of the Flathead fault, and the Couldrey fault. As these normal faults are younger it is more convenient to discuss them after considering the thrust structures in the Front Ranges.

Lewis Thrust Sheet

The Lewis thrust fault can be traced over an interval of more than 200 miles along the strike of the Rocky Mountains. Fernie map-area lies approximately midway along this interval and within it the thrust has been recognized over an interval of approximately 25 miles across the strike extending from the eastern edge of Clark Range to fensters at Cate Creek and Haig Brook in western Clark Range and at Howell Creek in north-central MacDonald Range. The maximum stratigraphic separation across the thrust is in the order of 25,000 to 30,000 feet and the maximum thickness of the thrust sheet preserved after Tertiary erosion is approximately 20,000 feet.

In Clark Range the Lewis thrust is essentially a bedding thrust relative to the stratigraphic layering in the thrust sheet. In the northeastern part of Clark Range, between Castle River and Waterton Lakes in the adjacent Waterton map-area (Douglas, 1952), several fault slices occur in the sheet. These are bounded at the base by the Lewis thrust and above by thrust faults that are splays from the Lewis thrust. In this part of the sheet the faults show a tendency to follow stratigraphic zones in the lower part of the Appekunny Formation and the upper half of the Siyeh Formation. Toward the southwest they merge and cut downward in the stratigraphic sequence of the thrust sheet. Southwest of a line joining Blakiston Brook and West Castle River essentially all the displacement has been transferred to the Lewis thrust and it follows a zone in the Waterton Formation. This zone of bedding-thrusting in the Waterton Formation is exposed above the thrust between West Castle River and Mount McCarty and in fensters at Cate Creek and Haig Brook, and was encountered in the Pacific-Atlantic Flathead well at Sage Creek.

At North Kootenay Pass the Lewis thrust rises abruptly in the stratigraphic sequence of the thrust sheet toward the northeast, from the Waterton Formation, through a stratigraphic interval approximately 6,000 feet thick, to a zone in the upper half of the Siyeh Formation. In the strata of the thrust sheet this abrupt change in stratigraphic position of the thrust is marked by the North Kootenay Pass monocline, a northwest-facing transverse flexure. A complementary southeast-facing transverse flexure occurs in the Lewis thrust surface and is reflected in the abrupt eastward swing of the trace of the Lewis thrust south of Carbondale River. The North Kootenay Pass monocline extends across the Front Ranges from North Kootenay Pass to the vicinity of Mount Broadwood and follows the path of the regional structural re-entrant. Whereas the northeastern part of the monocline is a relatively simple transverse flexure, the southwestern part is complicated by the fact that it trends across the strike of several folds in the Palaeozoic rocks of north-central MacDonald Range. There the monocline is marked by sharp inflections in the plunges of the fold axes. The relationships between the North Kootenay Pass monocline and the change in stratigraphic position along the Lewis thrust fault at North Kootenay Pass form the basis for the inference that to the southwest the monocline also marks a zone along which the Lewis thrust rises rather abruptly toward the northwest in the stratigraphic sequence in the thrust sheet.

North of North Kootenay Pass the Lewis thrust rises progressively in the stratigraphic sequence in the thrust sheet from the upper part of the Siyeh Formation in the vicinity of Carbondale River to the Banff Formation at Gould Dome. This change in stratigraphic position appears to occur in a series of 'steps' separated by intervals of bedding-thrusting. The more conspicuous of the bedding-thrusting zones occur a few hundred feet below the top of the Palliser Formation, below the Elko Formation, and several hundred feet below the top of the Siyeh Formation.

In Clark Range the structure of the Lewis thrust sheet is relatively simple. A broad 'synclinorium' extends along the range from Cameron Lake in the southeast, to Mount McCarty in the northwest. The southeastern end of this structure is marked by the Akamina syncline. The northwestern part is represented by a series of smaller folds including several en échelon synclines. A series of en échelon anticlines occurs along the west side of the range adjacent to Flathead River. In these anticlines, one of which is well exposed in Cate Creek and Haig Brook fensters, the Lewis thrust surface is folded almost concordantly with the strata above it.

In Flathead and High Rock Ranges the Lewis thrust sheet, in overall aspect, forms a west-dipping homoclinal succession. Several west-dipping thrust faults repeat part of this succession between North Kootenay Pass and Deadman Pass, and a group of folds occurs in the Flathead Range. The latter are neither large nor persistent. North of Crowsnest Pass the Lewis thrust sheet has been folded, essentially concordantly, with the underlying Mesozoic strata of the Coleman fault sheet along the Allison anticline and the Crowsnest syncline (see Section A-B).

