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CANADA
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BRÛLÉ MAP-AREA, ALBERTA

(REPORT AND MAP)

BY

A. H. LANG

OTTAWA

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Illustration

INTRODUCTION

Brûlé map-area (latitude 53°15' to 53°30', longitude 117°45' to 118°00') includes 180 square miles in the Foothills and the Boule Range of the Rocky Mountains, in west-central Alberta. The southwestern part of the area is in Jasper National Park, the east boundary of which follows the crest of Boule Range. The map accompanying this report has been extended about 2 miles south of latitude 53°15' to include Folding Mountain and some prominent structural features west of Brûlé Lake, but as no base map was available for this extension, the geology is only sketched.

From 1914 to 1928 a coal mine at Brûlé was one of the largest collieries in Canada, but it was abandoned and most of the town buildings have been removed. During the past few years the area has been the scene of much prospecting for oil, when wells were drilled unsuccessfully at Solomon Creek and Folding Mountain.

The south part of the area is crossed by the main line of the Canadian National Railway and the Edmonton-Jasper highway. A short branch road leads from the highway to the village of Entrance, just east of the map-area. A forestry road from Entrance passes Jarvis Lake and branches near Powder Creek, both branches extending to Wildhay River at points beyond the map-area. The more westerly of these branches, called the Lower Trail, is the main route to the Smoky River country and is travelled chiefly by pack-trains, but trucks have been taken as far as Moberly Creek in dry weather. Another poor road extends from Entrance along the north bank of the Athabaska and joins a good road built by the Shell Exploration Company from Brûlé station to the well on Solomon Creek. This road was extended to Wildhay River in 1945 by the Brûlé Lumber Company. Trails branch from these roads to various parts of the area, but most of them are little used and in poor condition. A pack-trail extends southward from Brûlé station, crosses a rocky ridge at the head of Brûlé Lake, and follows the north side of Athabaska Valley to Devona, west of the map-area. A little-used branch leaves the main trail near the abandoned Bedson coal mine and follows the valley of Moosehorn Creek. Some of the territory near Solomon Creek, Brûlé, and Miette has been burned cleanly and regrown by poplar, rendering travel there fairly easy; the rest of the map-area is difficult to traverse because of fallen timber in the foothills and the rugged terrain of the mountains.

Previous Work

Dr. Hector of the Palliser Expedition visited Athabaska Valley during the winter of 1859 (1863).[1] In 1898 James McEvoy of the Geological

[1] Year and page numbers in brackets are those of references at the end of this report.

Survey made a reconnaissance of the route from Edmonton to Tête Jaune Cache (1901). In 1910 and 1911 D.B. Dowling studied the coal deposits of Jasper Park and published brief descriptions of the formations near Brûlé Lake and Moosehorn Creek (1912). In 1916 J.M. MacVicar examined the coal occurrences between Brûlé and Smoky River (1917, 1920, 1924). R.L. Rutherford mapped the Foothills belt between McLeod and Athabaska River in 1924, under the auspices of the Research Council of Alberta (1925). His map, published on the scale of 1 inch to 2 miles, includes the southeast corner of Brûlé map-area. B.R. MacKay of the Geological Survey made a detailed study of the Brûlé coal deposits in 1927 (1929A), and in 1930 published the results of other coal examinations, including the seams at Folding Mountain (1930). In 1929 L.W. Collet and E. Parejas, of the University of Geneva, visited Athabaska Valley and published a structure-section that includes Boule Range (1932). In 1932 J.A. Allan, P.S. Warren, and R.L. Rutherford, of the University of Alberta, published a paper presenting an excellent summary account of the stratigraphy and structure of the mountains near Athabaska River, including Folding Mountain (1932). The writer made a preliminary study of a section between Obed and Brûlé Lake in 1943. He spent part of the season of 1944 in the Brûlé area and completed mapping it in 1945. He is indebted to officials of Anglo-Canadian Oil Company, Imperial Oil Company, and Shell Exploration Company of Canada, for permission to publish information gained from wells drilled in the area.

PHYSICAL FEATURES

Most of the map-area is in the western part of the Foothills belt, but the southwestern part is in Boule Range, an outlying part of the Rocky Mountains. The more westerly 'foothills' are mountainous, such summits as those of Black Cat and Solomon Mountains rising to about 6,000 feet above sea-level. Boule Roche, the highest point in Boule Range within the map-area, has an elevation of 7,826 feet. The sharp line of demarcation between the Foothills and Boule Range is marked by the Nikanassin-Boule fault that thrusts massive beds of Devonian limestone upon younger, softer formations, causing a precipitous mountain front. Most summits have steep cliffs on one side and gentle dip-slopes on the opposite side.

The dissection of the map-area presents a three-fold pattern. The master valley of Athabaska River and Brûlé Lake crosses the area in a northeasterly direction, and may be an antecedent valley. A wide, drift-covered valley extends northward from the outlet of Brûlé Lake and has its southern part occupied by the lower reaches of Solomon Creek, its central part undrained except by seepage, and its northern part occupied by a chain of small lakes that drain northward to Wildhay River. A bore-hole in this valley, near the Black Cat ranch, encountered 994 feet of overburden. It seems likely that the Tertiary ancestor of Athabaska River at one stage drained northward and carved this valley, and that at the close of Pleistocene time it was blocked by ice or a moraine, or both, causing the river to cut its present gorge. The secondary streams, of which Moosehorn, Solomon, and Paradise Creeks are the largest, flow southeasterly or northwesterly, parallel to the strike of the bedrock, and are responsible for the northwesterly trend of the ridges, both in the foothills and in the mountains proper. Moosehorn Creek flows in a large intermontane valley that separates Boule Range from Bosche Range, which lies immediately west of the map-area. The third class of streams are tributary and roughly perpendicular to the secondary streams, and are responsible for the dissection of the ridges into massifs.

A large valley glacier evidently moved down Athabaska Valley, truncating and polishing the spurs of Boule Range. A large terminal moraine from this glacier must have dammed the valley, thereby forming a lake about 2 miles wide and 60 miles long standing at least 350 feet higher than the present level of Brûlé Lake. Evidence of the part of this ancient lake that lay within the map-area is to be seen in wave-cut cliffs in sandstone between Brewster and Oldhouse Creeks, and in extensive deposits of stratified silt and gravel in the region between Brûlé Lake and the east boundary of the area. Brûlé Lake is being filled with silt as the present river erodes the silt deposited in the more westerly part of the ancestral lake.

Smaller valley glaciers occupied such lateral valleys as those of Scovil, Oldhouse, and Prine Creeks, which have large cirques at their heads. These creeks have recently cut gorges as much as 100 feet deep in parts of their valley floors, partly in morainal material and partly in bedrock. The work of alpine glaciers can be seen in some of the higher regions, but there are no glaciers now in the area.

GENERAL GEOLOGY

The area is underlain by marine and non-marine sedimentary strata, ranging in age from Devonian to Paleocene, that were deposited along the east flank of the Cordilleran geosyncline. These strata have been much deformed by folding about northwesterly trending axes, and by great thrust faults with traces parallel to the axes of the folds. As a result of this folding and faulting the formations are exposed in long, relatively narrow, northwesterly trending bands.

The oldest, Devonian, formations are brought to the surface in Boule Range, where the structure is in the form of a fan fold 4 miles wide, of which the most westerly anticline is recumbent toward the west and the most easterly is overturned toward the east. For convenience of reference in this report the western recumbent fold is called the "Moosehorn fold", and the eastern one the "Front fold". Carboniferous formations, as well as outcropping in Boule Range, are exposed in 'windows' in the more westerly Foothills. The exposed formations are increasingly younger toward the southeast, and toward the southwest in the intermontane valley of Moosehorn Creek. Jurassic strata are the youngest that occur in Boule Range, younger beds occurring only in the Foothills and in the intermontane valley. The formations in the northeastern part of the area are exposed in wider bands, partly because the folding and faulting there are less intense, and partly because these formations are thicker.

The formations of Brûlé map-area are the approximate counterparts of formations that were first studied and named in southwestern Alberta, 200 to 300 miles to the south. Some formations show remarkable similarity to the type localities, considering the distances over which they have been traced. Other formations of southern Alberta do not extend as far north as Brûlé area, and still others have changed lithologically to the extent that it is difficult to decide whether to continue the use of the original names or to introduce new ones. The most noteworthy differences between the stratigraphic succession of Brûlé area and that of southern Alberta are the presence of a shaly unit of probable formational rank in the middle of the Devonian strata; the absence of the Rocky Mountain quartzite; the occurrence of commercial coal seams in the Blairmore equivalent instead of in the Kootenay equivalent; and the absence of the Bearpaw formation, which makes it difficult to distinguish the Belly River equivalent from strata that may correspond to the Edmonton formation.

