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Geology of Highwood-Elbow Area Alberta

By

J. A. Allan and *J. L. Carr*

(With Appendix on Palaeontology by P. S. Warren)

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CHAPTER I.

INTRODUCTION

General Statement.

During and following the first World War in the years 1914 to 1918, extensive prospecting proved the presence of large deposits of high rank coal within the Rocky Mountains in southwestern Alberta, in the vicinity of the Highwood and Sheep rivers. The increased fuel demand during the years 1939 to 1945 in the second World War caused a revival of interest in these deposits. Since little geological information was available for this area, the Research Council of Alberta assigned a geological field party to study the coal deposits and associated strata. This field work, carried on during the summers of 1945 and 1946, forms the basis for this report.

Geographic Postion and Accessibility.

The Highwood-Elbow Area lies in southwestern Alberta, about 45 miles southwest of Calgary, and about 25 miles west of the Turner Valley oilfield. It consists of the northern part of a basin underlain by Mesozoic rocks, lying between the Highwood range, here the outermost range of the Rocky Mountains, on the east, and the Elk or High Rock range, on the west. The map area (see Plate 1) extends from Baril creek, in township 16, ranges 5 and 6, west of the fifth meridian, on the south, to the northern termination of the basin, in township 20, ranges 7 and 8, west of the fifth meridian. The lower Mesozoic strata shown outcropping on the headwaters of the Elbow and Little Elbow rivers are continuous with the Cascade basin to the north.

The southern part of the area is accessible by car over a twenty-eight mile road, which extends up the valley of Highwood river from Longview, in the south end of Turner Valley oilfield. Lumber roads, passable when dry, extend from Highwood river up McPhail and Loomis creeks. A road from the town of Turner Valley up Sheep river is passable, usually, to within a mile of Burns Mine. A road up Kananaskis valley, from Seebe to Kananaskis lakes, passes within four miles of the coal deposits on Pocaterra creek. The rest of the area is accessible only by pack trail.

Okotoks and High River, on the Calgary-Lethbridge branch of the Canadian Pacific Railway, lie about forty miles in a straight line from the eastern part of the map-area, and about 55 miles by road.

Previous Work.

The first geological work in the area was that by G. M. Dawson[(1)], in 1884. Dawson's work, part of a reconnaissance of a large part of the Rocky Mountains of southern Canada, included the Highwood, Sheep, and Elbow drainage basins. D. D. Cairns[(2)] in 1905 mapped part of the Sheep River basin. The first detailed geological work was that of B. Rose in 1918-19[(3)] in the southern part of the area, while the northern part was included in the area mapped by J. R. Marshall[4] in 1921 and by I. W. Jones[5] in 1924. The coal deposits were studied by J. A. Allan in 1920[6].

The Upper Elk and Upper Highwood Rivers sheet, published in 1924 by the Geological Survey of Canada, includes that part of the area south of 50°30′ N. Lat., and is the only published map showing any details of the geology of this area. This map is on the scale of 1:250,000.

Field Work, Maps and Report.

This report is based upon survey work carried out during the field seasons of 1945 and 1946, by J. L. Carr* under the supervision and direction of J. A. Allan**. G. H. Bull, student assistant, and C. T. McNichol, cook, rendered able assistance in 1945 and A. J. Beveridge, student assistant, and W. F. Ferguson, cook, in 1946. C. A. Barber acted as packer during both seasons.

Since the purpose of the geological survey was to gain information regarding the coal deposits in the area, the greatest emphasis was placed upon a study of the Mesozoic strata. The Paleozoic successions were not studied in detail.

Parts of the following topographic maps issued by the Geological Survey of Canada were used in compiling the topographic base for Map No. 20 (Plate 1) which accompanies this report: Upper Elk and Upper Highwood, 1920, Publication 1754; Palliser-Kananaskis Area, 1924, Publication 1962 and Mount Head Sheet, 1945, Map 814 A. Some minor corrections have been made in mapping the drainage and these are shown on the map.

Through the kind permission of the Research Council of Alberta, that part of the report dealing with the eastern half of the area was submitted by J. L. Carr to the University of Alberta as the thesis*** requirement for a Master of Science Degree.

Acknowledgments.

The writers wish to express their appreciation to those who aided the progress of the work. T. F. Blefgen, J. A. Alexander, M. Meister, F. Nash and W. Wallator, officers of the Alberta Forest Service, W. A. Slominski, Field Superintendent, Highwood Coal Mines Limited, and officers of the Calgary Power Limited provided invaluable information and assistance.

P. S. Warren, Professor of Geology, University of Alberta, identified the fossil collections, made many valuable suggestions regarding the stratigraphy, and prepared the accompanying appendix on a "Description of Jurassic Ammonites from the Fernie Formation." R. L. Rutherford, Associate Professor of Geology, University of Alberta, aided the authors in the understanding of lithology, and M. B. B. Crockford, Geologist, Research Council of Alberta, assisted in the preparation of this report. Mrs. V. Stover assisted in the compilation, the proofreading and the indexing of the report.

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*J. L. Carr, Assistant Geologist, Research Council of Alberta.

**J. A. Allan, Professor of Geology, University of Alberta, Edmonton.

***J. L. Carr "The Geology of the Highwood-Elbow Area, Alberta," Master of Science Thesis, University of Alberta, May, 1946.

Chapter II.

GENERAL CHARACTER OF THE AREA

Drainage.

The drainage of the entire area is tributary to the Bow river. The largest stream in this area is the Highwood river, which is formed by the junction of Storm and Mist creeks in township 18, range 7, west of the fifth meridian, southeast of Mist mountain. From the confluence of these two streams, the Highwood river flows southeastwards along a synclinal axis for about eight miles, then swings gradually eastwards, and passes through the Highwood range in sections 35 and 36, township 16, range 5, west of the fifth meridian. Storm creek, the larger of the two streams which form Highwood river, rises on the west slope of Storm mountain, while Mist creek rises on the east slope of the same mountain. The other tributaries of the Highwood river are small in this area. The most important are Odlum, Loomis, McPhail, Baril and Cat creeks.

The Sheep river is the next largest stream in the area. It rises east of Mt. Rae, and flows southeastwards through a broad glaciated valley for five miles, before swinging eastwards through the Highwood range. Its tributaries are all small.

The Elbow river, which rises in Elbow lake north of Mt. Rae, flows across the northeastern part of the area at right angles to the general strike of the strata. The extreme northeastern part of the area is drained by the Little Elbow river.

Pocaterra creek, which drains the northwestern portion of the area, rises on the west slope of Storm mountain, north of the Highwood pass, and flows northwesterly, passing through the Elk range in section 33, township 19, range 8, west of the fifth meridian. Pocaterra creek enters Kananaskis river a few miles below the Lower Kananaskis lake.

Elbow lake, the largest lake in the area, is about one-eighth of a mile in length. Small ponds exist at the heads of many of the smaller streams.

Physiography.

Although the Highwood-Elbow area lies within the Rocky Mountains, erosion of the relatively soft Mesozoic strata has resulted in physiography similar to that in the innermost foothills. While the relief is great, it is not so great as in those parts of the mountains where resistant Paleozoic beds form the mountains, nor is the topography as rugged. The Highwood and Elk ranges, on the east and west sides of the area respectively, and Misty range, which runs northwestwards from township 18, range 7, west of the fifth meridian, are composed of Paleozoic strata, and present the usual rugged mountain topography. The major features of the physiography of this area are due to water erosion, but glaciation has modified many of the forms so produced.

The lowest elevations in the area occur along the streams. Highwood river, in sections 35 and 36, township 16, range 5, west of the fifth meridian, lies at an elevation of about 4,875 feet. The Sheep river, as it passes through the Highwood range, is at an elevation of about 6,100 feet. The highest elevations on ridges underlain by Mesozoic strata are east of Storm mountain, where heights of almost 9,000 feet are reached. There is thus a total relief in the Mesozoic area of about 4,000 feet, while local relief approaches 3,000 feet. Relief locally is usually between 500 and 2,000 feet.

The highest points in the area are in the Misty range. Mt. Rae reaches an elevation of 10,576 feet, while Mist mountain is only slightly lower, with an elevation of 10,303 feet. In the Highwood range, Mt. Head with an elevation of 9,114 feet is the loftiest peak. The mountains in the Elk range rarely exceed 9,500 feet. The total relief in the area is therefore about 5,600 feet.

The physiography of this part of the Mesozoic basin is to some extent a reflection of the lithology of the underlying bedrock. The highest ridges are usually formed by the upper part of the Kootenay formation, and are frequently capped by the basal Blairmore conglomerate, although it should be understood that this conglomerate in itself is too thin to exert a pronounced effect upon the topography. The sandstones of the lower part of the Belly River formation, and of the Bighorn formation form somewhat lower ridges. The softer beds between these resistant groups of strata form valleys and saddles.

Glaciation has had a marked effect upon the details of the physiography. Almost every valley in the area shows the typical U-shape. Cirques are well preserved at the heads of many of the streams rising in the Paleozoic rocks. Small hanging valleys occur on the west slope of Misty range, near the Highwood pass. The valley glaciers probably did not extend much above 7,500 feet elevation. Below this elevation the mountains are rather subdued in outline, while above this elevation the mountains and ridges are sharp and rugged. This is clearly shown in the Highwood range at Highwood river, where the lower mountains on the south side of the valley are rounded, while those on the north side, which are higher, are very rugged towards their tops.

The valley of the Highwood river below the mouth of McPhail creek is broad, with flood plains and terraces occupying its bottom. (Figure 1). At least six terraces may be recognized between the mouth of McPhail creek and the Sentinel ranger station. The lower terraces grade upstream into the flood plain deposits. Two main terraces are present. The higher, in the vicinity of Cat creek, lies at an elevation of approximately 5,200 feet. The lower, on Stony creek, lies at about 4,950 feet. Other less important terraces lie between these two. The upper terrace is largely destroyed by erosion east of the northwest corner of township 16, range 5, west of the fifth meridian. These terraces are not continuous on both sides of the valley. There is a possibility that some of these represent a flood plain rather than a lake terrace.

For about two miles above the mouth of McPhail creek, Highwood river flows through a steep-walled canyon, physiographically much younger than the valley above and below McPhail creek. Paralleling the canyon on the east side of the Highwood is a shallow dry channel. Above the canyon, the valley of the Highwood broadens out again, although not to so great an extent as below the canyon. Here, particularly on the west side of the river, is a low, fairly even plain, about half a mile in width. Bedrock is close to the surface, and this plain probably represents an eroded surface rather than a flood plain or terrace.

At the junction of Storm and Mist creeks, five terraces are developed along a deltaic deposit at the mouth of Mist creek. These cannot be traced laterally for any great distance. The valley of Mist creek is fairly narrow, but not gorgelike. This valley has been glaciated. The valleys of the tributary streams flowing in from the west show remarkably well-preserved U-shapes. The divide between Mist creek and the Sheep river is high and sharp. The lowest point on this divide, over which the trail passes, is known as Rickert's pass, and lies at about 8,100 feet above sea level.

The valley of Storm creek is much broader than that of Mist creek. Small flood plains are developed along the creek. The upper part of the valley is narrower, and shows the U-shape characteristic of glaciated valleys. The gradient of Storm creek is rather gentle to its head, in the Highwood pass, which lies at about 7,300 feet. The pass itself, which lies between Storm and Pocaterra creeks, is not sharply defined.

Between the Highwood river and the Highwood range, long strike ridges underlain by Kootenay strata form the principal feature. Between these ridges and the Highwood range is a low valley, underlain by soft Fernie shales. Cat, Lineham and Picklejar creeks rise in this valley, and flow westwards, cutting through the Kootenay ridges. Of considerable interest is a small canyon in Cat creek, in section 12, township 17, range 6, west of the sixth meridian. The course of Cat creek for about half a mile is directly across the strike of the strata. In this interval Cat creek has eroded a canyon through hard sandstones and conglomerate about 100 feet deep and only slightly wider than the stream itself. Above the canyon Cat creek valley is fairly gentle. The other tributaries of the Highwood river on the eastern side rise on the west slope of the Kootenay ridges. West of the Highwood river, in the vicinity of McPhail creek, the surface gradually rises from the river to the west, for about three miles, then rises steeply in a ridge formed of Blairmore and Kootenay strata. In this vicinity, there is very little reflection of underlying bedrock on the topography, the hard Bighorn sandstones barely rising above the general level of the surface. Southwards, towards Baril creek, the relief becomes greater, and the Bighorn and Belly River sandstones form pronounced ridges. The Kootenay-Blairmore ridge persists northwards to Loomis creek, on the western edge of the area. Between Loomis and Odlum creeks, is an inter-stream ridge, which is roughly perpendicular to the general strike. On the west side of Storm Creek basin, short tributaries, heading in Elk range, have developed short ridges between them. The Kootenay strata on the east side of Storm creek form a strike ridge, rising 2,000 feet above the valley bottom, through which Storm creek cuts in section 30, township 18, range 7, west of the fifth meridian. This ridge continues north into Pocaterra Creek basin. To the west of this ridge, a tributary stream has carved a straight valley, known locally as "Paradise Valley", along the axis of a small anticline.

The valley of Sheep river is broad and deep, and shows a pronounced U-shape (Figure2). The gradient within this area is gentle. The divide between Sheep and Elbow rivers is low and poorly defined. The tributary valleys, from the west, usually are glaciated. These valleys are separated by ridges from 2,000 to almost 3,000 feet high. On the east side of Sheep valley, the Paleozoics rise steeply to over 9,000 feet above sea level.

The upper part of Elbow river, within Misty range, lies in a flat-bottomed valley up to half a mile in width. This valley is continuous across Misty range. The west end of this valley from the divide is drained to Pocaterra creek. The divide between Elbow river and Pocaterra creek, known as Elbow pass, is at an elevation of about 7,100 feet. The Elbow river has cut a shallow gorge through parts of this valley. Within the belt of Mesozoic rocks, the valley is quite shallow and terraced. The valley steepens and narrows sharply where Elbow river passes through the Paleozoic strata east of the Mesozoic belt. The gradient of Elbow river within this map area is approximately 1,400 feet in a distance of less than nine miles, or an average gradient of about 150 feet per mile.

Storm creek extends from the Highwood pass, with an approximate elevation of 7,250 feet, to the Highwood river at an elevation of about 5,750 feet, a distance of about eleven miles. This represents an average gradient of about 135 feet per mile.

The gradient of Pocaterra creek is greater than that of Storm creek. Between the Highwood pass and the Kananaskis river, a distance of about 10 miles, the average stream gradient of Pocaterra creek is approximately 155 feet per mile. The crest of the Kootenay ridge which is the continuation of that on Storm creek, drops northwards, but maintains an elevation of about 1,500 to 2,000 feet above the valley bottom. It is truncated by the westward swing of Pocaterra creek through the Elk range. That part of the area north of Pocaterra creek is drained by west flowing streams which cut through the Elk range. The valleys of these streams are separated by ridges of Kootenay strata, which form saddles between the Paleozoic beds on either side.

Changes in Drainage.

Lying to the east of the canyon on the Highwood river, and roughly paralleling it, is a shallow channel believed to represent an old drainage course of the Highwood river (Figure 3). About half a mile of fairly level ground separates this channel from the canyon. The northwestern end of the channel slopes gently into the present course of the Highwood river just south of Lineham creek, near the head of the canyon. The lower end of the channel is now blind, probably blocked by gravel deposits. The east bank is a high ridge of Kootenay and Blairmore strata. The west bank is less than fifty feet in height. The bottom is gently undulating, due to the formation of small alluvial fans by intermittent streams from the east bank. These fans vary up to about five hundred feet in diameter. The authors believe that during post-glacial laking on the Highwood river, sediments deposited by the small streams from the east side of the Highwood valley raised the floor of this portion of the Highwood channel sufficiently high to force the river to seek a new path. Above Lineham creek, the Highwood channel is farther away from the eastern side of the valley, and thus would not be filled by the sediments dropped in the quiet lake waters.

A somewhat similar channel is present northeast of the Highwood river, between Cat creek and the northwest corner of township 16, range 5, west of the fifth meridian (Figure 4). The upper end of this channel is blind, and is blocked by gravels, while the lower end opens on a low terrace. This valley is narrower than the first described, and somewhat more sinuous. The southwest bank is about seventy-five feet high, while the other is a steep ridge of Kootenay and Blairmore strata. It is probable that this is a former course of Cat creek. The head of the valley lies about half a mile from the canyon on Cat creek, with a flat, probably underlain by gravel, in between. It is possible that during laking in the Highwood valley, Cat creek deposited gravels as a deltaic deposit at the margin of the lake, filling the upper end of its channel. As the delta was developed, Cat creek would continuously change its course across the unconsolidated deposits. With the draining of the lake, the creek would start eroding downwards, and its course would be superimposed on the bedrock forming the canyon. A small abandoned channel is also present immediately northwest of the lower end of Cat Creek canyon, and possibly represents a former tributary of Cat creek.

A consideration of the physiography about the Sheep-Elbow divide has led to the conclusion that the Sheep river formerly included that part of the Elbow in this map area. The valley of the Sheep river is much larger than could be expected from the size of the stream now occupying it, and the present Sheep river drainage basin is not large enough to gather a heavy flow, regardless of past climatic conditions. The low divide between the two rivers, where Paleozoic and Mesozoic strata alike have been reduced to a low level, suggests erosion by a powerful agent over a long period of time. The difference between that part of the Elbow valley in Misty range where the valley is broad, and that part in the Highwood range where the valley is narrow, although the underlying bedrock is fairly similar, suggests that not only is the valley through the Highwood range physiographically younger, but also younger in time. It is concluded that the Elbow river captured the upper part of the Sheep river by headward erosion. This probably occurred in pre-glacial time, as otherwise the Sheep valley would not show the characteristic U-shape, unmodified by stream erosion (Figure 2).

It appears probable that at one time a pre-glacial stream crossed the entire Misty range through Elbow pass, but only the gap itself remains as evidence. The drainage west of Elbow pass might have been captured by the development of Pocaterra creek. The distance from Elbow pass to the Pocaterra is at present less than one mile and the difference in elevation is approximately 500 feet.

One other example of headwall erosion and stream piracy rests on fairly good evidence. Cliff creek rises in the depression occupied by the Fernie formation, on the west side of the Highwood range, then cuts partway through the range in a sharp canyon to join the Sheep river. Its valley is largely unglaciated. Two ridges of Kootenay strata lie between the head of Cliff creek and Mist creek, separated by a small saddle occupied by Fernie shale. A gap is present in the eastern of these two ridges, and the western part of the gap is drained by a small creek which passes through the western ridge to join Mist creek. It is probable that this small creek at one time extended to the west slope of the Highwood range, but that headwall erosion by Cliff creek enabled it to capture the drainage of part of the low trough of shale.

Culture.

No settlements are present in this area. The only permanent inhabitants are officers of the Alberta Forest Service, and employees of a small saw mill on Loomis creek. Lumbering and trapping are the principal industries. Summer pasture is found for cattle in the Highwood and Sheep valleys. Intermittent prospecting for coal has necessitated the erection of buildings to house the workers. One such camp is on the Sheep river, at Burns Mine, one is on Cat creek, and one is on the Highwood, one-quarter mile west of Sentinel ranger station. The entire area forms part of the Rocky Mountain Forest Reserve. That part of the area included in the Kananaskis drainage basin is a game preserve.

Fauna and Flora.

Game is fairly abundant in the area. Deer, elk, moose, mountain sheep, mountain goat, cougar, and black, brown and grizzly bear are present. Trout are plentiful in many of the streams.

The timber line is a little over 7,000 feet above sea level. Below this elevation most of the area has been heavily forested, but fire has destroyed much of the timber in the area. The present largest stands are at the heads of Loomis and Odlum creeks, on Mist creek and on Pocaterra creek. A few small stands are present elsewhere. Jackpine and spruce, with some aspen, are present at lower elevations, while tamarack, balsam, and limber pine are present close to the tree line.

Chapter III.

GENERAL STRATIGRAPHIC SUCCESSION

Rocks of Paleozoic and Mesozoic ages outcrop in the Highwood-Elbow area, while Glacial and Recent deposits locally form a thin mantle over the bedrock.

The Mesozoic succession, which was studied in detail, consists of a series of marine and non-marine sedimentary rocks with a maximum thickness of almost 15,000 feet. The geological succession is shown in the Stratigraphic Table 1 (pages 16 and 17).

PALEOZOIC

Beds of Paleozoic age form the Highwood, Misty and Elk ranges. These beds are dominantly calcareous and dolomitic, with smaller amounts of clastic materials. No detailed study was made of these beds.

The beds at the top of the Paleozoic succession on the west side of the Highwood range are dolomites and sandy dolomites, frequently with large quantities of chert in the form of nodules and small lenses. A horizon with abundant silicified *Spirifer* shells usually occurs a few feet below the top. Rare crinoid stem joints, and fish plates or teeth are also present. The *Spirifer* is close to *S. rockymontanus,* and suggests either an upper Rundle or lower Rocky Mountain age for these beds.

On the west side of the Misty range, the uppermost Paleozoic beds consist of fine, dense, grey to buff dolomites, and hard grey to white quartzitic sandstones, which are assigned to the Rocky Mountain formation on lithological grounds.

MESOZOIC

Triassic

Spray River Formation.

Distribution:—The Spray River formation outcrops as a narrow band along the west side of the Highwood and Misty ranges, about the southeast end of Misty range, and at the head of McPhail creek. It is also present on the headwaters of the Elbow and Little Elbow rivers, in the southern extension of the Cascade basin.

Thickness:—The Spray River formation varies from 240 to about 800 feet in thickness. In the vicinity of Stony creek, the formation is at a minimum thickness of 240 feet, while at the head of Picklejar creek, the formation is 360 feet thick. On the west side of Misty range the exposed sections are badly deformed and the thickness of 800 feet is estimated.

Lithology:—Over most of the area, the Spray River formation consists of brown to reddish-brown weathering, dark grey, fine grained, silty and sandy carbonate rocks, with fissile shales towards the base, and relatively coarse clastic beds at the base. North of Lineham creek, on the west flank of the Highwood range, the uppermost strata are white, grey and pink sandy and cherty limestone, fossiliferous limestone and silicified coquina, but similar beds were not observed elsewhere in the area.

TABLE 1.

TABLE OF FORMATIONS

Era	System	Series	Formation	Thickness (feet) East	Thickness (feet) West	Character
Cenozoic	Quaternary	Pleistocene & Recent		0-150		Gravels; minor sands and silts; till; tufa and travertine locally.
			Erosional unconformity			
Mesozoic	Cretaceous	Upper Cretaceous	Belly River and? later		4,000?	Upper, soft, poorly consolidated greenish-grey sandstone and shale. Lower, interbedded grey to greenish-grey cross-bedded calcareous sandstone and grey shale. Non-marine.
			Wapiabi		1,500	Dark grey, fissile shale and sandy shale. Ironstone nodules. Rare thin sandstone beds. Marine.
			Bighorn		613	Upper, hard, grey to light grey, platy sandstone with interbedded dark grey fissile shale. Lower, interbedded bluish grey silty sandstone and shale. Marine.
			Blackstone		1,100?	Grey to dark grey shale and sandy shale with interbedded thin sandstone and silty limestone. Upper part silty, bluish grey shale transitional to Bighorn. Decomposed volcanic ash 200 feet above base. Lenses of conglomerate at base. Marine.
			Erosional unconformity			
		Lower Cretaceous	Blairmore	2,500	3,300	Upper, green to grey shale and sandy shale with interbedded sandstone and arkose. Brown weathering calcareous concretions. Chert and igneous pebble conglomerate lenses. Volcanic tuff and maroon shale at top. Lower, grey shale and fine hard grey quartzitic sandstone, with blue-grey limestone near top and conglomerate at base. Pocaterra Creek member, grey, carbonaceous and maroon shale, hard fine grey quartzitic sandstone, grey, green, maroon limestone nodules, conglomerate at base (absent in the southeast of the map area). Non-marine and ? marine.
			Erosional unconformity			

			Kootenay	709	2,400	Brown, grey and black, often carbonaceous shale, siltstone and fine sandstone with some medium to coarse brownish sandstone with occasional pebble lenses. Coal. Ironstone nodules. Hard, grey, medium grained sandstone at base. Non-marine.
				Erosional unconformity?		
	Jurassic	Upper Middle Lower	Fernie	750	1,000	Brown weathering, brownish-grey sandstone at top, overlying interbedded sandstone and shale which grades down into fissile brown, grey and black shales. Calcareous concretions. Sandy horizon (Rock Creek member) near base. Phosphatic limestone at base on Pocaterra creek. Marine.
				Erosional unconformity		
	Triassic	Middle? Lower	Spray River	250-360	800?	Brown weathering, platy to massive silty and sandy carbonate rocks, with brown to black shales in lower part. Conglomerate sandstone and phosphate rock at base. Light grey to pink sandstone, limestone, silicified *Lingula*, coquina and chert at top near Burns Mine. Marine.
Paleozoic	Undivided					Limestone, dolomite, shale, sandstone.

The following section, measured on the south bank of Picklejar Creek valley, in section 17, township 18, range 6, west of the fifth meridian, shows the general character of the beds making up this formation.

Overlying beds (Fernie formation).

Erosional unconformity

	Feet
White, light grey, and pink, hard sandy limestones and cherty limestones	80
Sandy and shaly limestone, partially concealed	25
Light grey, partially silicified, sandy limestone and coquina	11
Brown weathering, dark grey, sandy and silty carbonates in beds one-half inch to four feet thick, becoming thinner bedded downwards	180
Dark grey to dark brown, fissile calcareous shales	60
Hard, dark grey, calcareous sandstone, with pyrite at top	4
Total thickness of section	360

Erosional unconformity

Underlying beds (Paleozoic sandy limestone).

The contact between the Spray River and underlying Paleozoic strata was observed at one locality on the west slope of Highwood range, and several localities along the west slope of Misty range. The contact is definitely erosional. In the northwest quarter of section 7, township 17, range 5, west of the fifth meridian, the surface of the uppermost Paleozoic bed is pitted by smoothed depressions up to one and one-half inches deep and from four to six inches across, which appear to have been formed by erosion of the softer parts of the bed. The basal sandstone of the Spray River formation lies upon this surface (Figure 5). On the west side of Misty range, similar surfaces are present below the basal Spray River.

At the locality above, the basal bed consists of two feet nine inches of fine grained, hard, dark grey calcareous sandstone, pyritiferous at the top, with rounded shale pellets, overlain by two feet six inches of hard dense green dolomite. Overlying these beds are the usual soft lower Spray River shales. The section of the basal beds on the west slope of Mist mountain is as follows:

	Feet	Inches
Brown weathering, lower Spray River shales		
Bluish weathering, dark blue-grey chert breccia, consisting of grains and splinters of white chert in a hard siliceous matrix, phosphatic towards top	4	0
Chert breccia, as above, nodular, with calcite veins and vugs	0	9
Soft sandy brown sandy shale with rounded quartzite boulders up to eight inches, and lenses of blue weathering chert breccia	1	3

Erosional contact

Underlying beds (Paleozoic quartzite).

Farther north, in the vicinity of Pocaterra creek, the basal bed consists of a well-indurated chert pebble conglomerate, with white and black angular to well-rounded pebbles up to one inch in diameter, with a dark grey phosphatic matrix. This bed varies up to eight inches in thickness, but locally is reduced to a thin coating on top of the uppermost Paleozoic bed. The conglomerate is overlain by phosphate rock carrying worn phosphatic nodules, about two and one-half feet thick, while a soft brown sandstone one foot thick lies at the top of this group of basal beds.