The change in structural trend within the Lewis thrust sheet that characterizes the regional re-entrant across Fernie map-area can be examined in detail in Flathead map-area (Price, 1959), particularly along the northwest side of the North Kootenay Pass monocline in the vicinity of Taylor Range. Folds in the Palaeozoic strata of the Lewis thrust sheet in Taylor Range have sinuous axes that alternately strike north and northwest. The geometry of these folds is intimately related to several north-striking and west-dipping thrust faults exemplified by the Squaw fault. North-striking segments along the folds occur immediately adjacent to the north-striking faults, whereas northwest-striking segments occupy the intervals between these faults. The anticlines are symmetrical and open but become asymmetrical, tight and overturned along those north-striking segments underlain by the thrust faults. The thrust faults intersect some of the fold axes obliquely and locally they have younger beds in the hanging-wall than in the foot-wall. These relationships form the basis for the inference that in this part of the Lewis thrust sheet the north-trending structures are younger than the northwest-trending structures, and have been superimposed discordantly over them.

In northeastern MacDonald Range, Palaeozoic strata and strata of the upper part of the Purcell sequence are exposed in the Lewis thrust sheet along the downthrown side of the Flathead fault. A complex domal structure occurs in the eastern part of the range and is cut by a series of northwest- and north-striking normal faults. A series of northwest-striking, northeast overfolds occur to the west adjacent to the MacDonald thrust sheet. All of these structures lie southeast of the Fernie basin along the southeast side of the North Kootenay Pass monocline and they all pass under an unconformable cover of Kishenehn and younger strata along the valley of Flathead River to the southeast.

Fossiliferous Upper Cretaceous rocks occur in the midst of these Palaeozoic and older rocks in north-central MacDonald Range along Howell Creek. These Upper Cretaceous strata are bounded by three prominent faults. The Harvey fault, a southwest-dipping normal fault, marks their northeastern limit. It is the youngest of the three faults and the other two abut it. Along the Harvey fault the southwest side is consistently downthrown relative to the northeast side but the stratigraphic separation across it varies markedly on either side of the other two faults. Where structural levels above or below the Upper Cretaceous beds occur in the hanging-wall, as in the vicinity of Lodgepole Creek and the mouth of Twentynine Mile Creek, the stratigraphic separation is small. On the other hand, where the Upper Cretaceous strata themselves occur in the hanging-wall of the Harvey fault its stratigraphic separation is several times as large. These relations simply reflect the fact that the Harvey fault has offset a structure of considerable magnitude, and part of its stratigraphic separation has been inherited from this older structure.

The Howell thrust marks the base of the Upper Cretaceous strata on the ridge between Howell and Twentynine Mile Creeks. Along it they lie in contact with Spray River, Rocky Mountain, and Rundle strata. These older beds are the downthrown equivalents of the Spray River, Rocky Mountain, and Rundle strata along the northeast side of the Harvey fault. The only faults overlying these beds on the northeast side of the Harvey fault are several small thrusts with small stratigraphic separation that repeat Spray River and Fernie strata in the vicinity of McLatchie Creek. These faults also abut the Harvey fault and the most southeasterly of them must be the offset equivalent of the Howell thrust.

The last of the three faults bounding the Upper Cretaceous strata marks their upper limit. Along it they are overlain by Purcell and Palaeozoic rocks. This fault converges with the Howell thrust south of Twentynine Mile Creek. Southeast of their junction the two faults are represented by a single southwest-dipping thrust fault that repeats part of the Palaeozoic succession along the southwest side of Howell Creek and is characterized by relatively small stratigraphic separation.

The relationships at the north and south ends of the structure—where the Upper Cretaceous rocks are absent and the upper and lower faults are represented by a single thrust fault with small stratigraphic separation repeating part of the stratigraphic succession in the Lewis thrust sheet, together with the fact that younger beds overlie older beds along part of the Howell thrust—form the basis for the interpretation shown in Section G-H. Purcell and Palaeozoic strata overlie the Upper Cretaceous beds along the Lewis thrust. The Lewis thrust has been offset by the Howell thrust and Upper Cretaceous rocks from beneath a more westerly part of the Lewis thrust sheet have been displaced along the Howell thrust over Palaeozoic strata of a more easterly part of the thrust sheet. Both thrusts have subsequently been offset by the Harvey fault and the Upper Cretaceous strata on the downthrown side of the Harvey fault are now exposed in a fenster through the Lewis thrust. Marked changes in the character and magnitude of the stratigraphic separation across the Howell fault from one locality to another reflect the fact that at various localities the rocks in its hanging-wall alternately represent parts of the foot-wall and hanging-wall sequences of the Lewis thrust. Where sub-Lewis thrust strata are exposed in the hanging-wall of the Howell fault, younger rocks overlie older rocks along it and the stratigraphic separation is relatively large. On the other hand, where part of the Lewis thrust sheet is exposed in the hanging-wall of the Howell thrust, older rocks overlie younger rocks along it and the stratigraphic separation is relatively small.