The formations are well exposed in Boule Range, but elsewhere they are found chiefly in canyons, cliffs, and on the higher ridges. In much of the map-area, therefore, the positions of contacts and structures can only be inferred from limited outcrop data. Probably many more faults and minor folds are present in the foothills part of the area than are indicated on the map.

TABLE OF FORMATIONS

Period or epoch	Formation and approximate thickness Feet	Subdivision and approximate thickness Feet	Lithology
Paleocene	4,000 +		Sandstone, shale, conglomerate (non-marine).
Upper Cretaceous	Brazeau 6,000 ±		Sandstone, shale, conglomerate (non-marine)
		Solomon member 95'	Sandstone
	Wapiabi 1,600 ±	*Baculites ovatus* zone --- *Scaphites ventricosus* zone	Chiefly black shale (marine).
	Bighorn 485		Quartzitic sandstone beds with intercalated shale (marine)
	Blackstone 1,500 ±	*Prionotropis* zone	Shale (marine)
		Sandstone probably equivalent to Dunvegan formation	Sandstone
		Lower shale zone	Shale (marine)
Lower Cretaceous	Luscar 2,000 ±		Shale, sandstone, conglomerate, coal (non-marine)
	Cadomin 12-30	Disconformity	Conglomerate
	Nikanassin 900 ±	Disconformity	Quartzitic sandstone, shale (non-marine)
Jurassic	Fernie 1,300 ±		Black shale, quartzitic sandstone, limestone (marine)
Triassic	Spray River 1,160	Whitehorse member 60-80	Limestone and dolomite (marine)
		Disconformity	Siltstone and sandstone (marine)

Period or epoch	Formation and approximate thickness feet	Subdivision and approximate thickness feet	Lithology
Mississippian and (?) Pennsylvanian	Rundle 759-945		Limestone and dolomite (marine)
Mississippian	Banff 545		Calcareous shale and limestone (marine)
Devonian	1,000 ±	Spirifer whitneyi zone Atrypa zone	Limestone and dolomite (marine)
	500 ±		Thin-bedded calcareous shale, limestone, and dolomite (marine)
	200 +		Limestone and dolomite (marine)

DEVONIAN

The oldest strata exposed in the area are massive, thick-bedded, grey, light weathering limestone and dolomite, squeezed into a very compressed anticline that forms the core of the Front fold. This core is exposed on the precipitous face of the mountain a mile southwest of Brûlé station, at least 200 feet of strata being involved. Similar beds form a minor anticline about 2 miles south of Brûlé station, and between this and the first-mentioned occurrence there are small isolated masses of similar limestone lying immediately above the Nikanassin-Boule overthrust, evidently remnants of the strata involved in the Front fold that were torn off by the thrusting. Considerable time was spent searching unsuccessfully for fossils in these beds. They are thought to be part of the Devonian succession, but are possibly pre-Devonian.

The above-described beds are overlain by about 500 feet of thin-bedded, grey, light weathering, calcareous shale, limestone, and dolomite. These beds are well exposed just west of the upper part of Brûlé Lake, where the Front fold is truncated by Athabaska Valley, and they extend along the mountain front for 4 miles, from Brûle Lake to Boule Roche Mountain, forming the apex of the Front fold. Fossils collected from these beds were determined by R.A.C. Brown, of the Geological Survey, as Upper Devonian.

The rocks of the succeeding map-unit consist of about 1,000 feet of massive, thick-bedded, grey, light weathering limestone and dolomite, which contain small, irregular-shaped masses of chert. These beds form high cliffs extending from the tunnel at the head of Brûlé Lake to the mountain behind Brûlé station, whence they continue along the mountain front to the 6th meridian line. Southeast of Boule Roche they form two bands, one lying above and one below the anticlinal core formed by the shaly beds. Northwest of Boule Roche, where erosion has not exposed the underlying shaly beds, the strata form the apex of the Front fold. Elsewhere they form three narrow bands along the crests of symmetrical anticlines in the Boule Range, and precipitous cliffs at the core of the spectacular Moosehorn anticline. Fossils from different horizons in this assemblage were determined by R.A.C. Brown to represent both the Spirifer whitneyi and the Atrypa zones of the Upper Devonian.

Correlation

In 1926 H.W. Shimer (1926, p. 2) published a report on field work done a few years earlier in which he applied the term "Minnewanka formation" to the Devonian strata at Lake Minnewanka near Banff. These strata had previously been mapped by Dawson, McConnell, and Dowling under such loose terms as the "Limestone series", "Devono-Carboniferous", and "Intermediate limestone". Shimer defined the Minnewanka as resting disconformably upon the Ghost River formation of unknown age, consisting of 285 feet of thin-bedded and shaly magnesian limestone, and as overlain by the Mississippian Banff shale. He divided the Minnewanka into an Upper Part composed of about 1,000 feet of heavy-bedded, light grey limestone, and a Lower Part consisting of about 1,500 feet of alternating fine- to coarse-grained limestone. Shimer states that the Lower Part contains abundant brachiopods that seem identical with Spirifer whitneyi, thus implying an Upper Devonian age for the entire Minnewanka formation.

P.S. Warren (1927) mapped the Banff area in 1923. He followed Shimer in the use of the term Minnewanka formation, and described the Upper Part as 1,000 feet thick and the Lower Part as 1,900 feet thick. He states (1927, p. 19) that he found Spirifer whitneyi in the upper 600 feet of the formation, and that this part could safely be ascribed to the Upper Devonian; the remainder of the formation, although containing definite Devonian fossils, could not be ascribed to any particular epoch, but he concluded that the great thickness of the Devonian succession indicated that Middle and even Lower Devonian strata might be represented.

In 1929 B.R. MacKay (1929A) published maps of the Cadomin and Mountain Park areas, lying 30 miles southeast of the Brûlé map-area. They show three unnamed Devonian map-units: the lowest described as consisting of "limestone and dolomite; shale and quartzite in lower part"; the middle, as "calcareous shale and argillaceous limestone"; and the upper as "limestone". Accompanying structure-sections indicate thicknesses of about 2,000 feet for the lowest, 1,200 feet for the middle, and 1,300 feet for the uppermost map-unit. W.A. Kelly, who was associated with MacKay in mapping these quadrangles, prepared a manuscript that has not been published, in which he used the term "Blackface Mountain shale" for the middle unit.

E.M. Kindle (1929, p. 184) used the term 'Minnewanka' to include all the Devonian of Jasper Park, and found a threefold division. He described the lower unit as consisting of 1,200 feet of heavy-bedded limestone and found in it fossils suggestive of the Lower Devonian. This is overlain by 1,300 feet of drab shales including a central 300 feet of coal-black shale. He used the term 'Miette shale member', but did not make it clear whether this was intended to cover the entire 1,300 feet or only the 300 feet of black shale. This member was stated to contain a fauna of probable Middle Devonian age. His upper unit was described as 1,000 feet of massive or heavy-bedded magnesian limestone containing an Upper Devonian fauna.

P.E. Raymond (1930) visited the Devonian section near Roche Miette in Jasper Park, and divided it into the following formations, in ascending order: "Flume", "Perdrix", "Boule", "Coronach", "Fiddle", and "Kiln". The Perdrix, Coronach, and Kiln were described as consisting of black shale, and the Perdrix was said to be equivalent to Kindle's Miette member. Raymond pointed out that the name "Miette" was inappropriate because it had already been used by Walcott for a Precambrian formation in the Rocky Mountains.

Allan, Warren, and Rutherford (1932, pp. 233-238) studied the Devonian of Jasper Park, and stated that the most westerly succession, in the Palisades near the town of Jasper, is very like the Banff section, consisting of an upper 1,000 feet of massive limestone and a lower 1,500 feet of more thinly bedded magnesian limestone and dolomite with occasional shale beds. They, therefore, continued the use of the term Minnewanka for all the Devonian strata of Jasper Park. They stated that, as the Minnewanka is followed eastward, black shale, in places more than 1,000 feet thick, is introduced between the upper and lower divisions. This was thought to be the same shale as Kindle had designated the "Miette member", and they considered it to be Kelly's "Blackface Mountain shale", and proposed the adoption of that name. They detected serious anomalies in Raymond's section, apparently due to misconception of the structure, and did not adopt the formational names proposed by him. Allan, Warren, and Rutherford described two distinct Upper Devonian faunas; the Spirifer whitneyi fauna in the "Upper Minnewanka", particularly in the uppermost beds, and the Spirifer jasperensis fauna in the limestone immediately below the "Blackface Mountain shale", and they stated that "the vertical distribution of these faunas is not as yet known, and much detailed work will be necessary to obtain this knowledge."

