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Geology of
Carbondale River Area
Alberta

BY

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Chapter I

INTRODUCTION

LOCATION, BOUNDARIES AND ACCESS

This report on the Carbondale River area is based on a survey carried out during the summer of 1949. The Carbondale map area lies within the foothill and mountainous district of southwestern Alberta. Its northern limit is seven miles south of the important coal mining centre of Blairmore, and about fifteen miles west of the town of Pincher Creek. The map areas adjoining are Blairmore on the north (Leach, Rose, 1920), and Beaver Mines on the east (Hage, 1940). There is a slight overlap with the latter map. Excepting for ten and one-half square miles in the northeast corner, the map area is within the Rocky Mountains Forest Reserve. That part south of the Carbondale river lies within a game preserve. The Carbondale River map area lies wholly within the drainage basins of the Castle and Carbondale rivers, both of which are tributary to the Oldman river.

The northern boundary of the Carbondale River map area is 49° 30′ north latitude, and the eastern boundary is 114° 15′ west longitude. The area is confined on the west by the British Columbia-Alberta boundary. The southern boundary is the northern limit of the Precambrian overthrust fault block, which within the map area traces a sinuous path through the northern part of township 4 and the southern part of township 5.

Three main roads serve the area. One branches from the Crowsnest highway at Bellevue, another forks south from the same highway at Burmis post office, and a third travels west from the town of Pincher Creek. The first mentioned is for the greater part a private road. This route passes through Hillcrest, and then follows the valley of Byron creek. It passes the Adanac coal mine on its way to the top of the divide. From thence it goes down the valley of Webb creek to the Carbondale river, a descent of some 1300 feet. The road then follows up the Carbondale valley to the Burmis Lumber Company camp in section 28, township 5, range 4, west of the fifth meridian. Here and there it gives off branches which lead to the various lumber camps on O'Hagen and Gardiner creeks. This road is kept in good condition and is passable even under severe conditions of rain or snow. The second entry to the map area, the Burmis route, proceeds south to the Castle river, follows this river to its confluence with the Carbondale river, and at this point bifurcates. One fork follows the Carbondale to join the Hillcrest road, and the other fork continues along Castle river to the Castlemount ranger station. There it trifurcates, two branches continuing along either side of the south fork of Castle river and the other following the west branch of the river. The road from Burmis is usually rough but was passable at all times. The third road, which approaches by way of the town of Pincher Creek, follows along Beaver Mines creek to about three miles southwest of Beaver Mines post office. At this point, just off the map area, the road bifurcates, the north branch passing over a low divide to join the Burmis road at the Castlemount ranger station. Many short branches of the above main roads have been built for lumbering operations, and some are still in use or are passable.

Pack trails, in the northern part of the area, follow along the main creeks, and are the only means of access. There are trails along Lynx creek and its branches, along Lost creek, and along Carbondale river. This last one commences at the termination of the road to the Burmis Lumber Company camp, continues west along Carbondale river to its headwaters, then goes over North Kootenay pass into the Flathead valley of British Columbia. These pack trails have not been kept in repair, it being necessary on all of them to cut out windfall and to detour many of the slideouts and marshes that had been corduroyed years before.

A pack train was used for part of the season, during which time approximately one-third of the area was covered. In surveying the remainder, transportation by automobile was possible.

PREVIOUS WORK IN THE REGION

The first records of the geology of the southwestern part of Alberta were made by J. Hector (Hector, 1863), who did the geological mapping for Captain J. Palliser's expedition. Hector did not visit the mapped area, but Palliser and his secretary went by way of North Kootenay pass on returning to Edmonton from British Columbia territory. G. M. Dawson (Dawson, 1885, 1886) made a preliminary survey in the area. He traversed the area from the east side of the present map area to the summit of North Kootenay pass. His observations include a description of coal seams, volcanic rocks, and a summary of the structure of the region. R. G. McConnell did work in the region, particularly that of dividing the rocks into formations (McConnell, 1886). D. B. Dowling worked in the Cascade coal basin (Dowling, 1903, 1904), and also made a compilation of the coal reserves of Western Canada. R. A. Daly (Daly, 1912) surveyed and described the formations and structure along the forty-ninth parallel.

The area immediately adjoining the Carbondale area on the north, owing to its importance as a coal field, has been thoroughly investigated. W. W. Leach (Leach, 1902) was one of the first to examine it. Leach surveyed the coal field in 1911 and 1912 and published stratigraphic and structural reports together with a preliminary map (Leach, 1911). The Flathead coal field, lying in British Columbia, immediately west of the Flathead and Clarke ranges, was surveyed by J. D. MacKenzie in 1912. In the same year he made a preliminary survey of the present area, which at that time was known as the South Fork area (MacKenzie, 1912). Leach's work in Alberta was continued by B. Rose (Rose, 1915), who published a detailed geological map of the Blairmore map area. This was followed in 1916 by a report on the stratigraphy and structure. In 1915 F. H. McLearn investigated and wrote an account of the Jurassic and Cretaceous of the Crowsnest pass (McLearn, 1915). He later published a bulletin describing the Mesozoic paleontology of the region (McLearn, 1929).

Later G. S. Hume, B. R. MacKay, Pierre de Bethune and Robin Willis contributed reports on the area and regional geology. Hume has contributed particularly to our knowledge of the structure of the area by his observations in North Kootenay pass (Hume, 1932). MacKay worked in the Crowsnest pass area from 1930 to 1932, and has described in some detail the stratigraphy and structure with special attention being given to the coal measures and coal mines. Pierre de Bethune, geologist with West Canadian Collieries, Blairmore, described the structure of the Rocky Mountain ranges adjacent to the Flathead and Elk River valleys (Bethune, 1936). R. Willis and B. R. Hake working for private interests compiled a map of the region.

P. S. Warren has described the rock sequence in the Crowsnest pass (Warren, 1933), and has also surveyed and described the Fernie formation in the region, particularly in the Fernie Basin (Warren, 1931, 1932, 1934).

In 1948 M. B. B. Crockford spent several days in the area making reconnaissance surveys, preparatory to detailed surveys which were being considered for 1949.

PRESENT WORK

Within the last few years the trend in coal mining has been toward the recovery of coal by strip mining rather than by underground methods. Since the successful development of strip mines requires rather exacting conditions, especially as to the depth of overburden and accessibility, their number is limited. Hence it was considered that detailed geological surveys, having as a principal objective the exploration of coal seams, should be restricted to unmapped areas within easy reach of railways. The Carbondale River area appeared to fulfill these requirements since it lies within easy reach of Blairmore, and since the coal measures mined near that town could be expected to extend southward into the map area. Accordingly it was selected as the locale for the field surveys of 1949. Moreover, this area was bounded on the north and east by areas which had been mapped in considerable detail, so that detailed surveys within it were desirable in order to complete the geological mapping of that part of the province. It was also thought that stratigraphic and structural data of considerable value could be obtained in this little known area.

Some monuments and survey lines, established by the Dominion Government early in this century, were used to some extent to establish horizontal control. Though these surveys should have supplied good control, it was found that most of the cut lines made at that time had been obliterated by forest fires and the regrowth of timber. Further horizontal control was obtained by the use of aerial photographs and reference to timber maps of the Burmis Lumber Company.

Topographic control was obtained from the Department of Interior maps of the Crowsnest Forest and Waterton Lakes Park, sheets three and four.

The amount of stratigraphic information obtained by the survey was disappointing. This was due largely to the wide extent and thickness of the glacial mantle, the density of forest cover, and also to the tremendous amount of earth movement to which the strata had been subjected. During these movements the rock formations were faulted and folded so many times that stratigraphic sections of more than a few hundred feet are rare. As a result, there are large missing intervals in the detailed descriptions of all the formations given in Chapter III, excepting the Kootenay, Crowsnest, Blackstone and Bighorn successions. Though the area has relatively few good outcrops suitable for stratigraphical studies, it does offer a great number of geological structures of considerable interest.