Overlying the basal beds is a series of thin-bedded, fissile brown weathering, dark grey, black and brown shales, which vary from about 60 feet in the eastern part of the area, to 100 feet in the western part. West of the Misty range, up to three beds, each less than one inch in thickness, of limonite stained clay are present at about the centre of these shales. The material looks bentonitic but does not show the swelling in water characteristic of that material.

Bentonite-like clays occur at several horizons in the Mesozoic succession. Besides the Spray River, somewhat similar beds are present in the Fernie, Blackstone and Wapiabi formations, and are characterized by showing no indication of swelling when soaked in water. It is probable that these clays represent bentonites which have undergone sufficient dynamic metamorphism to destroy the swelling property. If bentonite represents an altered volcanic ash, Spray River and Fernie clays probably are reflections of Triassic and Jurassic vulcanism in British Columbia to the west.

Upwards these shales pass into harder silty carbonate rocks. The contact is gradational, but the change usually takes place in a zone not over ten feet thick. Similar fossils are found at the top of the shales and at the base of the carbonates. The thickness of these beds varies from 180 feet on the east to possibly 700 feet on the west. These beds form a series of dark grey, fine gained calcareous and dolomitic siltstones, and silty carbonates. The material occurs in sharply defined beds varying up to ten feet thick, but the individual beds are often massive. Very fine banding is of frequent occurrence. These rocks are brittle in the outcrop, but the thinner bedded material may be folded sharply on a small scale. This part of the Spray River formation weathers a distinctive reddish-brown which contrasts strongly with the more sombre adjacent strata. Ripple-marking is not uncommon. Microscopic examination shows the presence of a small quantity of gypsum, besides carbonates and quartz.

On the west slope of the Highwood range, north of Lineham creek, these brown-weathering carbonates are overlain by light grey, white, and pinkish sandy limestones, cherts and silicified coquinas. Similar beds were not observed elsewhere in the area. The maximum thickness observed was on the south side of Picklejar creek, where 116 feet of these beds are present. (See stratigraphic section of Spray River formation, p. 18.) Near the Burns Mine, only 40 feet of beds, consisting largely of fossiliferous sandy limestone, belong to this formation. Microscopic examination shows that gypsum is quite abundant in some of the beds of this group.

The considerable variation in thickness of these strata, and their absence over most of the area is attributed to pre-Fernie erosion.

Age and Correlation:—The age of the basal clastics and phosphatic limestones are in doubt. A thin phosphate horizon is widespread in the upper part of the Rocky Mountain formation in southwestern Alberta, while the Spray River formation is not phosphatic in the Crowsnest pass(7). The inclusion of the clastic and phosphatic beds in the Spray River formation in the Highwood-Elbow are is based on the physical evidence. These beds rest upon a cleanly washed erosion surface, while the contact into the overlying Spray River shales appears to be conformable. These basal beds maintain an essentially uniform thickness, from four to six feet throughout the area, suggesting proof that erosion has taken place.

It is possible that on the west slope of the Misty range, the phosphatic beds represent the Rocky Mountain phosphate horizon reworked by the Spray River sea. The Spray River formation is only sparsely fossiliferous, and the fossils are rarely well-preserved.

The lowest horizon, about one hundred feet above the base west of the Misty range, carries *Ophiceras?* sp. and *Claraia* sp. These forms indicate a Lower Triassic age for these strata[8].

Casts of an ammonite referred to *Meekoceras mushbackanum* var.*corrugata* Smith, were collected from the carbonates on the west slope of Mist mountain. This form occurs with *Flemingites* in southeastern Idaho[9], and hence probably corresponds to the *Flemingites* horizon of Lower Triassic age reported by Warren from the Spray River formation[8].

Other forms from the brown weathering carbonates consist of *Lingula* sp., *Perna?* sp. and unidentifiable pelecypods, which are not significant for correlation. On the basis of the fossils listed above, the brown weathering carbonates and strata to the base of the formation are correlated with the Sulphur Mountain member of the Spray River formation[8].

The light grey beds at the top of the formation in the northeastern portion of the area carry no identifiable fossils except *Lingula* sp. These beds are correlated with the Whitehorse member of Middle Triassic age, on the basis of lithology. The presence of appreciable quantities of gypsum in some of these beds is considered to be especially significant, as gypsum in large amounts is present in the Whitehorse member at the north end of Jasper Park[10] and in the section penetrated in the Guardian well at Pouce Coupe[11].

JURASSIC

Fernie Formation.

Distribution:—The Fernie formation outcrops along the west side of the Misty range, and occupies a large part of the basin in the vicinity of the Elbow river. The upper part of the formation is brought to the surface by a fault between Lineham creek and the head of Mist creek, about half a mile west of the main outcrop. This formation also outcrops along the west side of the Misty range, and in a small area at the head of McPhail Creek.

Thickness:—The Fernie formation is rarely well-exposed, and usually is severely crushed. Reliable estimates of the thickness are consequently not readily obtained. A measured section near the Burns Mine gives a thickness of 745 feet. West of the Misty range, no sections which could be adequately measured were found, but the thickness may be as much as 1,000 feet.

Lithology:—The Fernie formation consists of a series of dark grey to brown shales, grading upwards into massive sandstone at the top with minor limestone, phosphatic limestone and sandstone in the lower part. A section measured near the Burns Mine, in about section 11, township 19, range 7, west of the fifth meridian, shows the character of the formation along the west side of the Highwood range as follows:

Overlying beds (Kootenay formation).

Contact apparently conformable

	Feet
Light brown weathering, brown-grey, fine grained, finely cross-bedded sandstone with lenses of hard, dark grey, yellow weathering sandstone	91
Interbedded sandstone similar to above, and grey to brownish sandy shales, the sandstone decreasing in thickness and amount downwards. Ironstone and thin beds of sandy limestone. Plant fragments. Pelecypods 110 feet below the top	141
Grey sandy shales, with ironstone nodules and thin, finely cross-bedded sandstone. Plant fragments	81
Dark grey to dark brown shale and sandy shale with minor ironstone	65
Black fissile shale	84
Olive-grey, fissile shale with yellow weathering limestone lenses to one foot in thickness	46
Black fissile shale weathering to thin flakes, with large, dark grey, orange weathering limestone concretions in upper hundred feet. Occasional Belemnites near base	155
Rock Creek member	47.5

	Feet
Dark grey, buff weathering, calcareous siltstone, highly fossiliferous	4
Light grey siltstone and silty shale, with Belemites, and small marcasite-coated black phosphate nodules at base; one inch grey bentonite-like clay 3 feet 3 inches above base	28
Sandstone, with abundant pyrite, Belemnites, and black phosphate nodules to one-quarter inch	1.5
Hard, black, medium grained, thin bedded, calcareous sandstone, with worn Belemnites at base	14

Black to dark brown fissile calcareous shales, with interbedded black argillaceous limestone	35
Total thickness of Fernie formation	745.5

Disconformity

Underlying beds (Whitehorse member of Spray River formation).

The basal beds along the Highwood range and in the Cascade basin consist of black shale and argillaceous limestone. Similar beds are not present at this horizon west of the Misty range, where phosphatic limestones occur below black fissile shale, as shown in the following section, measured on the east side of the Highwood pass:

	Feet
Blue-grey weathering, dark grey, finely banded, shaly phosphatic limestone, with fucoidal markings	7
Silty, brown to blue-grey weathering, dark grey phosphatic limestone in beds from six inches to two and one-half feet, with chert nodules	10
Blue-grey weathering, finely banded, grey phosphatic limestone in beds one half to six inches, with quartz vugs	10
Brown weathering, light grey, fine grained, calcareous sandstone, weathered surface ribbed parallel to the bedding	5

Contact apparently conformable

Underlying beds (Sulphur Mountain member of the Spray River formation).

The lowermost bed is quite similar to the Spray River strata, and rests on them with a sharp contact. Regionally, as shown previously, this contact is disconformable.

The Rock Creek sandy member, which forms an outstanding marker in the eastern portion of the area, is represented west of the Misty range by sandy shales and limestone lenses, carrying a typical fauna. Along the Highwood range, this member maintains a uniform aspect, except that towards the south, the lowermost sandstone is finer and thinner bedded.

The concretion zone (Figure 6) is well-defined in the eastern part of the area, but west of the Misty range, similar concretions, which reach a maximum diameter of six feet, extend from below the Rock Creek member for several hundred feet upwards (Figure 6). A zone of thin beds of dark grey, hard, brownish grey weathering limestones, interbedded with calcareous shale, occurs about the middle of the formation west of the Misty range. Small rosettes, up to one and one-half inches in diameter, consisting of quartz pseudomorphs after marcasite, are present above these limestones.

Towards the top of the formation, the beds become silty and sandy, and change from black to grey and brown in color. Thin beds of sandstone appear, and increase upwards, grading into a massive sandstone at the top. The interbedded sandstones and shales are referred to as the "passage beds" in the Crowsnest Pass[12]. These "passage beds" vary considerably in thickness, from 18 feet on Stony creek to 141 feet near the Burns Mine. The thickness of this member is unknown west of the Misty range. Stellate crystal aggregates, consisting of bluish calcite, occur in these beds in many parts of the area. Marine fossils are present, but broken plant fragments indicate near-shore deposition.

Above the "passage beds" is a massive, sometimes cross-bedded, light brownish grey weathering, brown grey fine grained sandstone. It tends to fracture in slightly curved plates up to two inches in thickness, perpendicular to the bedding. Yellow-weathering, hard, dense sandstone forms lenses in this bed in the eastern part of the area, but these are not present west of the Misty range. This sandstone, from which marine Jurassic fossils were collected on Stony creek, varies from 91 feet thick near Burns Mine, to about 150 feet thick on upper Storm creek. On Stony creek, it is 136 feet in thickness. The upper surface of this sandstone is gently irregular, and between this and the basal sandstone of the Kootenay formation there is usually a bed of soft, iron-stained shale less than one inch thick. The irregularity of the contact may indicate post-Fernie erosion.

Age and Correlation:—The lowest fauna found in the Fernie formation occurs in the black calcareous shales at the base, in the eastern part of the area. The forms collected are new, and hence cannot yet be used for correlation, but the fauna is probably Lower Jurassic. The following forms are present:

Pseudomonotis sp.
Posidonomya? sp.
Oxytoma sp.
Chlamys? sp.
"Belemnites" sp.
Cylindroteuthis sp.

The largest fauna, both in species and numbers of individuals, occurs at the top of the Rock Creek member. The following forms were collected:

Rhynchonella webbi Warren
Grammatodon ferniensis Warren
Cucullaea rockymontana Warren
Inoceramus ferniensis Warren
Gryphaea cadomenensis Warren
Oxytoma mclearni Warren
Entolium parviaure Warren
Modiolus sp.

Plagiostoma albertense Warren
Pleuromya burnsi Warren
Pleuromya cf. *burnsi* Warren
Arctica subtrigonalis Warren
"*Arctica*" sp. nov.
Astarte, two species
"*Pleurotomaria*" sp.
Stemmatoceras albertense McLearn
Stemmatoceras mclearni Warren
Stemmatoceras sp.
Saxitoniceras cf. *marshalli* McLearn
Saxitoniceras? sp. nov.
Saxitoniceras cf. *allani* McLearn
Itinsaites itinsae McLearn
Kanastephanus sp.
"*Belemnites*" sp.

This fauna is of Bajocian (lower Middle Jurassic) age, and is typical of the Rock Creek member in the Fernie formation in much of western Alberta.

Above the Rock Creek member, fossils are scarce. *Arcticoceras* sp. was collected from a concretion in the Fernie formation fairly low in the concretionary zone on the north side of Lineham Creek basin, while a few pelecypods were also found in concretions in various parts of the area. On Pocaterra creek, west of Elk range, in the northern extension of the Elk river Mesozoic basin, *Arcticoceras* sp. and *Proplanulites* sp. were collected. *Arcticoceras* ranges from upper Bathonian to lower Callovian, or latest Middle to earliest Upper Jurassic, while *Proplanulites* is considered Callovian, or lowermost Upper Jurassic[13]. Eight feet above the *Arcticoceras* zone on Pocaterra creek, *Cadoceras* sp. was found. This genus is lower Callovian. *Arcticoceras* or related forms are present in the *Corbula munda* fauna of the Crowsnest Pass (McLearn[12], p. 86), and also in the Ellis group of Montana, associated with both *Arctocephalites* and *Cadoceras*[13]. This Fernie horizon, then appears to correlate with the Rierdon formation of the Ellis group of Montana[14] and is probably of lowermost Upper Jurassic age.

The "passage beds" and upper sandstone of the Fernie carry few preserved fossils. Occasional plant fragments and pieces of fossil wood are present. Marine pelecypods also occur. A small fauna was collected twenty-five feet above the base of the upper sandstone on Stony creek, consisting of the following forms:

Oxytoma cf. *blairmorensis* McLearn
Modiolus cf. *frankensis* McLearn
Astarte sp.
cf. *Pachyteuthis densus* (Meek)

These forms are closest to species in the *Corbula munda* fauna at Blairmore, but definitely indicate only that this sandstone is Jurassic and marine. As this occurs well above *Arcticoceras*, it safely may be assumed to be Upper Jurassic in age. In addition to these forms, *Lima* sp. was obtained from the "passage beds" near the Burns Mine, and small Scaphopods occurred in the same group of beds southeast of Mt. Wintour. The upper sandstone probably correlates with the "Brown sand" of Turner Valley, the upper Fernie sandstone at Moose Mountain[15], and possibly with beds which have heretofore been mapped as basal Kootenay in other parts of the foothills of southwestern Alberta.

Cretaceous

Kootenay Formation.

Distribution:—Three bands of Kootenay strata designated as Eastern, Central and Western, separated by faults are present on the lower Highwood river within the Highwood-Elbow area (see Plate 1). The eastern band pinches out against a fault in Lineham Creek valley, while the two other bands continue north along the east side of Highwood valley and into the Sheep River basin. More Kootenay strata are brought to the surface along the northern part of the Highwood Valley syncline. On Loomis creek, below the mouth of Bishop creek, Kootenay strata are brought to the surface in a faulted anticline. This band continues north, and splits about the south end of the Misty range, one branch extending up the east side, where it is faulted on the Kootenay strata in the Highwood Valley syncline, while the western arm extends along the west side of the Misty range, following up the valleys of Storm and Pocaterra creeks. Kootenay strata are exposed also east of Elk range between Loomis and Muir creeks.

Thickness:—A measured section of the Kootenay formation, in section 5, township 17, range 5, west of the fifth meridian, in the southeastern portion of the area, gives a thickness of 709 feet for the formation, while plane table measurements near the same locality show from 750 to 850 feet of strata. Westwards, the formation shows a marked thickening, as on Picklejar creek the formation was found to be 2,100 feet in thickness by telemeter measurements. On Storm creek, in about section 31, township 18, range 7, west of the fifth meridian, a thickness of 2,400 feet for the formation was obtained by telemeter measurements.

Lithology:—The Kootenay formation consists of a series of interbedded shales, siltstones, and sandstones with minor amounts of coal, ironstone, conglomerate and cannel. The strata are generally brown to black, due to iron oxides and carbonaceous matter.

The following section of the Kootenay formation was measured in section 5, township 17, range 5, west of the fifth meridian, two miles northwest of the Sentinel ranger station.

Overlying beds (Blairmore formation).

Erosional contact

	Feet
Coarse to medium grained, light grey, cross-bedded, cherty sandstone, becoming darker towards base	58
Carbonaceous, dark grey shale and lighter grey, sandy shale	14
Buff weathering, fine grained, finely cross-bedded, shaly sandstone	30
Coarse grained, cross-bedded, massive brown sandstone	34
Concealed, probably shale	7
Dark grey, cross-bedded sandstone, fine at top, but becoming coarser and carbonaceous towards base; lenses of chert-pebble conglomerate up to 7 inches thick at base	21
Dark brown, fine grained sandstone, shaly at top	4
Carbonaceous and sandy shales, largely concealed	21
Hard, fine to coarse grained, buff to grey, cross-bedded sandstone; ironstone nodules at base	55
Hard, coarse, dark grey cherty sandstone with lenses of very coarse sandstone and chert pebbles at base	8
Black carbonaceous shale	1
Hard, massive, medium grained brown sandstone	5
Hard, fine grained, thin bedded, silty sandstone, carbonaceous at base	3

Grey sandstone, fine at top, becoming coarser and cherty towards base, thin beds of black shale near base	29
Black to brownish grey shales and sandy shales	38
Hard, medium grained, dark grey, cherty sandstone with pyrite; imprints of large stems at base	10
Hard, dark grey, very fine grained, yellow weathering sandstone, with ironstone nodules and scattered chert pebbles one foot below top	6
Shales, carbonaceous to sandy, partially concealed	46
Buff weathering, fairly coarse, dark grey, hard sandstone	4
Buff to yellow weathering, dark grey to dark brown, shaly sandstone and sandy shale	40
Carbonaceous and black, to grey, shales and sandy shales with thin beds of very fine hard, yellow weathering sandstone; some ironstone nodules; largely concealed	161
Hard, medium grained, finely cross-bedded, grey, cherty sandstone	16
Carbonaceous to sandy shales, thin beds of hard, very fine grained, yellow weathering sandstone, some ironstone; largely concealed	69
Hard, light grey weathering, cross-bedded, light to dark grey sandstone in beds up to one foot thick	29
Total thickness of Kootenay section	709

Conformable contact

Underlying beds (Fernie formation).

The contact between the Kootenay and Fernie formations in this area is marked by a thin bed, less than one inch thick, of sandy iron stained shale, resting on the gently irregular surface of the Fernie sandstone. Overlying the shale is a bed of hard, grey sandstone, varying in thickness from 19 feet at the Burns Mine, to 54 feet in the Highwood pass. This bed, which may be referred to as the basal Kootenay sandstone, is medium grained, and varies from light to dark grey in color, depending upon the percentage of dark chert and argillite grains, which give a salt-and-pepper appearance to the fresh rock. The bed weathers white to slightly pink, but usually supports a prolific growth of dark lichens, so that in the outcrop it appears dark, in marked contrast to the light brownish-grey weathering Fernie sandstone below it. Carbonized stems and shale pellets were observed in this bed on the upper part of Storm creek. Microscopically, the rock consists of rounded quartz, argillite and chert grains cemented by quartz. This sandstone has been included in the Kootenay formation, because of the nature of the contact with the massive Fernie upper sandstone, which may be indicative of erosion, because lithologically, it marks a sharp break with the Fernie type of sandstone, and because somewhat similar beds are also present in the Kootenay formation.

Throughout the area, the lower part of the Kootenay formation consists of soft shales, with lesser quantities of sandstone, siltstone, coal, and ironstone. These beds are relatively soft, and are usually not well exposed. This soft zone varies from about 330 feet on the east to 800 feet on the west. Hard, dense, yellow-weathering, sideritic siltstone, in massive beds up to two feet thick, are especially characteristic. The shales vary from blocky to fairly fissile, and from brownish grey to black. The more carbonaceous shales are usually the more fissile.

The beds overlying the soft zone vary widely. The upper part of the Kootenay formation consists of medium to coarse grained grey and brown sandstones, with interbedded shale, and lenses of pebble conglomerate in the eastern portion of the map area. Cross-bedding on a large scale is frequent. To the northwest, however, the intervening shale becomes more prominent. A zone of fairly coarse sandstones occur on Storm creek about eight hundred feet above the base of the formation. Overlying these are thinner beds of sandstone, with shales, and brown weathering, dark grey siltstones, which equal or exceed the sandstones in amount. Similar fine grained beds are not present in the southeastern part of the area.

Much of the clastic material, of silt size and coarser, consists of rock fragments—quartzite, argillite, and chert—rather than quartz. Some beds of sandstone are almost entirely made up of dark grains of these materials. The pebble beds also consist largely of black argillite, although a few white quartzite pebbles are present. The pebble beds are lenticular.

In the upper five hundred feet of the formation, west and north of the Highwood river and Mist creek, lenticular beds of cannel, less than six inches thick, are abundant. This varies from shaly, and fissile, to massive material with a conchoidal fracture. Some of the cannel intumesces when ignited. At the head of McPhail creek, shaly cannel carries numerous elongate rod-shaped forms on the bedding planes. Occasionally, a thin crust of chert is present on the weathered surface of the cannel. A white weathering cherty siltstone, actually a high-ash cannel, frequently occurs in association with cannel. The chert in both the cannel and siltstone is authigenic.

Coal is of widespread occurrence in the Kootenay formation, although it is a minor component. In the eastern portion of the map area, coal appears to be absent in the upper third of the formation. West of the Highwood river, however, coal seams occur within 75 feet of the top of the formation. The detailed consideration of the coal is discussed in Chapter V.

The Kootenay formation is overlain by the basal Blairmore conglomerate, which rests on the eroded surface. The contact is irregular and clearly shows at least local erosion. In the easternmost band of the Kootenay strata, west of the Sentinel ranger station on the Highwood river, measurements from a pebble horizon to the top of the formation indicate that about one hundred feet of beds have been eroded in a distance of about two miles. The rapid thickening of the Kootenay formation between the Sentinel ranger station and Lineham creek is more readily explained by erosion than by deposition. It is probable, therefore, that the erosion prior to the deposition of the basal Blairmore conglomerate was regional rather than local.

Age and Correlation:—Plant remains are abundant in the Kootenay formation. A small collection was made from a shale parting in the Holt coal seam, in the open cut on the road west of the Sentinel ranger station, about 50 feet above the base of the formation. W. A. Bell, of the Geological Survey of Canada, to whom the collection was submitted identified the following forms:

Cladophlebis virginiensis forma *acuta* Fontaine n. comb.
Cladophlebis virginiensis forma *pseudolatiloba* n. forma
Sphenopteris cordai Schenk
Coniopteris brevifolia (Fontaine) n. comb.
Ginkgo pleuripartita (Schimper)
Pityophyllum nordenskioldi (Heer)

Bell[16] states, "The florule, although comprising only a few species, indicates a Lower Cretaceous rather than a Jurassic age.

The most interesting species is *Sphenopteris cordai* . . . . The type of this species came from the Wealden of Germany."

The flora, stratigraphic position and lithology clearly indicate a correlation of these strata with the Kootenay formation of Crowsnest Pass.

The age of the Kootenay formation has been in doubt. Bell[17] states that the Kootenay flora indicates probably a Barremian age. R. W. Brown[18] suggests that the plants of the Kootenay formation are indicative of Jurassic time. In most parts of southwestern Alberta, the Kootenay-Fernie contact has been described as gradational. Since the uppermost dated fauna so far found in the Fernie formation is lower Upper Jurassic in age, the lack of a recognized time-break between the Fernie and Kootenay formations has naturally led to the conclusion that the Kootenay formation is partly or wholly Jurassic, and that the major time-break in the Jurassic-Cretaceous group occurs at the top of the Kootenay formation, where a disconformity has been recognized in both Alberta and Montana. The presence of an erosional unconformity at the top of the Fernie formation at Moose Mountain (Beach[15], p. 35), and the sharp, possibly erosional contact in the Highwood-Elbow area, however, tend to cast doubt upon the validity of the gradational contact reported elsewhere in southwestern Alberta. In the Highwood-Elbow map area, at least, the physical evidence is in accord with the paleobotanical evidence, indicating a Lower Cretaceous age for the Kootenay formation. Future study should be undertaken to indicate whether or not this is a regional or local feature.

Blairmore Formation.

Distribution:—The Blairmore formation underlies a large part of the valleys of the Highwood river and Storm creek, and adjacent areas. It also outcrops at the heads of Loomis, McPhail and Carnarvon creek.

Thickness:—Telemeter measurements in the vicinity of Lineham creek indicate a thickness there of about 2,500 feet for the Blairmore formation. In section 5, township 18, range 7, west of the fifth meridian, telemeter measurements gave a thickness of 3,300 feet.

Lithology:—The Blairmore group in this area consists of three members. The lowest member, for which the term *Pocaterra Creek member* is proposed, is absent southeast of Lineham creek, while the other two may be recognized throughout the area.

In southwestern Alberta, the base of the Blairmore formation is drawn at a chert pebble conglomerate, known as the basal Blairmore conglomerate, or the Blairmore conglomerate. This bed consists of pebbles of black, grey and green chert and white quartzite, in a siliceous sandy matrix[19]. In the part of the Highwood-Elbow map area, south and east of Lineham creek, a conglomerate bed which agrees lithologically with this conglomerate, occurs at the base of the Blairmore formation, and rests upon the eroded surface of the Kootenay formation. This conglomerate varies from about fifteen to twenty-five feet in thickness. It consists of black, grey and green chert and argillite pebbles, and white quartzite pebbles, which average about one inch in diameter, set in a light grey sandy matrix. The rock is highly indurated, and joints cut across matrix and pebbles alike. Lenses of coarse cross-bedded sandstone occur frequently in the conglomerate. A pebble consisting of silicified coral was found in this bed south of Fitzsimmons creek, indicating that the source of the materials was probably upper Paleozoic strata. As shown in the discussion of the Kootenay formation, there is probably a regional erosional unconformity below this bed.

In the rest of the area, strata similar to the Blairmore occur below a conglomerate lithologically indistinguishable from the basal Blairmore conglomerate, while the base of the group is drawn at the base of a conglomerate of a different character. The term *Pocaterra Creek member* is proposed for the group of Blairmore-like strata below the Blairmore conglomerate, and including the lower conglomerate. The name is derived from Pocaterra creek, near the headwaters of which this member reaches a maximum development. The thickness varies from 368 feet, at the head of Pocaterra creek, to 19 feet on Lineham creek, and this member apparently is completely absent a short distance south of Lineham creek. The following section of the Pocaterra Creek member was measured at the head of Pocaterra creek, in section 15, township 19, range 8, west of the fifth meridian:

Overlying bed (Blairmore conglomerate).

Erosional? contact

	Feet
Interbedded blocky grey to olive grey, and carbonaceous dark grey shale and fine grained, hard quartzitic sandstone, with minor grey to maroon limestone nodules and maroon shale	300
Coarse grey cherty sandstone with lenses of conglomerate, pebbles to one inch	42
Grey sandy shale and carbonaceous shale	12
Interbedded sandstone and conglomerate	14
Thickness of section	368

Erosional? contact

Underlying beds (Kootenay formation).

The lower conglomerate is readily differentiated from the normal basal conglomerate. The lower bed carries no green pebbles, and very few white quartzite pebbles. At any one locality, the lower is much finer. Frequently, the matrix of the lower is very fine and consists partly of chemically precipitated chert. The pebbles in the lower conglomerate vary from well-rounded to subangular, and at the head of McPhail creek, are angular. At some localities, the matrix is sandy, and west of Mist creek, occasional carbonized stems are present in the sandstone. The thickness varies from about 4 feet on Lineham creek to 68 feet, including non-conglomeratic beds, on Pocaterra creek.

The strata between the two conglomerates are typically Blairmore in lithology. The greater part of the strata consist of poorly bedded, blocky grey shales, but carbonaceous shales showing better bedding are also present. Thin beds of maroon shale are also present. Hard, fine grained quartzitic sandstones, which do not occur in the Kootenay formation but are present above the upper conglomerate, are present in the Pocaterra Creek member. Very irregular grey-green, honey-yellow and maroon limestone nodules, which reach a maximum diameter of eight inches, are also present, and, with the maroon shales, are characteristic of this member.