In the Moose Mountain and Morley areas, east of Banff, H. H. Beach (1943, pp. 10-17) gave the name Fairholme formation to strata equivalent to the lower Minnewanka. The fossils he found in this assemblage could only be determined as Silurian or younger. He named the strata equivalent to the Upper Minnewanka the Palliser formation, and confirmed the Upper Devonian age of at least the upper part of this unit. He stated that the strata designated as the Fairholme and Palliser formations are distinct lithological units; pointed out that both Shimer and Warren recognized a twofold division of their Minnewanka formation; and suggested that the Minnewanka constitutes a group rather than a formation.

The foregoing description of the succession in Brûlé map-area and the summary of work in nearby areas indicate that in this region the strata approximately equivalent to the Minnewanka exhibit a definite three-fold subdivision. The upper unit is Upper Devonian, but the remainder may include earlier Devonian strata, and the lowermost beds may even be pre-Devonian. The writer believes that all three units are of formational rank, and that the assemblage as a whole might well be called the "Minnewanka group" or given some other group designation. The lower and upper units probably correspond approximately to the Fairholme and Palliser formations, but the use of these terms seems inadvisable at present because of the long-range correlation it would involve, and because of the intervening shaly unit. For the purpose of this preliminary map and report the units are left unnamed.

CARBONIFEROUS

Exshaw Formation ?

Where the contact between the Devonian and the overlying beds is well exposed, as on the spurs near the head of the West Fork of Solomon Creek, the massive Devonian limestone is overlain conformably by 25 feet of soft, very thinly laminated, black, argillaceous limestone. The rock resembles coal-black shale, but effervesces strongly on the application of acid. It is so soft that its position in exposed sections is marked by a notch between the underlying Devonian beds and the succeeding Banff formation.

The age of this shale is uncertain, as no fossils could be found in it. Warren (1937) gave the name Exshaw formation to 34 feet of black, non-calcareous shale at the base of the Banff formation in Bow Valley, and extended the use of the term to somewhat similar beds near Cadomin, which he referred to as up to 600 feet of black shale coarser and lighter coloured than those at Exshaw. From fossil evidence obtained at the type locality he considered the age to be Upper Devonian. The beds described above, in the Brûlé area, appear to be equivalent to the Exshaw, but are very limy. They have not been separated from the Banff, however, because the lithology is not identical with the typical Exshaw; because no fossils were found in them; and because they are lithologically similar to much of the Banff.

Banff Formation

The Banff formation consists of relatively soft, thin-bedded, grey to buff weathering, grey to black, calcareous shale and argillaceous limestone, with a few thin beds of grey limestone. These strata show marked contrast to the harder, massive, cliff-forming limestone of the underlying Devonian and the overlying Rundle formation, and are very like the middle unit of the Devonian. A section measured near Boule Roche Mountain, including the 25 feet of beds that may be equivalent to the Exshaw, is 645 feet thick. The well at Folding Mountain penetrated 595 feet of strata classed as Banff and 20 feet classed as Exshaw; the strata nearby dip at an angle of 45 degrees, and on that basis the stratigraphic thickness would be about 420 feet.

The formation is well exposed in several bands, repeated by folding, in the Boule Range. In the Foothills it is exposed only at "windows" in the core of the Folding Mountain-Brûlé anticline, at Folding Mountain and Sheba Creek. It is probably close to the surface where the West Fork of Solomon Creek crosses this structure, but is obscured by overburden.

Shimer (1926) introduced the term "Banff formation" for about 1,200 feet of calcareous shales in the Lake Minnewanka section, containing Mississippian faunas. Fossils collected by the writer at Folding Mountain and Sheba Creek were reported by R.A.C. Brown to constitute "a lower Mississippian fauna, occurring in the Banff equivalent of the Jasper area". The stratigraphic relationships, lithology, and palaeontological evidence indicate the appropriateness of the use of the term "Banff formation" for the strata under discussion, with the possible exception of the beds that may be equivalent to the Exshaw. Raymond (1930) gave the name "Moosehorn formation" to the Banff near Moosehorn Creek, and called the Rundle the "Bedson formation" because he thought that the massive limestone lay below and the shaly limestone above. As this was evidently due to a misunderstanding of the structure and stratigraphy, there seems no reason for adopting the terms he proposed.

Rundle Formation

The Banff formation is overlain conformably by the Rundle, consisting of 760 to 945 feet of massive, thickbedded, grey to buff limestone and dolomite, with a little shale and anhydrite. The upper beds contain small, irregular chert masses. Two porous zones occur near the top; at Folding Mountain the upper one is 4 feet thick and 213 feet from the top, and the lower is 34 feet thick and 265 feet from the top. Other sections contain porous zones at roughly similar horizons.

The Rundle is well exposed in the Boule Range, where it forms several belts due to repetition by folding. In the Foothills it is brought to the surface only where the Folding Mountain-Brûlé anticline is deeply eroded, as at Folding Mountain, the West Fork of Solomon Creek, and on Sheba Creek.

The name "Rundle limestone" was proposed by Kindle (1924) for strata in the Bow River sections previously called the "Upper Banff limestone" by McConnell. The entire formation was considered Pennsylvanian by Kindle, but detailed palaeontological work by Shimer (1926), Warren (1927), and Beach (1943) indicated that the lower part is Mississippian and that the upper part may be Pennsylvanian. Fossils collected by the writer in Brûlé area proved mostly to be unidentifiable, but one Cyrtia-like brachiopod was reported by A. E. Wilson of the Geological Survey to be an Upper Palaeozoic genus suggestive of a rather high position in the Rundle. The stratigraphical and lithological similarities of these strata in the Brûlé area to the Rundle at its type locality, and the meagre palaeontological evidence seem sufficient reasons for continuing the use of the term Rundle in this area.

TRIASSIC

Spray River Formation

The Rundle is overlain by a succession of fairly hard, thin-bedded, slabby, grey to buff, rusty weathering siltstone and sandstone, some of which is calcareous. The assemblage includes some thin beds of shale and limestone. On the ridge north of the West Fork of Solomon Creek, near the crest of the Folding Mountain-Brûlé anticline, 2 feet of basal conglomerate containing subangular 2-inch pebbles of limestone similar to the Rundle was found resting on the Rundle and grading upward into sandstone.

These beds occupy large tracts in the Boule Range, and are also well exposed at Folding Mountain and near the upper reaches of Sheba Creek and the West Fork of Solomon Creek. The only locality where a complete section of these beds was seen is on a spur of Boule Roche west of the head of Prine Creek. This succession measured 1,090 feet.

The beds of siltstone and sandstone are overlain conformably by 60 to 80 feet of light grey, chalky weathering limestone and dolomite that are locally slightly sandy. This unit is found at all localities in the map-area where the top of the Spray River is exposed, as at Folding Mountain, Oldhouse Creek, on the ridges between Prine Creek and the West Fork of Solomon Creek, and on a tributary of Moosehorn Creek on the west side of the Boule Range. It is a useful horizon marker, and is mapped separately as the "Whitehorse member".

Kindle (1924) proposed the name "Spray River formation" for the Triassic strata in Bow River Valley previously called the "Upper Banff shale". This name was adopted by Shimer (1926) and Warren (1927), and its use was extended to the Mountain Park district by MacKay (1929) and to Jasper Park by Allan, Warren, and Rutherford (1932). Warren (1945) suggested the division of the Spray River formation into a lower "Sulphur Mountain" member and an upper "Whitehorse" member. The former is named after Sulphur Mountain near Banff, where the type section consists of 1,243 feet of laminated shale and limestone containing Lower Triassic fossils. The Whitehorse member is named from Whitehorse River near Cadomin, and is described as usually not more than 300 feet thick, consisting of light grey, almost white, chalky limestone, containing Middle Triassic fossils.

The basal conglomerate mentioned above indicates a disconformity between the Rundle and Spray River, which is to be expected as the whole of Permian time is probably unrepresented.