The inference that the fault between the Purcell and the Upper Cretaceous strata in the vicinity of Howell Creek is the Lewis thrust has important implications regarding the regional structure of this part of the Rocky Mountains. Purcell strata in Clark Range must originally have occupied a position west of the Upper Cretaceous strata in the Howell Creek fenster, yet they now lie up to 20 miles to the northeast across the tectonic strike. On the basis of the interpretation shown in Section G-H the minimum displacement of the top of the Waterton Formation along the Lewis thrust can be estimated on the assumption that the Lewis thrust cuts down relatively steeply in the stratigraphic succession of the foot-wall west of the Howell Creek fenster. If the angle of intersection between the bedding in the foot-wall and the Lewis thrust west of the fenster is in the order of 30 degrees, the offset of the top of the Waterton Formation along the line of this section is in the order of 40 miles. This would imply that Waterton strata lying above the Lewis thrust along West Castle River in Clark Range originally lay at least as far southwest at Galton Range. The inference that the fault above the Cretaceous rocks at Howell Creek is the Lewis thrust also implies that the Lewis thrust cuts upward in the stratigraphic succession in its hanging-wall toward the southwest from the Waterton Formation at the Cate Creek fenster, to the Roosville Formation and the lower part of the Palaeozoic sequence at Howell Creek, and that farther to the southwest it passes beneath the western part of the Rocky Mountains. Changes in stratigraphic position of this character suggest that the Lewis thrust has cut across pre-existing structures characterized by high relief. Furthermore, between Howell and Lodgepole Creeks this fault above the Upper Cretaceous strata rises abruptly in the stratigraphic succession in its hanging-wall toward the northwest, from the Roosville Formation at Howell Creek to the Mount Head Formation at the head of Lodgepole Creek. This northwestward rise in stratigraphic position occurs beneath the North Kootenay Pass monocline and supports the interpretation offered previously, that, in the southwestern part of the thrust sheet, the monocline marks a zone of abrupt northwestward rise in stratigraphic level of the Lewis thrust in the thrust sheet, comparable to that occurring at North Kootenay Pass.

Fernie Basin

The Fernie basin is a broad, doubly-plunging, complex, synclinal fold in Fernie, Kootenay, and Blairmore strata of the western part of the Lewis thrust sheet. Palaeozoic rocks exposed around the periphery form a series of north- and northwest-trending folds and thrust slices. The northwestern flank of the basin is underlain by Spray River, Rocky Mountain, and Rundle strata that are exposed as a series of north-trending folds and thrust slices west of Elk River. These structures plunge to the south beneath the flank of the basin adjacent to Sparwood Ridge and Fernie Ridge. They lie beneath the Hosmer thrust and their present structural elevation appears to be related to the displacement along the Hosmer thrust. Palaeozoic strata occurring along the southwestern margin of the basin comprise parts of the Hosmer thrust sheet in Lizard Range immediately west of the area, and of the underlying MacDonald thrust sheet to the southeast of Lizard Range at Mount Broadwood. These structural elements strike northwest in contrast to the north-trending structures beneath the northwestern flank of the basin, and the western part of the basin occupies a structurally low area in the re-entrant between the two divergent groups of structures.

The North Kootenay Pass monocline occurs along the southeast flank of the basin. The northerly and northwesterly plunge of the McEvoy syncline within the basin appears to reflect the structural relief across the monocline. The shape of the southwestern corner of the basin is controlled by the intersection of the MacDonald thrust and the North Kootenay Pass monocline.

The northwestern margin of the basin is marked by a zone of normal faulting embracing the Flathead fault and, en échelon from it to the north, the Loop fault and the Erickson fault with sinistral and dextral offset respectively. The Fernie basin occurs along the downthrown west side of these faults, and at least part of the structural relief from west to east across the basin is due to displacement along the zone of normal faulting embracing these three faults.

The geometry of the margin of the Fernie basin, as defined by the base of the Kootenay Formation, appears to be structurally discordant relative to some of the folds developed within the Palaeozoic rocks around the periphery of the basin. Folds in Palaeozoic rocks south of Lodgepole Creek and west of Sparwood Ridge are characterized by relatively high structural relief, yet where they pass under the margin of the basin they have little or no expression in the Kootenay-Fernie contact. The relief of the upper surface of the Palaeozoic succession is largely obliterated at higher levels by deformation within the relatively incompetent rocks of the Fernie Group. Folding of the Kootenay and Blairmore strata in the basin appears to have proceeded, in part, independently of that in the Palaeozoic strata beneath the basin. Furthermore, the geometry of the axial surface of the McEvoy syncline, and an apparent offset between it and the folds in the northern part of MacDonald Range, provide some measure of the apparent relative eastward translation of the Kootenay and Blairmore strata of the Fernie basin over the underlying Palaeozoic structures along the incompetent Fernie interval.

The structure within the Fernie basin comprises a series of synclines linked en échelon both with dextral and sinistral offset, by anticlines that are generally short and of low relief. The McEvoy syncline is the most prominent of the folds and is shown on Section E-F. To the north it is replaced by the two synclines shown in Section C-D. Several thrust faults occur within the basin between McEvoy Creek and the north end of Sparwood Ridge. The faults rise in the stratigraphic succession toward the east and pass downward into zones of bedding-thrusting in the west. They have been involved in at least some of the folding. Erosion has removed the western parts of the thrust plates in the region above Elk River valley. The plates are in part 'rootless'.