Stratigraphic sections were measured by steel tape, step method and plane table.

The geological field party was under the leadership of the senior author of this report. The junior author was able to visit the party from time to time during the field season, and thereby assist in the progress of the survey.

ACKNOWLEDGMENTS

Capable assistance was given in the field by D. E. Duff and G. L. Colborne, student assistants, R. Sharp, packer, and G. F. Wyatt, cook. S. J. Groot, draftsman for the Research Council of Alberta, prepared the accompanying map. D. E. Duff has further aided in the preparation of this report.

P. S. Warren spent five days with the field party during the summer and gave valuable guidance and direction. He also identified the fossils collected, and gave advice regarding the preparation of this report.

The courtesies extended to the party by T. Van Wyck, J. L. Stevens and V. Patinaude of the Burmis Lumber Company, F. Jones, W. Walliter and Robin Huth of the Alberta Forestry Service, and J. A. Brusset, H. Gardiner and N. Melnyk of the West Canadian Collieries are greatly appreciated. The assistance rendered by these persons greatly facilitated the survey.

Chapter II

GENERAL CHARACTER OF THE REGION

TOPOGRAPHY

The Flathead range, which is a unit of the front Rocky Mountain ranges, lies on the west of the area (Figure 1). The range has a north-south trend, and is in accord with the trend of the Rocky Mountain ranges in this region. Some peaks of the Flathead range are the highest of the area, and one of them, Mt. Darrah, is 9038 feet high.

The Clarke range situated immediately south of the south boundary of the map area has a regional and local southeast trend which is almost normal to the trend of the Flathead range. Syncline mountain in the Clarke range has an elevation of 8008 feet.

The ridges formed by the upheaval and subsequent erosion of the Mesozoic rocks strike in a northwesterly direction within the area. Those ridges north of the Carbondale river have a trend twenty degrees west of north, but those south of the Carbondale river have a general strike of about fifty-five degrees west of north. Erosional processes have caused the ridges to assume a variety of shapes. In some places they are eroded to near valley level whereas in other places they are high enough to be prominent hills. The highest of these hills are Prospect hill, having an elevation 6400 feet; Cherry hill, elevation 6300 feet; Carbondale hill, elevation 5921 feet; and Backus mountain, elevation 5924 feet. These elevations are approximately 900 to 1000 feet above the general level of the surrounding country.

Broad valleys lie between the ridges or are at right angles to them. These valleys have been formed by stream and ice action. That the main stream valleys have been heavily glaciated is exhibited by their U-shape and by the large amount of glacial debris found in them. Moreover, more than one stage in the ice advance is shown along the valleys, especially those of Lynx creek and Carbondale river. Three main terraces were observed in each of these valleys. The valleys lying between the ridges and having the same trend as the ridges are largely the result of differential erosion of the inclined strata by subsequent streams.

DRAINAGE

The drainage of the Carbondale area is tributary to the Oldman river. The two main streams are the Castle and the Carbondale rivers, the latter being tributary to the Castle and flowing into it in the northeast corner of the mapped area. Early geographical accounts referred to the Carbondale river as the South Fork and to the Castle river as the Little Fork. The whole area was referred to as the South Fork country.

The Carbondale river has its source in two small tandem lakes about a half mile from the summit of North Kootenay pass. The river flows in an easterly direction to its confluence with the Castle. Four large creeks, Gardiner, Lost, Lynx and O'Hagen are tributary to it. These creeks, with the exception of O'Hagen, have their sources in cirques of the Flathead and Clarke ranges. Lost creek has at its headwaters four large cirques, and Lynx creek three at the source of its west branch. O'Hagen creek rises from small tributary streams which drain the tract of rolling hills between Gardiner creek and Castle river. Castle river arises in the Clarke range some distance south of the map area, and it and its tributaries provide the drainage for the southeasterly section of the map area. The Castlemount ranger station is situated at the confluence of the west and south branches of Castle river. From this junction, the river flows through the map area in a northeasterly direction.

All the streams mentioned in the above description are antecedent for the major part of their courses. Occasionally they become subsequent as they pass from resistant to weak strata. This is illustrated on George and Lynx creeks both of which are incised in the soft arenaceous shales of the Blackstone formation, a formation lying adjacent to the more resistant Crowsnest volcanics. Furthermore, many of the smaller tributary streams follow the trend of the ridges to their confluence with the creeks. George creek, a tributary of Lynx creek, follows the Blackstone-Crowsnest contact for the larger part of its course.

CULTURE

The map area does not support any community centres. Several lumber operators have established semi-permanent camps which are moved from time to time, their site being dependent upon the operational area. The largest of these camps is that of the Burmis Lumber Co., located in section 28, township 5, range 4, west of the fifth meridian. This camp has several temporary family dwellings, a school and a commissary. There is a ranger station at the forks of the Castle river and another at the junction of the Lynx creek and Carbondale river. A fire lookout is situated on Carbondale hill. There are several small ranches in the northeastern and the eastern parts of the map area.

The Adanac strip mine, owned by West Canadian Collieries, is in operation on the ridge lying between George and Webb creeks (Figure 2).

FAUNA AND FLORA

Although the southern part of the map area lies within a game preserve and the northern portion is fairly inaccessible to hunters, wild life is not abundant. Black bears and grizzly bears are present, but not in great numbers. Only a few moose, elk, deer and mountain goats were observed, and it is concluded that the animals are not present in the area in large numbers. Of the smaller animals, Columbian ground squirrels and coyotes are the most abundant; red squirrels, chipmunks, conies, beavers, porcupines and weasels occur in lesser numbers. The streams offer very good trout fishing. Grouse are plentiful through the southern part of the area.

Forest growth is in parts quite dense. The entire map area, with the exception of an area of grassland centering about the confluence of the Carbondale and Castle rivers, is or has been heavily wooded. That sector lying between Castle and Carbondale rivers and west of Carbondale hill was swept by a forest fire in 1936, and consequently is covered with dead timber. A tree regrowth of a height of six to eight feet is beginning to appear. The fallen timber and regrowth make traverse very difficult. That part north of the Carbondale river and west of George creek, excepting for a few of the ridges, is very heavily wooded. The principal trees are spruce, balsam and pine Poplar occurs, but is usually of a scrubby nature. Douglas fir is present in scattered clumps. In places, especially on the north and east slopes of hills and ridges, the undergrowth is very thick. The tree line is 6500 to 7000 feet above sea level. A varied alpine flora was observed, the flowering plants being very abundant both above and below tree line.

Small muskegs occur locally in the map area. They are largely confined to those sections of the river valleys which are broad and flat. The upper valleys of Lynx and Lost creeks have many small muskegs.

Chapter III

STRATIGRAPHY

GENERAL STATEMENT

The rocks of the Carbondale map area range in age from Proterozoic to Recent. The Proterozoic rocks include partially metamorphosed sediments and volcanics of late Precambrian age. Lying conformably on the Precambrian formations is a quartzitic formation which is placed in the Cambrian (Hage, 1940). The quartzitic rock is overlain by shales, dolomite and limestone of the Devonian system and these are succeeded by Carboniferous limestones and shales.

The oldest Mesozoic strata belong to the Jurassic system. The Lower Cretaceous group conformable with the Jurassic, is represented by the Kootenay, Blairmore and Crowsnest formations. This last formation is volcanic in origin and is one of the few occurrences of rocks of this type in Alberta. The Upper Cretaceous formations are a series of marine shales and sandstones which have been divided into the Blackstone, Bighorn and Wapiabi formations; a succession of fresh water and brackish water strata of the Belly River formation; and the marine and brackish water strata of the Bearpaw formation. The thicknesses of Tertiary rocks in regions adjacent on the east would indicate that strata of this age were at one time present in the map area, but have been removed by erosional processes. Pleistocene and Recent consisting of deposits of gravel, sand, clay, a fairly well consolidated conglomerate and a thin soil mantle are very prominent.