The relationships of this member to the underlying Kootenay formation are unknown. The change of lithology may be indicative of a break in sedimentation. Deposition of the conglomerate was probably accompanied by local erosion, but the areal relationships are unknown. The absence of cannel in the upper part of the Kootenay formation, below the Pocaterra Creek member, east of the Highwood river suggests that a small thickness of beds may have been removed by erosion prior to deposition of the conglomerate.

The top of the member is drawn at the base of a conglomerate which carries well-rounded black, grey, green and white pebbles of chert, argillite and quartzite, which become coarser to the northwest. On Storm creek, pebbles up to four inches in diameter are abundant. This conglomerate is indistinguishable, except for the larger pebbles, from the basal conglomerate at the southeastern portion of the map area, and is correlated with it. It is probable that the erosional unconformity below the basal conglomerate is also present above the Pocaterra Creek member. Where this member is not present, the Kootenay shows a marked thinning towards the southeast, from 2,100 feet on Picklejar creek, to between 700 and 800 feet near the Sentinel ranger station. The Pocaterra Creek member thickens from 19 feet on Lineham creek to 368 feet on Pocaterra creek, while the Kootenay formation shows only slight thickening in the same direction. Erosion prior to the deposition of the basal conglomerate appears to offer a reasonable explanation for these facts. If this is so, the Pocaterra Creek member is earlier in age than any other strata assigned to the Blairmore formation in the foothills of southwestern Alberta.

The Blairmore formation proper consists of two members separated entirely on the basis of lithology. The lower is predominantly grey, while the upper member is varicolored, with green predominating.

The character of the lower member of the Blairmore formation is shown in the following section, measured on Picklejar creek:

Overlying beds (Upper member of Blairmore group).

Contact conformable

	Feet
Shale and shaly grey sandstone, largely concealed	57
Freshwater limestone, light grey weathering, dark grey, pyritiferous towards base, with poorly preserved gastropods. Shaly towards top	34
Interbedded dark grey to light grey, rubbly weathering shales, sandy shales, and fine, hard, light grey quartzitic sandstone; becomes greenish grey towards top	450
Sandstone, fine, brownish to light grey, thin bedded, with a few scattered quartzite pebbles to 1 inch	24
Sandstone, hard, fine, quartzitic, and siliceous light to dark grey shales. Lenses of coarse sandstone with chert and quartzite pebbles at base	41

Underlying beds (Pocaterra Creek member).

Erosional? Contact.

On the Highwood river, about one mile below the mouth of Cat creek, a 50-foot group of dark grey calcareous shales and argillaceous limestones, which the included fossils indicate is marine, lies about 570 feet above the base of the member. A two-inch coal seam, with associated black carbonaceous shales, is present 75 feet above the base, on the lower part of Loomis creek. Apart from the variation in the conglomerate at the base, which has already been described, this member maintains the same general character throughout the area. The dark limestones near the top of the member are useful markers, as they tend to outcrop frequently. The dark blue-grey color, and the presence of non-marine fossils, which are sometimes numerous enough to form a coquina, are diagnostic.

The upper member of the Blairmore formation consists of greenish shales, sandy shales, sandstones and arkoses, with tuffs and maroon shales interbedded with normal sediments near the top. On Picklejar creek, the base is marked by a 31-foot bed of olive-green sandstone with lenses of pebble conglomerate. At other localities, a non-conglomeratic sandstone occupies the same position.

The most prominent marker in the upper member is a lensing igneous pebble conglomerate which occurs about 1,200 feet above the basal Blairmore conglomerate. The maximum development of this bed is in section 17, township 17, range 6, west of the fifth meridian, south of Loomis creek, where 85 feet of coarse conglomerate are overlain by 25 feet of soft green arkosic sandstone and 6 feet of poorly consolidated conglomerate (Figure 7). One and a half miles to the northwest, on Loomis creek, the igneous pebble conglomerate has been reduced to about ten feet of soft green arkosic sandstone with a few small igneous pebbles scattered along the bedding planes. The conglomerate normally does not exceed 10 feet in thickness, and with the associated sandstone, rarely exceeds 50 feet. The pebbles reach a maximum diameter of about 5 inches, with the finer pebbles usually in the thinner beds. Sorting, however, is not particularly good. The pebbles consist of black, grey and green chert and argillite, white green and rose quartzite, green purple and pink syenite, pink to purple feldspar porphyry, and rare pink granite and fine conglomerate. The syenites are the most abundant type of igneous pebble. Generally, the pebbles are well rounded.

East of the Highwood river and Misty range, a coarse brown arkose, approximately 600 feet below the top of the formation, constitutes a fairly reliable marker. This bed was not recognized west of the Highwood river. In section 11, township 17, range 6, west of the fifth meridian, this arkose measured 79 feet in thickness. The weathered surface shows a characteristic rough appearance. Microscopic examination shows that the rock is composed usually of altered orthoclase euhedra and grains, augite euhedra, fragments of tuff made up of recognizable chards, and a few argillite grains, in a dense greenish groundmass. It is probable that this bed is a normal sediment derived from the erosion of a nearby volcanic series. A similar arkose has been reported from the Moose Mountain area. (Beach[15], p. 40).

On the Highwood river, about half a mile below the mouth of Cat creek, a zone of green ellipsoidal calcareous concretions occurs in well-bedded green sandy shales, about 1,500 feet above the base of the group. These were not recognized elsewhere.

The larger part of the upper member, however, exclusive of the tuffs at the top, consists of soft green to grey green, olive green, and violet sandy shales, with irregular calcareous brown weathering grey to green concretions. Sandstone and arkose beds are present, and are usually brown in color, but constitute a minor component. Lenses of chert pebble conglomerate are sometimes present.

At least the upper 300 feet of the formation carry beds of volcanic tuff. The tuffs are of two types. The more abundant are hard, dense, dark grey to dark green, and occur in beds usually less than two feet thick. Rarely, quartz, calcite and zeolite occur as cavity fillings. Occasionally a pink powder is developed on the weathered surface. The other type is soft, green, and fairly coarse, and resembles a sandstone. The grains, however, are chards. Tuffaceous, brown weathering, calcareous nodules also occur in this zone.

Associated with the tuffs, and with a similar stratigraphic range, are beds of maroon shale, and mottled green and maroon shale, usually less than two feet in thickness. Soil derived from these beds retains the maroon coloration, and hence these beds form very valuable markers.

In the southwestern portion of the area, in the vicinity of McPhail and Carnarvon creeks, at or close to the top of the Blairmore formation, is a coarse, highly cross-bedded, white weathering, grey sandstone with lenses of fine chert and quartzite pebble conglomerate. This bed is over 20 feet thick, and forms an excellent marker in that part of the area. Northwards, this bed is represented by one to three beds of pebble conglomerate, and at the mouth of McPhail creek, by coarse cross-bedded sandstone.

A poorly consolidated conglomerate, consisting of polished pebbles of white quartzite, grey to black argillite, and very rare syenite up to 5 inches in diameter, occurs close to the top of the Blairmore formation on the ridge between Loomis and Odlum creeks. Many of the argillite pebbles are veined with quartz.

Age and Correlation: A small fauna, consisting of fresh-water gastropods, *Unio*, silicified sponge spicules, and *Chara*-like forms, was collected from the limestone horizon of the lower member of the Blairmore formation one mile northwest of Lineham creek. Dr. P. S. Warren, in a personal communication, states that this assemblage, largely undescribed, is commonly present low in the Blairmore.

On the Highwood river, in the calcareous shales about 570 feet above the base of the Blairmore, *Inoceramus* or *Aucella*, *Tellina*, *Unio*, and *Pleuromya*? are present, and point to marine conditions. This fauna also is present in the lower member.

Grammatodon? and *Astarte*? were obtained from a calcareous nodule within the tuff zone near the top of the formation, on the ridge between Odlum and Storm creeks. These also are indicative of marine conditions, but, lacking specific identification, cannot be used for age or correlation.

The Blairmore formation in the Highwood-Elbow area is correlated with the Blairmore formation in the foothills and the Crowsnest Pass largely on the basis of lithology, while the poorly preserved, fresh-water fauna in the limestone horizon corroborates the lithologic evidence. The age of the Blairmore formation in the

Crowsnest Pass is Aptian and Albian, of the Lower Cretaceous (Bell[17], p. 11), although the uppermost beds may be early Upper Cretaceous[20]. The tuffaceous zone at the top is correlated with the Crowsnest Volcanics, the age of which is probably early Upper Cretaceous.

If the correlation of the conglomerate above the Pocaterra Creek member with the basal Blairmore conglomerate is correct, then the Pocaterra Creeek member is earlier in age than the Blairmore formation in other areas. If so, it must either be late Barremian or early Aptian. It is possible that this member correlates with some part of the lower Blairmore succession in the Elk and other Mesozoic basins of southeastern British Columbia, where more than one conglomerate are present. The Pocaterra Creek member is included in the Blairmore formation because of the similarity of the lithology, although it is realized that it probably does not correlate with any part of the Blairmore group in the Crowsnest Pass, which is the type locality. Until the validity of the conclusions regarding these beds can be checked by observations in adjacent areas, it is thought best to retain this member within the Blairmore formation rather than to define a new formation.

Blackstone Formation.

Distribution:—The lower part of the formation is present along a synclinal axis in the Upper Highwood valley, and west of Mist creek. The entire formation is present west of the Highwood river, from Odlum creek to the southern border of the map area. This formation also outcrops a short distance east of Elk range. Small areas are underlain by portions of this formation southwest of Mist mountain, and on lower Baril creek.

Thickness:—Due to the soft and incompetent nature of the beds, this formation usually shows considerable deformation, and exposures are poor. Consequently, the determination of the thickness cannot be accurate. On Carnarvon creek, where the section appears to be least deformed, telemeter measurements indicated a thickness of about 1,100 feet. This thickness may be excessive.

Lithology:—The Blackstone formation is a marine series of grey to dark grey shales, with thin beds of fine sandstone, silty limestone, limy concretions, and decomposed volcanic glass.

The contact with the underlying Blairmore group has been observed at several localities (Figure 8). It is sharp, with no gradational features. In some localities, the Blackstone rests upon the Blairmore with no suggestion of erosion, while in others the contact is undulating and erosional. Chert pebbles are always present at the base of the Blackstone. These may be small, well-rounded pebbles the size of beans, scattered through the lowermost 6 inches of marine shale, or may be concentrated in lenses up to 2 feet thick, consisting of rounded to sub-angular chert and quartzite pebbles in a fine sandstone matrix.

The shales in the lower 200 feet of the formation are very fissile, dark grey in color, and frequently weather rusty. Ironstone concretions up to 3 feet in diameter are abundant in this part of the formation. In the lower 40 feet, lenses of fine to coarse, light grey calcareous sandstone, with well-rounded pebbles of chert, quartzite, and occasionally pieces of coal, are present, and may correspond to the "grit bed" of Turner Valley.

About 200 feet above the base of the formation there is a horizon marked by several beds of white to orange, micaceous bentonite-like, clay shale. These beds represent decomposed volcanic glass. The orange beds usually are cemented by calcite. Biotite crystals are common, and an altered mica is very abundant in some of the white beds. As many as five beds, varying in thickness from one-half inch to 2 feet, have been observed interbedded with dark grey shales in a 30-foot section.

The greater part of the formation consists of grey shales, with thin beds of silty sandstone, silty limestone, and more rarely, fine grained micaceous sandstone in beds usually less than 6 inches thick. The limy beds tend to weather buff to orange. A few ironstone concretions are present but these are not so numerous as in the lower 200 feet.

The upper 200 feet is lithologically similar to the shales of the overlying Bighorn formation. The shales become silty, and bluish grey in color and are less fissile than the lower part of the formation. Near the base of these shales there is a fine grained grey calcareous sandstone averaging 2 feet in thickness.

Age and Correlation:—In the lower 200 feet of the Blackstone formation, fish scales appear to be the only organic remains present. *Inoceramus labiatus* Schlotheim first appears close to the volcanic ash horizon, and persists for at least 300 feet upwards. The following forms were collected 400 feet above the base on the east bank of the Highwood river just above the mouth of Odlum creek:

Inoceramus sp.
Pelecypod unidentifiable
Prionotropis woolgari (Mantell)
Exiteloceras cf. *pariense* (White)
Scaphites sp. nov.
Fish scales

A large form of *Prionotropis* occurs occasionally about 500 feet below the top of the formation.

These fossils are indicative of Coloradoan age of the Upper Cretaceous (Turonian of the European chronology). The following three zones—fish scales, *Inoceramus labiatus* and *Prionotropis woolgari*—are typical of the Blackstone formation[21]. For this reason, the term "Blackstone" has been used rather than "Lower Alberta."

Bighorn Formation.

Distribution:—The Bighorn formation outcrops west of the Highwood river as two bands, the eastern extending from Loomis Creek valley to the southern margin of the map area, and the western from McPhail creek, south. Small areas at the head of Odlum creek are also underlain by this formation.

Thickness:—A well-exposed section on McPhail creek, measured by tape, was 613 feet thick.

Lithology:—The Bighorn formation is a marine series of sandstone and shale, with pebble beds near the upper part.

The following section was measured on McPhail creek.

Overlying beds (Wapiabi formation).

Contact conformable

	Feet
Grey to black chert pebbles up to 2 inches, average ¾ inch, in soft, shaly matrix with *Ostrea* sp.	1
Thin-bedded, fine grained, hard, buff weathering, grey sandstone with lenses of ironstone, and pelecypods	10
Concealed, probably shales	67
Sandstone, fine grained, grey	5
Concealed, probably shales	52
Hard, fine grained, thinly bedded, grey sandstone, with fucoids, and invertebrate tracks at base	4
Grey, poorly bedded sandy shales, becoming darker and more fissile downwards, with ironstone nodules. *Inoceramus* and *Scaphites*	80
Chert pebble bed, with soft sandy shale matrix, pebbles average ¼ inch, maximum size 1 inch, with pebbly ironstone	5
Chert pebble bed, average size ⅛ inch	1.5
Dark grey rubbly shale, with ironstone nodules	3
Thin-bedded, hard, platy, fine grained, light grey to brownish grey sandstone, sometimes ripple-marked, with minor ironstone and occasional shale beds to one foot; pelecypods and fucoids	61
Interbedded sandy shale and shaly sandstone in beds up to 4 inches	32
Interbedded grey sandstone to one foot, siltstone and fissile grey shale	25
Sandy, grey shale	21
Hard, grey sandstone	6
Grey, sandy shale	6
Brownish weathering, poorly bedded, grey sandstone, shaly towards base	20
Largely concealed, mostly shale	70
Hard, thin bedded but poorly bedded light grey to brownish sandstone weathering white to brown, with ironstone nodules, ripple marks and fucoids	6
Grey, white weathering, fine to medium grained sandstone with fucoids and worm burrows, becoming shaly towards base	7
Thin bedded, dark grey, sandy shale	35
Hard, dark grey, silty sandstone	4
Silty and sandy, dark grey shale	26
Grey, silty sandstone, with white weathering, dark grey clay nodules up to two inches	9
Grey, sandy shale	17
Bluish grey to grey, silty shales, silty, poorly bedded sandstone, partially concealed	41
Total thickness of Bighorn formation	613

Contact conformable

Underlying beds (Blackstone formation).

The sandstones of the Bighorn formation are distinctive, as they are usually hard, fine-grained and rarely calcareous. The upper sandstones, which are relatively hard, outcrop frequently, but the lower portion of the formation is usually not exposed.

The pebble beds are usually too soft to outcrop. Pebbly ironstone is not uncommon. A pebble bed near the top of the formation, consisting of 6 inches of well-rounded chert and quartzite pebbles averaging one quarter inch in diameter in a sandstone matrix, may be followed for over a mile north of Loomis creek. Well-rounded and polished, black chert pebbles up to one and one-half inches in diameter are scattered through the shales immediately above the lowest sandstone north of Odlum creek.

The base of the formation as mapped is drawn at the lowest sandstone which is over 3 feet thick. The upper part of the Blackstone as mapped is lithologically similar to the lower part, although without the thick sandstone beds. There is a possibility that the presence of lensing sandstones at the base has caused some stratigraphic variation in the position of the lower contact.

Age and Correlation:—Few fossils occur in the Bighorn formation as a whole, but locally organic remains are abundant. The fossils are usually not well preserved. The following forms were collected from this formation:

Invertebrate tracks
Worm burrows
Pinna sp.
Inoceramus cf. *mcconnelli* Warren
Pteria sp.
Ostrea (*Alectryonia*) sp. nov.
Liopistha? sp.
Cardium pauperculum Meek
Tellina? sp.
Mactra? sp.
Gastropods
Scaphites sp.

This assemblage is not diagnostic. *Cardium pauperculum* is Coloradoan, but has a long range. Close correlation is impossible, and these beds are referred to the Bighorn formation chiefly on lithological considerations.

Wapiabi Formation.

Distribution:—The Wapiabi formation is present in the southwestern portion of the area, where its outcrop closely parallels that of the Bighorn formation.

Thickness:—A section on Carnarvon creek, from the top of the Bighorn to the base of the lowest exposed Belly River sandstone, apparently unfaulted, was measured by telemeter, and was found to be 1,500 feet thick.

Lithology:—The Wapiabi formation consists of grey marine shales, with ironstone nodules and a few thin sandstone beds. Generally, the shales are lighter in color than the Blackstone formation. The numerous silty sandstones and limestones, which are characteristic of the Blackstone, are not present in the Wapiabi.

The contact with the underlying Bighorn formation appears to be sharp but conformable. The lower part of the formation consists of dark grey shales, with abundant ironstone nodules, while 300 feet above the base is a 2-foot bed of white, bentonite-like clay shale which, however, does not show appreciable swelling when wet.

The middle part of the formation is also made up of dark grey shales, which are quite fissile. Ironstone is not present in large quantities. Towards the top of the formation some ironstone occurs, the shales become sandy, and a few thin grey sandstone beds appear. The upper 200 feet of the formation are not exposed in the map area.

Throughout the greater part of the formation, fibrous calcite, derived from the shells of large specimens of *Inoceramus*, is quite abundant. This material is also present in the upper part of the Bighorn formation, but was never observed in the Blackstone formation.

Age and Correlation:—The fossils collected from the Wapiabi formation in the Highwood-Elbow area comprise several species of *Inoceramus*, *Scaphites ventricosis* Meek and Hayden, *Scaphites ventricosis* var. *oregonensis* Reeside, and *Baculites asper* Morton.

These forms are of upper Coloradoan age. They have been reported from many other areas of western Alberta.

Apparently throughout the foothills, the uppermost beds of the Wapiabi formation are of Montana age. Since these beds are concealed in the area, it is impossible to state whether beds of Montana age are present at the top of the Wapiabi formation in this area.

Belly River Formation and Later.

Distribution:—The Belly River formation is present in the southwestern portion of the area, and extends from Muir creek to the southern margin of the map area.

Thickness:—The thickness of these beds is unknown, as most of the formation is concealed. The maximum possible thickness, calculated from average dip values, on Baril creek is about 4,000 feet, with the upper part of the formation faulted off.

Lithology:—The lowermost bed of the Belly River formation which is exposed in this area is a platy to massive, sometimes cross-bedded, fine grained, grey, calcareous sandstone. Ripple marking is common. Fucoids and shale pellets are of frequent occurrence. This bed, which is either at or close to the base of the formation, does not appear to exceed 20 feet in thickness.

Exposures of the overlying beds are poor, and usually consist of isolated sandstone outcrops. These sandstones vary from fine to medium grain, are grey to greenish grey in color, and are usually of the "salt-and-pepper" type. Cross-bedding is general. Calcite appears to be an ubiquitous cement. Shale pellets, light grey, calcareous nodules, and scattered chert and quartzite pebbles are often present. Crushed and carbonized plant stems are abundant. These hard sandstones are more prominent in the lower than in the upper part of the formation.

Interbedded with the sandstones are blocky, poorly bedded, grey to olive-green shales. Small irregular, grey, limestone nodules which may weather pinkish are often present. A little carbonaceous matter is sometimes present.

The upper part of the formation in this area contains few hard beds of any kind. Both sandstones and shales are soft and poorly indurated. These beds are somewhat more greenish than the lower beds, wherever seen, but the very few exposures do not permit generalization. However, the almost complete lack of outcrop in this part of the formation indicates the non-resistant character of the beds.

Age and Correlation:—The only organic remains found in the Belly River formation consisted of plant fragments. Consequently, these beds are correlated with the Belly River formation of the foothills on the basis of stratigraphic position and lithology. The Belly River formation is assigned to the Upper Cretaceous and to the Montana group as known in the United States.

The upper strata assigned to the Belly River in the Highwood-Elbow area may be younger in age than the Belly River of the foothills, but no upward limit has been recognized in this area.

PLEISTOCENE AND RECENT

Unconsolidated deposits of Pleistocene and Recent age form a thin mantle over the bedrock in many parts of the area.

Glacial deposits are not widespread in the area, and were definitely recognized only in the vicinity of the Elbow river. The ridges extending east from Misty range both to the north and south of the Elbow are capped by an unknown thickness of boulder clay, with abundant large blocks of Paleozoic limestone. A few large erratics occur in other parts of the area, but these are readily distinguished from blocks which have rolled down into the valleys. A block of basal Blairmore conglomerate, about 6 feet by 6 feet by 8 feet lies on top of the ridge west of Cat creek, at an elevation of approximately 6,900 feet and about 1,000 feet above any outcrop of this bed in the immediate vicinity. It is believed to be a glacial erratic. Gravel dumps at the heads of a few creeks rising on the east side of the Elk range probably represent small terminal moraines of fairly recent glaciers.

Post-glacial deposits are much more widespread. Terraces along the Highwood river consist of gravels made up of pebbles and boulders of Paleozoic and Mesozoic rocks, with the Paleozoic materials predominating. There are about 40 feet of bedded gravels at the mouth of Cat creek, and these are believed to represent deltaic deposits. An unknown thickness of bedded gravels occurs near the mouth of Stony creek. Up to 100 feet of waterlaid gravel is present in the basin of Lineham and Picklejar creeks. Cementation of the Recent gravels by calcite, frequently in the form of travertine, is not unusual.

Calcareous tufa is being deposited by several small springs in the Highwood valley below Cat creek. The largest of these is on the south bank of the Highwood river, three-quarters of a mile below the mouth of Cat creek.

Chapter IV

STRUCTURE

General Statement.

The eight structure sections shown on the margin of the geological map accompanying this report (Plate 1), also Figure 12, show the structural relationships of the formations in this map area, and will be referred to by their respective numbers in describing the structure of the area.

The Highwood-Elbow area lies in the eastern part of the Rocky Mountains. The type of structure found there is similar to that in other parts of the front ranges. The relatively incompetent Mesozoic strata of the Highwood-Elbow area, however, exhibit structural features on a smaller scale than do the harder Paleozoic strata.

The Highwood range, on the east side of the map area, is a fault block, thrust up eastward on Mesozoic strata of the innermost foothills[22]. The southern portion of the area, might be considered part of this block. The structure is essentially a west-dipping monocline, broken by thrusts and minor folds, and limited on the west by the Elk range, another major fault block. In the northern part of the area, the monocline is interrupted by the Misty range fault block.

The general strike in this area is about north 20 degrees west, with deviations due to local structural conditions. Thus, about the south end of Misty range, strikes vary to east-west. The strata generally dip westwards at high angles so that dips of less than 45 degrees are not commonly encountered. There is a general southwards plunge which brings older beds to the surface to the north, and this feature is largely responsible for the northwards termination of the Highwood-Sheep coal basin.

West-dipping thrust faults, generally dipping at a high angle, control the principal structural features, but folding, not usually on a large scale, is also prominent. Oblique faults, trending slightly east of north, are usually on a small scale, but will probably be of considerable importance in the development of the coal deposits of the area.

West Slope of Highwood Range.

Included here is that portion of the area west of the Highwood range, limited on the west by the structures along McPhail creek and in Misty range. The structure is generally synclinal, with the above named units forming the west limb. The east limb, comprising most of this portion of the area, is interrupted by faults and a few folds.

There are three important west-dipping thrust faults in this portion of the area. The most easterly, called the First Fault in Chapter V, is in the western portion of township 17, range 5, west of the fifth meridian. Towards the southern end of this fault, displacement is so small that drag has almost removed stratigraphic displacement, but it increases rapidly northwards. In section 7, township 17, range 5, west of the fifth meridian, the strike of the fault trace swings from northwest to north, the change of strike coinciding with the appearance of Paleozoic strata above the fault plane. There has been considerable crumpling of the beds west of the eastern fault. The strike of these beds swings to the west, with south dips, resulting in a south-plunging structure which permits the rapid increase in displacement northwards along this fault.

The middle fault or Second Fault, was traced from the southern margin of the map area to the headwaters of Lineham creek. A short distance north of Baril creek, the middle band of the Kootenay formation is brought to the surface above this fault. The top of the Kootenay formation in the eastern band is cut off by the middle fault southeast of Cat creek, and the entire eastern band pinches out on Lineham creek (Figure 9). The dip of this fault was calculated from its trace through Cat creek to be about 45 degrees to the west.

The western fault or Third Fault, extends from beyond the southern margin of the map area to north of the Elbow river, where it appears to die out in Paleozoic beds. It is probably displaced by an oblique fault south of Fitzsimmons creek. Kootenay strata of the west band lie above the fault over most of its length, while the top of the middle band of Kootenay is truncated by this fault northwards from Cat creek. The fault is believed to dip westwards. The trace of this fault is fairly straight, so that the dip is probably high. Drag along the western fault has resulted in fairly complex folding in both the upthrown and downthrown blocks west of Cat creek.

A syncline, which is occupied by the upper part of the Highwood valley, extends from near the mouth of McPhail creek northwards as far as the Elbow river, and probably extends to the headwaters of the Little Elbow. Blackstone beds occur along the axis from McPhail creek to Mist mountain, and Blairmore, Kootenay and Fernie beds are successively brought to the surface farther north. The pitch of this fold is northwards to the neighborhood of Picklejar creek, where a reversal occurs. West of Mist creek the southward pitch was calculated to be about five degrees. Dips on both limbs are steep, and the western limb is frequently overturned. At the south end, the syncline is very tightly compressed. About two miles above the mouth of Mist creek, a fault cuts the east limb of this syncline, and a fault, disrupting the west limb, first occurs east of Mist mountain. Both faults are vertical. The centre of the syncline has been displaced upwards with respect to the limbs producing a horst. East of Misty range, the western limb is truncated by a narrow wedge of lower Kootenay and Fernie beds faulted on the east-dipping beds of the syncline. South of Storm creek, the anticline which forms part of the Misty range structure limits the syncline on the west (Plate 1), while in the vicinity of McPhail creek another anticline east of the Misty range structure lies to the west of the syncline (E-F).

An anticline and syncline, east of the Highwood valley syncline, extend southwards from section 10, township 17, range 6, west of the fifth meridian (C-D). Within the map area, these folds involve Blairmore, Blackstone, Bighorn and Wapiabi strata. The folds are slightly asymmetrical, but contrary to the usual relationships the axial plane dips steeply eastwards. Both folds pitch southwards. The strata of the east limb of the syncline have been displaced by the oblique fault south of Fitzsimmons creek, but it is not known whether the axis of the syncline has been similarly affected. These folds are not so tightly compressed as the Highwood valley syncline.