No fossils other than an unidentifiable ammonoid were found in the siltstone and sandstone beds lying between the Rundle and the Whitehorse member. There seems no doubt that they represent the lower part of the Spray River formation and they have been so mapped. They have not been designated the "Sulphur Mountain member" because of the lack of palaeontological evidence and the slight difference in lithology as compared with the description of the type locality, but they are probably equivalent to that member. The lithology of the Whitehorse member is very distinctive from that of the rest of the Spray River, so it may eventually be desirable to call it a formation and to use a group name for all the Triassic strata.

There seems little doubt that the white limestone unit of Brûlé map-area corresponds to the Whitehorse member, although it is thinner. No fossils were found in it within Brûlé area, but many were found where it extends just north of Wildhay River. F. H. McLearn of the Geological Survey reports that these include _Spiriferina_ cf. _onestae_ and _Myophoria_ cf. _elegans_, probably of Middle Triassic age.

JURASSIC

Fernie Group

The Whitehorse member of the Triassic Spray River formation is overlain conformably by about 50 feet of fissile, black, phosphatic, argillaceous limestone that is assumed to represent the base of the Fernie group. No section could be found that exposed the next few hundred feet of beds above this limestone, but the log of the Jasper No. 1 well at Folding Mountain indicates that these consist of dark grey to black shale some of which is calcareous and some phosphatic, with thin interbeds of argillaceous limestone. The upper beds are best exposed at the head of Prine Creek, where the following section was measured:

Top of Section	Feet
Slight disconformity with overlying bed of massive quartzitic sandstone, regarded as base of Nikanassin formation	
Hard, dark grey, fine-grained, quartzitic sandstone in beds 6 inches to 3 feet thick, with interbedded black shale constituting about one-half of this part of the section......	166
Dark grey, yellow weathering, calcareous siltstone..................	1
Black shale and sandy shale with a few ribbons of quartzitic sandstone up to 4 inches thick..............................	22
Crumbly, black shale with interbeds of black, yellow weathering limestone less than 1 foot thick. The upper half of this part of the section is a little harder and sandier than the lower half..	104
Covered..	22
Crumbly black shale..	20
Fine-grained, hard, grey quartzite...............................	6
Total thickness	341

A graphical measurement of the stratigraphic interval between the basal limestone and the disconformity at Prine Creek provides an estimate of 1,300 feet for the thickness of the Fernie group in this region. This may be exaggerated by faulting in the covered part of the section, but there is no evidence of faulting in the part exposed.

An interesting exposure of the Fernie occurs on the ridge southwest of the head of Prine Creek. There a section of Fernie strata is inverted, due to the overturning of the Front fold, and this inverted succession is faulted by the Nikanassin-Boule overthrust on a normal Fernie section.

The name "Fernie shale" was applied by Leach (1906) to Jurassic shales in the Crowsnest Pass region that had formerly been grouped with the Kootenay, but the limits were not strictly defined. Warren (1934) pointed out that the Fernie appears to pass upward into the Kootenay or Kootenay equivalent by the intercalation of sandstone beds, but that a hiatus is probably present because the highest fauna so far obtained in the Fernie is of middle Upper Jurassic age. The term has been extended by several workers to designate Jurassic strata as far north as Athabaska Valley, including beds of different lithological characters and representing different Jurassic epochs. The present practice of the Geological Survey is to use the term Fernie as designating a group rather than a formation.

The writer has considered the slight disconformity found at the base of a bed of quartzitic sandstone about 6 feet thick to mark the top of the Fernie in the Prine Creek section. This horizon is not well exposed in other parts of the area and the boundary is mapped where this sandstone is estimated to occur. Belemnite guards are common throughout the shales mapped as Fernie. Ammonoids and pelecypods were found at several localities in both shale and quartzitic sandstone. F. H. McLearn reports that most of these were indicative only of Jurassic age, but that one collection, from a tributary of Moosehorn Creek, indicated an early Middle Jurassic age, and that one from Drystone Creek, near Folding Mountain, was probably Middle Jurassic.

LOWER CRETACEOUS

Nikanassin Formation

The Fernie strata are overlain by a succession of hard, grey, buff- to chocolate-brown weathering, quartzitic sandstone beds from 1 to 50 feet thick, interbedded with shale, carbonaceous shale, and sandy shale, and containing a few, thin, non-commercial coal seams. These strata have been correlated with the Nikanassin formation by MacKay, who placed the top of the formation at the base of the Cadomin conglomerate. No complete section is exposed. The best section is on Brown Creek, near the abandoned town of Brûlé, where MacKay (1929A) measured a total of 1,046 feet of strata, but considered that the lower 92 feet might represent the Fernie. This section may contain repetitions due to minor faults and folds. About 500 feet of these strata overlie the disconformity at the head of Prine Creek, the remainder of the formation having been removed by erosion. Rutherford (1925) considered that at Folding Mountain 850 feet of strata lay between the uppermost beds containing Jurassic fossils and the base of the Cadomin.

Between Scovil Creek and Brûlé Lake the strata beneath the Nikanassin-Boule overthrust are much contorted. Most of these contain carbonaceous partings and resemble the Nikanassin, but some contain belemnite guards and evidently belong to the Fernie group. As it was impossible to separate these, the whole assemblage was mapped as a unit.

G. M. Dawson (1886, p. 162B) gave the name "Kootenai series" (first proposed by Sir William Dawson) to the Lower Cretaceous, coal-bearing rocks of the Crowsnest Pass region, pointing out that the lower beds that he included in this series contained marine fossils of probable Jurassic age. In 1913 Leach applied the name "Blairmore" to the upper part of this series, which did not contain commercial coal seams, placing the base of the Blairmore at the base of a prominent conglomerate bed subsequently referred to as the Kootenay or Blairmore conglomerate. As work proceeded northward the term Kootenay was applied to Lower Cretaceous coal-bearing strata, but in the central Foothills it was found that the commercial coal seams lay above a conglomerate bed that seemed undoubtedly equivalent to the Blairmore conglomerate, and palaeobotanical evidence showed that the strata above this conglomerate were of Blairmore age. Many workers used the term "Kootenay" to include all the Lower Cretaceous strata. In the Mountain Park area MacKay (1929, 1930) named the strata lying between the Fernie and the Blairmore conglomerate the "Nikanassin formation" and the coal-bearing beds above it the "Luscar formation". Despite its relative thinness, he named the conglomerate the "Cadomin conglomerate" because it outcrops prominently and is an important horizon marker for coal prospecting, and on later maps he used the term "Cadomin formation". He gave the name "Mountain Park formation" to a series of green, ridge-forming sandstone beds lying above the coal-bearing strata and below the Upper Cretaceous marine strata. In 1927 MacKay (1929A) mapped a small area at Brûlé and extended the use of the names Nikanassin, Cadomin, and Luscar to the Lower Cretaceous rocks of that area, but was unable definitely to recognize the Mountain Park formation.

The strata mapped by the writer as the Nikanassin formation correspond to those so mapped by MacKay at Mountain Park and Brûlé. No recognizable fossils were found in them in Brûlé map-area, but W. A. Bell (personal communication) reports that plants found in the upper part in nearby areas are probably equivalent to the Kootenay flora. The lower part of the succession could be Jurassic and of marine origin.

Cadomin Formation

The Cadomin formation consists of hard, massive conglomerate that is resistant to erosion and forms conspicuous outcrops. The pebbles are well rounded, commonly ovoid, and closely packed, consisting chiefly of light grey quartzite, commonly of black chert, and rarely of red and green chert and white quartzite or vein quartz. They range from 1/4 inch to 5 inches in size and are generally from 1 to 2 inches. Outcrops seen by the writer were 12 to 30 feet thick, but MacKay reports thicknesses of from 5 to 70 feet. The matrix is so consolidated that the rock generally fractures across the pebbles rather than around them.

The formation outcrops at intervals from Folding Mountain to the line of the 6th meridian and in places is repeated by faulting. It is exposed on both flanks of an anticline in the intermontane valley, near Miette. This anticline noses out 3 miles northwest of Miette. MacKay (1929A, p. 11) reports a disconformity at the base of the Cadomin near Brûlé.

Luscar Formation

The Luscar formation overlies the Cadomin conformably, and consists of a succession of dark grey, sandy shales, black, carbonaceous shales and grey and greenish grey sandstones, with commercial coal seams reportedly as much as 30 feet thick. Shales constitute about 60 per cent of the formation.

At Folding Mountain an 18-foot bed of conglomerate lithologically somewhat like the Cadomin occurs apparently 900 feet stratigraphically above it. None of the intervening strata are exposed. This is considered to be a separate bed rather than a repetition of the Cadomin because it is thinner than most exposures of the Cadomin, and because the matrix is more abundant and softer, the rock tending to break around the pebbles instead of across them.