Little difficulty was encountered in the determination of boundaries of formations because the lithological breaks are usually quite pronounced. However, the faulting and folding within formations and the thrusting of older formations over younger strata have made the measurement of some formational thicknesses difficult.

PRECAMBRIAN FORMATIONS

Precambrian rocks occur within the area only in the Flathead and Clarke ranges. The mountains of the Clarke range are, within the map area, composed largely of Precambrian strata. Precambrian formations underlie the Paleozoics of the Flathead range. The total estimated thickness of the Precambrian formations in the vicinity of North Kootenay pass is 2000 feet.

The survey did not concern itself with details of the Precambrian and Paleozoic formations. Casual observation of the Precambrian

TABLE I

TABLE OF FORMATIONS

Group	System	Series	Formation	Character	Thickness feet
Cenozoic	Quaternary	Recent and Pleistocene		Soil, gravels, till and conglomerate.	
			Unconformity		
Mesozoic	Cretaceous	Upper Cretaceous	Bearpaw	Blue-grey, sandy shales with carbonaceous layers and shell beds. Marine and brackish water.	
			Belly River	Soft, greenish-grey sandstones and shales with brackish water fossils. Non-marine and brackish water.	2500
			Wapiabi	Dark grey to black shales and sandy shales with concretions. Some thin sandstone bands. Fossiliferous. Marine.	1400±
			Bighorn	Upper part hard, grey quartzitic sandstone. Conglomeratic layer and dark grey sandy shales. Lower part, greyish, quartzitic sandstone and shale. Fossiliferous. Marine.	100
			Blackstone	Medium grey to dark grey shales and sandy shales. Dark chert conglomerate at the base. Fossiliferous. Marine.	325
			Unconformity		
		Lower Cretaceous	Crowsnest	Tuffs, agglomerates, breccias and bedded ash.	465
			Blairmore	Green, grey and maroon shales, grey-green and greenish-grey sandstones. Limestone nodules and a fossiliferous layer near the base. Large lenses of conglomerate about 700 feet from base. Hard, massive cherty conglomerate at the base. Non-marine.	1800
			Unconformity		

TABLE I (Continued)

TABLE OF FORMATIONS

Group	System	Series	Formation	Character	Thickness feet
			Kootenay	Brown, dark grey and black shales, often carbonaceous; coarse- to fine-grained, brown sandstones. Coal seams. Thick basal sandstone member. Non-marine.	280
	Jurassic		Fernie	Brownish-grey sandstone at top; overlie interbedded sandstones and shales which grade downwards to brown and black fissile shades. Nodules. Black, sandy, phosphatic bed at bottom.	1035
			Disconformity		
Paleozoic	Carboniferous		Rundle	Limestone.	
			Banff	Limestone, calcareous shale, shale.	
	Devonian	Upper	Exshaw	Shale.	
			Palliser	Limestone and dolomite.	
			Fairholme	Dolomite, shale and limestone.	
			Unconformity		
	Cambrian			Quartzites.	
			Unconformity		
Precambrian	Proterozoic (Late Precambrian)		Kintla	Red, green and grey argillites, quartzittes and diorite sills.	
			Sheppard	Brown argillite, limestone and sandstone.	
			Purcell	Sill of dark green and purplish vesicular and amygdaloidal basalt.	
			Siyeh	Grey and green argillite, argillaceous limestone, cryptozoan limestone.	

rocks led to the conclusion that the oldest rocks present are those of the Siyeh formation, which is represented in the area by thin bedded argillaceous limestone, cryptozoan limestone, and a sill of basic igneous rock which C. O. Hage identified as a diorite (Hage, 1940). Overlying the limestones is a massive bed of amygdaloidal basalt, which has in it a layer of basic rock containing numerous feldspar laths. The feldspar crystals show very distinct zoning. The remainder of the strata lying between the above mentioned igneous bed and the Cambrian is largely red argillite with a sill of basic rock near the Precambrian-Cambrian contact, and is considered to belong to the Sheppard and Kintla formations.

PALEOZOIC FORMATIONS

The Paleozoic rocks of the area occur in the Flathead range and the Turtle Mountain anticline. The base of the Flathead range within the map area is composed of Precambrian rocks. Overlying the Precambrian and apparently conformable with it is a pinkish quartzite about fifty feet thick, which C. O. Hage (Hage, 1940) places in the Cambrian. Lying above the quartzite, and having the same attitude as it there is a bed of shale four hundred feet thick. The shale is green in color, and has thin calcareous sandstone beds at intervals of eight to ten feet. The sandstone layers contain poorly preserved remains of trilobites, conodonts and pelecypods, to which P. S. Warren (Warren, 1949) assigns an Upper Devonian age. The most complete section of this shale was observed in sections 34 and 35, township 5, range 4, west of the fifth meridian, and on the ridge which forms the divide between the north and south branches of Lost creek (Figure 1). The ridge in section 14, township 6, range 5, west of the fifth meridian and immediately north of the north branch of Lost creek also exhibits the green shale, but there the section is much thinner. These were the only two observed outcrops of this particular shale. It is thought that the erosion of these shale beds has produced North Kootenay pass, but the talus slope has covered the shale outcrop.

The green shale grades upwards into intercalated thinly bedded limestones and shales, which Warren (Warren, 1949) correlates with the Fairholme formation. This series includes a forty-foot bed of collapsed breccia and two fossiliferous horizons. The lowest fossiliferous horizon, about four hundred feet above the base, is a biostrome, from which a number of corals were collected. The stratigraphic position of the other fossiliferous horizon was not observed, but its presence was noted by the abundance of the brachiopod, ***Atrypa sp.***, on the talus slopes. Massive limestone beds of the Palliser formation overlie the Fairholme formation. In the vicinity of North Kootenay pass the Palliser formation forms the precipitous cliffs common to the mountains. Farther north, in the extreme northwestern corner of the map and at the headwaters of the west branch of Lynx creek, the complete Palliser section is apparently present. The Palliser formation is overlain by the Exshaw shale, which at this locality is but twenty feet in thickness. The Banff formation was recognized, but was not examined closely.

Rocks of Carboniferous age which form the southward plunge of the Turtle Mountain anticline outcrop in the area. Some of the strata exposed on the road cut to the Adanac strip mine were chiefly thick bedded limestones, which in places are dolomitized, and are presumed to belong to the Rundle formation. No faunal evidence for the age of these strata was obtained.

MESOZOIC

JURASSIC

Fernie Formation

NAME AND DISTRIBUTION: In 1902 W. W. Leach (Leach, 1902) referred to the dark shales underlying the Kootenay coal measures as Fernie shales. In 1911 he applied this name formally to the group of shales to which he assigned a Jurassic age. The Fernie formation or its equivalents subsequently have been traced from the forty-ninth parallel as far north as the northern boundary of British Columbia.

The Fernie formation in the Carbondale area does not cover large areas. Two bands, one on either flank of the Turtle Mountain anticline are present in the northern sector. These bands have the same attitude as the limbs of the anticline, and therefore plunge toward the south with it. With the plunging out of the Carboniferous, the Fernie bands unite and the resulting band is exposed as such in the valley of Carbondale river at the mouth of Webb creek, and also in the gorge cut by O'Hagen creek. South of O'Hagen creek the formation plunges out beneath overfaulted Kootenay and Blairmore strata. Only two other occurrences of Fernie rocks are found in the map area; these are slices brought up under the main thrust fault. One slice was observed on the ridge south of the south fork of the west branch of Lynx creek, and the second is exposed on the northern slope of one of the ridges of Mt. McCarty.