Alexander Fault Sheet

The Alexander fault sheet lies within the Lewis thrust sheet west of High Rock Range and is exposed in Wisukitsak Range, Erickson Ridge, and Loop Ridge. The sheet has been downthrown to the west along the Erickson fault and presumably lies beneath the north end of the Fernie basin and embraces the rocks exposed within the area between Grave Creek and the north end of Fording Mountain. The Alexander fault sheet comprises Rundle, Rocky Mountain, and Spray River strata that have been displaced eastward over Rocky Mountain, Spray River, and Fernie strata. The Alexander fault has been folded, apparently essentially concordantly with an anticline in the strata beneath it (see Section A-B). Several fault splays occur in association with it. These are also folded and they merge with the Alexander fault from above toward the east, possibly indicating thrusting during several stages in the development of the anticline. The individual faults are exposed in erosional re-entrants and fensters and around a klippe that occurs along Wisukitsak Range and Erickson Ridge. Tight drag-folds occur along the eastern edge of the sheet where the Alexander fault transects the upper part of the Palaeozoic succession in the sheet. The structure plunges toward the south and the south end appears to be truncated against the Erickson fault. On the downthrown southwest side of the Erickson fault the Alexander fault may be represented by the group of thrust faults along the west side of Flathead Range that includes the Squaw fault, and these in turn are probably represented on the downthrown side of the Flathead and Harvey faults by the Howell thrust.

MacDonald Thrust Sheet

The MacDonald thrust sheet embraces the western part of MacDonald Range from Inverted Ridge to Wigwam River. North of MacDonald Range it includes Mount Broadwood and, beyond the western boundary of the area, the southern end of Lizard Range (Henderson and Dahlstrom, 1959; Leech, 1960). At the latter locality both the MacDonald thrust sheet and the Wigwam thrust sheet overlying it on the west are overlapped by strata lying above the Sand Creek fault west of the area (Leech, 1958). These strata comprise part of the Hosmer nappe of Henderson and Dahlstrom (1959).

The gross form of the MacDonald thrust sheet is that of an anticline that becomes progressively more overturned and complex toward the southeast. A conspicuous change in plunge occurs along the structure south of Lodgepole Creek and marks the zone along which the thrust sheet intersects the North Kootenay Pass monocline. To the southeast the plunge is shallow; to the northwest it is relatively steep.

The MacDonald thrust marks the sole of the thrust sheet, and separates the overturned strata of the eastern part of the sheet from the upright strata of the Lewis thrust sheet below. From Mount Broadwood to the south end of Inverted Ridge the stratigraphic separation across the MacDonald thrust is small and inconspicuous. Overturned Fernie and Spray River beds occur in the hanging-wall and upright Fernie and Spray River beds in the foot-wall. However, in the vicinity of Couldrey Creek where erosional re-entrants in the thrust sheet provide exposures of a more southwesterly part of the thrust, the position of the thrust falls rather abruptly toward the southwest in the stratigraphic succession of the overturned structural panel along its hanging-wall; and within an interval of a few miles the stratigraphic separation across it increases from in the order of a few hundred feet or less to between 6,000 and 10,000 feet. Whereas along the east side of Inverted Ridge and Mount Broadwood there is little or no evidence of a thrust fault with appreciable displacement beneath the overturned structural panel, the relationships at Couldrey Creek indicate a horizontal displacement in excess of 4 miles for the overturned panel.

Two principal faults cut the strata of the MacDonald thrust sheet west of the MacDonald thrust. The more westerly of these is the Couldrey fault, a southwest-dipping normal fault that extends from the north end of Mount Broadwood to beyond the International Boundary east of Frozen Lake. The Couldrey fault cuts the thrust faults and folds and divides the area into two blocks. The downthrown block to the southwest of it comprises the upright beds of the western part of the MacDonald thrust sheet and it has been tilted toward the northeast along the Couldrey fault. The principal structure in this part of the thrust sheet is the Wigwam anticline, a broad symmetrical fold that extends from the southwestern part of MacDonald Range to Bighorn Creek where it abuts the Couldrey fault.

The Hefty thrust, the second of the two prominent faults cutting the strata of the MacDonald thrust sheet, generally marks the boundary between an overturned and an upright structural panel in the sheet. In the vicinity of Couldrey Creek it merges to the southwest with the MacDonald thrust. It appears to represent a splay from the MacDonald thrust that has been propagated upward along the axial region of an anticline in the strata of the MacDonald thrust sheet.

It occurs between the Purcell strata and the overturned Palaeozoic succession on Mount Hefty and can be traced northward along the southwest side of Inverted Ridge to Mount Broadwood, where it appears to abut the Couldrey fault.