The other folds in the area are minor. A small anticline west of Sentinel ranger station brings Spray River strata to the surface, and the small area of Fernie beds in sections 8 and 17, township 17, range 5, west of fifth meridian, may lie along the axis of the accompanying syncline. Folding has also occurred in the eastern band of the Kootenay formation at the head of Cat creek (E-F). The Blairmore and Kootenay formations east of Misty range, have suffered considerable crumpling. The folds are overturned eastwards but are not recumbent. These folds die out rapidly along the strike and are probably the result of drag.

Throughout most of this part of the area, the dips are steep and, with the exceptions noted above, are westwards. In that part of the eastern band of Kootenay lying west of Stony creek, dips as low as 22 degrees to the west were recorded, but these are probably due to creep. On the steeply-sloping east side of the Highwood valley, between Lineham and Picklejar creeks, Kootenay strata, usually dipping west at steep angles, have been overturned at the surface by creep so that outcrops show dips to the east as low as 38 degrees.

McPhail Creek Structure.

South of Loomis creek and immediately east of the thrust fault, on the east side of the mountains along the continental divide, there is a large structural unit which is essentially anticlinal throughout most of its extent (C-D and E-F). On the east, this structure is limited by a west-dipping thrust fault. Its southern termination lies beyond the southern margin of the map area, while on Loomis creek, it appears to plunge steeply northwards.

The east limb of the anticline is vertical to overturned. In the region south of Loomis creek some dips are 90 degrees. The dip gradually increases southwards until between McPhail and Muir creeks the basal Blairmore conglomerate has been turned through 161 degrees, to dip 19 degrees to the west, with the top of the bed eastwards. South of this again the amount of overturning decreases so that dips range from 150 degrees to 120 degrees. The overturning has been accompanied by a thinning of the strata. On the east slope of Mt. Armstrong the Blackstone and Bighorn formations are only 515 and 330 feet thick respectively, while the normal thicknesses of these two formations are about 1,100 and 600 feet.

The structurally high point is at the head of McPhail creek, where Spray River strata are brought to the surface. Just north of Muir creek small recumbent folds overthrust to the east are present in Kootenay strata near the crest of the anticline. The west limb dips at 45 degrees or less to the west; part of the Spray River beds on McPhail creek are almost horizontal, but contain some small flexures a few inches across. A small thrust fault displaces the Fernie-Spray River contact at the head of McPhail creek. South of Muir creek, the west limb lies under the Paleozoic overthrust block and the structure exposed east of this block consists of an overturned and almost recumbent wedge of Cretaceous strata bounded on the east and west sides by thrust faults (A-B and C-D).

Immediately north of the middle branch of McPhail creek small folds occur (E-F). A drag fold beneath the Paleozoic overthrust exposes Fernie strata in a small area between Mt. Loomis and Mt. Bishop. North of the north branch of Loomis creek, in the Blackstone shales there is a small anticline which may correlate with a similar structure between Loomis and Bishop creeks.

In the northeast corner of township 17, range 7, between Odlum creek and the north branch of Loomis creek, there is shown on the accompanying map an oval-shaped area of the Bighorn overlain by the Wapiabi strata. The exact structure of this area has not been determined. On the north side the Bighorn strata strike east-west and dip 22 to 47 degrees to the south. The structure in this small area is not clearly defined because of the scarcity of outcrops. On the accompanying map the structure is shown as synclinal, although the possibility of a transverse fault truncating the structure cannot be disregarded. No evidence of such a fault was found in the Paleozoic beds to the west, or in the Cretaceous beds to the east. The abrupt change in strike in the Bighorn formation is ascribed to "squeeze" between the Misty range and McPhail Creek structures, which would produce an east-west trending syncline.

East of the McPhail Creek structure, as described above, there is a belt of Upper Cretaceous strata, mapped as about three miles wide south of Baril creek and narrowing northwards to less than one mile on Bishop creek. On the west side of this belt there is a fault extending from beyond the south boundary of the map, as far north as Bishop creek. The fault was not observed on Loomis creek where there appears to be no marked displacement in the Blackstone. No accurate determination could be made of the position and dip of this fault because exposures are few in the soft Upper Cretaceous beds. However, the overturning and thinning of the beds west of the fault suggest that the fault plane should be dipping westward at a lower angle than the beds above the fault (A-B and C-D). As the amount of overturning in these beds west of the fault decreases from Baril creek northwards, the dip of the fault plane increases (E-F). In one outcrop south of Carnarvon creek an east dip of 80 degrees in the Belly River strata is attributed to drag along this fault.

West Paleozoic Thrust Fault.

On the west side of the map area, the Elk mountains and the High Rock range constitute a fault block of Paleozoic strata thrust over the Mesozoic strata of the Highwood basin. In the southern part of the Highwood-Elbow map area, the trace of this fault is sinuous and hence indicates a low west dip for the fault plane. Farther north the dip increases, and on Pocaterra creek it is almost 70 degrees. North of Pocaterra creek, this fault is displaced eastwards by a large oblique fault. This is the only break observed in the major overthrust throughout the entire length of the map area.

A zone of black, carbonaceous gouge, 15 to 20 feet in thickness, and underlain by as much as 30 feet of highly jointed strata, was present below the Paleozoic thrust wherever it was observed. Angular fragments of sandstone and limestone were present in the gouge. Larger blocks of Blairmore and Kootenay strata, with the bedding not greatly disturbed, were observed immediately below the thrust at several localities south of Odlum creek. These were apparently detached from the parent body at depth and dragged up along the thrust fault. Two of these are sufficiently large to be shown on the accompanying map; one is at the head of Odlum creek, the other on the east slope of Mt. Armstrong.

Misty Range Structure.

The Misty range structure extends from south of Loomis creek to beyond the northern limit of the map area. It constitutes a large thrust block which is anticlinal at the south end, and shows some anticlinal features at the north. This uplift has brought to the surface the Paleozoic strata of Misty range.

The Misty range structure first appears as a small anticline in the Blairmore between McPhail and Bishop creeks and immediately west of the Highwood Valley syncline. North of Odlum creek the strike of the beds on the west limb swings westwards, and the structure broadens rapidly. Between Odlum and Storm creeks the amount of uplift increases, and Fernie strata appear at the surface on the west side of a thrust fault which begins south of Bishop creek (G-H).

The uplift on this part of the structure has been accompanied by crumpling of Fernie, Kootenay, and lower Blairmore strata, and small scale faults have also developed (G-H). An unusual structure shown on G-H is an east-dipping thrust fault of small displacement which occurs less than one mile west of the fault mentioned above. This fault was not observed on Odlum or on Storm creeks.

Paleozoic strata are brought to the surface north of Storm creek, in a south-plunging anticline, which is cut on the southwest corner by an oblique fault with a north-south trend. The relationship of this anticline to the faulted structure south of Storm creek is not clear. It is believed that the soft Mesozoic strata have undergone greater deformation than the more competent Paleozoic strata, and that the details of the structures north and south of Storm creek will not correspond.

On the east slope of Mist mountain, a west-dipping thrust has developed in the east limb of the anticline of Paleozoic strata. East of the fault the Spray River and Fernie formations, and possibly the lower part of the Kootenay formation, are greatly thinned or are in part concealed by the overthrusting. At the head of Mist creek, the plane of the thrust fault dips westwards about 60 degrees (Figure 10). The minimum dip is probably only slightly less. Northwards from Mist mountain the thrust fault was traced about two miles beyond the northern boundary of the map area. There, the Paleozoics suddenly plunge northwards, with almost 90 degrees of dip, in a faulted anticline.

A west-dipping thrust, truncating the western limb of the Highwood Valley syncline, and bringing a narrow wedge of Fernie and lower Kootenay strata to the surface, parallels the Misty Range thrust fault south of the Elbow river. At the head of the Little Elbow river an oblique thrust fault which brings up Paleozoic strata below the Misty Range thrust, deviates from the main fault.

The belt of Mesozoic rocks lying between the Misty range and the Highwood range is cut off by this oblique fault.

Most of the Paleozoic beds in the Misty range dip steeply westwards. In the vicinity of the pass at the head of the Elbow river the beds are nearly vertical, resulting in "sawtooth" profile (Q-R). Folding is not common but there is a series of tight folds at Mt. Rae. These tight folds pass into a thrust fault northwards at Elpoca mountain. The lower part of the Banff formation (Paleozoic), which is exposed along the east face of the Misty range, is shaly and frequently shows small sharp anticlines with axial planes dipping westward.

The thrust fault which is developed from the folds in Mt. Rae was traced northwards (beyond the margin of the map area), where it was found to form the western limit of the southern part of the Cascade Mesozoic basin. Spray River beds occur beneath this thrust fault in the drainage depression west of Tombstone mountain and northwards. Another fault, probably a steeply west-dipping thrust fault, appears a few hundred feet east of the first fault and at the north boundary of township 20. Between the two faults there is a block of uppermost Paleozoic and Spray River beds dipping at 80 degrees to 90 degrees to the east.

North of the Elbow river the large oblique fault previously mentioned in connection with the Paleozoic overthrust, displaces the greater part of the Misty range structure. This fault does not extend as far north as the Misty Range thrust fault. Numerous other small oblique faults occur on the west slope of Misty range. These are considered below.

Structure Along Storm and Pocaterra Creek.

This part of the area may be considered the west flank of the Misty range structure. The strata here are the less competent Mesozoic beds, and have been more highly deformed than the Paleozoic rocks of Misty range. On the west, these Mesozoic beds are limited by the Paleozoic thrust fault. (Northwards, the Spray River strata pinch out against the Paleozoic thrust fault about five miles beyond the north boundary of the map area). Folding is more prominent in this part of the area than in any other, and thrust faulting is of less importance (Figure 11). Oblique faults are prominent.

In most cases, the folds in this part of the area are sharp, but small, and generally cannot be traced for any great distance. "Crumpling" would possibly be a more accurate term than "folding". West of Storm creek, between townships 18 and 19, however, an anticline and syncline are sufficiently well-defined to be traced for about five miles. These folds reach a maximum development near Highwood pass, and gradually change into minor folds both northwards and southwards. Northwest of the large oblique fault north of Pocaterra creek, the Kootenay formation is folded into an anticline with a syncline on either side of it, but these folds do not persist (S-T). Throughout the rest of this part of the area the strata are broken by numerous small folds, frequently asymmetrical, with the axial planes dipping steeply westwards. The effect of this minor folding has been to broaden the width of outcrop of the various formations out of all proportion to their increase in thickness.

Thrust faulting is of minor importance in this part of the area. Two faults of small displacement occur west of Mist mountain. Another fault, on which the displacement is not great, is present just east of the Paleozoic thrust fault between Mt. Tyrwhitt and Storelk mountain. Of much greater importance are the oblique faults in this part of the area, which are considered separately.

In the vicinity of Highwood pass, creep has caused the upper part of the Spray River formation, normally steeply west-dipping, to be overturned down hill, so that at the surface these beds have a moderate eastward dip. The Spray River formation appears to be particularly susceptible to minute folding, in spite of the brittle character of the beds at the surface. Very frequently, small folds usually less than three feet across are present in the platy, silty carbonate beds.

Oblique Faults.

At many localities in the Highwood-Elbow area, faults oblique to the general structural trends have been observed. Although the horizontal displacement along most of these faults is less than 100 feet, it is obvious that these faults will be of considerable importance in any coal mining operations which may be undertaken in the future. Only the larger oblique faults are shown on the geological map. Most of these faults which were observed occur along the west side of Misty range, but such faults are also present in several other localities.

The oblique faults strike slightly east of north, at an angle of about 30 degrees to the general strike of the displaced beds. The trend and angle of dip of these faults are not known definitely in most cases. On the west side of the Misty range, in a few cases, the faults are practically vertical, and no evidence was obtained to indicate that any of these faults have a low dip. With only two minor exceptions, the downthrow side on these faults is to the west. Displacement along one fault south of Fitzsimmons creek is known to have had a large dip-slip component, but in the other faults observed, no evidence was found to indicate whether movement was parallel to the dip or to the strike, or to a combination of both. Where an oblique fault passes through hard or brittle strata, brecciation occurs for a few feet on each side of the break, and close jointing extends for only a short distance beyond the zone of brecciation.

The largest number of oblique faults observed occurs along the west side of the Misty range. Here these faults displace the Spray River-Paleozoic contact and consequently are readily detected. At least twelve small faults were observed. Ten of these are immediately north of the Highwood pass, one is west of Mist mountain, and one is at the southwest corner of the Misty Range anticline. The trace of each of these faults through the hard Paleozoic strata is marked by a narrow gully, which has been eroded in the fault breccia, and a deeper but less regular gully is generally present along the trace of the fault in the lower part of the Spray River formation. One of the group of faults just north of the Highwood pass was traced through the Spray River formation and into the Fernie formation. In most other cases, lack of exposures does not permit tracing these faults for any considerable distance. In about section 13, township 19, range 8, one of the oblique faults shows the downthrow side to the east, but in all other cases the downthrow side is to the west.

A major oblique fault extends across Pocaterra valley near the top of township 19, through the west arm of the Highwood Mesozoic basin, and most of the way across the Misty range structure (see Plate 1). This fault could not be traced continuously along its length. Displacement of the Mesozoic-Paleozoic contact on the west side of the Elk mountains has been noted above. The Paleozoic thrust fault is believed to be displaced by this oblique fault, although an abrupt and local change in strike would also produce the same effect. Kootenay strata on the north side of the fault are adjacent to Fernie and Spray River beds on the south side of the oblique fault, west of Elpoca mountain. On the east side of the basin, Fernie strata are adjacent to Paleozoic (S-T). There can be no doubt of the displacement in the south end of the Cascade basin, east of Mt. Jerram. The alignment of the localities where oblique faulting has taken place, suggests that one fault with a northeasterly trend extends from Pocaterra valley to the area east of Mt. Burney. Immediately south of this large fault, two oblique faults in the Highwood basin were mapped. The displacement of the major overthrust faults by this large oblique fault shows that the oblique faulting is later in age than the principal movements in this area.

At the head of the Sheep river, on the west slope of the Highwood range, an oblique fault is present, trending about north 35 degrees east. This fault has displaced Paleozoic and early Mesozoic beds. On the north side of this fault gentle dips and gentle folding occur, while on the south side the strata appear to dip uniformly and fairly steeply to the west.

Only one other large oblique fault was recognized in the Highwood-Elbow area. This fault, south of Fitzsimmons creek in the southern portion of the area, displaces Wapiabi, Bighorn, Blackstone, Blairmore and Kootenay beds, and probably displaces a thrust fault. As mapped, the width of the outcrop of the Kootenay formation east of the fault is considerably wider than that west of the fault. The trend both of the Blairmore-Kootenay contact and of the thrust fault to the east of the Kootenay strata suggests a displacement by an oblique fault. This oblique fault has a downthrow on the west side.

Several other minor oblique faults too small to show on the accompanying map were observed along the Highwood river in the vicinity of the area where prospecting for coal has been undertaken. In the southwest quarter of section 6, township 17, range 5, two small oblique faults displace the basal Blairmore conglomerate. Another oblique fault may be present cutting the basal Blairmore conglomerate in the northern part of the same section. In section 28, twonship 16, range 5, displacement along an oblique fault of the Blairmore-Kootenay contact is about 100 feet. In section 5, township 17, range 5, the Kootenay-Fernie contact shows a vertical displacement of about 50 feet, with the downthrow side to the east.

Only a few oblique faults were found cutting the coal-bearing strata. It is possible that others are concealed. Although the displacement is usually small, it is great enough to add materially to the problems of coal-mining in this area.

CHAPTER V.

ECONOMIC GEOLOGY

COAL

General Statement.

The Highwood-Elbow map area comprises a portion of the Highwood Coal Area (see index map, Plate 1). Coal was first reported in this area by G. M. Dawson[1]. Prospecting on Sheep river was commenced early in this century by the P. Burns Coal Mining Company, and by 1922 an exploratory tunnel 2,250 feet in length, besides numerous smaller tunnels and trenches had exposed several seams of coal. After 1922, very little work was done on this property until 1944, when Allied Industrials, Limited, excavated a small open cut. On Highwood river, H. A. Ford, of Calgary, opened up numerous prospect tunnels in the vicinity of Cat creek, a few years prior to 1922, and a limited amount of work was continued subsequently. In 1944-45, Highwood Coal Mines, Limited, now the Ford Highwood Collieries, exposed coal seams in several cuts, most of which are a short distance west of the Sentinel ranger station. Prospecting on Pocaterra creek was carried on by G. W. Pocaterra following the first Great War. However, in spite of the intensive prospecting, no mines have operated in the Highwood-Elbow area.

The economically-important coal in the area occurs in the Kootenay formation of Lower Cretaceous age. In the southeastern portion of the area, the economically-important coal seams lie in the lower two-thirds of the formation, but to the northwest, coal is distributed throughout the Kootenay. The seams have been involved in the faulting and folding of the adjacent strata, and in many cases have suffered more severe deformation than the accompanying sandstone and shale. The resultant metamorphism has raised the rank of the coal to low volatile bituminous over most of the area, and to semi-anthracite in some, but not all, of the seams on Sheep river.

FORD COAL PROPERTY

The Ford property on the Highwood river consists of a block of coal-mining leases extending from Picklejar creek, where they adjoin the Burns property, to about three miles south of Highwood river, in township 16, range 5, west of the fifth meridian. The Ford Highwood Collieries obtained an option on this property in 1944, and in the winter of that year and the first two months of 1945, commenced preliminary prospecting of the coal-bearing beds adjacent to the north side of Highwood river and Cat creek. This prospecting was limited to the excavation of eleven open cuts by bulldozer and shovel on the outcrop of the Kootenay formation (Figure 12). A well-equipped camp has been built west of Sentinel ranger station and east of the first band of coal-bearing beds (Figure 14).

Thrust faulting has caused repetition of the Kootenay formation, so that in the southern part of the property, three bands of coal-bearing strata are present, which may be referred to as the Eastern, Central and Western bands. The eastern band pinches out in Lineham Creek basin against the thrust fault to the west of it known as the First Fault. The two other bands are continuous to the northern boundary of the property. Figures 13A and 13B show the positions of the eastern and central bands.

Eastern Band

Location.

The eastern band of the Kootenay in the Ford property, crosses the Highwood river about one-half mile west of Sentinel ranger station. South of the Highwood river, it forms a ridge which extends at least as far as Cataract creek. The eastern band becomes involved in the *First Fault* (see page 38) about two miles north of the Highwood river and swings to the west, but resumes a normal strike in section 12, township 17, range 6, west of the fifth meridian. This band crosses Cat creek and pinches out against the *Second Fault* (see page 39) in the valley of Lineham creek.

Structure.

The southern part of the eastern band strikes about north 35 degrees west and dips towards the southwest. South of the Highwood river dips average about 60 degrees to the southwest. On the north side of the river dips are frequently as low as 25 degrees to the southwest. The *First Fault* cuts the eastern band in the northeast quarter of section 6, township 17, range 5, although the displacement is probably less than 200 feet. However, on the west side of the *First Fault* the strike of the Kootenay formation swings to about north 70 degrees west. In section 12, township 17, range 6, west of the fifth meridian, the continuation of the eastern band meets the *Second Fault* and the strata assume a more normal strike of north 25 degrees west. Northward, the Kootenay formation is gradually cut out by the *Second Fault* and the last of the coal-bearing beds pinch out in Lineham Creek valley. The northern part of this band shows minor folding. Drag has occurred along the *First Fault* and the beds are badly twisted between the *First* and the *Second* Faults. A small transverse fault cuts the base of the formation almost two miles north of the Highwood river. A small fault is suspected to cause a repetition of about 100 feet of beds just north of the Highwood river.

Coal Exposures.

A number of prospect cuts have been opened on the eastern band, exposing considerable coal. In addition, a few outcrops occur (Figure 14).

Cut 1. (Figures 12, 13A and 14). This cut lies above the road on the north bank of the Highwood river. It is about 800 feet in length. The cut is mostly in superficial deposits, largely till, but has been deepened to bedrock in places to expose the coal seams (Figure 15). The following section is exposed in Cut 1 and along the adjacent road:

Top of the Kootenay formation	Feet	Inches
Sandstones and shales	335	0
Coal, shaly, and carbonaceous shale	2	0
Sandstone and shale	84	0
Coal, badly crushed and mixed with carbonaceous shale	5	6
Sandstone and shale	161	0

Coal (concealed by slumping; information from company officials), *Egbert seam**		7	6
Sandstone and shale		156	0
Coal, with irregular lenses of shale, *Connors seam* (sample No. 6)**		7	2
Sandstone and shale		104	0
Coal, thin shale partings, *Douglas seam* (samples 7 and 8)		12	4
Sandstone and shale		153	0
Coal, fairly hard (sample No. 9)	*Holt seam* (samples 10 & 11) (Figure 15)	3	11
Shale, carbonaceous to silty		3	7
Coal, crushed		1	5
Shale		0	1
Coal, crushed		3	0
Shale		0	1
Coal, crushed		3	2
Shale		0	6
Coal, crushed, becoming shaly towards base		10	6
Sandstone and shale		40	0

Base of the Kootenay formation

* The names of the seams are those applied by the Ford Highwood Collieries.
**These sample numbers refer to samples taken for analysis. Table 2.

There are 56 feet 4 inches of coal in a total section of 1,092 feet.

The coal in this cut is all very friable and badly crushed. The faces of the seams are coated with white salts, which may be due to decomposition of iron sulphide in the soil or may be derived by leaching from the overlying unconsolidated deposits or from the mineral matter in the coal. At no point is coal exposed more than twelve feet below the surface of the coal. As will be shown in the discussion of the correlation of the seams of the eastern band, the *Egbert* may be a repetition of the *Connors*, due to faulting (Figure 13A).

Cut 11. (Figure 14). This cut, in about legal sub-division 16, section 32, township 16, range 5, west of the fifth meridian, is shallow and has not exposed much coal. The following section was measured:

	Feet	Inches
Shale	3	0
Coal	1	6
Shale, carbonaceous	2	8
Coal	1	7
Shale, carbonaceous	0	6
Coal and shale	3	6
Shale		

Cut 10. (Figure 14). This cut is in legal sub-division 1, section 5, township 17, range 5, west of the fifth meridian. One seam is exposed but slumping has obscured the detailed structure of the coal. The seam dips about 40 degrees to the west. The coal is powdery and weathered. A thickness of 24 feet of coal was measured but the actual thickness may be less, if creep has caused the rather low dip.

Cut 6. (Figures 14, 16). This cut is in legal sub-division 7, section 5, township 17, range 5, west of the fifth meridian. The following section is exposed:

	Feet	Inches
Sandstone roof		
Contorted powdery *coal*	30	0
Shale and shaly sandstone	23	0
Coal, highly contorted and crushed, with shale partings (see Figure 16)	32	0
Shaly sandstone	15	0
Coal, shaly	1	0

Shale	1	5
Coal, shaly, and carbonaceous shale	2	0
Shale, sandy	12	0
Coal and shale	16	0

This cut is about 10 feet deep at a maximum and has not penetrated below the highly-weathered portion of the coal. All the thicker seams show considerable internal folding. The strike has swung almost east-west and the sandstones above the coal show a dip of 42 degrees to the south. A small local disturbance has probably caused the contortions (Figure 16).

Cut 9. (Figure 14). This cut is in legal sub-division 12, section 5, township 17, range 5, west of the fifth meridian. One 9-foot seam of badly crushed coal is exposed and a few thin seams occur along the road below the cut. The beds dip 37 degrees in a southwesterly direction.

Cut 5. This cut is on a tributary of Cat creek, in the northeast quarter of section 12, township 17, range 6, west of the fifth meridian. The cut is about 220 feet long and exposes about 155 feet of strata. The east end of the cut coincides with the base of the Kootenay formation. When examined, only one seam was partially exposed at the west end of the cut. About 4 feet of coal were visible. Bloom in the bottom of the cut suggests that three other seams may be present below this seam, but their thicknesses are unknown. They may, however, represent blocks of coal lodged in the unconsolidated material above bedrock.

Other Exposures:—Coal is poorly exposed through the rest of the eastern band. Four feet of weathered coal are exposed on the bulldozed road, 1,700 feet southeast of Cut 11. Between Cuts 10 and 11 coal is encountered and for a few feet the road follows a seam, but neither top nor bottom of the seam is exposed. This material is mostly bloom.

On the road north of Cut 6, a few feet above the base of the Kootenay formation, the following section is exposed:

	Feet	Inches
Coal	3	0
Shale	3	0
Coal	0	6
Shale	2	6
Coal	2	0
Shale	3	6
Coal	5	0
Shale	2	2
Coal	2	0
Shale and sandstone, to base of the Kootenay formation	30	0

The coal in this cut is weathered and dirty.

On the small creek flowing south through section 6, township 17, range 5, west of the fifth meridian, at least 15 feet of coal, associated with carbonaceous shale, outcrop. On Cat creek the eastern band is largely concealed. On the divide between Cat and Lineham creeks, an old trench has exposed about 8 feet of coal. Between Cat creek and the Highwood river, coal showings are frequent in the burrows of small animals.

Correlation of Seams.

The stratigraphic position is based upon a plane-table survey. As far as possible the coal seams have been related to the base of the formation rather than to the upper contact, which has suffered erosion.

The only coal which may be correlated with the *Holt* seam of Cut 1 appears to be the series of thin seams occurring near Cut 6. This horizon is not well exposed elsewhere.

The *Douglas* seam occupies approximately the same horizon as the coal in Cuts 9 and 10. The slight difference in position would be readily accounted for by small changes in dip in concealed intervals between the coal and the base of the formation. The variation in thickness of these seams is not great enough to make this correlation unreasonable.

The coal in Cuts 6 and 11, and on the bulldozed road south of Cut 11, will probably correlate. The seams in Cut 6 have been thickened by folding. However, the thickness is so much greater than in the other exposures that the authors consider that some of the coal may be concealed in these cuts. In Cut 1, the *Connors* seam may correlate with the lower part of the coal in Cut 6, in which case more coal may occur above the *Connors* seam. That interval is not well exposed.

The *Egbert* seam in Cut 1 does not seem to correlate with any of the coal exposed farther north. According to the mine officials, this seam is seven feet six inches in thickness, which is very similar to the thickness of the *Connors* seam. The section at Cut 1 shows a thickness of 1,092 feet of beds in the Kootenay formation. It was shown in Chapter IV that the average thickness of the Kootenay is 750 to 850 feet in this part of the area and that approximately 100 feet of beds, present near Cut 1, have been removed from the top of the formation farther north. This leaves 150 to 200 feet of beds unaccounted for. The authors suggest that faulting has caused a repeat of the *Connors* seam in Cut 1 and that the *Egbert* seam is the same as the *Connors* seam.

Insufficient data are available to correlate most of the other exposures with the seams in the south end of the eastern band. At Cut 5, however, there is an indication of coal about 40 feet above the base of the Kootenay, which is the approximate horizon of the *Holt* seam. The seam in Cut 5, 155 feet above the base, may correlate with the *Douglas* seam, although it is a little low stratigraphically.

Seams 000 to 4, inclusive, on Cat creek, as described by Allan[6], lie to the west of the *Second Fault* and to the east of the *Third Fault*, and therefore belong to the eastern band. Seam 000, which appears to be the most easterly, probably correlates with the *Holt* seam. The other seams cannot be correlated. Some of the old prospects in the eastern band are on the same seam, only at different places along the strike of the beds, and hence some of the seams mentioned by Allan may represent the same seam.