THICKNESS AND LITHOLOGY: The thickest section of Fernie strata examined is that which has been bared in the cuts of the branch road leading to the Adanac strip mine, situated in section 24, township 6, range 4, west of the fifth meridian. Exposures of Fernie strata are almost continuous along this road from the summit in section 30, township 6, range 3 to the mine. Here the road travels principally along the strike of the strata, so that the stratal succession is not easily measured. Other Fernie shale exposures on Carbondale river and O'Hagen creek are so badly faulted and contorted that the thickness of the formation and the sequence of the beds in it are not easy to determine.

The Fernie formation decreases in thickness from west to east. In the Corbin coal field, MacKay (1931) measured it to be 2800 feet. He found it to thin eastwards, for in the Crowsnest Pass area it ranges from 900 feet to 700 feet.

The Fernie formation rests disconformably on limestone beds belonging to the Rundle formation. The only Rundle-Fernie contact observed was that on the Adanac Strip Mine road on the east side of Turtle Mountain anticline (Figure 3). Only a few feet of the contact is exposed at this point, so that the nature of the unconformity could not be exactly determined. However, it was noted that the basal Jurassic bed is a coarse-grained sandstone with some phosphatic material disseminated in it. Chert pebbles of one-half inch diameter are scattered throughout the sandstone, but no quartzite pebbles occur. The underlying rocks, presumably of Carboniferous age, are a dark limestone. McLearn (1915), had previously examined the Fernie-Paleozoic contact on the north and west sides of Bluff mountain, some miles north of the Carbondale map area, where it is also disconformable. There he found that the underlying Paleozoic rocks are a white quartzite, and that the overlying Jurassic bed is a conglomerate with reddish quartzite pebbles.

The section as measured on Hastings ridge along the road to the Adanac strip mine is given below:

HASTING RIDGE SECTION OF THE FERNIE FORMATION

Overlying beds: Kootenay sandstone.

Fernie-Kootenay Contact

	Thickness Feet
Sandstone, dark, grey-brown, in beds from a few inches thick to several feet, fine-grained	24.0
Shale, drak grey, alternating with thin bands of sandstone; sandstone beds show fine banding, and some increase in thickness towards the top	65.0
Shale, dark green to dark grey; thin sandy lenses	15.0
Shale, dark grey with thin bands of light greyish-green, sandy siltstone (about 50%)	10.0
Shale, dark grey, thin-bedded; weathers into fine flakes, micromicaceous; attitude 39°W, N. 15°W	28.0
Sandstone, bright emerald green, glauconitic; two or more lenses of hard rusty weathering shale	10.0
Shale, brown, blocky	6.6
Shale, sandy, yellowish-green to green in color; one band one foot wide, pistachio green (glauconitic)	9.8
Shale, green and brown layers generally blocky but in places quite plastic; crumbly weathering; very sandy near top	41.0
Concealed in part, largely brown shale and finely banded brown sandstone	40.0
Shale, brown, hard and blocky; weathers very light brown and crumbly	75.0
Concealed	250.0

	Thickness Feet
Shale, dark brown, fissile, light greyish-brown weathering	6.5
Limestone, sandy; upper beds more so than lower ones; more sandy in upper part of bed; approximately same horizon as *Corbula munda* fauna; basal bed crystalline, showing in one place a band of calcite three-quarter inch wide	15.0
Shale, brown, hard, blocky; weathering light brown and crumbly; appears to be almost fresh water in nature; slightly silty; somewhate plastic; nodular in topmost fifteen feet	163.2
Shale brown, very fissile, light brown weathering; crumbly in places; very limy, blocky streaks; contains numerous light nodules; at top one six-inch layer of nodular concretions	117.2
Concealed, in part shale, black, brown weathering, fissile with blocky streaks	48.0
Shale, black, brown weathering; fissile with blocky streaks; occasional sandy layer two inches thick	36.2
Shale, brown, very fissile, weathers light brown with one band of nodular sandstone eleven inches wide	39.5
Concealed	7.7
Shale, black, fissile, black weathering, slickensided	16.8
Shale, black, platy, sandy; weathers into plates of one-eighth inch to one-quarter inch; dark brown weathering, badly squeezed	8.5
Sandstone, dark reddish-brown, coarse-grained; some phosphatic material in the form of nodules, concretions and mineral aggregates; chert pebbles	2.0
Total thickness Fernie beds	1,035.0

Underlying beds: Carboniferous limestone.

The basal sandstone with phosphatic material and chert pebbles probably occupies the same stratigraphic position as the phosphate bed which has been mined at Crowsnest. However, there is little lithological resemblance between the phosphate beds at these two localities. The Crowsnest bed is of a dense nature, whereas at this locality the phosphate is disseminated in a sandstone which is fairly loose and consists essentially of quartz grains.

The Fernie formation consists largely of marine shales. The basal shale overlying the phosphatic sandstone is slightly sandy and fractures with a platy habit. Freshly exposed surfaces reveal plates of one-eighth inch to one-quarter inch in thickness. The dark shale overlying this is very fissile, and at this locality gives indications of flowage due to pressures exerted upon it presumably during the orogenic movements of the Rocky Mountain uplift. The thick brown shale beds, which succeed the black, are a phase of the Fernie not previously observed (Warren, 1949). These shales weather to a characteristic crumbly surface. In fresh exposures the shale has a somewhat blocky habit. Nodules which occur throughout the bed were found to be hollow in the centre, and as they are somewhat porous it is presumed that the interior has been removed by leaching. Near the top of the brown shale zone a persistent horizon of arenaceous fossiliferous limestone occurs. Overlying the limestone are more brown shales and then green sands. The green sands were observed also along Carbondale river, and in the slice at the headwaters of Lynx creek. Microscopic examination of the sand shows it to be composed largely of glauconite. The upper part of the formation is a series of shales and interbedded sandstones commonly referred to as "the ribbon sands." The sandstone bands are two to four inches in thickness and occur at intervals of approximately one to four feet. The shale is black, fissile and silty. Near the top of the shale and sandstone sequence, the sandstone beds become progressively thicker and the shale bands thinner until the shale disappears. This gradual change in sequence indicates continuous deposition.

Deposition of the Fernie strata terminated in a massive sandstone member. Lithologically this sandstone varies, in that it is fine-grained to medium-grained near the base, and has a rhythmical banding, whereas the upper part is fairly coarse-grained and without any banding. Moreover, the lower beds are more calcareous. The contact between the Fernie and Kootenay formations is placed within this sandstone member at the point where the difference in lithology occurs. No unconformity is visible there. Similar conditions were observed in the Ribbon Creek area, and a more detailed study resulted in this same conclusion (Crockford, 1949). As a result of detailed investigations of the Fernie-Kootenay contact in the Fernie area, C. Newmarch (Newmarch, 1949) has concluded that the contact is gradational, and that if any time break occurs at the contact, it must be slight.

The measured thickness of the section given is 1035 feet. This is thicker than the section at Fernie which was given by Warren (Warren, 1934) as 800 feet. The difference in thickness may be due to minor faulting and folding in the shale members, particularly in the thick shale beds lying 300 to 400 feet above the base.

AGE AND CORRELATION: Faunal collections were made from the Fernie at two localities, one where the section given above was measured, and the other from the exposures on the Carbondale river. The specimens which were obtained are ***Inoceramus obliquiformis*** McLearn, ***Gryphaea impressimarginata*** McLearn, ***Entolium leachi*** McLearn, ***Lima albertensis*** McLearn, ***Pleuromya obtusiprorata*** McLearn, ***Pleuromya summissiornata*** McLearn, ***Thracia canadensis*** McLearn, ***Protocardia schucherti*** McLearn, ***Cadoceras*** sp. and ***Miccocephalites concinnus*** Buckman. This fauna is assigned to a Callovian stage of the Upper Jurassic by Buckman (Buckman, 1929). The highest faunal horizon observed in the Jurassic in the map area is that of the green sand beds. There belemnites and one specimen of a large pelecypod, too poorly preserved for collecting, were noted. McLearn suggests that green sand bed fauna may not be far removed in age from that of the ***Corbula munda.*** These Fernie exposures did not yield the Sinemurian (Lower Jurassic) fauna described by Warren (Warren, 1929, 1934) of the ***Chlamys mcconnelli*** horizon reported by McLearn (McLearn, 1949). The ***Corbula munda*** fauna described by McLearn (McLearn, 1929) is abundant in the two places mentioned.