The Hefty thrust is folded about a synclinal axis that passes through Mount Hefty and extends northwestward along the southwestern slope of Inverted Ridge (see Sections G-H and I-J). This fold is expressed in the overturned Palaeozoic strata along the foot-wall of the thrust but not in the plate of Purcell strata lying above the thrust. Along the hanging-wall the fold in the thrust is related to the rate at which the thrust cuts downward to the southwest in the stratigraphic succession of the Purcell strata. The northeastern limb of the syncline in the thrust surfaces corresponds with a zone along which the thrust cuts downward in the stratigraphic succession of the plate of Purcell strata at angles up to and exceeding 90 degrees. The southwestern limb on the other hand corresponds to a zone in which the thrust is almost parallel to the stratigraphic layering of the Purcell strata.

Southwest of this synclinal fold in the Hefty thrust, between Bighorn Creek and Couldrey Creek, the thrust is folded into an anticline. This anticline is exposed around the periphery of fensters in the Hefty thrust plate that lie adjacent to the Couldrey fault at Desolation Creek and at Fenster Creek. At the latter locality the exposure is relatively complete and it is clear that the fold in the thrust surface lies above an anticline in the overturned Palaeozoic strata in the foot-wall and is overlain by an anticline in the Purcell strata of the thrust plate. The anticline in the thrust surface is an open and apparently symmetrical fold. The anticline beneath the thrust exhibits a similar shape and has Banff strata in its core overlain by Palliser strata. It represents a part of the overturned structural panel that has been refolded. The anticline in the Purcell strata of the Hefty thrust plate provides a sharp contrast with those below it. It is tight and asymmetrical and has an axial surface that dips toward the southwest. The entire fold structure appears to have been initiated in the Purcell strata of the thrust plate during translation along the Hefty thrust. Folding of the thrust surface and the overturned foot-wall sequence appears to have occurred later, when displacement along the Hefty thrust had effectively ceased.

The complex wedge of overturned strata lying between the Hefty and MacDonald thrusts embraces the stratigraphic interval from the Fernie Group to the base of the Palaeozoic succession, and represents the inverted limb of an overturned and recumbent anticline. In general these strata underwent rotation toward the northeast through an angle of between 100 and 135 degrees; but locally, as at Mount Hefty, Couldrey Creek, Desolation Creek, and Fenster Creek, they have subsequently been refolded and the total rotation is in excess of 180 degrees. Thrust faults in the overturned panel typically place older rocks over younger; they are marked by an omission of part of the normal stratigraphic sequence; and they pass upward into zones of bedding-thrusting. These faults dip to the southwest and merge in that direction with the MacDonald thrust, or the Hefty thrust which in turn appears to be a splay from the MacDonald thrust. They presumably originated as splays from the MacDonald thrust subsequent to the overturning of the Palaeozoic strata in the eastern part of the MacDonald thrust sheet. They have effected a foreshortening of the overturned structural panel by displacing older strata which lay adjacent to the MacDonald thrust to the southwest over younger strata which lay above the MacDonald thrust in the thrust sheet to the northeast.

Wigwam Fault Sheet

The Wigwam fault sheet underlies Galton Range in the southwestern part of the area. It comprises Siyeh, Gateway, Phillips, and Roosville strata that have been displaced eastward over Roosville and younger strata. The principal structure within the sheet is a broad open syncline that follows the crest of Galton Range. Several complex fault slices occur in the eastern part of the sheet in the vicinity of Rabbit Creek. These structures are not well exposed. Details relating to their form and shown on the map are based largely on inference. In part at least they involve overturned structural panels that may be similar to those in the eastern part of the MacDonald thrust sheet.

Flathead Fault and Related Normal Faults

Normal faults with stratigraphic separations greater than a few hundred feet are restricted, in this region, to the Front Ranges structural subdivision where they cut the strata of the Lewis thrust sheet and MacDonald thrust sheet. All of the more prominent normal faults dip toward the southwest or west. Along each of them the strata in the hanging-wall generally dip toward the fault, and during displacement along the fault have been rotated toward it, relative to the strata in the foot-wall.

The Flathead fault extends along the southwestern side of Clark Range, across the southern ends of Flathead and Taylor Ranges, and along the western side of Taylor Range to the headwaters of Leach Creek. The west and south side is consistently apparently downthrown relative to the east and north side. No thrust faults or folds can be traced across the fault without offset. At their junction with the Flathead fault all such structures appear to abut it. Along the northwestern flank of Clark Range, the southern end of Flathead Range, and the western flank of Taylor Range, exposures are sufficiently complete to establish that at these localities the fault dips toward the downthrown side. Elsewhere the fault zone is generally covered by a mantle of Pleistocene and Recent deposits. Along the southwestern side of Clark Range between Commerce Creek and Packhorse Peak the stratigraphic separation across the Flathead fault zone is distributed among a series of discrete fault blocks so that each successively more southwesterly block is downthrown relative to that on the northeast. Although the individual bounding faults are not exposed and their direction of dip cannot be established with confidence, the distribution of exposures on either side of them clearly indicates that they are steeply dipping and discordant relative to the shallow dip of the Lewis thrust in the fensters along the northeastern side of the Flathead fault zone in Clark Range. Breccia zones cutting the strata in some of the fault blocks strike northwest and dip southwest. Bedding in the Kishenehn conglomerates adjacent to the fault zone consistently dips toward the fault. The composition and texture of the coarse detritus in the Kishenehn Formation adjacent to the fault zone indicate that it has been derived from an upland northeast of the Flathead fault and accumulated adjacent to a relatively steep scarp. Breccia zones and small faults cut the Kishenehn strata locally and they also dip to the southwest.