Central Band

Location.

In the central band the Kootenay strata are brought to the surface by the *Second Fault* a thousand feet north of Baril Creek (Figure 13A). Basal Kootenay beds are first exposed southeast of Cat creek. This band extends north through the Ford property and into the Burns property, in continuous outcrop.

Structure.

The central band is brought to the surface by the *Second Fault* and for most of its length, the upper beds are cut off by the *Third Fault*. Transverse faulting has probably taken place in this band south of Cat creek. A fold occurs in the upper beds between the Highwood river and Cat creek, and at least two sharp anticlines occur in the canyon of Cat creek. The beds in the long ridge west of Cat creek are somewhat folded, and on the west side drag has caused some folding along the *Third Fault*. North of Lineham creek, only the lower part of the formation is present. The eastern side of the central band shows fairly low dips, while the western side, closer to the fault, shows dips of 60 to 80 degrees to the west.

Coal Exposures.

The central band has not been prospected by Ford Highwood Colleries to as great an extent as has the eastern band. Four cuts have been made on a hill in section 31, township 16, range 5, west of the fifth meridian, while one cut has been opened near Cat creek.

Cut 2. This cut lies near the base of the hill mentioned above, on the south side, and is a slight widening of a bulldozed road. The following section is exposed:

	Feet	Inches
Shale roof		
Powdery *coal*	1	7
Shale	0	½
Coal, hard, glossy, brittle (sample 5)	2	2
Shale, highly carbonaceous	1	0

This coal occurs about 800 feet below the top of the Kootenay formation.

Cut 4. A large but contorted seam, called the *Glover* seam by the mine officials, is exposed in Cuts 4, 4a and 7, which are in alignment up the side of the hill. In Cut 4 (Figure 17), the seam is somewhat folded. The footwall strikes between north 10 degrees west, and north 20 degrees west, and is about vertical with minor undulations. The hanging wall of the seam strikes north 30 degrees west, but dips to the west at 45 to 50 degrees. This results in a wedge-like seam. The greatest horizontal width of the *Glover* seam in Cut 4, normal to the strike, is 48 feet. The coal is highly crushed and slickensided. Small patches of iridescent coal are present. Lenses of shale, apparently pinched out during folding, occur in the seam. Samples 1, 2, 3, and 4 were collected from this seam. The *Glover* seam lies about 1,100 feet below the top of the Kootenay formation (Figures 13A and 17).

Cut 4a. The *Glover* seam here strikes north, 35 degrees west and dips 65 degrees to the west. The coal is closely folded and badly crushed. Shale partings show minor faulting. The following section was measured:

	Feet	Inches
Shale roof		
Coal	4	5
Shale	0	1
Coal	2	0
Shale	0	2
Coal	0	4
Shale	4	9
Coal and shale, highly contorted	15	20
Shale floor		

Cut 7. This cut, also on the *Glover* seam, at the top of the hill, exposes very little bedrock. There appears to be less than 10 feet of coal present.

Cut 3. This cut lies on the south bank of Cat creek in section 12, township 17, range 6, west of the fifth meridian. The bottom of the cut is in badly weathered rock, and consequently only weathered coal is exposed. The true character of the coal is not known. The following section was measured:

	Feet	Inches
Shale and sandstone roof		
Coal	4	6
Shale	1	0
Coal	0	8
Shale	0	2
Coal	0	1
Shale	1	6
Coal	0	10
Shale	1	0
Coal	0	8
Shale floor		

This section is probably not representative of the coal at depth. The coal lies about 560 feet above the base of the Kootenay formation. Due to folding, its position with respect to the top of the Kootenay formation is not known, but is probably lower than the *Glover* seam.

Other Exposures.

A 10-foot seam of coal is exposed about one-third of a mile above the lower end of Cat Creek canyon. The seam is crushed, but has very few shale partings. The bed is dipping vertically. This seam lies about 1,200 feet below the top of the Kootenay. Two hundred feet upstream, the zone exposed in Cut 3 crosses Cat creek, but is poorly exposed. Showings of coal are abundant on the ridges to the north of Cat creek, which are underlain by Kootenay strata of the central band. Bloom on the bulldozed road north of Cut 3 suggests that coal is present within a few feet of the base of the Kootenay.

Seams 5 to 9 inclusive (Allan[6]) occur in the central band.

Correlation of Seams.

Largely because of the folding which the Kootenay strata of the central band have undergone, the exact stratigraphic position of the coal seams is not known and correlation is difficult. The 10-foot seam on Cat creek may correspond to the *Glover* seam, as it apparently lies at about the same distance below the top of the formation. This correlation is tentative, as minor structures would influence the apparent stratigraphic position of both these seams.

Correlation of the seams in the central band with those of the eastern band is probably impossible. This central band apparently is much thicker than the eastern band since the *Glover* seam lies about 1,100 feet below the top, while the maximum thickness of the eastern band is only about the same amount. The bloom seen on the road north of Cut 3, however, apparently occupies a similar stratigraphic position to the *Holt* seam. The coal in Cut 3, lying about 560 feet above the base, may correspond to one of the thin seams above the *Egbert* seam. The other seams could be correlated.

The Glover Seam.

The Glover seam (Figures 13A and 17) shows a progressive thickening from less than 10 feet in Cut 7, to 27 feet 7 inches in Cut 4a, and to 48 feet in Cut 4. The *Second Fault* lies about two hundred feet east of these three cuts. To the west there is a small syncline and an anticline. Internal folding in the seam has taken place. Part of the movement along the *Second Fault* probably took place within the *Glover* seam and the great increase in thickness represents a "swell" due to this movement. It is possible, too, that some of the thickening is due to closer proximity of the lower exposures to the synclinal axis. If this explanation is correct, great variations in thickness of the coal seam would be expected both up and down dip, and along strike. The thickness of almost 50 feet shown in Cut 4 must be regarded as purely local.

Western Band

Location.

The western band of Kootenay strata also crosses the Ford property and is continuous into the Burns property. It is brought to the surface by the *Third Fault* (see p. 39) on Baril creek, and is also present north of the Highwood river, but may not be continuous between the two points. It continues northwestwards and crosses Cat creek at the lower end of the canyon. It forms the crest and much of the western slope of the ridge that lies east of the Highwood river.

Structure.

South of Lineham creek the lower part of the Kootenay formation is cut off at the surface by the *Third Fault,* but north of the creek the entire formation is present. Southwards, towards the Highwood river, the outcrop narrows as more beds are cut out by the fault, and between the Highwood river and Fitzsimmons creek, where all exposures are concealed by alluvial deposits, Kootenay strata may not occur. South of Fitzsimmons creek, an oblique fault crosses the trace of the western band, and south of this fault, a broad outcrop of the Kootenay formation is present which apparently extends south of Baril creek for some distance. In the southern portion of the Ford property, drag-folding is marked, but the folding dies out north of Lineham creek.

Coal Occurrences.

No development work has been done on the western band by Ford Highwood Collieries. Seams 10 and 11 (Allan[6]) , are in this band. Thin beds of coal occur near the fault on Baril creek, but are very highly distorted.

On the ridge south of Lineham creek, coal showings are quite abundant in piles of dirt brought to the surface by burrowing animals. About 400 feet above the base of the Kootenay formation, one burrow showed blocks of coal up to three inches long, two inches wide and one-half inch thick. This is clean-looking coal and does not show the crushing so prominent in other coals at the outcrops which are seen on Ford property. Showings in burrows are also common north of Lineham creek.

Correlation of Seams.

Due to the few exposures, no correlation can be made with certainty. Some showings indicate that coal is present at the horizon of the *Holt* seam. The showing are restricted to the lower part of the formation. The upper 500 feet of beds in the Kootenay appear to be barren.

BURNS COAL PROPERTY

The Burns property extends from Rae creek on the north to Picklejar creek on the south and includes the northward continuation of the central and western bands, and much of the Kootenay brought to the surface east of the Misty range. While a great deal of work has been done on this property in the past, the tunnels have caved in or have been blocked. Allied Industrials, Limited, opened one cut, from which a small tonnage of coal is said to have been extracted for testing purposes.

Structure.

The geological map (Plate 1) shows that the central and western bands of Kootenay strata which cross the Ford property, continue north of Picklejar creek into the Burns property.

The continuation of the central band comprises only the lower beds of the Kootenay formation, the upper having been cut out by the *Third Fault*. The dip of the beds varies, usually being lower in the eastern part of the band and higher on the west. The prevailing dip is towards the west, but drag folds are common close to the fault. At the head of Cliff creek, the base of the Kootenay formation is displaced slightly by a very low angle thrust fault which apparently is represented a little farther north by closely folded shales and thin sandstones in the lower beds of the Kootenay. The northern extension of this zone passes into the bottom of the Sheep River valley where exposures are few. The central band apparently pinches out against the *Third Fault* near Burns creek.

A measurement of the Kootenay beds in the western band on Picklejar creek indicated a thickness of 2,100 feet. This must be considered a maximum value, as minor structural conditions may have resulted in thickening. The Kootenay strata probably maintain a constant thickness throughout the western band except where some beds are lost by faulting and erosion.

This band extends almost completely across the property. The base of the Kootenay lies on Fernie beds brought up along the *Third Fault*, except for a short interval east of the headwaters of Mist creek, where the lowermost beds are pinched out at the surface. This band is overlain by Blairmore beds, almost to Burns creek where the Blairmore formation pinches out against the fault cutting the east limb of the Highwood valley syncline. From Burns creek north, this fault cuts the upper strata of the Kootenay of this zone. The Kootenay strata in the western band end abruptly near Rae creek due to faulting and folding. The beds are not severely folded in the southern part of the property. Overturning of the upper beds is pronounced north of Picklejar creek, but this may be due to creep. Folding, however, becomes more prominent northwards. Sharp anticlines of small dimensions, overturned to the east, occur through the lower half of the formation as it passes into the Sheep River valley near Burns mine. The folding becomes more intense northwest of Burns mine, then gradually becomes less intense and develops into a single anticline with an accompanying syncline, bringing Fernie beds to the surface. Due to this fold, this zone of Kootenay strata ends abruptly at Rae creek. However, the folding at the northern end of the western band involves the entire Kootenay section present, and not just the lower beds.

Close folding is characteristic of the strata to the west of the western band. Two belts of Kootenay beds occur. The eastern one rises four miles northwest of the junction of Mist and Storm creeks, as two narrow strips forming the limbs of the Highwood valley syncline. These unite between Burns and Rae creeks and extend along the synclinal axis to the Elbow river. A certain amount of minor folding has occurred in this belt. It is bounded on both sides by almost vertical faults. This belt is faulted on the western band in the vicinity of Burns creek.

The Kootenay strata between the western band and Misty range represent the northern continuation of the eastern arm of the belt of Kootenay which outcrops on Bishop creek. This band narrows rapidly northwards and in the northern part of township 18, range 7, it becomes apparent that a west-dipping thrust fault has truncated the east-dipping Kootenay beds so that only the upper beds outcrop at the surface. Folding is intense throughout this band. Between Burns creek and Rae creek, this band is brought into contact with the Kootenay beds of the syncline. On the west, this band is limited by the above mentioned thrust, which brings up Fernie and lowermost Kootenay beds against the upper Kootenay beds to the east of the fault. North of Rae creek, this fault cannot be traced. The Kootenay beds both above and below the fault have been mapped together to the divide between the Elbow and Little Elbow rivers. Only the lower beds are present north of Rae creek, and considerable deformation of these has occurred.

Coal Occurrences.

Due to the collapse or blocking of the old prospect tunnels, much less information is now available regarding the coal seams of the Burns property, than twenty years ago. The principal work has been in Sheep River valley where at least eleven small prospects have been opened and one major tunnel about 2,250 feet in length was driven across part of the coal measures.[4]

The thickness and description of the seams as given by Allan[6] follows:

"The section exposed in the tunnel is approximately as follows:

	Feet
Sandstone and shale, strike north, 27 degrees west, dip 70 degrees west	950
Coal, Burns seam	35
Sandstone and shale	375
Coal, Sharp seam	38
Shale and sandstone	140
Coal	18
Sandstone	133
Coal	7
Sandy shale	60
Coal	3½

The tunnel terminates just beyond this seam.

"Along Sharp creek a few hundred yards west of the tunnel six seams were examined. Others are reported to occur farther up the creek but these were not visited. The following seams were examined in prospect tunnels beginning at the mouth of the valley:

No. 1. *Burns seam* passes west of the outlet of the valley.
No. 2. *Sharp seam,* 32 feet of coal.
No. 3. Seven feet six inches. This one is 18 feet in tunnel.
No. 4. Eight feet coal.
No. 5. Five feet coal.
No. 6. Seven feet coal.
No. 7. *Corlet seam;* 2 feet solid coal; 4 feet 9 inches rock; 12 feet solid coal; 14 feet rock; 13 feet soft coal; no foot wall in sight.

"In Rickert creek the following seams are exposed:

No. 1. *Burns seam,* 20 feet coal in the foot wall, 5 feet soft rock, 9 ft. 11 inches coal in the hanging wall.
No. 2. Seam, coal 21 feet.
No. 3. Seam, coal 12 feet 6 inches.
No. 4. Seam, coal 7 feet.
No. 5. Seam, coal 9 feet 6 inches."

It would appear that the long tunnel started in the Fernie formation. This opinion is based on the trend of the Kootenay-Fernie contact and the lack of coal in the first 950 feet of strata penetrated by the tunnel. On Sharp creek seven prospect tunnels with coal about the entries, may still be found and probably correspond to the seven seams described above. The five easterly entries are in the central band and probably correspond to seams 1 to 5. The other two are probably in the western band and may correspond to seams 6 and 7. Seam 7, however, appears to be similar to the *Burns* seam in thickness and may correlate with it, in which case seam 6 would lie east of the *Third Fault.* It appears that the No. 1, *Burns* seam is the lowermost seam in the section and probably lies in the same horizon as the *Holt* seam of the Ford property. The prospects on Rickert creek were not all found, hence it is not known how the seams are distributed between the central band and the western band.

Allied Industrials, Limited, opened a cut about one-fourth of a mile south of the large tunnel and about 300 feet above it in elevation (Figure 18). The following section is exposed in this cut:

	Feet	Inches
Roof, carbonaceous shale		
Coal, hard, banded with bright and dull coal (sample 12)	9	6
Sandstone, carbonaceous	0	5
Coal, slightly crushed	0	7
Shale, and sandy and silty shales	9	10
Coal, hard, banded with bright and dull coal (sample 13)	5	0
Coal, somewhat crushed, becoming severely crushed towards the base (sample 13)	2	5
Shale, carbonaceous	0	11
Coal, dirty, crushed, with small lenses of harder coal (sample 14)	6	8
Coal, very badly crushed and weathered (sample 14)	3	10
Floor, carbonaceous shale; floor not well exposed.		
Sample 15 is a composite of samples 13 and 14.		

About 20 feet below the floor of this seam a sandstone occurs that resembles the basal Kootenay sandstone. Immediately below this sandstone are beds similar to the Upper Fernie sandstone. It is believed that this coal occupies the same horizon as the *Holt* seam, close to the base of the Kootenay formation. If this is so and if the previous correlation of the *Burns* seam with the *Holt* seam is correct, then the cut is made on the *Burns* seam. The thickness of coal is also in agreement with this. This cut is in the central band.

A small exposure in this band about 200 feet above the base of the formation was found four miles northwest of Picklejar creek. The following section was measured:

	Feet	Inches
Roof, shale		
Coal, very dirty	4	3
Shale and ripple-marked sandstone	5	0
Coal	1	0
Shale	0	2
Coal, fairly hard	3	0
Floor, shale		

Several trenches in the central and western bands between Picklejar creek and Rickert's pass, show the presence of coal but these are now caved in and no details could be ascertained. One trench, just east of Rickert's pass, shows the presence of a five-foot seam in the western band. Burrowing animals frequently bring coal fragments to the surface.

Coal exposures are not common in the western part of the property. Coal occurs in the *Holt* seam horizon. Lensing beds of cannel occur in the upper 500 feet of the Kootenay formation in this part of the property. These usually average two to three inches and never exceed six inches in thickness. Consequently, they are at present of no economic value.

PHYSICAL CHARACTER OF THE COAL

In all the exposures examined on the Ford property near the Highwood river, the coal was very badly crushed and so friable that it could be powdered between the fingers. The largest block seen was from the uppermost seam in Cut 5 (Figure 19). This coal, however, shows numerous cone-like pressure fractures. Slickensiding is very common. Bedding is usually completely destroyed.

Allan[6] records the presence of blocky coal in several seams on Cat creek. These seams were examined in prospect tunnels, which extended well beyond the weathered portion of the coal. The recent open cuts, however, do not expose more than 12 feet of coal, and there is thus a strong possibility that the seams have been affected to some extent by weathering. If so, some of these seams may show blocky coal at depth.

The coal in the open cut on the Burns property on the Sheep river shows an interesting gradation from hard, blocky coal at the top (Figure 20), down to soft, crushed and powdery coal at the base of the seam. Overlying the upper part of the seam is 30 to 40 feet of bedrock, while the lower part of the seam is almost at the outcrop. The blocky coal has been subjected to sufficient pressure to raise it to semi-anthracite. Cone-like pressure fractures are developed in it. In many of the Kootenay coal areas of Alberta within the Rocky Mountains, badly crushed coal is common.

LATERAL VARIATION

The only coal-bearing horizon which was recognized throughout the area is that close to the base, which is known by the Ford

Highwood Collieries as the *Holt* seam. The study of this seam shows considerable lateral variation in thickness. This variation appears to be related to deposition and not to thickening under deformation.

In Cut 1, (Figure 15), the *Holt* seam shows 22 feet of coal in 26 feet 3 inches of section. Less than two miles away, near Cut 6, this same horizon shows only 12 feet 6 inches of coal in a total thickness of 23 feet 8 inches of section. Seam 000 on Cat creek, the easternmost seam in the eastern band and apparently occupying the same horizon as the *Holt* seam, is only four feet thick. On the Burns property, the *Burns* seam is correlated with the *Holt* seam, and shows 35 feet of coal in the large tunnel, while in the open cut it shows about 28 feet of coal. The characteristics of the lowest coal seam in the western band on the Burns property has not been definitely determined.

In the eastern band the *Holt* seam shows marked variations in thickness. This is apparently caused by an increase towards the north in thickness of the shale partings at the expense of the coal. The small seam on Cat creek further indicates the thinning of the seam in that direction. This probably means that the margin of the basin of deposition of the *Holt* seam was not far north of Cat creek.

Equally marked are the variations in the other seams which have been exposed towards the south end of the eastern band. The general impression gained is that the coal seams were deposited in rather small basins or else in larger basins with very irregular margins.

If these conclusions are correct, then the outlining of the basin of deposition for any one seam will be of considerable importance. Ash content should decrease from the margins of the basins towards the centres, and the coal should become thicker in the same direction. It should be realized, of course, that the basins of deposition of the different seams will not coincide, except accidentally. Carefully located bore holes would permit a general outline of the basins and amplification of the above hypothesis.

ANALYSES OF COAL SAMPLES

As mentioned previously, at a number of places in the Highwood valley the coal seams were exposed by stripping the outcropping coal and the surface deposits. In the Sheep River valley, in the Burns Property, one coal seam was exposed in the same manner. From these places, channel samples of coal were taken for the Mines Branch, Department of Lands and Mines, by the District Inspectors, W. G. Heeley and W. Hall, during 1946. Samples 1 to 11 inclusive, were taken by District Inspector W. G. Heeeley and samples 12 to 15 inclusive by District Inspector W. Hall. M. B. B. Crockford and J. L. Carr, geologists for the Research Council of Alberta, were present and assisted in the sampling. The samples from the localities shown on Figure 12, were analyzed in the Fuel Laboratory of the Research Council of Alberta. The analytical results are published with the permission of John Crawford, Chief Inspector of Mines.

It is important to recognize that unless a seam is sampled by a recognized method such as channel sampling, the sample cannot be regarded as truly representative and the analytical results may be valueless and frequently misleading.

It must be pointed out that seam samples taken from an outcrop or near the surface are likely to differ considerably in chemical composition and physical character from a sample from the same seam taken at a distance from the surface. Moreover the structure of a coal seam may vary from district to district. Thus, a single channel sample does not truly represent the seam throughout the whole of the deposit.

In the case of samples Nos. 5 and 14 reported upon in Table 2, weathering appears to have caused a decrease in the calorific value and an increase in the moisture content of the coals. In these instances the rank of the coals can only be indicated and cannot be stated specifically. . The coal analyses are given in Table 2 on page 60.

LOOMIS CREEK TO MOUNT WINTOUR

This portion of the area includes the outcrops of Kootenay strata between Loomis creek and Storm creek, those in Storm and Pocaterra creek basins, and the northern continuation of this arm of the Kootenay strata to its termination near Mt. Wintour.

Structure.

The Kootenay strata in this portion of the area are brought to the surface on Loomis creek in a tightly-compressed, faulted anticline. The outcrop broadens rapidly to the north, due to a swing in strike on the west limb of the structure, towards the west. This structure represents the southern end of the Misty range uplift. Between Storm and Odlum creeks, the strata are highly faulted and folded, and the Kootenay strata here diverge about Misty range. West of Mist mountain the Kootenay formation shows many small folds, but none of great magnitude. As the outcrop crosses Storm creek, in the northwest corner of township 18, range 7, west of the fifth meridian, these folds disappear. West of the upper part of Storm creek, a south-plunging anticline and syncline bring Kootenay strata to the surface over almost the entire width between Storm creek and Elk mountains. At Highwood pass, numerous small folds are again present throughout the Kootenay strata. The folding becomes of lesser magnitude west of Pocaterra creek, and immediately north of Pocaterra creek the strata are essentially vertical. The trace of the oblique fault, shown passing across the basin, was not observed in the Kootenay strata, but is believed to be concealed. A small thrust fault, dipping west at a low angle, is believed to be present south of the oblique fault, as trenching operations on the lowermost coal seam showed that lower Kootenay strata had been thrust over the basal Kootenay sandstone, truncating it. North of the oblique fault, the Kootenay is involved in fairly open folding, which disappears rapidly northward. The Kootenay formation terminates against the Elk thrust on the east side of Mt. Wintour.

Structural conditions in this portion of the area are such that at the present time, the coal where observed in the Kootenay band on Storm and Pocaterra creeks must be considered as unfavorable for mining operations.

TABLE 2

ANALYSES OF COAL SAMPLES FROM THE HIGHWOOD AREA

Sample No. R.C.A. Lab No.	1. 2-46	2. 3-46	3. 4-46	4. 5-46	5. 6-46	6. 7-46	7. 8-46	8. 9-46	9. 10-46	10. 11-46	11. 13-46	12. 19-46	13. 20-46	14. 21-46	15. 22-46
Moisture, %	3.4	1.8	1.7	2.3	9.4	1.6	3.0	3.1	1.5	1.7	1.6	2.0	2.9	7.3	6.1
Ash, %	26.1	13.6	18.5	20.4	10.7	27.0	22.7	23.5	13.4	20.4	18.5	14.8	12.4	18.1	15.4
Volatile Matter, %	17.1	18.2	17.8	17.7	20.8	14.2	15.2	15.0	14.9	14.4	14.6	11.9	12.1	13.3	13.0
Fixed Carbon, %	53.4	66.4	62.0	59.6	59.1	57.2	59.1	58.4	70.2	63.5	65.3	71.3	72.6	61.3	65.5
Calorific value, B.t.u./lb.	10,560	13,020	12,190	11,750	10,900	10,810	10,970	10,840	13,130	11,950	12,240	12,700	12,820	10,870	11,560
Fuel Ratio	3.1	3.6	3.5	3.4	2.9	4.0	3.9	3.9	4.6	4.4	4.5	6.0	6.0	4.6	5.0
Fixed Carbon, dry, mineral matter-free, %	78.7	79.7	79.5	79.3	75.1	83.2	82.1	82.2	83.8	83.7	83.7	87.2	87.0	84.2	85.1
Rank of coal; A.S.T.M. classification	Low Volatile Bituminous				Doubtful	Low Volatile Bituminous						Semi-Anthracite		Low Volatile Bituminous	

Ford Coal Property (Samples taken by Heeley, Crockford and Carr, 1946).

1. Cut No. 4, Glover Seam, 21 feet 9 inches.
2. Cut No. 4, Glover Seam, 7 feet 1 inch.
3. Cut No. 4, Glover Seam, 17 feet 5 inches.
4. Cut No. 4, Glover Seam, Composite sample of samples Nos. 1, 2 and 3.
5. Cut No. 2, 5 feet 1 inch (includes 2 inch clay band).
6. Cut No. 1, Connors Seam, 7 feet 9 inches (mainly carbonaceous shale).
7. Cut No. 1, Douglas Seam, 12 feet 9 inches.
8. Cut No. 1, Douglas Seam, including 11 inches of shale.
9. Cut No. 1, Holt Seam, upper 4 feet of coal.
10. Cut No. 1, Holt Seam, all except 3 feet rock inclusion.
11. Cut No. 1, Holt Seam, sample No. 10 but omitting 1 foot of bone and shale.

Burns Coal Property (Samples taken by Hall, Crockford and Carr, 1946).

12. Upper seam of series, 9 feet 6 inches hard coal showing well-defined cleat of 6 inches, sample coal only.
13. Top 7 feet 6 inches of the lower bench of seam; 2 feet 6 inches lower coal softer than top 5 feet of coal.
14. Lower 10 feet 6 inches of the lower bench of seam; coal crushed, no cleat.
15. Composite sample of samples Nos. 13 and 14.

Coal Occurrences.

No coal showings of great importance were observed in the southern portion of this band of the Kootenay strata. On Loomis creek, a one-foot seam is present about 75 feet below the top of the formation. Between Storm and Odlum creeks, coal showings are present. The largest seam appeared to be about 12 feet in thickness, but was very badly crushed. On Storm creek itself, two seams are present, each about 5 feet in thickness, but these are shaly, and outcrop in closely-folded strata.

On the west slope of Mist mountain, six seams were observed, varying from 3 to 10 feet in thickness. The lowest of these, a 4-foot seam, lies only a few feet above the top of the basal Kootenay sandstone, and in the outcrop shows blocks of coal with a maximum diameter of 3 inches. Another seam, about 30 feet above the first, is over 6 feet thick, and likewise contains some blocky coal. The other seams appear to be badly crushed. These seams all occur in the lower half of the Kootenay formation.

Little coal was observed west of Storm creek. One 6-foot seam, however, was found about 150 feet below the top of the Kootenay formation. Where observed, this coal was crushed. This occurrence, showing the presence of workable seams high in the section, is of considerable importance.

Few showings of coal are present between Pocaterra creek and Elk mountains. In about section 28, township 19, range 8, west of the fifth meridian, three trench prospects, now almost completely caved, showed the presence of coal, but gave no idea of the thickness of the seams. No blocks of coal were observed.

North of Pocaterra creek and south of the oblique fault, five prospects were found, including one adit. These are on the former G. W. Pocaterra claim. Caving has covered the coal, but about the entry to the adit, there are a few blocks of coal up to 8 inches in diameter.

Trenching was carried out along the top of a high ridge north of Pocaterra creek, in about section 34, township 19, range 8, west of the fifth meridian and revealed the following section in the Kootenay:

Fault Contact (Paleozoic thrust on Kootenay).