The zones in the Fernie formation of the Carbondale area do not wholly correspond to those more northerly sections seen in the Highwood-Elbow (Allan and Carr, 1947), Ribbon Creek (Crockford, 1949), and Mountain Park areas. One prominent faunal zone, namely the Rock Creek member, which usually occurs about 100 feet above the base of the formation, is absent. This member has been observed elsewhere in the Crowsnest area, where it carries abundant belemnites.

CRETACEOUS

LOWER CRETACEOUS

Kootenay Formation

NAME AND DISTRIBUTION: The Kootenay formation was named in the Crowsnest Pass area by G. M. Dawson in 1885 (Dawson, 1886) and on the basis of fossil plants was assigned to a Lower Cretaceous age by Sir J. W. Dawson (Dawson, 1885). W. W. Leach placed the shales below the Kootenay in the Jurassic (Leach, 1911), and gave the upper boundary as a bed of conglomerate which persists throughout the region. Later B. Rose noted during his investigations that an unconformity existed at the base of the conglomerate, and consequently divided the Kootenay from the overlying Blairmore at the unconformity.

Coal seams of the Kootenay age have been widely prospected in the southwestern portion of Alberta and southeastern British Columbia. Faulting and folding of this strata has brought the seams to the surface or near enough to it to be observed, prospected and mined in places. The Kootenay strata or their equivalents extend northerly throughout the foothills and mountains of Alberta, but are not coal-bearing at Nordegg and northwards of that point.

The Crowsnest coal field lying adjacent to the map area on the north has numerous mines driven into Kootenay coal measures. These measures have been discussed in some detail by B. R. MacKay (MacKay, 1931, 1932, 1933).

In the Carbondale map area seven bands of Kootenay are faulted to the surface. The most westerly band lies under the main overthrust fault of the Precambrian and Paleozoic rocks (Figure 4). A slice of the formation occurs a mile and a half east of the main thrust in the Carbondale area and a third follows along Willoughby ridge. Two bands occur on the west limb of Turtle Mountain anticline and one on the east limb. Two of the bands on the anticline join to form one band south of the Carbondale river. The seventh band is observed in the northeast corner of the area.

THICKNESS AND LITHOLOGY: Only two of the six Kootenay bands provided sections suitable for measurement. The most complete section is exposed at the Adanac strip mine in section 24, township 6, range 4, west of the fifth meridian. There the formation measures 280 feet in thickness. On Lynx creek, in section 10, township 6, range 4, west of the fourth meridian, a measured section gave a thickness of 275 feet, but the base of the formation is not present, having been faulted out. The Kootenay formation thickens rapidly from the eastern Alberta foothills westwards into the mountains of Alberta and British Columbia. In a well, Alliance No. 1, which was drilled for oil about four miles east of the eastern boundary of the present map area, the formation is but 74 feet thick (Hage, 1940). Along Crowsnest river, south of the town of Blairmore, Rose obtained a thickness of 450 feet for the formation (Rose, 1916). B. R. MacKay (MacKay, 1932) found a thickness of 584.5 feet on York creek just north of the map area. In British Columbia the Kootenay formation reaches relatively great thicknesses, one of 1854 feet being reported in the Fernie basin (MacKay, 1931). This westward thickening of the formation may be due in part to repetition of beds by unsuspected faulting and to differential erosion at the top of the formation.

The only section which is exposed sufficiently to allow detailed measurements is that which is continuous with the Fernie section given above, and is exposed along the Adanac Strip Mine road. The section is as follows:

KOOTENAY SECTION AT THE ADANAC STRIP MINE

Overlying beds: Blairmore basal conglomerate.

Contact unconformable

	Thickness Feet
Shale, black	1.0
Coal, friable to lumpy (seam is mined)	15.0
Concealed interval	44.0
Shale, brown, weathers into small concretions	20.0
Shale, dark grey, blocky	3.4
Coal	0.5
Shale, dark grey, blocky, sandy in places; brown concretions have centres of light grey clay (sideritic?)	15.0
Coal, hard, blocky, dirty	2.0
Shale, dark grey, black, with one and one-half-foot sandstone band in middle	7.0
Coal, seam shows small fault	2.5
Shale, grey, blocky; rusty weathering sandstone lenses	10.0
Sandstone, dark grey, dense, becomes shaly at top, fine-grained	17.0
Coal	3.5
Shale, blocky, brown to black	8.0
Coal	2.0
Shale, grey	1.5
Shale, greenish-grey, sandy, rusty weathering	5.0

	Thickness Feet
Shale, grey	2.0
Coal, stained white on fractures	1.8
Shale, greyish-green, sandy, blocky	9.5
Shale, fissile, dark grey, fault trace at base	2.5
Shale, dark grey, blocky	4.2
Coal, fairly solid, white stains on fractures	4.1
Shale, sandy, dark grey to dark green, thin sandstone bands, weathering rusty brown	14.5
Shale, dark grey to black, with few inches of coal	3.0
Sandstone, fine-grained, greenish-grey, argillaceous	4.5
Shale, grey, fissile, sandy, with indurated sandstone beds	9.0
Coal, crushed	5.5
Sandstone, dark grey, fine- to medium-grained, highly micaceous on bedding	21.0
Sandstone, massive, dark grey, weathers greyish-brown; two-foot soft rusty weathering band 20 feet above base	41.0
Total thickness of Kootenay beds	280.0

Contact apparently conformable

Underlying beds: Sandstone, fine-grained to medium-grained (Fernie formation).

The basal sixty-two feet of sandstone is a continuation of the massive upper beds of the Fernie formation. The contact was chosen, as was explained in the discussion of the Fernie formation, at a lithological break. No unconformity in this sandstone succession was observed here, or on a tributary of O'Hagen creek where the contact is again exposed. A five and one-half-foot coal seam overlies the sandstone unconformably (Figure 5). The sequence above this is largely shale with some sandstone and seven thin coal seams. The coal seams are thin and shaly. The uppermost seam of coal, which is fifteen feet thick, is being strip mined by West Canadian Collieries (Figure 2). This seam is overlain by a hard black shale which is unconformable with the Blairmore conglomerate. This unconformity is quite marked at this locality.

Sections of the Kootenay formation observed elsewhere in the map area were not sufficiently thick to be of value in studying the complete formation lithologically. The exposed upper portion of the formation on Lynx creek shows two massive sandstone beds. One, 102 feet below the Blairmore conglomerate, has a thickness of thirty-three and three-fifths feet (Figure 6), and the other, forty-eight feet below this, is thirty-six feet thick. Coal seams do not outcrop in this section. They may be covered, but some way have been faulted out or squeezed out by the intense mountain building movements. Development of the seam immediately underlying the Blairmore conglomerate has been attempted at this latter outcrop, but the tunnel has long since caved and covered the operational face. Consequently the thickness of the seam and the character of the coal could not be ascertained.

AGE AND CORRELATION: The economic importance of the Kootenay formation and its correlatives has resulted in the tracing and prospecting of these measures throughout practically the entire length of the Alberta foothills. Consequently the lithological character and the stratigraphic position of the formation are well known. Fossil plants have been collected from many areas which have been mapped geologically, and indicate that Kootenay strata are Lower Cretaceous in age. In European chronology the Kootenay flora is designated Neocomian-Barremian by Bell (1944, 1946) with a preponderance of Barremian types. Some of the places where these fossil collections have been made are the Carbondale river (formerly known as the South Fork river); Blairmore area; Corbin coal area, British Columbia; the Highwood river; and the Canmore area.