MacKay considered that the Mountain Park formation either thinned out south of Athabaska Valley, or that the beds lost their ridge-forming character and typical green colour, and, therefore, he mapped all the Lower Cretaceous non-marine beds above the Cadomin as Luscar, with the provision that the uppermost beds might correspond in age to the Mountain Park (1929A, p. 12). This practice has been followed by the writer. Near the Shell Solomon Creek No. 1 well the uppermost beds mapped as Luscar are fairly massive, hard, light green sandstone, suggestive of the Mountain Park.

The Luscar formation outcrops at Folding Mountain and has also been encountered there by drilling. Between Brûlé Lake and the 6th meridian line it is exposed in two principal bands due to repetition by folding or faulting, the more westerly being 1/2 to 1 mile wide extending northwestward from the Brûlé mine, and the other 1/2 mile wide and lying 1 to 2 miles farther east. Still farther east the formation is exposed at several small "windows" where the crests of anticlines are eroded.

Because of limited exposures no satisfactory estimate of the thickness of the Luscar in this area can be given. By drawing structure-sections and scaling the intervals between the upper and lower limits of the formation figures of about 2,000 feet are obtained, but this over-all thickness may be exaggerated by minor folds and faults.

Fossil leaves from these strata in Brûlé map-area were determined by W. A. Bell to be of Lower Cretaceous Aptian age, equivalent to a lower part of the Blairmore group.

EARLY UPPER CRETACEOUS

Blackstone Formation

At the two localitiles where the top of the Luscar is well exposed, namely in the southwest corner of sec. 33, tp. 50, rge. 27, and immediately across Solomon Creek from the Shell Solomon Creek No. 1 well, the Luscar is overlain by 6 inches of conglomerate composed chiefly of black chert pebbles up to one-half inch in diameter. This bed is analogous to a bed termed "The Grit" near the base of the Alberta shale at Turner Valley.

The conglomerate is overlain by fissile, black shale and sandy shale, in which fossils were not found, mapped as the lower part of the Blackstone formation. Near the Shell Solomon Creek No. 1 well a bed of sandstone about 20 feet thick occurs in these shales about 400 feet above the conglomerate. This bed has not been found exposed in other parts of the map-area, but what is believed to be its northwestward continuation occurs at several localities beyond the area, thickening rapidly and assuming the attributes of a formation. McLearn (1945, p. 1) correlates the sandstone northwest of Brûlé area with the Dunvegan formation from fossils collected by oil geologists. The bed in Brûlé area is regarded as a member of the Blackstone formation, and may be the south-easterly extension of the Dunvegan. The age of the shales between it and the Blairmore strata is doubtful as no fossils were found, but as the sandstone may correspond to the Dunvegan, which is the lowermost Upper Cretaceous formation in the Peace River district, the underlying shales may be equivalent to part of the Fort St. John group of that district.

The above-mentioned sandstone bed is overlain by a thick succession of fissile black shales, commonly concretionary, with thin interbeds of calcareous siltstone. Inoceramus labiatus is abundant in the upper part of this succession.

The thickness of the strata classed as Blackstone could not be determined accurately. The interval between the conglomerate bed and the base of the lowest bed mapped as Bighorn was estimated graphically to be about 1,500 feet, but this may include some thickening by minor folds.

A core-hole drilled by the Shell Exploration Company at the Black Cat ranch to gain geological information passed through 994 feet of overburden and then penetrated 287 feet of black shale and greenish black, sandy, glauconitic shale. This rock resembles the upper part of the Wapiabi formation more than the exposures of the Blackstone seen in the area, but it is regarded as Blackstone by the writer because it is in line with exposures of that formation; and because the postulation of Wapiabi strata at that locality would require structural conditions for which there is no other evidence.

Bighorn Formation

The Blackstone is overlain on Solomon Mountain and on the ridge northeast of Solomon Creek by a succession of hard, massive, conspicuous sandstone beds that represent the Bighorn formation. On Solomon Mountain four such sandstone beds from 3 to 80 feet thick occur within an interval of 800 feet, the intervening beds being black shale similar to that of the Blackstone and Wapiabi formations. On the ridge northeast of Solomon Creek there are three beds from 25 to 150 feet thick within an interval of about 500 feet, and additional beds may have been lost by erosion. These beds form a dip-slope on the northeast side of the ridge, accounting for the wide outcrop width of the formation in that part of the area. They lie in a syncline that plunges southeastward, and, accordingly, "nose out" on this ridge near the 6th meridian line. Fossils found in the shales between these sandstone beds are indicative of the Bighorn (and Cardium) formation.

Wapiabi Formation

The uppermost sandstone bed mapped as Bighorn is overlain by a thick succession of fissile, black shales and sandy shales that outcrop poorly. The top of the series consists of about 200 feet of coarser grained, greenish black, glauconitic sandstone. These strata extend from Solomon Mountain northwestward through the valley of Paradise Creek, and are repeated by a fault on Solomon Mountain. On the ridge north of Solomon Mountain there are several repetitions, due to a complex system of folds and faults.

The name "Wapiabi formation" was given to the shaly strata above the Bighorn by Malloch (1911, p. 37), who also introduced the names "Blackstone" and "Bighorn". The Wapiabi is generally considered to consist of a lower "Scaphites ventricosus zone" and an upper "Baculites ovatus" zone. Fossils indicative of the Scaphites ventricosus zone were found at several localities in the lower part of the Wapiabi in Brûlé map-area, but no fossils were found in the upper part.

LATE UPPER CRETACEOUS AND TERTIARY

The Wapiabi formation is overlain by a very thick succession of strata of which all but the lowest member are non-marine. On the map accompanying this report these are divided into two main units, the older of which is called the Brazeau formation, of Upper Cretaceous age, and the younger of which is not designated by a formational name, but is considered to be of Paleocene age.

The reasons for this treatment are outlined in a subsequent section of this report.

Brazeau Formation

The Wapiabi is overlain by 95 feet of fairly hard, cliff-forming, grey, buff weathering sandstone, which, because of its distinctive, horizon-marking character, is mapped as a separate member and called the Solomon sandstone. The lower half is thin-bedded and slabby and the upper half is massive. It contains Upper Cretaceous marine fossils. Analogous beds have been described at several localities to the south and variously called the "Chungo member", "transitional member", "Brazeau-Pierre", and "Highwood sandstone", and have been classed by some writers as uppermost Wapiabi. The Solomon sandstone is here regarded as the base of the Brazeau, to which it bears more resemblance than to the underlying Wapiabi strata.

The Solomon sandstone is overlain by 120 feet of softerm dark green sandstone and sandy shale containing plant fragments.

The remainder of the Brazeau formation consists of roughly 6,000 feet of interbedded, grey, buff, and greenish weathering sandstone, grey and greenish grey shale, and pebble-conglomerate. The conglomerate is abundant in the lower half of the formation, and consists of widely spaced pebbles of quartzite and chert in a sandy matrix that fractures around the pebbles. The lowest pebble bed rests on sandy beds overlying the Solomon sandstone. The sandstone strata and pebble-beds of the Brazeau formation are commonly crossbedded. No fossils other than unidentifiable plant fragments were found in the Brazeau formation above the Solomon sandstone.

Paleocene

In the adjoining Entrance map-area the only horizon marker other than coal seams found above the Solomon sandstone is a distinctive conglomerate bed termed the "Entrance conglomerate". This bed outcrops in the Entrance area (Lang, 1945) close to the east boundary of the Brûlé area, and in the Gregg Lake map-area (Irish, 1946) close to the north boundary of the Brûlé area. This conglomerate could not be found exposed within the Brûlé area, but two linear ridges beside the Lower Trail, in line with exposures in the Entrance and Gregg Lake areas, almost certainly mark its position, and an assumed geological boundary has, accordingly, been drawn through them. Northwest of this boundary the region is almost entirely drift covered, but a few scattered outcrops of coarse-grained, grey and greenish sandstone, sandy shale, and pebble-conglomerate occur. No fossils were found in these rocks.

Age and Correlation

The exact age and terminology of the Upper Cretaceous and early Tertiary non-marine strata and the precise delimitation of the Cretaceous-Tertiary boundary in many parts of Alberta are still unsolved problems. They are made difficult by the great thickness of strata of fairly similar lithology, with few horizon markers and few fossils other than plant remains. As the study of these strata has progressed many revisions of terminology and changes of correlation have been made. To explain the usage adopted for the present map and report and the different treatment of corresponding units in the Entrance map-area, the following brief review of the subject is given.