	Feet	Inches
Sandstone and shale	111	0
Coal, shaly	0	8
Shale and sandstone	40	0
Shaly coal	1	2
Shale	3	0
Coal, with occasional thin non-continuous shale partings	10	4
Shale	0	8
Coal	4	10
Sandstone, shale (chert pebble conglomerate 52 feet from top)	89	0
Coal, powdery	1	11
Shale	2	0
Coal, shaly	1	3
Shale and sandstone	7	0
Shaly coal and shale	3	0
Shale	16	0
Coal	3	0
Sandstone and shale	48	0
Coal, crushed	13	5
Shale	10	0

	Feet	Inches
Coal, shaly	1	2
Shale and sandstone	36	0
Coal, crushed	0	10
Sandstone and shale	13	0
Coal 14 inches, shale 2 inches, coal 10 inches	2	2
Shale and sandstone	28	0
Coal, very dirty	11	4
Sandstone and shale	177	0
Coal, crushed	8	0
Strata concealed by heavy overburden	225	0
Coal crushed	1	0
Coal, hard, blocky, dirty	4	0
Coal, crushed, with shale	2	0
Shale and sandstone	56	0
Coal	0	6
Shale, and minor sandstone	25	0
Coal and shale	6	5
Shale	22	0
Coal, crushed 2 ft.; shale 1 ft. 4 in.; coal, shaly 8 in.; shale 4 in.; coal, shaly 2 ft. 3 in.; shale 1 ft.; coal, shaly 2 ft.	9	7
Shale	19	0
Coal	0	6
Shale	2	6
Coal	0	7
Shale, and thin sandstones	198	0
Coal, crushed (for analysis see sample 2, page 60)	11	0
Shale	2	0
Coal, shaly, with some shale	3	1
Shale with thin sandstone	47	0
Coal, shaly towards base	5	7
Oolitic ironstone	0	3
Coal, with minor shale	1	2
Shale	1	5
Coal, dirty	0	7
Shale	0	3
Coal	0	8
Shale	0	8
Coal, crushed, dirty and shale	4	9
Shale	18	0
Coal, crushed	1	0
Shale	2	7
Shale, very carbonaceous	2	0
Shale and thin sandstone	45	0
Coal, shaly	2	0
Shale and sandstone	44	0
Coal, crushed to slightly blocky	5	2
Shale	0	10
Coal, crushed	2	2
Shale	1	0
Coal, crushed, with 2 in. shale band in middle	1	3
Shale and silty sandstone	13	0
Coal, crushed, shaly towards top	3	0
Shale	22	0
Coal, shaly	2	6
Shale	8	2
Coal, blocky, bony and shaly coal	11	2
Shale, carbonaceous	0	9
Coal, crushed, bony towards base	2	1
Shale	0	3
Coal, crushed, shaly towards base	3	8
Shale and siltstone	1	2
Coal, crushed, shaly towards base	1	3
Coal, badly crushed, clean (for analysis see sample 1, page 60)	3	7
Shale, carbonaceous	0	2
Coal	0	10
Shale	2	10

	Feet	Inches
Coal, in blocks up to 1½ in.	3	0
Shale and fine sandstone	7	0
Basal Kootenay sandstone, badly broken		
Total thickness of section	1,506 feet	
Total thickness of coal	157 feet 8 inches	
Thickness of coal in seams 3 feet or over	135 feet 5 inches	

No indication of repetition was observed in this section, but the possibility that unrecognized faults have thickened the section must not be ignored. Much of the coal is dirty or shaly, and does not appear to be of commercial value. Most of the coal is badly crushed, and this crushing may have led to local thickening of the coal seams.

Two channel samples were taken from two of the coal seams. The samples were taken from about four feet below the surface and may not be representative of the character of the coal at depth. The samples were collected in the middle of July and the coal was still frozen, so that the moisture shown in the analysis is higher than it would be at a greater depth from the surface.

Analysis of the samples by the Fuel Laboratory of the Research Council of Alberta show:

	1	2
Moisture, %	4.5	6.5
Ash, %	10.1	8.5
Volatile matter, %	14.6	15.9
Fixed carbon, %	70.8	69.1
Calorific value, B.t.u. per lb.	12,660	12,250
Fuel Ratio	4.9	4.3
Fixed Carbon, dry, mineral matter-free, %	33.9	82.1

1. Channel sample taken by J. L. Carr in 1946 from coal seam 4 feet 3 inches thick situated about 45 feet above the base of Kootenay formation in the ridge north of Pocaterra creek, in about sec. 2-20-8, W5. Sample taken 4 feet below the surface.
2. Channel sample taken by J. L. Carr in 1946 from coal seam 11 feet thick, 321 feet above the base of the Kootenay formation. The location was the same as with No. 1 sample. The sample was taken 4 feet below the surface.

Structural conditions both to the north and south appear to be very unfavorable for mining operations. Small folds are numerous south of Pocaterra creek, and some faulting may have taken place. The large oblique fault is believed to cross the basin near the above section, and indeed may have been responsible for unrecognized duplication of strata. Folding is marked to the north of the oblique fault.

Regardless of the character of the coal, and of the unfavorable mining conditions along Pocaterra valley, however, difficulty of access alone rules out this portion of the area for development at the present time. Railway construction to Pocaterra creek might follow either of two routes, namely up the Highwood valley from the east and over the Highwood pass, or up the Kananaskis valley from Seebe station. The former would involve construction of about 60 miles of line from Okotoks or High River to Sentinel ranger station, and another 30 miles or more to the lower part of Pocaterra creek. The Highwood pass lies at an elevation of about 7,300 feet, and the valley gradients on both sides amount to over 150 feet per mile. A route up the Kananaskis valley would involve at least 60 miles of railway line from Seebe. From the mouth of

Pocaterra creek to the east side of the gap through Elk range, there is a difference of elevation of about 1,000 feet in 6 miles.

North of the oblique fault, some interesting coal showings are present. In section 9, township 20, range 8, west of the fifth meridian, the following seams were observed in about 500 feet of section:

		Feet	Inches
Coal, crushed		2	0
Coal, hard, blocky		1	0
Coal and shale, crushed		4	0
Coal, crushed	1ft. 6in.		
Shale	2ft. 0in.		
Coal, crushed	4ft. 0in.	7	6
Coal, blocky		3	6
Coal, blocky		1	6
Coal, blocky, shaly at top		4	0
Coal, blocky, 50 feet above the top of basal Kootenay sandstone		7	0

In addition to these, there are numerous showings of crushed coal, which in part at least represent repetitions of some of these seams. At least eight of the crushed coal seams are over 2 feet in thickness. The presence of good blocky coal in the outcrop is of considerable interest as this is the only part of the Highwood-Elbow area where such coal was noted in appreciable quantities.

The folding which has affected these strata (see Structure section S-T, Plate 1), has reduced the number of seams, and has limited the amount of coal present. This coal might be reached from Kananaskis valley, but the gaps through the Elk mountains cut by the small streams which drain this portion of the Mesozoic basin, are narrow and steep. Consequently, these deposits are regarded as unfavorable for development at present.

Cannel

Thin beds of cannel, at no place exceeding 6 inches in thickness, and of limited lateral extent, are common in the upper beds of the Kootenay formation, in that part of the area west of the Highwood river, Mist creek, and the Sheep river. Because of the thinness and irregularity of the seams, this material cannot be considered to be of economic value.

The cannel is tough, and the purer beds break with a conchoidal fracture. The surface is rough-weathering. Chemically precipitated chert is present in some beds. A sample obtained from an outcrop at the west side of the Highwood valley syncline, on the east slope of Mist mountain, was analyzed in the laboratories of the Research Council of Alberta. This sample burns with a long yellow smoky flame, with considerable intumescence. The analysis is as follows:

Moisture, %	2.2
Ash, %	10.6
Volatile Matter, %	58.6
Fixed Carbon, %	28.6
Calorific Value, B.t.u. per lb.	13,890

Phosphate Rock

Phosphatic rock occurs at two horizons in the Mesozoic succession in this area. The lower of these horizons occurs in the basal beds of the Triassic, Spray River formation, while the upper horizon is in the basal beds of the Fernie formation. In both cases, the phosphatic beds are present west of Misty range, but are apparently absent over the rest of the area.

The phosphatic zone at the base of the Spray River formation is rarely over 2 feet thick, and was never observed to exceed 3 feet. It commonly occurs as a dark grey phosphatic limestone, sometimes acting as a matrix for chert breccia and occasionally as a hard siliceous phosphatic limestone. Two samples analyzed in the Industrial Laboratories at the University of Alberta for phosphoric acid (P_2O_5), gave the following results:

Dark grey phosphatic limestone, west slope of Elpoca mountain, bed 2½ feet thick	5.14% P_2O_5
Siliceous and sandy phosphatic limestone and "chert breccia", west slope of Mist mountain, bed 1½ feet thick	1.44% P_2O_5

The phosphate content is much too low for the limestone to be of economic value.

The phosphatic limestone at the base of the Fernie formation is about 27 feet in thickness west of Misty range, but is very low in phosphate, and also is not of present economic value. East of Misty range, a horizon of small phosphatic nodules is present in the *Rock Creek member* of the Fernie formation, but the nodules are few.

Gravel

Large deposits of post-Glacial gravels underlie the terraces of the Highwood river, and occur as fans about the mouths of several of the creeks emptying into the Highwood. In addition, the basins of Pocaterra and Lineham creeks contain thick deposits. The gravels consist largely of limestone and chert pebbles derived from the Paleozoic strata, with lesser quantities of softer pebbles derived from the Mesozoic succession. Sorting is usually not very good, and boulders are frequent. The gravels are unconsolidated except where locally weakly-cemented by travertine. As most of the gravels are coarse to very coarse, screening and crushing would be necessary before utilization.

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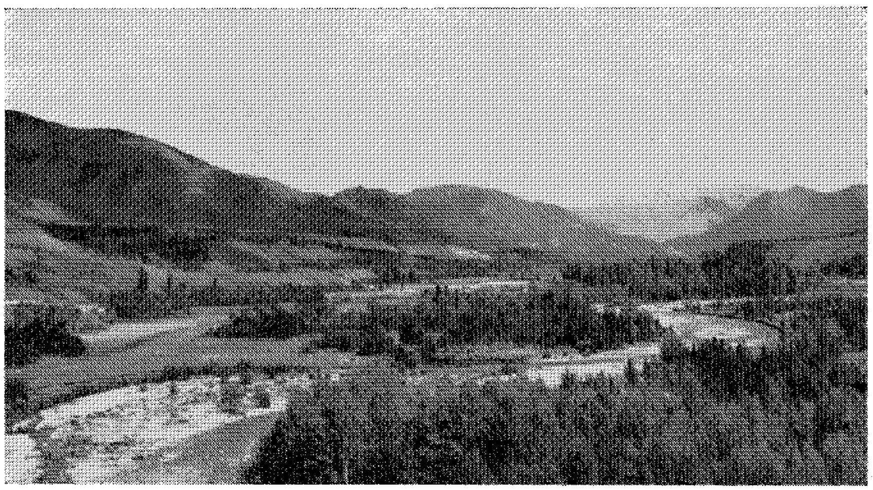

Figure 1.—Looking down Highwood valley from section 11-17-6 W. 5, showing flood plains and terraces.

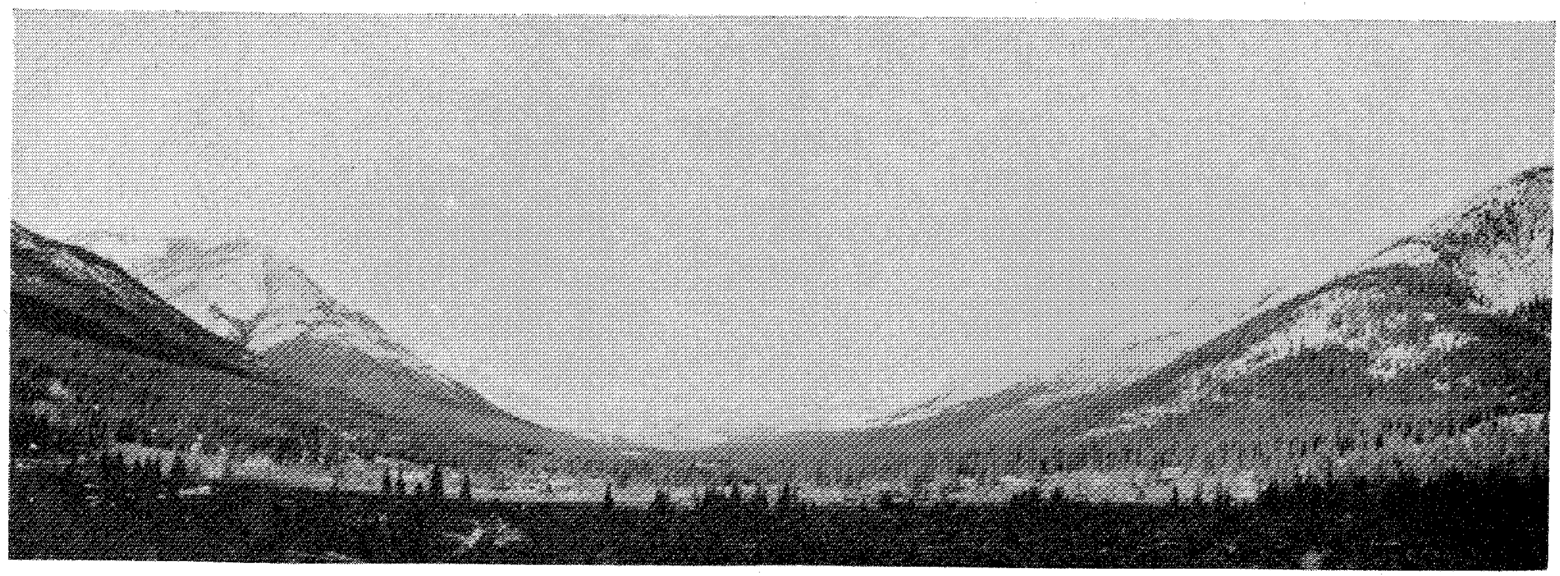

Figure 2.—Glaciated valley of Sheep river, looking upstream from Burns mine. Kootenay strata on left of valley, Paleozoic on right.

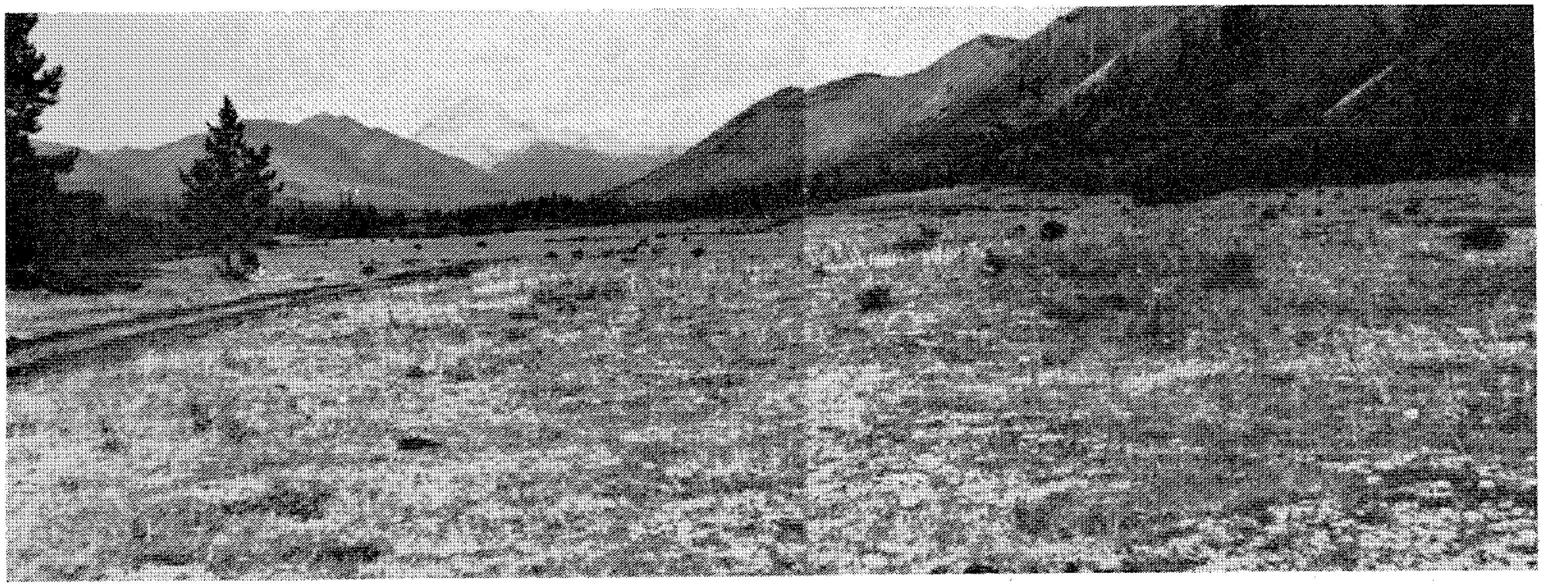

Figure 3.—Looking northwest along deserted channel of Highwood, below Lineham creek.

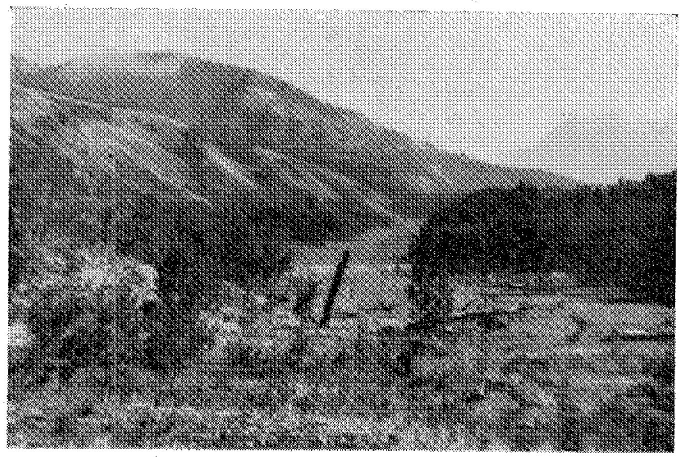

Figure 4.—Looking southeastwards down deserted channel of Cat creek. Note outcrops of basal Blairmore conglomerate on left bank in middle distance, showing slight displacement due to transverse faulting.

Figure 5.—Erosional contact of Spray River formation on Paleozoic beds, in section 7-17-5 W. 5. Hammer handle one foot long.

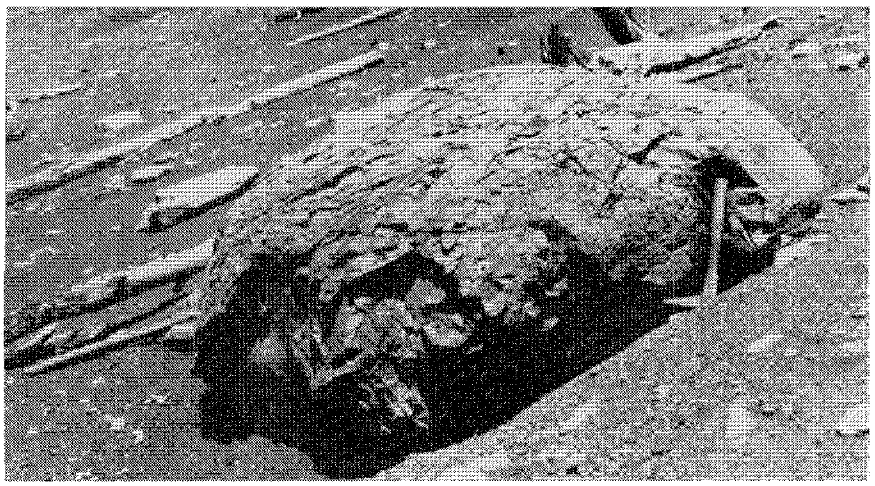

Figure 6.—Large ferruginous limestone concretion in Fernie formation, exposed southeast of Mist mountain. Hammer handle one foot long.

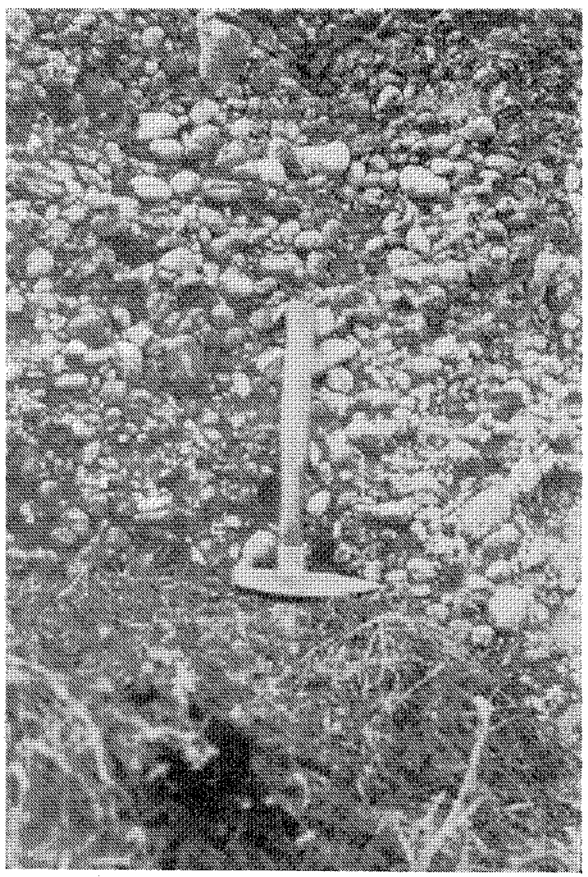

Figure 7.—Igneous pebble conglomerate, Blairmore formation south of Loomis creek. Hammer handle one foot long.

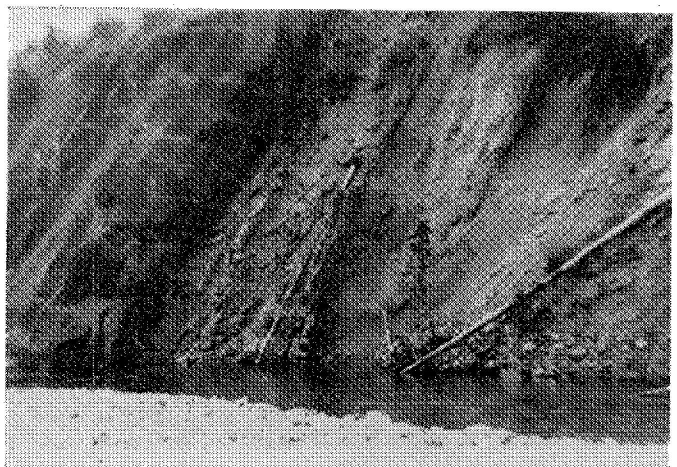

Figure 8.—Contact of Lower Alberta formation (dark beds on left) on Blairmore formation. Highwood river downstream at mouth of Odlum creek.

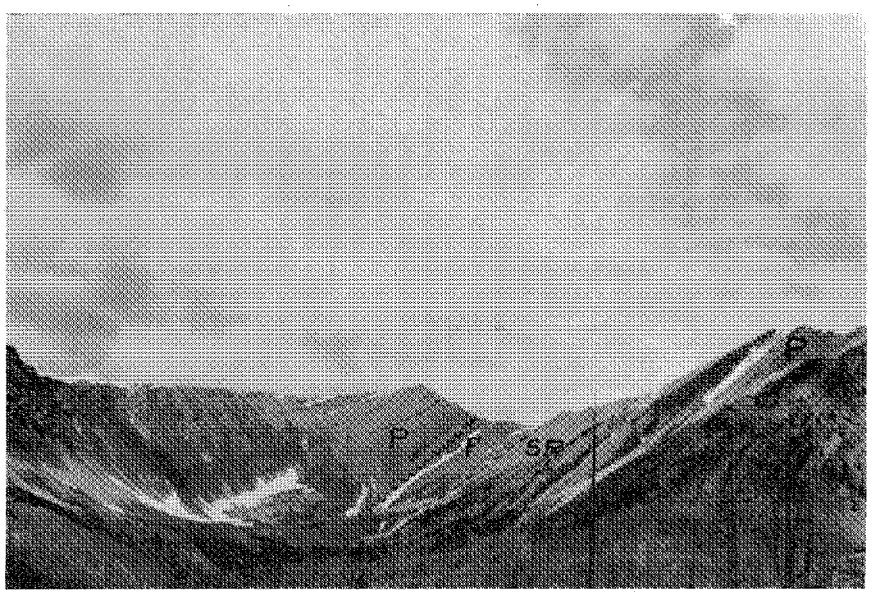

Figure 9.—Paleozoic beds (P), thrust on lower Fernie(F), and Spray River(SR), along the Second Fault, north side of Lineham Creek valley.

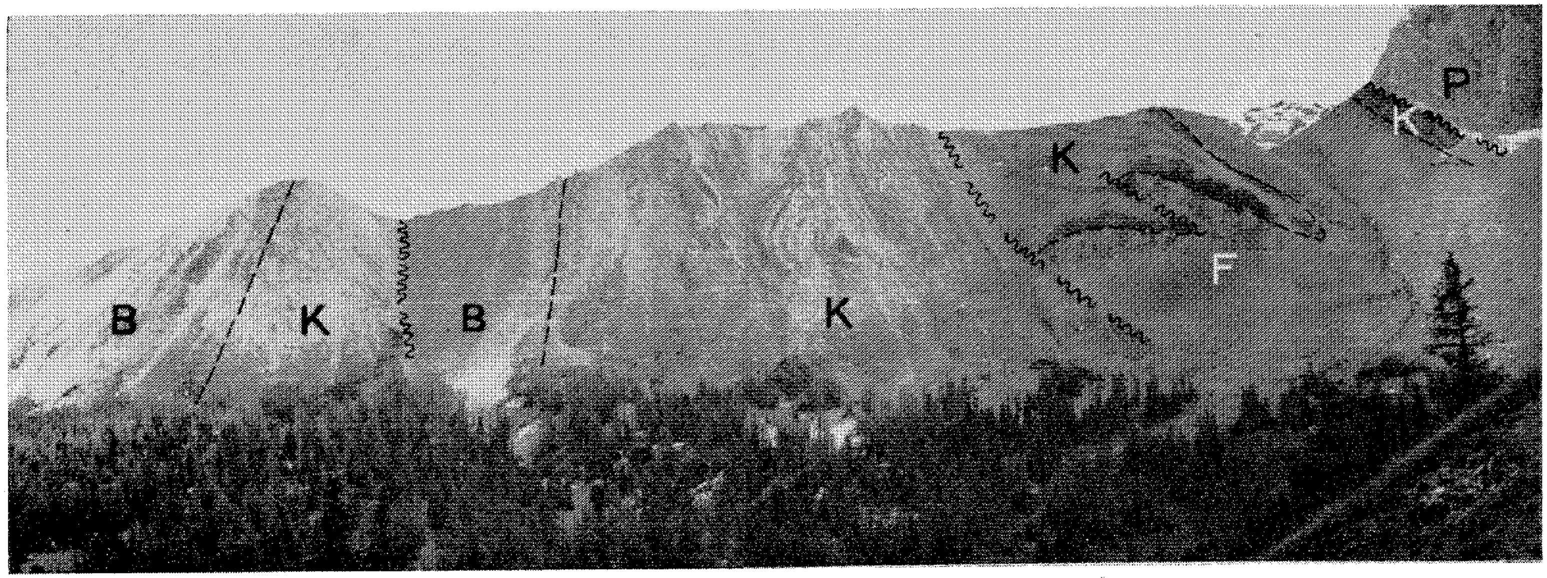

Figure 10.—North side of ridge at headwaters of Mist creek, looking south, showing folding and faulting of lower Mesozoic strata east of Misty range, Paleozoic (P); Fernie (F); Kootenay (K); Blairmore (B). Photograph by J. A. Allan.