A Jurassic age for the Kootenay formation, or for at least a lower part of it, has been suggested by some workers. However, evidence for such an assumption appears to be meagre or contradictory, and may have originated from: (1) Early workers in the foothills placed the lower contact of the Kootenay formation at the base of a massive sandstone member, into which the Fernie strata is gradational. However, present practice is to put the contact in about the middle of the member. This procedure should probably eliminate any Jurassic elements; (2) Some fossil plants in the Kootenay are closely related to Jurassic types. Bell (1944) states that too much significance should not be attached to such relationships for all of them are long ranging types, and some even carry into Blairmore time; (3) Certain European stages of the upper Jurassic have not yet been identified in the Fernie formation, and it is concluded that these may be represented by all or part of the Kootenay. This absence of some stages has not been satisfactorily explained, but may be due to a restricted lateral development of the typical faunas, to lack of recognition of index fossils, or to insufficient field studies.

It has been shown by fossil flora that the Kootenay formation of the southern foothills and mountains has the same age as the Nikanassin formation of the adjoining northern region (McLearn, 1944). Rocks of Kootenay age extend into northeastern British Columbia, and are equivalent to almost all of the Dunlevy formation and to the lower part of the Bullhead group. The formation is probably equivalent to the lower part of the Kootenai of Montana. There are no known Kootenay or equivalent rocks underlying the plains of Alberta.

Blairmore Formation

NAME AND DISTRIBUTION: The Blairmore formation was named by Leach in 1911 (Leach, 1911). Previously, in 1902, he had recognized it as a lithological unit (Leach, 1902).

Blairmore rocks and rocks of equivalent age outcrop throughout the full extent of the Rocky Mountains and foothills of Alberta. The formation is composed of hard sandstones and softer shales. Resistance of the sandstones to weathering often produces ridges.

Blairmore strata outcrop abundantly in the Carbondale River area. Two bands outcrop adjacent to the mountain front on the western side of the map area. Immediately west of Turtle Mountain anticline four bands are present two of which fault out within short distances. The eastern of the two remaining bands continues southeastward throughout the map area. Bedrock in the northeastward portion of the map area is largely composed of folded and faulted Blairmore strata. Blairmore rocks are also present in a continuous band in front of the Flathead and Clarke overthrusts.

THICKNESS AND LITHOLOGY: The Blairmore formation as exposed along Carbondale river on either side of the mouth of Lynx creek is the most nearly complete section of these strata in the area; and although the greater part of the formation is concealed, it afforded an opportunity to determine the thickness, since the lower contact is exposed, and the upper can be placed within 100 feet. This section measured by steel tape yielded a thickness of 1680 feet. Thicknesses of 2300 feet and 2150 feet have been given by MacKay for the formation in the Blairmore area. Details of this section are as follows:

CARBONDALE RIVER SECTION OF THE BLAIRMORE FORMATION

Overlying beds: Tuffs and agglomerates of the Crowsnest formation.

Contact gradational

	Thickness Feet
Concealed	100.0
Shale and sandstone, interbedded	7.8
Shale, maroon	11.5
Sandstone, green, fine-grained	6.0
Shale, dark green	16.5
Sandstone, massive, green	2.7
Shale, green	0.8
Sandstone, massive, greenish	1.8
Shale, green, hard, blocky	20.0
Sandstone, with plant fragments	4.0
Shale, green with some interbedded sandstone	10.0
Sandstone, massive, greenish-grey weathering	4.5
Shale and sandstone, interbedded, both green	15.5
Sandstone, massive, grey-green weathering	2.8
Sandstone, beds one-half inch to two inches thick, greenish-grey weathering	30.0
Sandstone, massive brown weathering, shows fine bedding	3.6
Shale, black, fissile	0.3
Sandstone, massive, brown weathering	1.2
Shale, black, fissile	1.0
Sandstone, with sandy green shale	4.0
Sandstone, greenish, massive, fine-grained; plant remains and pelecypods at base	2.9
Shale, crumbly weathering; interbedded with green sandstone	20.6
Sandstone, platy weathering	1.7

	Thickness Feet
Shale, partly concealed but mostly green and light green, blocky, hard	160.6
Sandstone, bedded, green	3.0
Shale, green, blocky	5.0
Sandstone, massive, fine-grained, green weathering	2.3
Shale, green, blocky	107.3
Sandstone and shale, green, sandstone weathers brown	2.8
Sandstone, soft, light green, fine-bedded, some cross-bedding	3.7
Sandstone, medium-grained, greenish-grey, brown weathering	0.9
Shale, green, blocky	17.5
Concealed	1,160.0
Conglomerate, basal, quartzite and chert pebbles	10.0
Total thickness Blairmore beds	1,680.0

Contact unconformable

Underlying beds: Shale and sandstone (Kootenay formation).

The Blairmore rocks are a succession of greenish shales and sandstones. The proportion of shale to sandstone is greater in the middle of the formation. The shales are largely green in color, quite blocky in habit and unfossiliferous. Occasional beds of maroon shale occur and are not indicative of definite horizons. One bed of fresh water limestone was observed on the east slope of Maverick hill in the northern part of the map area. It has a thickness of twelve feet, and is bedded in layers of six inches to one foot. The sandstone members near the base of the formation are on the whole well indurated and cross-bedded. One sandstone member, of which the exact stratigraphic position could not be determined, has a thickness of twenty feet, and contains many fragments of plant stems.

The upper bed of shale grades into reworked volcanic ash. The contact interval in the measured location may be considered a four-foot bed of ash and shale, the lower part of which is maroon shale, the middle a mixture of ash and shale, and the upper a green reworked ash.

The basal Blairmore conglomerate lies unconformably on the Kootenay formation. The pebbles of the conglomerate are composed of quartzite and chert. The quartzite pebbles are white, grey or pinkish white; the chert pebbles are black and occasionally green. The pebbles are roughly an oval shape and to some extent show flattening due to water action. The average size of pebble in this area is one inch in the largest diameter. In the section detailed above, ten feet of basal conglomerate is exposed. The average thickness is twenty feet but on the north side of Mt. McCarty it thickens to thirty-five feet. It was noted that in the easterly part of the map area the pebbles become much smaller and fewer in number. Occasionally the conglomerate is missing, in which case it is replaced by a coarse sandstone. On Maverick hill, no conglomerate was observed at the base of the Blairmore, and it is thought that its disappearance is due to faulting. Evidence in support of this conclusion is the presence of a fault and the presence of basal conglomerate itself one-half mile south of this locality. Approximately six hundred feet above the base of the formation, lenses of conglomerate sixty to seventy feet thick occur. One lens was observed on the east side of Maverick hill, and on the north side of Carbondale hill, but two lenses are present on the northwest of Backus mountain. Pebbles of the conglomerate are about seventy-five percent igneous rock and twenty-five percent chert and quartzite. The kinds of igneous rock comprising the pebbles include porphyritic, granitic and basic types. The chert pebbles are black, and the quartzites are white or pinkish. The pebbles are roughly of an oval shape with flat sides that indicate water erosion. They range in size from one inch to three inches in their shortest diameter and two inches to six inches in the longest diameter. The average pebble size is one and one-half inches by two to two and one-half inches across. The matrix is sandy. The lenses are 100 feet to 300 feet in length and rest in sandy shale. It is suggested that these lenses are gravel bars which were formed near the ancient Cretaceous shoreline.

A small pebble chert conglomerate was noted in a locality in the valley west of Prospect hill. This conglomerate occurs near the top of the formation. It has a loose, calcareous matrix. No other outcrop of this conglomerate was seen.

Above the massive sandstone series near the top of the formation beds of shale with thinner bands of sandstone are the predominant types. In the measured section these occupy the uppermost 100 feet of the formation.

Near the top of the formation massive sandstone, some of which contains plant fragments and animal remains, is the dominant rock type. It comprises most of the detailed section, given above.