In

In the Foothills of southern Alberta the Upper Cretaceous strata above the Upper Alberta or Wapiabi formation have long been divided into the Belly River, Bearpaw, and Edmonton formations, all of which are of Montana age. The Belly River is non-marine, the Bearpaw is marine, and the Edmonton is non-marine. This would be an ideal classification were it not for the fact that the Bearpaw disappears to the west and northwest and where it is not present the Edmonton cannot be separated satisfactorily from the Belly River.

The Edmonton is overlain by the Paskapoo formation, of Paleocene age, composed of sandstone, shale, and conglomerate, with some coal. In places a disconformity has been found at the base of the Paskapoo (Allan, 1924, p. 39; 1925, p. 240; 1943, p. 36; Allan and Sanderson, 1945), but where neither this disconformity nor diagnostic fossils are found, it may be impossible to separate the Edmonton from the Paskapoo.

In the Bighorn area Malloch (1911) found that the Bearpaw was absent, and applied the name "Brazeau formation" to some 1,700 feet of non-marine beds overlying his Wapiabi formation. From their lithology and the few fossil remains found in them, he considered them the approximate equivalent of the Judith River (Belly River) formation. These were the youngest consolidated sediments in the Bighorn area, and, therefore, the upper limit of the Brazeau formation was not defined.

In the central Foothills, where the Bearpaw is absent, Allan and Rutherford (1923) and Rutherford (1925) gave the name "Saunders formation" to all the strata above the Wapiabi. This was thought to be, mainly at least, Upper Cretaceous and to be essentially equivalent in age to the combined Belly River, Bearpaw, and Edmonton strata of more southerly areas where the Bearpaw could be identified, though it was suspected that the uppermost beds might be correlative with part of the Paskapoo. Subsequent work by Rutherford (1926) between Athabaska and Embarass Rivers, supplemented by the identification by P. S. Warren of many fossil invertebrate and plant collections, indicated that in that area a minimum thickness of 5,300 feet of strata above the uppermost main coal seams of the Coalspur field was mainly, if not entirely, of Paleocene age. Included in this section, about 2,000 feet above the base, lay the McPherson Creek coal seams, of somewhat inferior rank to those of the Coalspur field, which extend for about 1,000 feet below the base of the section.

MacKay (1930) traced the Brazeau formation from the Bighorn area to the Coalspur district where it was found to be equivalent to the Saunders formation of that district, and the name "Brazeau" was retained by him on the basis of priority. As used by MacKay on the Cadomin sheet (1929) the Brazeau formation included the coal measures of the Coalspur region.

More recently MacKay, in preparing a series of preliminary geological maps of the Wapiabi Creek, George Creek, and Pembina Forks map-areas and the Wawa Creek area, and in compiling a more general preliminary geological map of the Foothills Belt of Central Alberta, subdivided the post-Wapiabi strata into a lower or Brazeau formation, believed to be the approximate equivalent of the Belly River formation, and an upper or Edmonton formation, which was considered to be the equivalent of the formation of that name in the western Alberta plains, and which carried important coal measures. In making this separation without the intervening guide furnished by the marine Bearpaw formation of more southern and eastern areas the contact was placed at a conglomerate that lay about 900 feet below the lowest main coal seam, an horizon that seemed to correspond, at least approximately, with the base of the Edmonton as observed in areas to the southeast where remnants of the marine Bearpaw could still be identified. At the same time it was recognized by MacKay that the Edmonton formation, as mapped above the Brazeau, in places probably included at the top beds equivalent to and, seemingly, lithologically like the Paskapoo formation of Paleocene age, and the base of the Paskapoo was drawn at the bottom of a thick bed or series of beds of massive, hard, brown weathering sandstone that lay about 3,000 feet above the assumed base for the Edmonton. Only in the Wawa Creek map-area, however, was an attempt made to map the Paskapoo separately from the Edmonton; in the other areas the combined Brazeau and Edmonton formations, together with such Paleocene strata as might be present but undifferentiated from the Edmonton, constituted essentially what had been referred to many years earlier by MacKay as the Brazeau formation of the Mountain Park and Cadomin areas, and as the Saunders formation in areas mapped by Allan and Rutherford between North Saskatchewan and Athabaska Rivers.

In the early history of the use of the term Saunders formation, attempts had been made to effect a workable subdivision of the thick series of strata represented. The division proposed was threefold, and consisted of a Lower Saunders formation, an intermediate or Saunders Coal series, and an Upper Saunders formation, the lower two divisions regarded as entirely Upper Cretaceous, and the Upper Saunders as in part or entirely Paleocene. Difficulty, however, was experienced in attempts to maintain this subdivision across the various areas being mapped, and in more recent years the subdivision names have not been used, and the succession of post-Wapiabi strata, as proposed by MacKay, into Brazeau, Edmonton, and Paskapoo formations has been the one most generally employed.

This was the situation until 1945, when the writer (1945) mapped the Entrance conglomerate in the Entrance area at what was believed to be the base of the coal-bearing Edmonton formation, 800 feet below the lowest coal seam. The conglomerate proved to be an extremely persistent and, therefore, useful horizon marker, and its position below the lowest coal seam corresponds very closely with that of the base of the Edmonton formation as defined by MacKay in areas of the Foothills farther to the southeast. In the same area the writer regarded as part, probably a lower part, of the Paskapoo formation a thick section of largely cobble-conglomerate that occupied much of High Divide Ridge and that lay about 3,500 feet above the Entrance conglomerate. Elsewhere in the map-area, however, no possible lithological subdivision between Edmonton and Paskapoo strata could be recognized, but a fossil plant collection obtained on Fish Creek, at an estimated stratigraphic interval of about 3,500 feet above the Entrance conglomerate, was considered by W. A. Bell, of the Geological Survey, as probably Paleocene. No identifiable fossils were found between this horizon and the Entrance conglomerate at that time.

In the Entrance map-area the strata between the Wapiabi and the Entrance conglomerate were mapped as Brazeau in accordance with MacKay's later usage, and regarded as essentially correlative with the Belly River. Fossil plants obtained from the upper part of this succession were reported by Bell to be probably Upper Cretaceous.

In 1945 Bell visited several areas in the Foothills, including the Coalspur and Entrance districts, with the object, in part, of placing more certainly the boundary between the Upper Cretaceous and Paleocene formations. Collections from the top of the Mynheer or lowest commercial coal seam at Coalspur and Sterco, and, consequently, well below what had hitherto been regarded as the probable upper limit of the Upper Cretaceous succession, were identified by Bell as definitely of Paleocene age, and the flora was considered to be typical of the Paskapoo formation. Collections obtained near Entrance, south of Athabaska River and not far below the Entrance conglomerate, were identified by Bell as Upper Cretaceous and probably of Edmonton age. On the basis of these determinations it now appears probable that all strata in this region down to the Entrance conglomerate, including both the upper, coal-bearing part of the Saunders formation of Allan and Rutherford, and the Edmonton formation of MacKay, are of Paleocene age, and that the only equivalents of the Edmonton formation proper would be strata lying beneath the Entrance conglomerate within what had been mapped as the Brazeau formation. The inclusion of the coal-bearing series with the overlying Paleocene strata is in harmony with Rutherford's earlier report (1926) in which all beds above the uppermost coal seam of the Coalspur field, including the coal seams of McPherson Creek, were regarded as probably Paleocene. On the other hand, these combined Tertiary strata can no longer be fittingly defined as Paskapoo, for coal in appreicable quantity is not known in the type areas of that formation.

In the present report and on the accompanying map the term Brazeau is retained in the sense originally applied by MacKay for all post-Wapiabi Upper Cretaceous strata. These are considered to be mainly of the same age as the Belly River, but may include some overlying Upper Cretaceous Edmonton equivalents. The strata above the assumed position of the Entrance conglomerate are, in the light of Bell's recent findings, mapped as Paleocene.

STRUCTURAL GEOLOGY

Brûlé map-area includes parts of three main structural units, which are, from west to east, the Pocahontas-Moosehorn basin, the Boule Range, and the Foothills belt. Each of these units is structurally complex and, excepting the Boule Range, doubtless contains more minor folds and faults than the limited exposures indicate. The principal structural features are described briefly in a west to east order.

POCAHONTAS-MOOSEHORN BASIN

The Pocahontas-Moosehorn basin is, structurally, the continuation of the Bighorn-Mountain Park basin, and lies between the first main range of the Rocky Mountains and outlying ranges. Where crossed by Athabaska Valley it is 2 1/2 miles wide. It is separated from the main range, called the Bosche Range, by the main Rocky Mountain overthrust. Its structural connection with the Boule Range to the east is obscured by overburden.