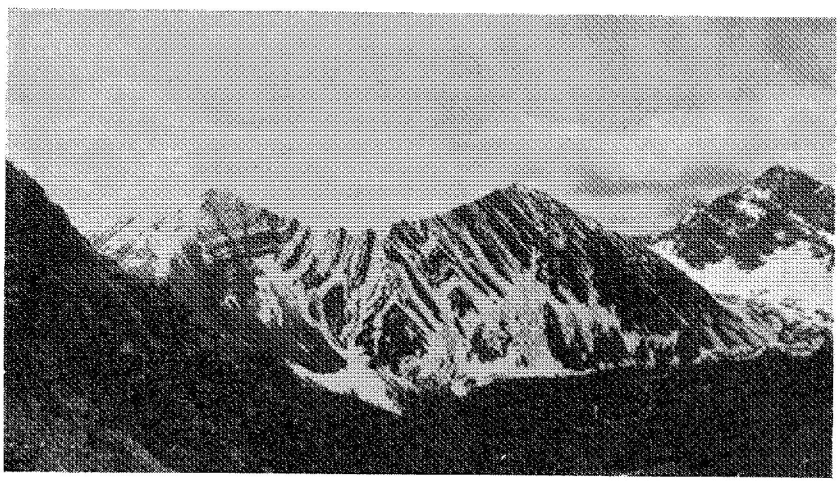

Figure 11.—Folded Lower Cretaceous strata, west of Highwood pass, looking south. Elk mountains, forming Continental Divide and Interprovincial Boundary on right.

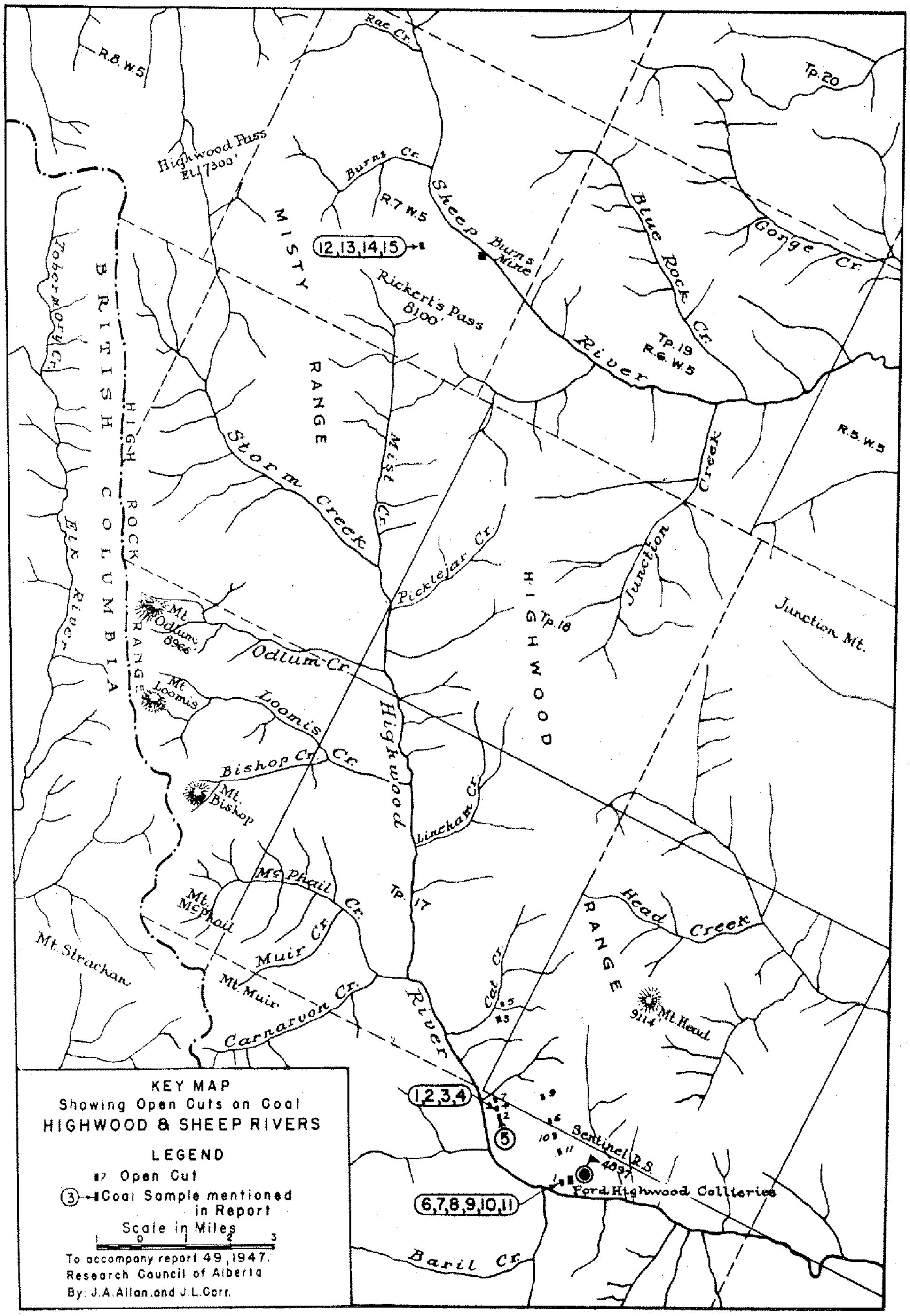

Figure 12.—Map showing open cuts and location of coal samples analysed.

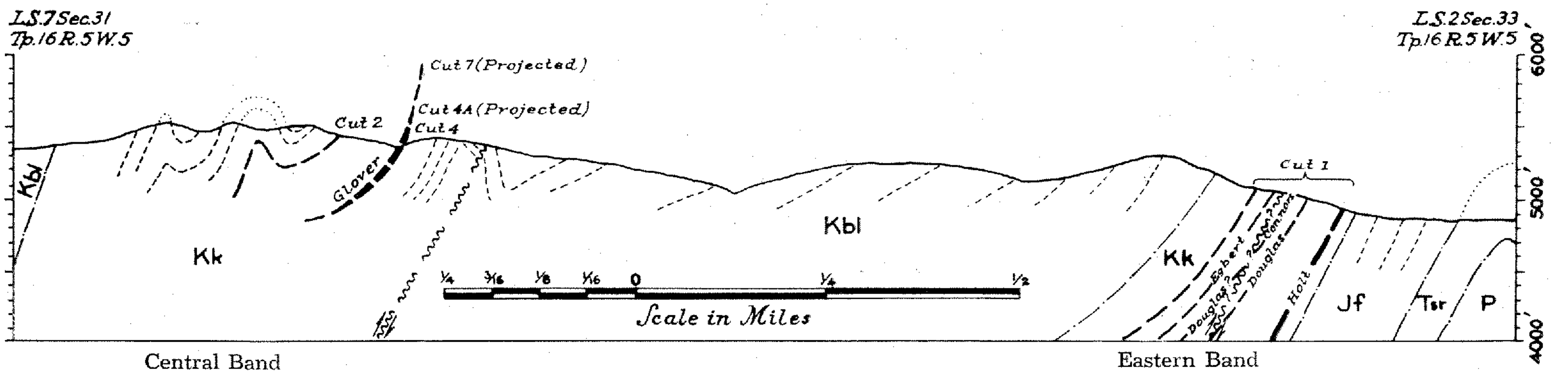

Figure 13A.—Profile along line of section in 13B, showing the eastern band and the central band, containing coal seams.

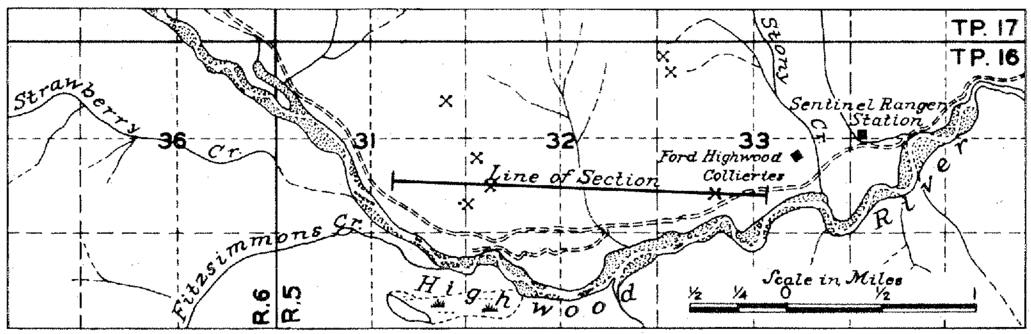

Figure 13B.—Key map to Figure 13A.

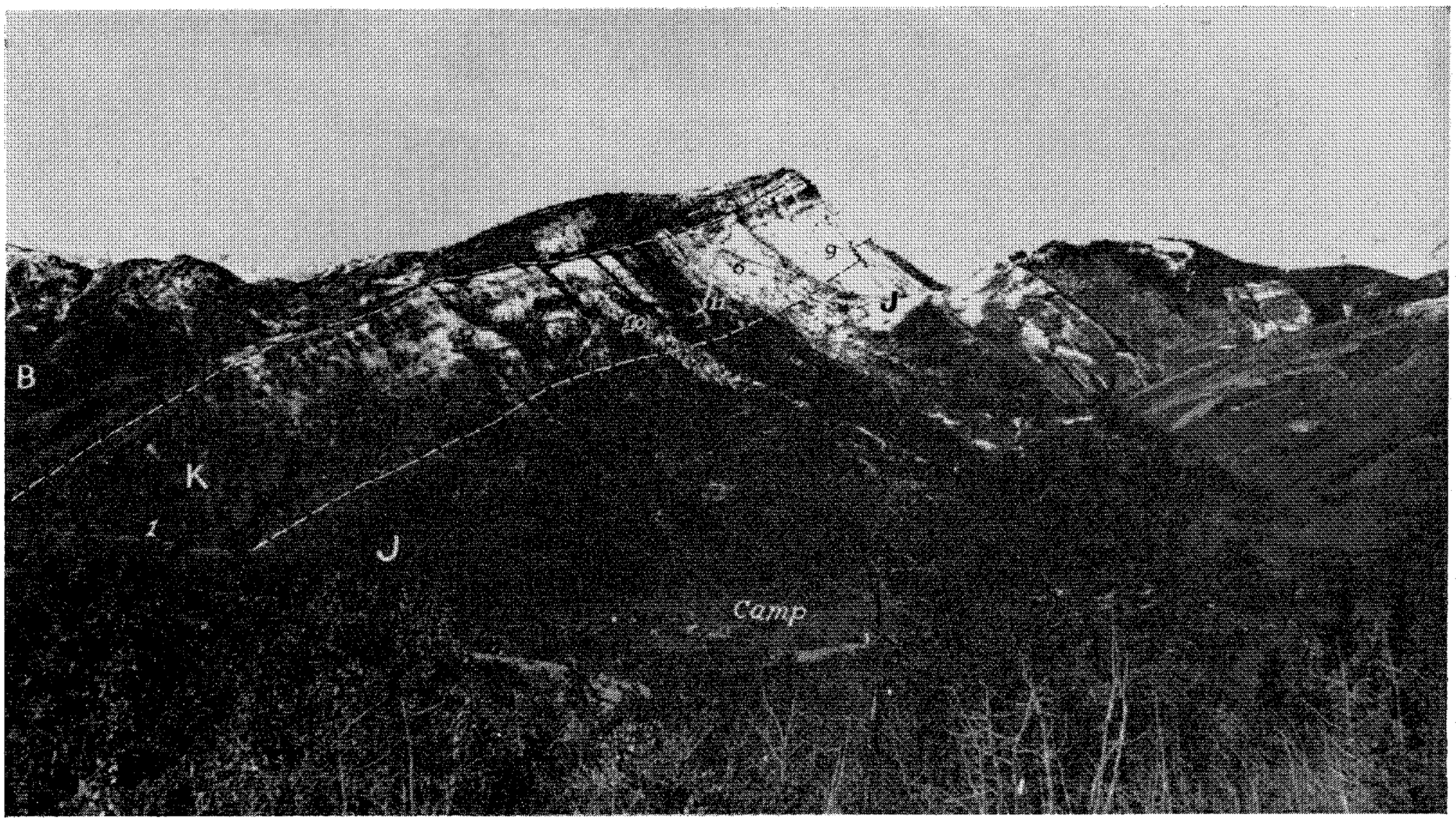

Figure 14.—Eastern band from south side of Highwood river, opposite Sentinel ranger station, showing bulldozed roads, positions of open cuts (numbered), and Ford Highwood Collieries, Ltd. (Highwood Coal Mines, Ltd.) camp. Jurassic (J); Kootenay (K); Blairmore (B).

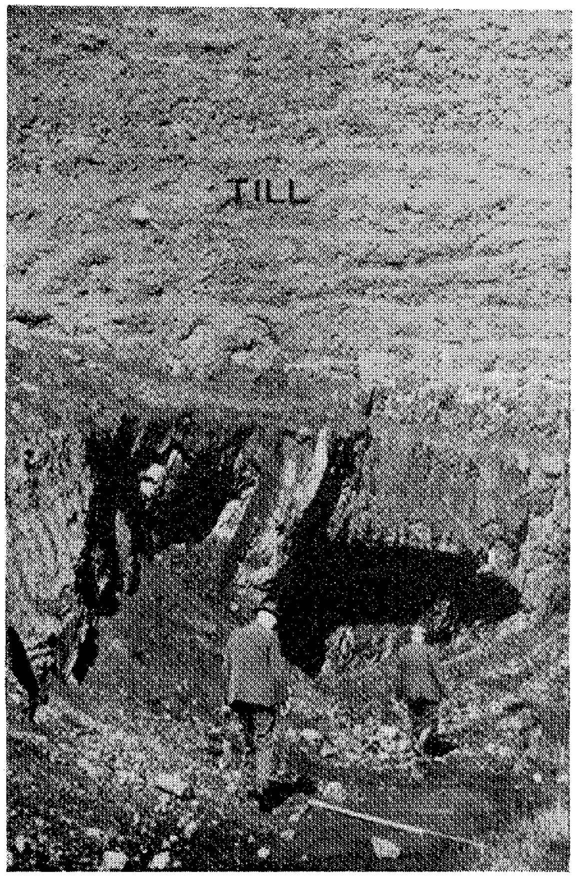

Figure 15.—Holt seam in Cut 1 in eastern band, overlain by till, Ford Highwood Collieries, Ltd. Photograph by J. A. Allan.

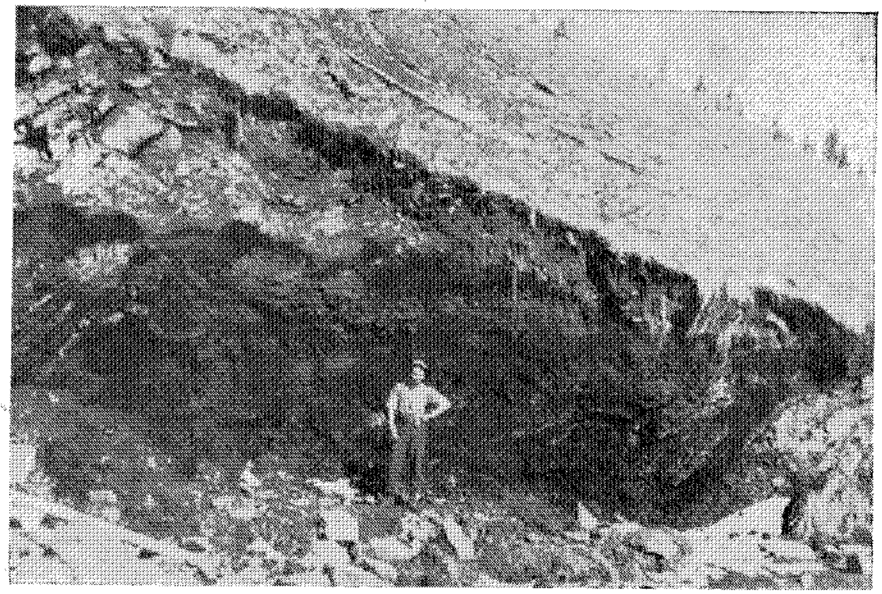

Figure 16.—Contorted seam exposed in Cut 6, eastern band, Ford Highwood Collieries, Ltd.

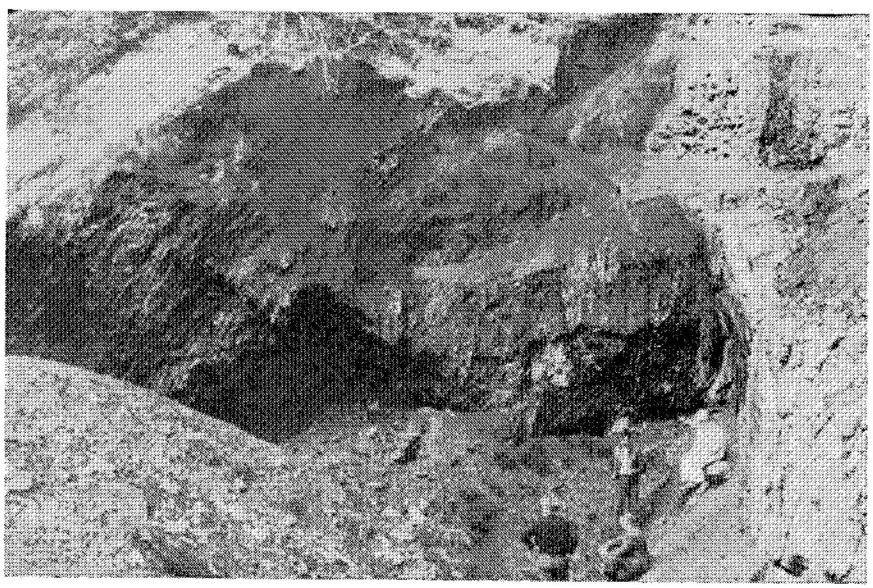

Figure 17.—Glover seam, Cut 4, central band, Ford Highwood Collieries, Ltd., headwall on right. Photograph by J. A. Allan.

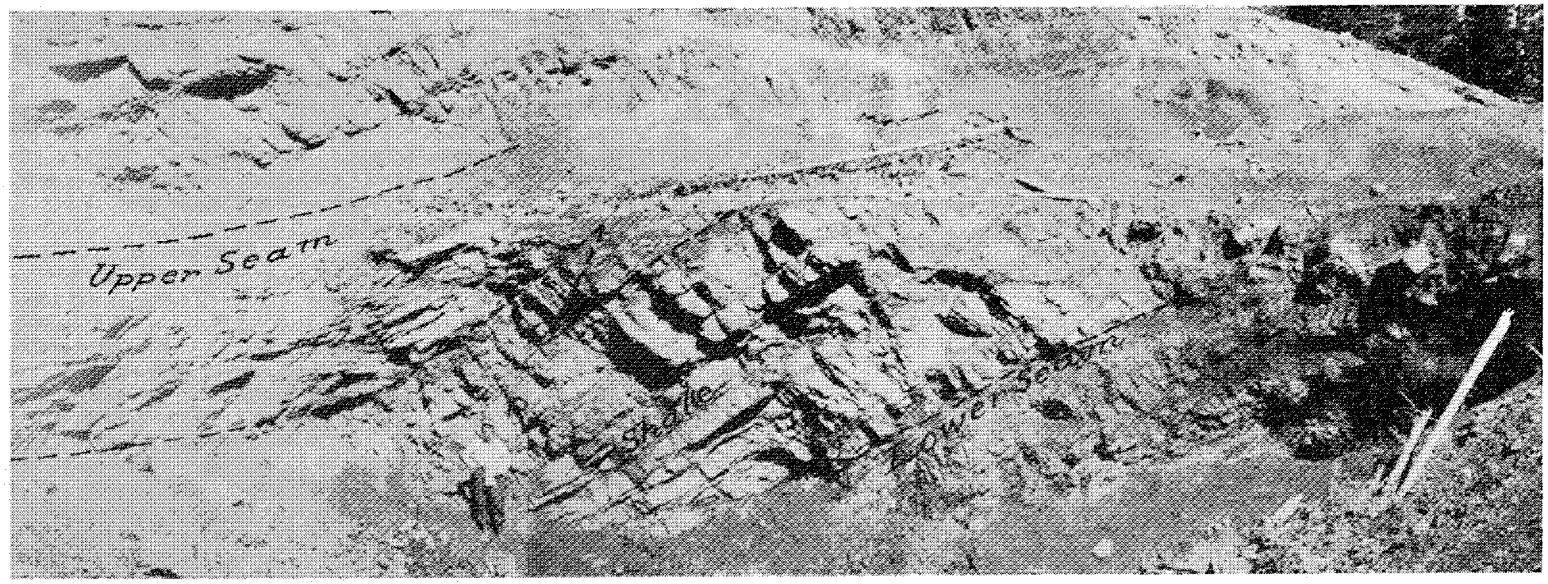

Figure 18.—Open cut of Allied Industrials, Ltd., Burns Property, Sheep river. Shows lower and upper coal seams, separated by shale band.

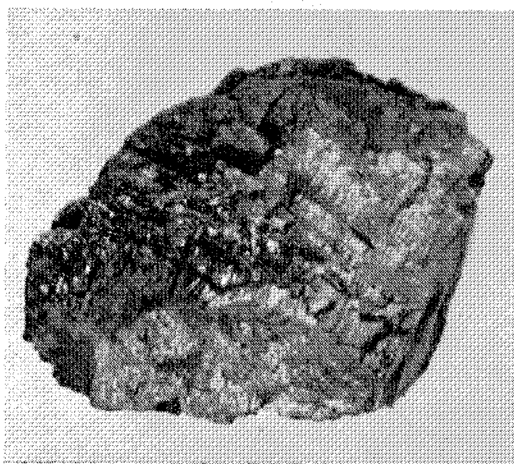

Figure 19.—Block of coal from Cut 5, eastern band, Ford Highwood Collieries, Ltd., showing cone-like pressure fractures (x½).

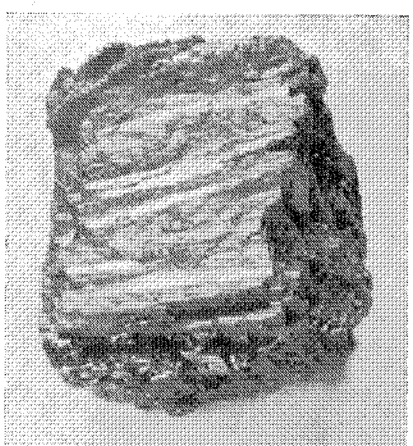

Figure 20.—Block of coal from open cut of Allied Industrials, Ltd., Burns mine, showing blocky character and laminations of the coal (x½).

Appendix

PALAEONTOLOGY

Description of Jurassic Ammonites from the Fernie Formation

By P. S. Warren*

Among the fossils collected by J. L. Carr, geologist of the Research Council of Alberta, in the Highwood-Sheep River area in the summer of 1945 and sent to the writer for identification, were a considerable number of ammonites from the Fernie formation of Jurassic age. Most of these specimens were obtained from the Rock Creek member of the Fernie[9] which has proved to be the most fossiliferous horizon in the formation. A few of the ammonites from the Rock Creek horizon have already been described by F. H. McLearn[4,5]. Carr was fortunate in obtaining examples of some of McLearn's species which are better preserved than the holotypes and show features not hitherto described. Other specimens in the collection are new. In making a study of these specimens, the writer has compared the specimens collected by Carr with other Rock Creek species in the collections at the University of Alberta and has included descriptions of specimens from other localities in this present study.

Genus *STEMMATOCERAS* Mascke

Many ammonites collected from the Rock Creek member of the Fernie formation are referable to Mascke's genus *Stemmatoceras*[3]. McLearn has already described two species which he ascribes to this genus, namely *S. albertense*[4] and *S. palliseri*[5]. These two species differ principally in the more compressed whorl of *S. albertense* with a corresponding flatter venter. The ribbing also differs in that *S. albertense* has 38 costae on the outer whorl preserved whereas *S. palliseri* has 26. The latter species has stouter ribs and more conspicuous tubercles and a greater number of secondary ribs to each primary.

Collections at the University of Alberta from the Rock Creek member show several specimens or parts of specimens which can be identified with *S. albertense*, but only one with *S. palliseri*. It is, apparently, the rarer species. There are, however, many specimens of *Stemmatoceras* in the collections which cannot be referred to either of these species and are here described as new. Some particulars of the living chamber of *S. albertense* and *S. palliseri* will also be added to McLearn's descriptions.

Stemmatoceras albertense McLearn

Plate V, Figure 1.

The holotype of *S. albertense* is entirely septate and the living chamber of the species was not described. Specimen No. Jr.482 collected by Carr from the saddle above Burns mine, Sheep river, and from the same general area from which the holotype was collected, though not complete, shows nearly half a whorl of the

* Professor of Geology, University of Alberta.

living chamber. The measurements of the whorl at the last septa are, height 43 mm., width 68 mm. The dimensions of the whorl of the holotype at the outermost septa showing are, height 33 mm., width 58 mm. Some of the septate portion of the shell of the holotype is undoubtedly missing but the proportions of the two specimens are reasonably close. In specimen Jr.482, at the beginning of the living chamber, the whorl becomes proportionately higher with more rounded venter and umbilical enlargement is rapid. Ornament tends to become faint and may completely disappear toward the end of the living chamber. The last measurements obtainable from the living chamber are, height 57 mm., width 75 mm. (approximate).

Stemmatoceras palliseri McLearn

Plate III, Figure 1.

McLearn's species *S. palliseri* is distinguished from *S. albertense* chiefly by its stouter whorls, fewer and more prominent primary ribs and deeper umbilicus. The primary ribs are usually slightly curved whereas the secondaries pass straight across the venter. The holotype does not show any part of the living chamber.

One complete though badly eroded specimen in our collection has been identified with *S. palliseri*. A comparison of the two specimens shows that the holotype lacks about half a whorl of septate shell and the whole living chamber which occupies about three-quarters of a whorl. The dimensions of this second specimen are as follows:

Diameter of shell—253 mm.
Diameter of umbilicus—125 mm.
Height of ultimate whorl at anterior end—77 mm.
Width of ultimate whorl at anterior end—61 mm. (approx).

These are the only measurements which may be obtained with any degree of accuracy.

The primary ribs become less prominent on the living chamber and may completely disappear at the anterior end. This point cannot be established on this specimen. The secondary ribs can be observed on the venter within 95 mm. of the mouth, but are not present within 50 mm. of the mouth. There is no depressed band or ridge visible near the mouth.

The last half whorl of the septate shell commences drawing away from the row of nodes of the previous whorl and the whorl becomes higher and narrower. This continues in the living chamber with a corresponding flattening of the umbilicus. Erosion of the surface of the shell prevents accurate observation of detail.

Specimen: Jr.483, University of Alberta collections.

Horizon and Locality: Rock Creek member of the Fernie formation, on Whitehorse river about 6 miles from the mouth, near Cadomin, Alberta.

Stemmatoceras mclearni sp. nov.

Plate I, Figure 1; Plate IV, Figure 1.