These data confirm the interpretation offered by Willis (1902), Daly (1912), and MacKenzie (1916) that the Flathead fault is a southwest-dipping normal fault cutting the strata of the Lewis thrust sheet and that "Tertiary Lake beds" were deposited in a structural trough along its downthrown side and subsequently tilted. They are inconsistent with interpretations proposed subsequently by Clapp (1932), Hume (1933), Link (1935), and Bêthune (1936) that ascribe thrust displacement to the Flathead fault or imply that it is an east-dipping thrust fault.

In the area between Clark, MacDonald, Flathead, and Taylor Ranges the strata along the downthrown side of the Flathead fault are cut by a group of smaller normal faults that outline a series of fault blocks within an overall graben structure. The Shepp fault, an east-dipping thrust fault with a maximum stratigraphic separation in the order of 2,500 feet, marks the eastern and southern boundary of the graben. The graben is arcuate in plan. The southern part strikes north-south and the northern part east-west. The structurally lowest blocks within the graben occur at Shepp Creek in the southern part and south of Flathead Range in the northern part. These relationships indicate that in addition to the northeast-southwest extension across the southern part of the Flathead fault there is a component of sinistral strike-slip that is reflected in a north-south extension in the northern part of the graben. The relative position of the North Kootenay Pass monocline between the various fault blocks is of particular interest in this context. The monocline shows an apparent sinistral offset across the Flathead fault and an apparent dextral offset across the Shepp fault. The cumulative apparent offset across the graben is sinistral but relatively small in comparison with the maximum stratigraphic separation across the Flathead fault a few miles to the southeast. These relationships indicate that although there is probably a sinistral strike-slip component of displacement along the north-striking segment of the Flathead fault between Cate Creek and Flathead Range, this component is relatively small in comparison to the dip-slip component and consequently this segment of the Flathead fault is fundamentally a normal fault rather than a strike-slip or wrench fault.

The maximum stratigraphic separation across the Flathead fault along the southwest side of Clark Range is in the order of 25,000 feet. Therefore, the maximum displacement along it must also be at least 25,000 feet. The mutual relations between the thrust and fold structures, the Flathead fault, and the Kishenehn strata provide a basis for determining the approximate ages of the two groups of structures in the area. The Kishenehn strata were deposited adjacent to the Flathead fault scarp subsequent to the initial displacement along the fault and were tilted in response to later displacement along the fault. They have been dated as latest Eocene or earliest Oligocene, and consequently the Flathead fault must have been active during this part of the Tertiary. Furthermore, since the Flathead fault cuts the thrust and fold structures in this area, these structures, which involve rocks as young as Late Cretaceous near Flathead River and Paleocene in the eastern Foothills, must have developed prior to Late Eocene or Early Oligocene.

The Loop fault lies en échelon from the Flathead fault to the north, with sinistral offset. It extends along Leach Creek and Michel Creek at least as far north as the north end of Loop Ridge. It is marked by a relative downthrow to the west, and the stratigraphic separation across it reaches a maximum of a few thousand feet near the mouth of Leach Creek. The stratigraphic relations across it and its spatial relations with the Flathead fault form the basis for inferring that it is a west-dipping normal fault even though its direction of dip has not been observed.

The Erickson fault, in turn, lies en échelon to the north of the Loop fault, with dextral offset. It extends along the west side of Loop Ridge, Erickson Ridge, and Wisukitsak Range and is also marked by a relative downthrow to the west. Its trace can be located along the west side of Loop Ridge with sufficient accuracy to establish that it is west-dipping. Along Erickson Creek it marks the boundary between two contrasting structural subdivisions within the Lewis thrust sheet—the Alexander fault sheet and the Fernie basin. Together with the Loop fault it appears to mark the northern extension of the Flathead fault zone.

The Harvey fault extends along Howell Creek and the headwaters of Harvey and Lodgepole Creeks to the headwaters of Foisey Creek. It is well exposed immediately north of Lodgepole Creek where it cuts Kootenay, Fernie, and Spray River strata along the southwestern flank of the Fernie basin. There, it is southwest-dipping, has the southwest side downthrown, and is marked by a stratigraphic separation of approximately 1,000 feet. To the southeast it marks the boundary between the Howell Creek fenster and a broad dome in the Palaeozoic rocks of northeastern MacDonald Range. Near the mouth of Twentynine Mile Creek the displacement across the Harvey fault is in the order of 3,000 feet. Farther southeast it splits into two branches and the more prominent of these extends along the west side of Howell Creek into the valley of Flathead River. Several steep faults that apparently dip toward the southwest extend across the south end of Playsoo Ridge and appear to terminate against the Harvey fault. Along each of these faults the southwest side is downthrown and tilted toward the fault relative to the northeast side. These are assumed to be south- and southwest-dipping normal faults that are related to the Harvey fault. They have provided adjustment between a southwest-plunging displacement vector on the Harvey fault and the marked departure from the general northwest strike of the fault between Leslie Creek and the vicinity of Twentynine Mile Creek.