The basin is underlain by Lower Cretaceous strata whose structures are imperfectly known because of the extensive drift cover. The exposures indicate close folding, probably accompanied by faults. An anticline marked by exposures of Cadomin conglomerate noses out 3 miles northwest of Miette because the fold plunges northwestward. This anticline is flanked to the northeast by a syncline which again brings the Cadomin to the surface.

BOULE RANGE

The Boule Range is an outlying range of the Rocky Mountains that dies out northwest of Brûlé map-area. It consists structurally of a large fan fold 4 miles wide. The most westerly unit of this structure is a conspicuous anticline here termed the Moosehorn fold, which is recumbent toward the west with its axial plane almost horizontal. The most easterly unit is an anticline overturned toward the east, and here termed the Front fold. Its axial plane dips about 45 degrees to the southwest, and its lower limit dips toward and is truncated by the Nikanassin-Boule overthrust. Collet (1932) interpreted this structure as a nappe. Between these two, flanking, overturned folds are two main symmetrical anticlines, three main synclines, and small minor folds.

No faults were mapped within the Boule Range, but one or more may be present in the Devonian shaly strata near the core of the Front fold.

The Nikanassin-Boule overthrust is a pronounced fault that extends northwestward from the Brazeau district, and forms the Fiddle and Boule Ranges by thrusting resistant Devonian strata upon the Mesozoic strata of the Foothills. South of the Athabaska this fault lies near the foot of Roche à Perdrix, but there its exact location is obscured. It is well exposed from Brûlé Lake to the line of the 6th meridian, where the fault plane dips about 30 to 45 degrees southwest. The downward extension of the Boule Range folds and the Nikanassin-Boule overthrust are unknown, and at least three possibilities can be postulated. The fan fold may lie in a wedge bounded to the east by the Nikanassin-Boule overthrust, and to the west by an east-dipping fault whose trace would be along the east border of the Moosehorn basin. Such a fault is postulated on the map accompanying this report. According to this conception, the strata forming the range were forced upward and squeezed laterally to develop the fan fold. As the lateral pressure continued the flanking folds were overturned and their lower limits finally faulted.

An alternative explanation is that only the east flank is faulted, and that the strata forming the lower limit of the Moosehorn fold pass by folding into the deep-seated strata of the Moosehorn basin. Lack of outcrops prevented the study of the structures in this part of the area, so that it could not be determined whether or not such folds exist.

A third possibility is that the Nikanassin-Boule overthrust extends continuously beneath the Boule Range and re-appears as the fault postulated in the first explanation. According to this theory the entire mass of the Boule Range was thrust eastward, or the underlying strata were underthrust. The objection to this theory is that it does not offer any explanation for the reversed recumbence of the Moosehorn fold.

FOOTHILLS BELT

The western part of the Foothills belt consists of a series of fault blocks in which the strata are folded. Folding seems to have occurred first, with overturning toward the east, and to have been followed by thrusting along fault planes that dip westward. In the eastern part of the belt, chiefly north and east of Brûlé map-area, faulting is less common, and the folding is more open and more symmetrical.

Folding Mountain-Brûlé Anticline

The Folding Mountain-Brûlé anticline is a fairly compressed fold whose axial plane is inclined about 70 degrees to the southwest. It extends northwesterly from Folding Mountain across Black Cat Mountain and the ridges near the heads of Prine and Sheba Creeks. A minor fault displaces the strata on the west flank of Folding Mountain.

A fault was postulated in the Luscar formation at the east flank of Folding Mountain to explain the anomaly between the structure at Folding Mountain and at the head of Maskuta Creek (Lang, 1944). In 1945 the Jasper No. 1 well, at the west side of Folding Mountain, after passing through Devonian strata, encountered a fault at a depth of 4,900 feet and penetrated beds of the Luscar formation. This fault appears to be the same as the one postulated at the east side of the maountain, and the strata forming the mountain appear to be part of a fault-block thrust over the Luscar and bounded on the west by the Nikanassin-Boule overthrust. The probable continuation of the fault at the east side of Folding Mountain extends from Scovil Creek to the 6th meridian line, thrusting Luscar, Nikanassin, Fernie, and Spray River strata on the Luscar.

Several faults occur on and near Black Cat Mountain, the more prominent of which are indicated on the map. One of these is interpreted as repeating the Cadomin conglomerate. Two conglomerate bands outcrop on the east side of the mountain. One is narrower than the other but for lithological reasons it is regarded as a repetition of the Cadomin rather than the higher bed already described as occurring in the Luscar at Folding Mountain. The simplest explanation is to consider that this bed is repeated by a normal fault.

Fault between Luscar and Blackstone Formations

The western boundary between the Luscar and Blackstone formations is shown as an assumed fault. This relationship could be a normal one, with the Blackstone occupying a syncline, but it is thought more likely that the Luscar is thrust on the Blackstone.

Solomon Creek Anticline

At the mouth of Stimson Creek the upper beds of the Luscar (or Mountain Park) formation are exposed at the crest of an anticline, with the lower beds of the Blackstone on each flank. This structure was drilled by the Shell Solomon Creek No. 1 well, but instead of penetrating the expected thickness of about 2,000 feet of Luscar strata, 4,774 feet were encountered, indicating either that the folding is more complex than suggested by the surface exposures or that the Luscar is repeated by one or more faults for which there is no surface evidence. The writer suggests that the main anticline lies between Solomon Creek and the ridge, known locally as the Cardium ridge, on which the Bighorn outcrops, and that the strata near the mouth of Stimson Creek are thrust over the west limit of this fold by a fault whose trace lies in the depression half a mile northeast of the well and in line with the upper part of Solomon Creek. This explanation, shown on the structure-section on the map accompanying this report, seems to be the simplest one to conform with the limited data available, but the actual relations are probably even more complex.

Structure of Solomon Mountain, Black Bear Ridge, and Cardium Ridge

The strata on Solomon Mountain and on Black Bear and Cardium Ridges lie in a syncline whose northeastern limb is faulted. The southwestern limb exposes, in ascending order, the Blackstone, Bighorn, and Wapiabi formations and the lower part of the Brazeau. Because the syncline plunges southeast, the Bighorn forms a "nose" near the line of the 6th meridian, and the Solomon sandstone "noses out" on the summit of Black Bear Ridge (a local name for the ridge immediately north of Solomon Mountain). The upper part of the Wapiabi, and the Solomon sandstone, are repeated by faults on the east side of Solomon Mountain and on Black Bear Ridge. These are thought to be westward dipping thrusts, and at least one of them must extend down the valley of Paradise Creek.

Entrance Syncline

In the adjoining Entrance map-area the Entrance syncline is a broad fold that becomes increasingly compressed to the northwest. It crosses the northeast end of Solomon Mountain, and its probable continuation was found on the upper part of Jarvis Creek. Northwest of that creek the few outcrops all dip northeast, but the fold probably continues, obscured by overburden.

Prairie Creek Anticline

The Prairie Creek anticline, in the Entrance area, is the continuation of the faulted Coalspur anticline. Near Orchard Creek it is represented by a series of minor anticlines and synclines. To the northwest it continues across Brûlé map-area immediately south of Athabaska Lookout and at Jarvis Creek, beyond which it could not be found because of the few rock exposures.

ECONOMIC GEOLOGY

OIL AND GAS POSSIBILITIES

The oil and gas possibilities of Brûlé map-area have been investigated in recent years as part of the general exploratory campaign along the Foothills belt. Several oil companies made geological studies, and two wells were drilled unsuccessfully. The Shell Exploration Company drilled the Shell Solomon Creek No. 1 well on the Solomon Creek anticline in 1942-3. This well was spudded in near the top of the Luscar formation, and was abandoned at a depth of 4,774 feet when the great thickness of Luscar strata penetrated indicated structural complexities not evident at the surface.

The Anglo-Canadian Oil Company drilled the Jasper No. 1 well on the west flank of the Folding Mountain anticline in 1944-5. The erosion of Athabaska Valley exposes the Rundle at the crest of this anticline, and the floor of the valley, beneath the overburden, may be eroded into the Devonian. Because the anticline is overturned toward the east, the well was located on the west flank in the hope of encountering oil-bearing Devonian or Cambrian strata near the axis. The well was commenced in the Fernie and, as already explained, struck a fault at 4,900 feet and entered strata that probably belong to the Luscar formation. The well was abandoned at a depth of 5,096 feet.