A three-inch bed of coquina occurs in several outcrops and is thought to be in the upper 600 feet of the formation. Near the base of the formation, probably about 450 feet above the basal conglomerate a marked unconformity appears. The unconformity consists of a well indurated, brown weathering sandstone, with pockets eroded as deeply as six inches, and overlain by a light green, cross-bedded sandstone. This break is probably due to contemporaneous erosion, and hence has no important significance.

AGE AND CORRELATION: Berry (1929) studied the flora of the Blairmore formation in the Crowsnest Pass area, and assigned the lower part of the formation to the Lower Cretaceous and the upper part to the Upper Cretaceous. Bell, however, on the basis of further studies of the flora, concluded that the upper part of the formation also belongs to the Lower Cretaceous (Bell, 1946). A Lower Cretaceous age for the whole formation is now generally accepted.

Plant fragments are abundant in the Blairmore rocks of the Carbondale area, but no identifiable specimens were obtained. Fossil pelecypods collected from a sandstone bed 427 feet from the top of the formation include ***Aucella*** sp., ***Unio hamili, Unio douglassi*** and ***Sphaerium onestae***. These are typical Lower Cretaceous fossils. These specimens were also found by McLearn (1929) in the vicinity of Hillcrest, but there they are 270 feet above the base. It consequently appears that these are long-ranging species, since they span a stratigraphic interval of over 1000 feet.

Crowsnest Formation

NAME AND DISTRIBUTION: The first record of the volcanic rocks which comprise this formation was made by G. M. Dawson (1885). C. W. Knight (1905) made a petrographic study of them. They have been described in some detail by W. W. Leach (1902) and J. D. Mackenzie (1914).

The Crowsnest formation is found only in the Crowsnest Pass area. Within the Carbondale River map area, it has been faulted to the surface in a number of places, there being at least seven bands of outcrop. Because some phases of the volcanics are more resistant to erosion than other rocks, they form several prominent ridges and hills. One of the highest of these ridges is that at the southwest end of Carbondale hill, upon which the fire lookout is situated.

THICKNESS AND LITHOLOGY: The Crowsnest formation has a maximum thickness of 1100 feet in the vicinity of Coleman, and thins in all directions from this point (MacKay, 1932). In the western part of the map area, on upper Carbondale river, the formation is 615 feet thick. The formation was measured on Lynx creek in section 12, township 6, range 4, west of the fifth meridian, and gave a thickness of 465 feet. On the lower Carbondale and Castle rivers the formation, although its boundaries are not clearly defined, has thinned appreciably from the Lynx creek section. Details of the measured section on Lynx creek are as follows:

CROWSNEST FORMATION ON LYNX CREEK

Overlying beds: Chert pebble conglomerate, sandstone and shale (Blackstone formation).

	Thickness Feet
Unconformity	
Agglomerate, massive; medium sized, well formed crystals; angular weathering; top beds have analcite crystals	167.5
Concealed, in part weathered agglomerate	136.9

	Thickness Feet
Agglomerate, massive; beds two feet to four feet in thickness; finely-bedded ash; crystal size varies; uppermost bed coarsely crystalline with abundant garnets	22.3
Agglomerate, massive; fine-grained to coarse-grained; well indurated; crystals in coarse-grained phase; dark green in color	8.5
Ash and agglomerate, interbedded; agglomerate, massive, fine-grained, light green; ash, shaly weathering, many small crystals	17.9
Agglomerate, coarsely crystalline, greenish, massive; crystals fairly well formed	4.2
Ash and agglomerate, very fine crystalline; thin-bedded to massive; thin bands shaly weathering, green	7.7
Tuff (?), very fine texture, light grey; almost quartzitic in appearance; small lenses of iron sulphide, a few crystals present	2.7
Ash and agglomerate, interbedded; ash medium-grained with small crystals; fine-grained with very few small crystals	6.8
Agglomerate, very fine-grained, greenish, medium-sized crystals, very rough weathering, rudely bedded, in places massive	52.3
Ash, fairly coarse crystals, bedding visible	12.5
Agglomerate, green; crystals of medium size, some garnets; rudely bedded	6.0
Ash or tuff, green, very fine-grained, containing small crystals	19.7
Total thickness	465.0

Underlying beds: Blairmore sandstone and red shale mixed with green volcanic ash or tuff.

The Crowsnest formation is a series of igneous breccias, volcanic tuffs and occasionally some flow rocks. These pyroclastics occur in beds from a fraction of a foot to ten feet in thickness. There appears to be no uniformity in the sequence of rock types from place to place, and many of the beds are lenticular. The type of rock varies from fine-grained highly feldspathic tuffs to very coarse, heterogenous breccias of explosive ejecta.

The contact between the Crowsnest and Blairmore formations has been considered in the discussion of the Blairmore formation. The upper contact of the volcanics with the overlying Blackstone formation is shown in Figure 7. The uppermost volcanic beds are green ash, which appears to have been reworked. They lie unconformably below the basal Blackstone sediments.

The rock types vary throughout each section and also from section to section. J. D. Mackenzie (1914) has discussed these types in considerable detail, and the writers have little to add to his descriptions. Petrographic examination of a few specimens, taken from the above measured section during the present surveys, lead to the conclusion that feldspars constitute about eighty percent of the crystals of feldspar garnet, and that analcite occurs abundantly in places. The crystals range from subhedral to euhedral, and are frequently zoned. Crystals of analcite as large as one inch in diameter were obtained from an erratic on Carbondale river. Pyrite was observed in one specimen. In the eastern part of the area the amount of reworking of the volcanics is greater than in the west.

Blairmorite is common, especially near the top of the formation it was noted to be particularly well developed in the volcanics lying on the western side of Willoughby ridge (Figure 8).

MacKenzie, in his remarks on deposition, has concluded that the stratified nature of the deposits, the rounded nature of some fragments, and the occurrence of coal suggest shallow water deposition. Furthermore, he observes that the absence of flow indicates an eruptive source, which, in consideration of the thickness as to the lateral extent, probably was a series of small cones of the eruptive type.

AGE: The gradational contact between the Blairmore and Crowsnest formations and the unconformity at the top of the Crowsnest formation indicate that the age of the Crowsnest formation is upper Lower Cretaceous. MacKenzie has suggested that these intrusives mark an early phase of the Laramide Revolution, which was followed by a long period of comparative quiescence during Upper Cretaceous time. This in turn was followed by the post-Cretaceous uplift of the Rocky Mountains.

UPPER CRETACEOUS

Blackstone Formation

NAME AND DISTRIBUTION: Earliest reports of the geology of the Crowsnest Pass area refer to this formation as the Lower Benton or Lower Colorado shales. The name, Blackstone, as applied to this division in the Bighorn basin by G. S. Malloch (1911), is now in common usage for these shales throughout Alberta foothills.

Several bands of Blackstone appear throughout the map area. The rocks of this formation are incompetent and therefore have been folded, faulted and squeezed considerably. However, due to the competent nature of the underlying Crowsnest formation and overlying Bighorn formation, the folding and faulting have not been as severe as is the case in many places elswhere in the foothills, especially where the Crowsnest formation is absent.

THICKNESS AND LITHOLOGY: Two localities presented sections where the thickness could be measured, since the upper and lower contacts were exposed. One section was observed on Lynx creek and the other on Castle river just above its junction with the Carbondale. The section on Lynx creek was exposed from the bottom to the upper contact, and as there did not appear to be any faulting, it is considered that this is the true thickness for this area. The section, measured by steel tape, was determined to be 325 feet. This is just seventy-five feet less than the thickness given by Hage (1940) for the area adjoining on the east.

BLACKSTONE SECTION ON LYNX CREEK

Overlying beds: Sandstone of the Bighorn formation.