The Couldrey fault extends along the central part of MacDonald Range from beyond the International Boundary at Couldrey Creek to Mount Broadwood. The southwest side is consistently downthrown relative to the northeast side and at several localities the trace of the fault can be located with sufficient accuracy to establish that it dips to the southwest. The Hefty fault abuts it at Couldrey Creek, around the fensters at Desolation Creek and Fenster Creek, and probably also on the south slope of Mount Broadwood. Like the Flathead fault and the Harvey fault it is a southwest-dipping normal fault that has offset pre-existing thrust and fold structures.

ECONOMIC GEOLOGY

PETROLEUM AND NATURAL GAS

Fernie map-area embraces part of one important gas-and-oil field and lies adjacent to several others. The Savannah Creek gas field lies within the central part of the Foothills, 15 miles north of the area. The Pincher Creek gas-condensate field and the Turner Valley oil-and-gas field lie within the eastern part of the Foothills, 6 miles east and 35 miles north of the area respectively. Within the area, recent deep exploratory drilling has resulted in important discoveries of natural gas and petroleum in Palaeozoic strata lying beneath the Lewis thrust sheet along the eastern side of Clark Range. These discoveries, which form the Waterton field, began early in 1957 with the completion of Shell Waterton No. 1 well at the eastern edge of Clark Range adjacent to Pincher Creek. Later the same year the Texaco Castle River A-3-4 well was completed as a gas well 10 miles northwest of the Shell Waterton No. 1 location, near Beaver Mines Creek. Subsequent drilling has resulted in an additional 12 gas wells and one gas-and-oil well (Shell 12 Waterton), the latter lying within the most southwesterly part of the field adjacent to Drywood Creek. Several more wells are being drilled at present.

In each of these fields within the Foothills the main reservoir occurs within carbonate rocks of the Rundle Group, although significant volumes of gas have also been reported from Upper Devonian carbonate rocks in part of the Waterton field.

In the Waterton gas field the reservoir occurs within a group of west-dipping thrust plates of Palaeozoic strata, all appearing to lie above the Mill Creek thrust. At the north end of the field near Beaver Mines Creek (see Section G-H) gas has been obtained from two separate fault plates both of which lie between the Mill Creek thrust and the Livingstone thrust. Farther south, in the vicinity of Pincher Creek, at least three separate plates of Palaeozoic strata appear to lie between the Mill Creek thrust and the Harland Lakes and Twin Butte thrusts. The most westerly of these may represent the Livingstone thrust sheet (see Section I-J). The northern extension of the field probably lies beneath the west flank of Livingstone Range (see Section A-B). The Shell Calalta Coleman well, drilled a few miles west of Livingstone Range, appears to have penetrated the west flank of the structure at a level below that encountered in the Shell Calalta Carbondale well. The inferred structural position of the northern extension of the Waterton field is comparable to the structural position of the Savannah Creek field (e.g. see Fox, 1959, Fig. 8). In both cases the reservoir structure lies beneath the Livingstone thrust sheet and west of the Palaeozoic culmination in the sheet.

Marked changes in structural geometry between the surface and the Palaeozoic rocks at depth seem to be commonplace in the Foothills and are well exemplified by parts of the Waterton field. Consequently, inferences as to the position of culminations of Palaeozoic strata along thrust faults in the subsurface, that are based solely on observations of geological structures occurring at the surface, are often fraught with uncertainty. Nevertheless it is possible to outline a few prospective structures on the basis of surface data, and a few general comments on prospective structures in other parts of the Foothills seem to be warranted by the data at hand.

Palaeozoic strata occur above thrust faults in the eastern part of the Foothills in the Pincher Creek and Turner Valley fields and similar structures may occur beneath the eastern part of the Foothills in Fernie map-area. Palaeozoic strata probably occur above the Mutz fault along the west flank of the Turtle Mountain Palaeozoic culmination. The Allison anticline appears to mark the eastern limit of Palaeozoic strata above the Coleman fault, and a culmination occurs along it between Crowsnest River and Tornado Pass.