The failure of these wells does not condemn the possibilities of the area as a whole, but indicates the necessity of gaining subsurface information before the deep-seated structures can be interpreted in detail.

Comparison with the productive horizons in southern Alberta suggests that the Rundle is the most promising formation, but Cambrian, Devonian, and Mesozoic strata could contain oil or gas. The porous zones near the top of the Rundle have already been described. The only bituminous residue seen in the area was a small amount in fracture planes in sandstone of the Spray River formation west of the head of Prine Creek.

COAL

The Luscar formation contains a great deal of coal in seams of commercial thickness, which, being near transportation, may be mined at some future date. Coal seams have been described in earlier reports (MacKay, 1929A, 1930) and, as no activity has occurred since, and as the workings cannot now be studied, they are only briefly discussed.

Brûlé

From 1914 to 1928, 1,836,743 tons of bituminous and semi-bituminous coal are reported to have been mined at Brûlé by the Brûlé Coal Company and the Blue Diamond Coal Company, in one of the largest and best-equipped collieries in Canada. MacKay reports that the Luscar formation there contains six or more coal seams, three of which, 5, 7, and 9 feet thick respectively, were mined. He was unable to determine the interval between these seams and the Cadomin conglomerate, but estimated the No. 3, or lowest, seam to be 700 feet above the conglomerate.

The northwestward extension of the Brûlé coal measures received some development where crossed by Scovil Creek and two branches of Prine Creek. A small tonnage was mined at Prine Creek by the Mount Cavell Collieries, Limited, and hauled to a tipple at Solomon Siding. MacKay reported that the seams at Prine Creek were 3, 9, and 7 feet thick, and that they lay at apparent intervals of 960, 1,020, and 1,180 feet respectively above the Cadomin, but that these intervals were probably exaggerated by faulting.

Folding Mountain

What appear to be the same general measures as those at Brûlé occur at the east side of Folding Mountain. These were explored by open-cuts and adits several years ago, when the property was known as the "Drinnan prospect". More recently drilling was done by Sterling Collieries, Limited. MacKay (1930, p. 12) reports that the earlier work indicated four seams with average thicknesses of 5, 10, 12, and 3 feet. The drilling indicated a 24-foot seam 1,000 feet above the Cadomin, and, at another locality, a 14-foot seam that may be the same as the 24-foot one, lying 900 feet above the Cadomin.

Ronde Creek

Coal was mined at the Bedson mine near Ronde Creek by Jasper Park Collieries when they operated their main mine at Pocahontas, across the river. The seams are described by Dowling (1911, p. 214) and MacKay (1930, p. 9).

GYPSUM

Gypsum has been reported at the top of the Whitehorse member of the Spray River formation in nearby areas (Allan, 1933; Warren, 1945, p. 482). This mineral was not noted in Brûlé map-area, but prospecting might locate it along the Spray River-Fernie contact. The matter is worthy of mention as the Brûlé area is close to transportation.

PHOSPHATE

The occurrence of phosphatic limestone at the base of the Fernie formation has already been mentioned. Samples taken by the writer have not yet been analysed, but others are said to contain about 0.5 per cent P_2O_5.

REFERENCES

Allan, J. A.: A New Deposit of Gypsum in the Rocky Mountains, Alberta; Trans. Can. Inst. Min. and Met., vol. 36, p. 619 (1933).

_____ General Geology of Alberta; Research Council of Alberta, Report No. 34, pt. I, 1943.

_____ and Rutherford, R. L.: Geology along the Blackstone, Brazeau, and Pembina Rivers in the Foothills Belt, Alberta; Research Council of Alberta, Report No. 9, 1923.

_____ and Sanderson, J.O.G.: Geology of the Red Deer and Rosebud Sheets, Alberta; Research Council of Alberta, Report No. 13, 1945.

_____, Warren, P. S., and Rutherford, R. L.: A Preliminary Study of the Eastern Ranges of the Rocky Mountains in Jasper Park, Alberta; Trans. Roy. Soc., Canada, sec. IV, pp. 225-248 (1932).

Beach, H. H.: Moose Mountain and Morley Map-areas, Alberta; Geol. Surv., Canada, Mem. 236 (1943).

Collet, L. W., and Parejas, E.: Résultats de l'Expédition géologique de l'Université de Harvard dans les Montagnes Rocheuses du Canada (Jasper National Park), 1929. - Note No. 6. Profil géologique à travers les Montagnes Rocheuses, le long de l'Athabasca; Compte Rendu des seances de la Societé du physique et d'histoire naturelle de Genève, vol. 49, pp. 44-52 (1932).

Dawson, G. M.: Preliminary Report on the Physical and Geological Features of that portion of the Rocky Mountains between latitudes 49° and 51°30'; Geol. Surv., Canada, 1886.

Dowling, D. B.: Geology of Roche Miette Map-area, Jasper Park, Alberta; Geol. Surv., Canada, Sum. Rept. 1911, pp. 201-219 (1912).

Hector, J.: Journals of the Exploration of British North America, London, 1863.

Irish, E.J.W.: Gregg Lake Map-area, Alberta; Geol. Surv., Canada, Paper 46-4, 1946.

Kindle, E. M.: Standard Palaeozoic Section of Rocky Mountains near Banff, Alberta; Pan-American Geologist, vol. XLII, pp. 113-124 (1924).

_____ The Succession of Fossil Faunas in the Eastern Part of Jasper Park; Am. Jour. Sci., 5th ser., vol. XVIII, 1929.

Lang, A. H.: Drinnan to Brûlé Lake, Athabaska Valley, Alberta; Geol. Surv., Canada, Paper 44-11, 1944.

_____ Entrance Map-area, Alberta; Geol. Surv., Canada, Paper 45-11, 1945.

Leach, W. W.: The Blairmore-Frank Coal Fields; Geol. Surv., Canada, Sum. Rept., 1902-3, pp. 169-181A (1906).

MacKay, B. R.: Mountain Park Sheet, No. 208A; Cadomin Sheet, No. 209A; Geol. Surv., Canada, 1929.

_____ Brûlé Mines Coal Area, Alberta; Geol. Surv., Canada, Sum. Rept. 1928, pt. B, pp. 1-29 (1929A).

_____ Stratigraphy and Structure of Bituminous Coalfields in the vicinity of Jasper Park, Alberta; Trans. Can. Inst. Min. Met., 1930, pp. 473-509.

MacVicar, J.: Foothills Coal Areas North of the Grand Trunk Pacific Railway, Alberta; Geol. Surv., Canada, Sum. Rept. 1916, pt. C, pp. 85-93 (1917).

_____ Coal Areas Northwest of Brûlé Lake, Alberta; Geol. Surv., Canada, Sum. Rept. 1919, pt. C, pp. 8-13 (1920).

_____ Preliminary Investigations of Coal Deposits on Smoky, Hay, and Berland Rivers, Alberta; Geol. Surv., Canada, Sum. Rept. 1923, pt. B, pp. 21-62 (1924).

Malloch, G. S.: Bighorn Coal Basin, Alberta; Geol. Surv., Canada, Mem. 9-E, 1911.

McEvoy, J.: Geology and Natural Resources of the Country Traversed by Yellowhead Pass Route from Edmonton to Tête-Jaune Cache; Geol. Surv., Canada, Ann. Rept. 1898, pt. D, pp. 1-44 (1901).

McLearn, F. H.: The Upper Cretaceous Dunvegan Formation of Northwestern Alberta and Northeastern British Columbia; Geol. Surv., Canada, Paper 45-27, 1945.

Raymond, P. E.: The Palaeozoic Formations in Jasper Park, Alberta; Am. Jour. Sci., 5th ser., vol. XX, 1930.

Rutherford, R. L.: Geology of the Foothills Belt between McLeod and Athabaska Rivers, Alberta; Research Council of Alberta, Report No. 11, 1925.

——— Geology of the Area between the Athabaska and Embarras Rivers, Alberta; Research Council of Alberta, Report No. 15, 1926.

Shimer, H. W.: Upper Palaeozoic Faunas of the Lake Minnewanka Section, near Banff, Alberta; Geol. Surv., Canada, Bull. 42, 1926.

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

——— Present Status of the Fernie Shale, Alberta; Am. Jour. Sci., 5th ser., vol. XXVII, pp. 56-70 (1934).

——— Age of the Exshaw Shale; Am. Jour. Sci., 5th ser., vol. XXXIII, pp. 454-57 (1937).

——— Triassic Faunas in the Canadian Rockies; Am. Jour. Sci., vol. 243, pp. 480-491 (1945).