This species has a strong superficial resemblance to *S. albertense* but differs chiefly in the following respects: (1) the whorls are stouter, (2) the primary ribs are fewer in number and are curved, and (3) the suturee line differs in that the lateral lobe is very irregular and tends to become bifid instead of regularly trifid as in *S. albertense*. The dimensions of the specimens are as follows:

	Diameter	Width of umbilicus	Width of whorl	Height of whorl
No. 1	143 mm.	73 mm.	54 mm. (approx.)	39 mm.
No. 2	195 mm. (approx.)	102 mm.	60 mm. (approx.)	42 mm.

Both forms are ovoid and the measurements of the whorls are given on the long diameter but at different stages, the long diameter of No. 1 coincided with the beginning of the living chamber, whereas that of No. 2 was on the living chamber. The width and height of the whorl on both specimens were measured at the beginning of the living chamber. Specimen No. 2 possesses nearly half a whorl of living chamber and one good measurement may be obtained on it as follows: width of whorl, 58 mm.; height of whorl, 58 mm. These measurements show the heightening and narrowing of the whorl on the living chamber, which is quite characteristic of the genus. The ultimate whorl of No. 1 shows 31 major ribs with about 3 minors to a major. The same whorl in *S. albertense* has 36 major ribs with about 3 minors to a major.

S. palliseri has a little stouter whorl than *S. mclearni* and the primary ribs of the ultimate whorl of the holotype number 25 with from 4 to 5 secondaries to each primary. The primaries are much stouter than in *S. mclearni* with a much more prominent node. The suture line of *S. palliseri* resembles that of *S. albertense* rather than *S. mclearni*. Specimen No. 1 is considered the holotype and specimen No. 2 the paratype.

Types: Holotype Jr.192, University of Alberta collections.
Paratype Jr.480, University of Alberta collections.

Horizon and Locality: The holotype was obtained from float in Miners creek near Cadomin, Alberta, and undoubtedly was derived from the Rock Creek member of the Fernie formation. The paratype was collected by J. L. Carr on Stony creek, Highwood river, Alberta, from the Rock Creek member of the Fernie formation.

Stemmatoceras carri sp. nov.

Plate IV, Figure 2; Plate VI, Figure 3.

Stemmatoceras carri bears quite a strong resemblance to *S. albertense* but differs in several important aspects. The inner whorls are very similar to those of *S. albertense*, being strongly compressed but the rate of lateral expansion is greater, thus making a deeper umbilicus. At a diameter of about 60 mm. the whorl becomes higher with rounded nodes, the venter remaining gently rounded. At this stage the cross-section of the whorl is quite strongly quadrate with dimensions, height 23 mm., width 40 mm. and the line of contact with the preceding whorl does not draw away from the line of nodes. The venter gradually becomes a little more arched and about the beginning of the living chamber, at a diameter of 150 mm., the whorl narrows and heightens, and the venter becomes more strongly arched. Dimensions of the whorl at the beginning of the living chamber are, height 40 mm., width 55 mm. There is a variation in different specimens in the arching of the venter, but all agree in the early flattening of the flanks of the whorl.

The costation of *S. carri* differs from that of *S. albertense* in that the primary ribs are a little more numerous, not nearly so strongly expressed and with a very low tubercle on the outer end. They are quite strongly curved forward and the secondary ribs, about three to each primary swing forward in crossing the venter. The suture lines of *S. carri* and *S. albertense* are very similar, differing only in minor details. In a rapid analysis of the two species, *S. carri* can be distinguished by its slightly deeper umbilicus, less pronounced costation, curved primaries and the flat flanks of the outer whorls. It does not assume the ovoid shape as does *S. albertense*.

S. carri differs from *S. mclearni* by the deeper umbilicus, flatter flanks on the outer whorl, more feebly expressed costation and in the nature of the suture line.

Types: Plesiotypes, Jr. 484, University of Alberta collections, a large specimen with half a whorl of living chamber but the innermost whorls not showing. Jr.485, University of Alberta collections, a small specimen preserving the inner whorls. Jr.486, University of Alberta collections, a partially preserved completely septate specimen, showing the gradational links between Jr.484 and Jr.485.

Horizons and Localities: Jr. 484 and Jr. 486 were collected from the Rock Creek member of the Fernie formation, six miles above the mouth of Whitehorse river, near Cadomin, Alberta. Jr.485 was collected from the same horizon at the headwaters of Sheep river, near Burns mine, southwest of Calgary, Alberta. Other partial specimens were collected from both these localities.

Genus *TELOCERAS* Mascke

Teloceras allani sp. nov.

Plate II, Figure 1.

Description: Dimensions of the holotype—Longest diameter of shell 267 mm., umbilicus 152 mm. Dimensions of whorl at outermost septum—width 70 mm., height 45 mm. Width of living chamber near end 88 mm., height 77 mm.

The large specimen preserves four-fifths of a whorl of the living chamber and assumes the ovoid shape. Inner whorls are cadoconic, outer whorls platyconic. Inner whorls are depressed with venter broadly rounded to the end of the septate shell. Living chamber increases in height by the arching of the venter, and also increases slightly in width. Platyconic stage commences nearly half a whorl from the end of the septate shell. The outermost whorl of the cadoconic stage develops 26 primary ribs which are oblique and curved with a sharp node at the outer end with 4 to 5 secondary ribs to each. The ornament of the living chamber becomes continuously more subdued but traces of the ribbing may be observed to the end. Judging by the erosion of the venter, about one-fifth whorl of the living chamber is missing.

The suture line is typical of the genus *Teloceras* and does not appear to differ materially from that of *Teloceras dowlingi* McLearn[5].

This species may be little more than a variety of *T. dowlingi* McLearn. *T. allani* is a much larger shell, however, with finer ribbing and lacking the coarse blunt nodes at the end of the primary ribs which are characteristic of McLearn's species. *S. allani* assumes the ovoid shape, though McLearn's holotype of *T. dowlingi* and two examples of his species in our collection do not do so. The species is named for Dr. J. A. Allan, University of Alberta.

Holotype: Jr. 479, University of Alberta collections, collected by J. L. Carr.

Horizon and Locality: Rock Creek member of the Fernie formation between Picklejar and Cliff creeks, Highwood-Sheep River area.

Teloceras stelcki sp. nov.

Plate VI, Figure 1.

Description: This species is described from one nearly complete specimen, preserving about half a whorl of living chamber. Dimension—width 232 mm., width of umbilicus 112 mm. Height of whorl near end of septate shell 55 mm., width of whorl at same place 78 mm.

The penultimate whorl has 21 primary ribs which are oblique and end outwardly in a very coarse conspicuous tubercle which forms the flank of the shell. Secondary ribs, four to five to each tubercle, are fairly sharply defined and curve in crossing the venter.

Inner whorls are cadoconic, fairly stout with a low arched venter. Outer whorl becomes platyconic, commencing to draw away from the line of nodes about half a whorl before the living chamber begins, the whorl gradually becoming higher and proportionately narrower. The venter becomes highly arched, a rounding flank develops on the flank of the whorl and the ribbing and nodes become more subdued. Measurements at the end of the living chamber as preserved, height 68 mm., width 70 mm. (approx).

The suture line cannot be made out in detail and does not appear to differ materially from that of *Teloceras dowlingi.*

Remarks: This species differs from *T. dowlingi* in its larger size, stouter whorl and coarser ornament. It has the coarsest ornament of any of the species of Stephanoceratids from the Rock Creek member of the Fernie. The umbilicus is not so steep walled as *T. warreni* McLearn[5], but the highly arched venter of the ultimate whorl is very similar in contour. It has a much stouter whorl and much coarser ornament that *T. allani*. *Teloceras dowlingi* stands midway between *T. stelcki* and *T. allani* in stoutness of whorl and coarseness of ornament. In respect of the steepness of the umbilical wall, the same three species of *Teloceras* form a connecting link between *T. warreni* and *Stemmatoceras palliseri* McLearn, which has the steepest walled umbilicus of the *Stemmatoceras* group in the Rock Creek member of the Fernie formation.

The species is named for Mr. C. R. Stelck of the Imperial Oil Ltd. of Canada.

Types: Holotype—Jr. 490, University of Alberta collections.

Horizon and Locality: Rock Creek member of the Fernie formation on Whitehorse river, 6 miles above its mouth, near Cadomin, Alberta.

Genus *ZEMISTEPHANUS* McLearn

Three specimens in our collections must be ascribed to McLearn's genus *Zemistephanus*[6]. The specimens are all incomplete but probably represent one species which may be referable to Whiteaves' species *Z. richardsoni* as described by McLearn. The ornament, however, differs a little, with the secondary ribs being fewer and coarser. The coarser ornament tends to produce a strong resemblance to *Teloceras warreni* McLearn. The distinction between the genera *Teloceras* and *Zemistephanus* appears to rest on rather doubtful ground.

Genus *STEPHANOCERAS* Waagen

Stephanoceras cf. *skidegatensis* (Whiteaves)

Plate V, Figure 2; Plate VII, Figure 1.

Two partially preserved specimens of a *Stephanoceras* were collected by H. H. Beach from a sandstone bed about 300 feet above the base of the Fernie formation on the west flank of Folding mountain on Athabaska river. The horizon is undoubtedly the Rock Creek member. One specimen (Jr.495) shows most of the inner whorls (Specimen A) and the other specimen (Jr. 496) lacks the inner whorls and the two outer whorls are represented only by fragments (Specimen B). The specimens are preserved in a coarse sandstone so that fine details of the ornament are missing and the suture line is very indistinct, especially on the larger specimen. The two specimens are believed to be co-specific.

The species is very large with a diameter of at least 265 mm. Six whorls are completely or partially preserved. Specimen A shows the inner whorls down to an umbilical width of 11 mm. Specimen B shows parts of the four outer whorls. There is an overlap of about half a whorl between the two specimens.

The innermost whorl preserved on specimen A, with umbilical diameter of 11 mm., has 28 primary ribs with nearly three times the number of secondaries, the ratio being 3 to 8. Measurements of the second whorl preserved give a width of 31 mm. and a height of 28 mm. The suture line of this whorl is finely divided with LI a little shorter than EL and the first auxiliary lobe rather short and not strongly inclined.

The innermost whorl preserved on specimen B with umbilical diameter of 56 mm. has 14 primary ribs on one-half the whorl with 8 secondaries to 3 primaries. The second whorl preserved on this specimen gives the following measurements (approximate), width 50 mm., height 39 mm. No exact measurements can be obtained on the fragments of the two outer whorls, due to poor preservation. The suture line on specimen B could not be worked out with any degree of accuracy and the auxiliary lobes were not observed.

The costation is provided by the division of the primary rib into two secondaries and, usually, the implanation of an extra secondary for each primary. On the ultimate whorl as preserved, however, there is no dichotomy of the primaries and all secondaries are implanted and there appear to be no tubercles. The costation also tends to become feeble.

This species bears a very close resemblance to *Stephanoceras skidegatensis* (Whiteaves)[7]. The whorl shape is very similar as well as the costation. The species is considerably larger than Whiteaves' and the suture cannot be compared at present. It is preferable not to erect another species for this large form, until more and better preserved material is on hand.

Fragments of ammonites, identified with the genus *Stephanoceras* have been observed in other collections from the Rock Creek member of the Fernie and they are referable to this species. They provide little help, however, in obtaining a more accurate knowledge of the form.

The figured specimens are numbered Jr.495 and Jr.496 in the collections of the Geological Museum, University of Alberta.

Genus *ITINSAITES* McLearn

Plate VI, Figure 2; Plate VII, Figure 2.

Two partial specimens of ammonites from the Rock Creek member of the Fernie formation have been referred to McLearn's genus *Itinsaites*[6].

The two specimens represent totally different species, neither of which is referable to the one known species *I. itinsae* McLearn. Neither specimen is sufficiently well preserved to warrant a description at the present time. The specimens are numbered Jr.494 and Jr. 491, in the University of Alberta collections.

Genus *KANASTEPHANUS* McLearn

Plate VII, Figure 3.

One nearly complete specimen in our collections from the Rock Creek member is referred to McLearn's genus *Kanastephanus*[6]. The inner whorls are well preserved, showing the typical cadicone shape with sharp tubercles and about four secondary ribs to each tubercle. The secondaries bow forward a little in crossing the venter. A portion of the ultimate whorl is preserved as part of the living chamber, showing a narrower and higher conch with increase of primary ribs, decrease of secondaries and the tubercles not so conspicuous. This incomplete specimen cannot be identified as to species. Fragments of ammonites from the Rock Creek member have been questionably referred to this genus. The specimen referred to above is numbered Jr.497 in the University of Alberta collections.

Genus *MICCOCEPHALITES* Buckman

Several specimens of a small macrocephalid ammonite were collected by J. L. Carr in nodules, no more than 200 feet above the Rock Creek member of the Fernie formation. There are no complete specimens in the collection, but there is little doubt that the genus represented by this collection is *Miccocephalites* Buckman[1]. Some specimens approach quite closely to *M. laminatus* Buckman. All the specimens have strongly laminated costae. One specimen shows part of the outer whorl to be eccentric and the ornament shows no sign of diminishing on the living chamber.

Dr. L. F. Spath, in describing the fauna from the Jurassic succession of Jameson Land of East Greenland[8], considered that the several genera of Macrocephalids described by Buckman from the Blairmore area should be placed in the genus *Arctocephalites*. It seems to the writer that the genus *Miccocephalites*, at least, has far closer affinities with the genus *Cranocephalites*. More recently R. W. Imlay[2] has reported both *Cranocephalites* and *Arctocephalites* in the western interior of the United States. He follows Spath in considering these species to be Upper Bathian in age.

The writer is quite in accord with the opinion of an Upper Bathian age for these genera.

Genus *DEFONTICERAS* McLearn

McLearn erected the genus *Defonticeras* to include a group of species represented in a Bajocian fauna on Queen Charlotte Islands, British Columbia. The genus is closely allied to Masche's genus *Chondroceras*, differing only in small details, but nevertheless is considered sufficiently distinctive to warrant generic rank. Later, McLearn erected the genus *Saxitoniceras* for *Chondroceras*-like forms which occur in the Bajocian of the Fernie formation in the Canadian Rockies[4]. The distinction betweeen the genera *Defonticeras* and *Saxitoniceras* is based largely on detail of the suture.

Included in the geological collections at the University of Alberta are several dozen specimens of *Chondroceras*-like forms from the Rock Creek member of the Fernie. The majority of the specimens were collected from the headwaters of Sheep river, southwest of Calgary. The collection has been subjected to preliminary study which has tended to demonstrate a great variety of species but considerable difficulties are encountered in placing the species under the two genera so far described from the Canadian Jurassic. Unfortunately, the preservation of the specimens is not sufficiently good to warrant the erection of new genera and species. The distal end of the living chamber is missing in most specimens, which precludes definite generic reference. Better preserved material must be acquired before a thorough study can be made of this interesting group.

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EXPLANATION OF PLATES

PLATE I

Stemmatoceras mclearni Warren, view of holotype Jr. .192.

PLATE II

Teloceras allani Warren x ½, view of holotype Jr. 479.

PLATE III

Stemmatoceras palliseri McLearn, view of specimen Jr. 438 x ½.

PLATE IV

Figure 1.—*Stemmatoceras mclearni* Warren, view of paratype Jr. 480 x ½.
Figure 2.—*Stemmatoceras carri* Warren, view of plesiotype Jr. 484 x ½.

PLATE V

Figure 1.—*Stemmatoceras albertense* McLearn, view of specimen Jr. 482 x ½.
Figure 2.—*Stephanoceras* cf. *skidegatense* Whiteaves, view of specimen Jr. 495.

PLATE VI

Figure 1.—*Teloceras stelcki* Warren, view of holotype Jr. 490 x ½.
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Figure 3.—*Stemmatoceras carri* Warren, view of plesiotype Jr. 485.

PLATE VII

Figure 1.—*Stephanoceras* cf. *skidegatense* Whiteaves, view of specimen Jr. 496 x ½.
Figure 2.—*Itinsaites* cf. *itinsae McLearn,* view of specimen Jr. 491.
Figure 3.—*Kanastephanus* sp., view of specimen Jr. 497.

PLATE I.

1

Stemmatoceras mclearni Warren, view of holotype Jr. 192.

PLATE II.

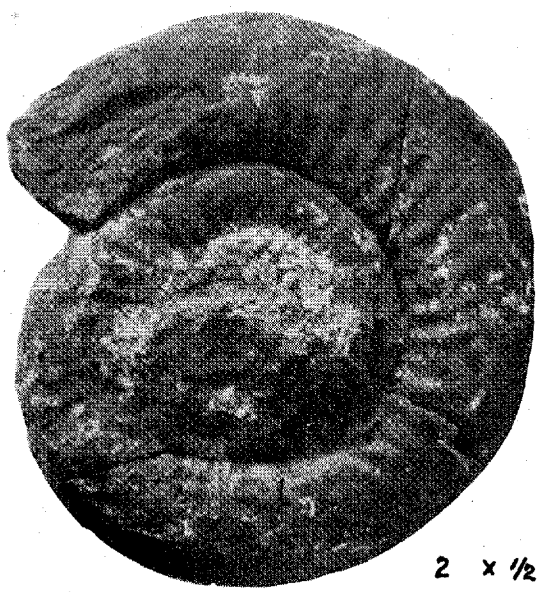
Teloceras allani Warren x ½, view of holotype Jr. 479.

PLATE III.

Stemmatoceras palliseri McLearn, view of specimen Jr. 483 x ½.

PLATE IV.

1. x ½

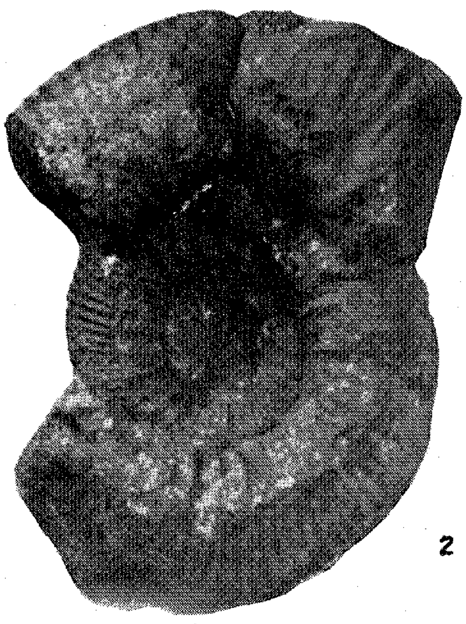


2 x ½

Figure 1.—*Stemmatoceras mclearni* Warren, view of paratype Jr. 480 x ½.
Figure 2.—*Stemmatoceras carri* Warren, view of plesiotype Jr. 484 x ½.

PLATE V.

1. x ½



2

Figure 1.—*Stemmatoceras albertense* McLearn, view of specimen Jr. 482 x ½.
Figure 2.—*Stephanoceras* cf. *skidegatense* Whiteaves, view of specimen Jr. 495.

PLATE VI.

1. x ½

2

3

Figure 1.—*Teloceras stelki* Warren, view of holotype Jr. 490 x ½.
Figure 2.—*Itinsaites* cf. *itinsae* McLearn, view of specimen Jr. 494.
Figure 3.—*Stemmatoceras carri* Warren, view of plesiotype Jr. 485.

PLATE VII.

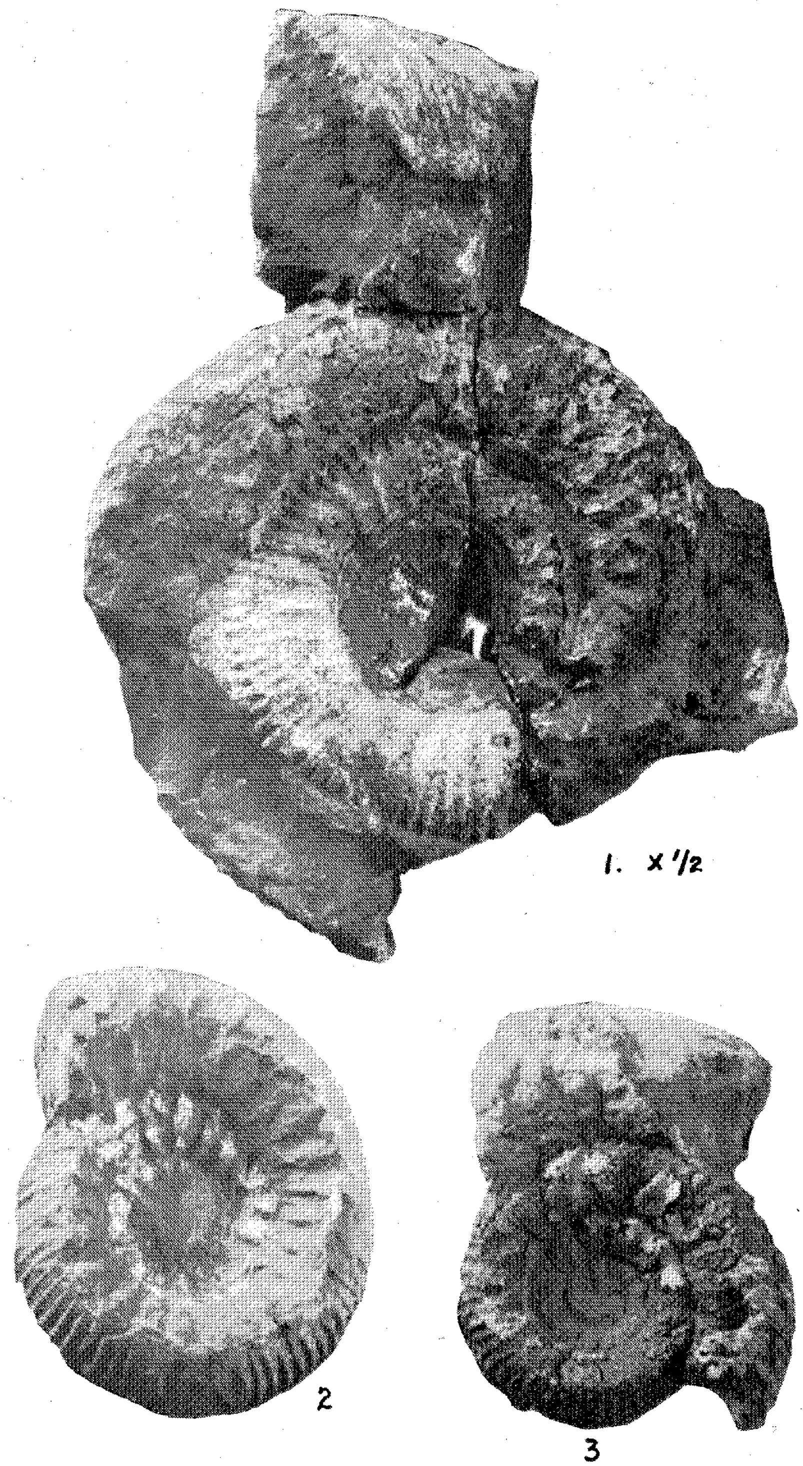


Figure 1.—*Stephanoceras* cf. *skidegatense* Whiteaves, view of specimen Jr. 496 x ½.
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RESEARCH COUNCIL OF ALBERTA 1947 Map 20 Report 49 Plate 1

GEOLOGICAL MAP
HIGHWOOD-ELBOW AREA
WEST OF FIFTH MERIDIAN
ALBERTA

Scale in Miles

1 ¾ ½ ¼ 0 1 2

LEGEND

MESOZOIC
CRETACEOUS
UPPER CRETACEOUS

Kbr	BELLY RIVER FORMATION: non-marine; grey to green sandstone, shale.
Kw	WAPIABI FORMATION: marine; dark grey shale, sandstone, ironstone nodules.
Kbg	BIGHORN FORMATION: marine; grey sandstone and shale, pebble beds.
Kbk	BLACKSTONE FORMATION: marine; grey to dark grey shale and sandy shale, thin beds sandstone and silty limestone; decomposed tuffs grey to orange near base, pebbles at base.

LOWER CRETACEOUS

Kbl	BLAIRMORE FORMATION: marine and non-marine; green, grey, brown shale, sandstone, arkose, conglomerate, limestone; tuff near top.
Kk	KOOTENAY FORMATION: non-marine; brown, grey, black shale, siltstone, sandstone, pebble beds, COAL.

JURASSIC

Jf	FERNIE FORMATION: marine; dark grey to dark brown fissile shale, sandy shale; sandstone, concretionary and phosphatic limestone.

TRIASSIC

Tsr	SPRAY RIVER FORMATION: marine; brown-weathering, silty and sandy carbonate rock and shale, minor phosphatic limestone near base; light grey, sandy, cherty, gypsiferous limestone at top in northeast of map area.

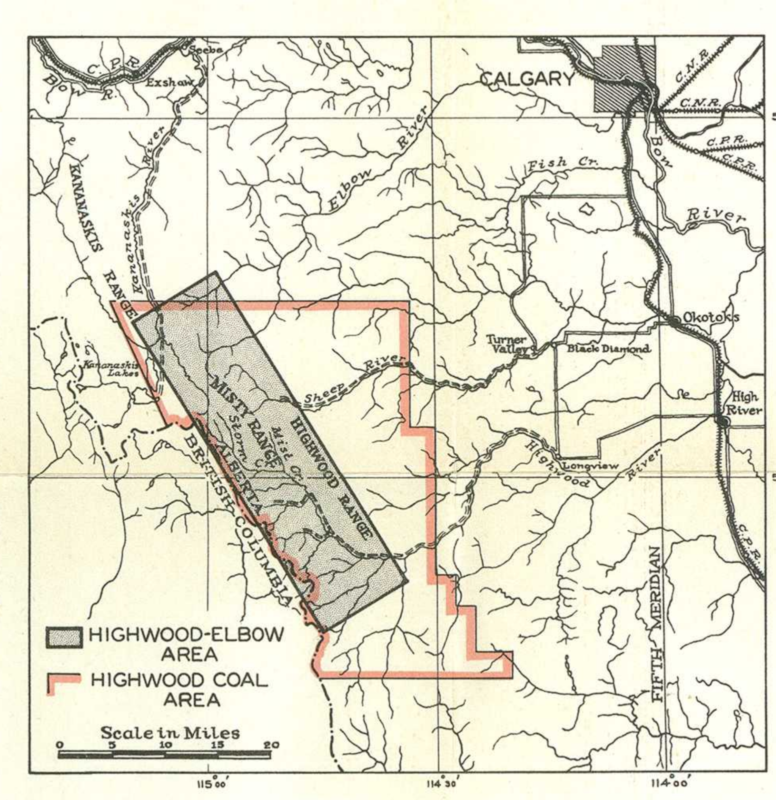
PALEOZOIC

P	UNDIVIDED: marine; grey limestone, dolomite, shale, sandstone.

Geological boundary (defined, approximate)
Bedding (inclined, overturned)
Fault (defined, approximate)
Anticlinal axis
Synclinal axis
Coal prospect (recent)
Road (not well travelled)
Trail
Building
Township boundary (surveyed)
Township boundary (unsurveyed)
Section line
Intermittent stream
Marsh
Sand or gravel
Contours (interval 200 feet) 2000
Height in feet above mean sea-level 6875'
Provincial boundary

Base-map from surveys and topography by the Topographical Survey, with minor additions by the Authors.

Geology by: J. A. Allan and J. L. Carr, 1945, 1946.



STRUCTURE SECTIONS
HORIZONTAL AND VERTICAL SCALES SAME AS SCALE OF MAP