In Clark Range, a series of en échelon anticlines adjacent to the valley of Flathead River involve the Purcell strata of the Lewis thrust sheet and the Lewis thrust fault. The Pacific-Atlantic Flathead No. 1 well was drilled on the west flank of this structure in the vicinity of a group of gas-seeps at Sage Creek. At relatively shallow depth it encountered several fault plates of Palaeozoic strata, some of which are overturned (see Section I-J). Although gas from some of the seeps adjacent to the well contains a light condensate and is combustible, the gas encountered in the Livingstone Formation in the lower fault plate in the well is reported to be incombustible and to contain 69% carbon dioxide (B.C. Dept. Mines, 1956). Palaeozoic rocks probably also occur at relatively shallow depths beneath this structure in the areas to the northeast and southwest of Sage Creek, but their importance as prospective reservoirs for economic occurrences of natural gas is limited by the high carbon-dioxide content of gas from the Sage Creek well.

Downthrown blocks comprising Palaeozoic strata of the Lewis thrust sheet are outlined by normal faults in northeastern MacDonald Range and along the valley of Flathead River. The Palaeozoic strata in some of these blocks may form reservoirs for hydrocarbons where they are truncated against the normal faults.

Several culminations occur within the strata of the upper part of the Palaeozoic sequence along the west side of Flathead and High Rock Ranges. The most southerly of these culminations is in Taylor Range southwest of Flathead Pass. There, Palaeozoic strata lying above the Squaw fault form a group of folds that plunge to the south and the northwest. Livingstone strata and possibly Fairholme strata occur within the cores of the anticlinal culminations at relatively shallow depth.

North of Taylor Range an anticline occurs in Rocky Mountain strata that lie beneath the Alexander fault sheet on Erickson Ridge and in Wisukitsak Range. Livingstone and Fairholme strata occur within the Lewis thrust sheet beneath this structural culmination, probably at relatively shallow depth. It may also mark a structurally high part of the Palaeozoic sequence above the underlying Coleman fault sheet.

At Fording Mountain an anticlinal culmination occurs on the downthrown side of the Erickson fault in Rocky Mountain strata that are inferred to represent part of the Alexander fault sheet. Both the Rundle strata of the Alexander fault sheet and the subjacent Palaeozoic succession lying above the Lewis thrust fault are presumed to occur within this structural culmination and to abut the Erickson fault to the east of it.

A mineral spring and gas-seep occur on the west flank of the anticline between Fording Mountain and Elk River. The gas is fetid and the mineralized water and gas support a prolific growth of calcareous algal structures. The Calstan Fording Mountain well, located near the culmination on the anticline on the summit of Fording Mountain, was abandoned at a depth of 16,540 feet late in 1960.

COAL

Large reserves of medium and high volatile bituminous coal occur in the Kootenay Formation and the Belly River and St. Mary River Formations respectively.

The mining of medium volatile bituminous coal in the Kootenay Formation has been the principal industry in the Crowsnest Pass district since it was originally settled. Commercial coal seams in the Kootenay Formation are intercalated with carbonaceous sandstones, siltstones, and mudstones in the interval between the Moose Mountain Member and the conglomeratic upper part of the formation. The greatest aggregate thickness of coal in the Kootenay Formation occurs along the western side of the Fernie basin. There is a progressive eastward thinning of the coal-bearing interval and concomitant decrease in the aggregate thickness of coal toward the eastern part of the Foothills. The thinning is partly a result of pre-Blairmore erosion.

The high volatile bituminous coal of the Belly River and St. Mary River Formations has been of less economic importance than the coal in the Kootenay Formation. It occurs in the upper part of the Belly River Formation and the lower part of the St. Mary River Formation in association with brackish-water beds that mark a transition to the intervening marine shales of the Bearpaw Formation.

PHOSPHATE

Phosphatic sedimentary rocks occur at several horizons within the stratigraphic succession of the east half of Fernie map-area. During the period 1926 to 1933, phosphate deposits throughout much of the area were prospected by The Consolidated Mining and Smelting Company of Canada Limited (Telfer, 1933). The following is a modified summary of Telfer's data on the stratigraphic distribution of phosphatic rocks in the area:

1. Oolitic and nodular phosphate rock occurs in the shales of the lower part of the Banff-Exshaw sequence.

2. Nodular and oolitic phosphates occur in association with dark siltstones, silty dolomites, and black chert in the upper part of the Rocky Mountain Formation west of Elk River.

3. Brecciated, dense, light grey dolomite, cemented in part with very fine grained purple apatite, occurs in the upper part of the Rocky Mountain Formation in parts of MacDonald Range.

4. Dark phosphatic sandstone marks the base of the Spray River Formation and overlies sandstones and cherty dolomites of the upper part of the Rocky Mountain Formation.

5. Nodular and oolitic phosphate rock and phosphatic shale mark the base of the Fernie Group and overlie the dolomitic siltstones of the upper part of the Spray River Formation in British Columbia.

6. Phosphatic sandstones occur in the Rock Creek Member of the Fernie Group.

The phosphatic beds are generally thin and of a low grade. None appear to be of economic importance at present.

BARITE

Quartz-calcite-barite veins cut strata of the Roosville Formation in the southwestern part of MacDonald Range. Three barite occurrences were discovered in the course of the present study and these all lie in the crestal region of the Wigwam anticline. The veins are steeply dipping fracture-fillings that vary in thickness from a few inches to several feet.

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