Conformable contact

	Thickness Feet
Shale, sandy, brown, blocky weathering; in places thin-bedded; some bands of nodules	120.0
Shale, very thin-bedded, black, fissile; fossiliferous containing abundant *Inoceramus labiatus* and *Watinoceras* sp.; brown to whitish weathering; occasional sandy layer two inches to three inches thick	200.0
Shale, black, rusty weathering; interbedded with well rounded chert pebbles	3.0
Conglomerate and sandstone interbedded; sandstone, grey, fine-grained, brown weathering; pebbles mostly black chert; fossiliferous, yielding numerous *Exogyra laeviuscula*	2.6
Total thickness Blackstone beds	325.0

Contact Unconformable

Underlying beds: greenish, shaly weathering, ash (Crowsnest formation).

The basal conglomerate of the Blackstone formation is composed of well rounded chert pebbles with a maximum diameter of one inch and an average diameter of three-quarters of an inch, set in a sandy calcareous matrix. The lower part of the shale is nodular and the upper part becomes sandier with an occasional sandstone band. The increase in sand content is accompanied by a blockier appearance, and by more distinct bedding lines. No bedded ash or tuffaceous material was noted above the basal conglomerate.

Blackstone shales are very similar lithologically to those of the Wapiabi and are differentiated with difficulty. They may be identified by their greater degree of induration and blockier habit. Fossils, if present, are a ready means of identification.

AGE AND CORRELATION: The basal conglomerate and sandstone contain the pelecypod ***Exogyra laeviuscula.*** The basal twenty feet of shale contain an abundance of ***Inoceramus labiatus, Inoceramus*** sp., and ***Watinoceras*** sp. Since ***Inoceramus labiatus*** is usually present in a zone 200 or more feet above the base of the formation, its position at the base of the formation in the Carbondale River area would indicate that the lower 180 feet or more of the formation was not deposited there. Moreover, fish scales usually present below the ***Inoceramus labiatus*** zone were not observed. A loose boulder containing***Dunveganoceras*** sp. was found on Castle river, and is believed to have come from the basal beds of the Blackstone. If so, it establishes these beds as being of Upper Cenomanian (Lower Upper Cretaceous) age (Stelck, 1950), and it also correlates them with the upper Pouce Coupe sandstone. The occurrence of ***Dunveganoceras*** in the Carbondale River map area is rather unexpected, since previously it had been found only in the Peace River area; and has not been reported from the intervening area.

The *Watinoceras* and *Inoceramus labiatus* zone marks the top of the Cenomanian. The *Prionocyclus* horizon, which marks the top of the Turonian, was not observed, and it is believed to be absent in this area. Within the map area, the major part of the formation lies between these two zones and is, therefore, of Turonian age.

Bighorn Formation

NAME AND DISTRIBUTION: G. S. Malloch (Malloch, 1911) first applied this name to a 390-foot group of sandy shales, shaly sandstone and conglomerate bands occurring in the Bighorn coal basin. The name has recently come into common usage throughout Alberta foothills to replace the term Cardium sandstone. The Bighorn formation is part of the Colorado shale. It has a wide distribution, being found in the foothills of Alberta and the Peace River district of Alberta and British Columbia.

THICKNESS AND LITHOLOGY: Two sections, one on Lynx creek and a second in section 5, township 5, range 3, west of the fifth meridian, on an unnamed creek tributary to the south branch of Castle river, were measured. The section on Lynx creek just below its junction with George creek, is completely exposed and apparently free from faulting. The thickness of the formation there is 101 feet, and is given below in detail. The other section measured 150 feet thick, but as it is partially concealed, the excessive thickness may be due to repetition by faulting.

BIGHORN SECTION ON LYNX CREEK

Overlying beds: dark grey shale (Wapiabi formation).

Contact conformable

	Thickness Feet
Sandstone, dark grey, very irregularly bedded, calcareous matrix, pyritic	16.0
Shale, black, fissile; nodular; contains thin black chert pebble zone, four inches thick	17.0
Shale, dark grey, blocky, with many ironstone nodules	38.0
Sandstone, dark grey, quartzitic, with pyrite flecks; basal sandstone	30.0
Total thickness of Bighorn beds	101.0

Contact Conformable

Underlying beds: Sandy shales (Blackstone formation).

The basal sandstone member ranges in thickness from twenty feet to forty feet. The rock type observed was always quartzitic, but

Figure 1—Flathead range viewed from North Kootenay pass; peaks are formed from Paleozoic strata; Precambrian strata forms slopes on right; Precambrian-Paleozoic contact at right of dark patch (green shale) in saddle in right middle.

Figure 2—Adanac strip mine; basal Blairmore conglomerate is light colored rock on left; shovel in middle is resting on Kootenay coal seam; interval between seam and conglomerate is black shale.

Figure 3—Paleozoic-Mesozoic contact; Adanac Strip Mine road; Jurassic strata of the Fernie formation lies disconformably upon the Paleozoics; hammer head is resting upon basal Fernie phosphate bed (Jf).

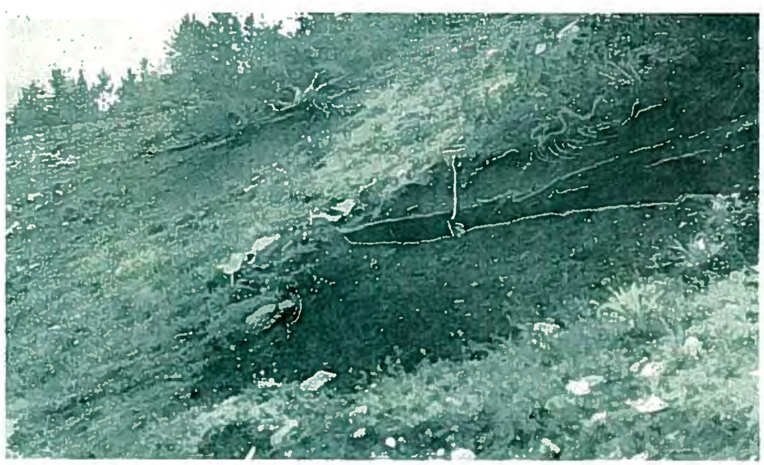

Figure 4—Kootenay strata underlying the overthrust in legal subdivision 12, section 13, township 6, range 5, west of the fifth meridian; coal seam is exposed at the top of a small anticline.

Figure 5—Kootenay coal lying directly upon basal Kootenay sandstone; Adanac Strip Mine road.

Figure 6—Vertical Kootenay strata; Lynx creek, legal subdivision 16, section 10, township 6, range 4, west of the fifth meridian.

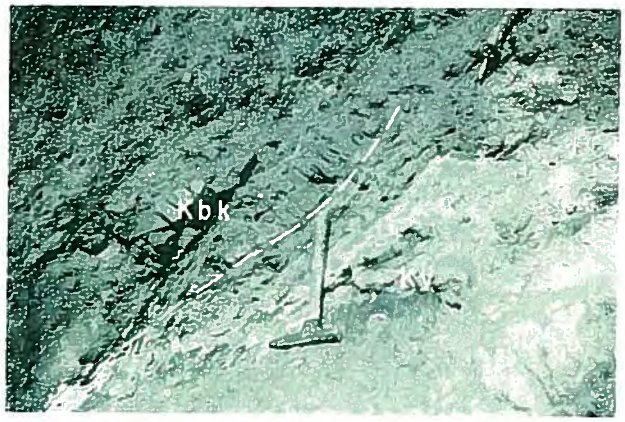

Figure 7—Contact between Crowsnest formation and Blackstone formation; sandstone and conglomerate of basal Blackstone on left overlying bedded ash of the Crowsnest formation; one-half mile upstream on George creek from its junction with Lynx creek.

Figure 8—Blairmorite; light colored analcite crystals in a green fine-grained tuffaceous matrix; Crowsnest formation.

Figure 9—Waterfall formed by Bighorn sandstone; lower Lynx creek.

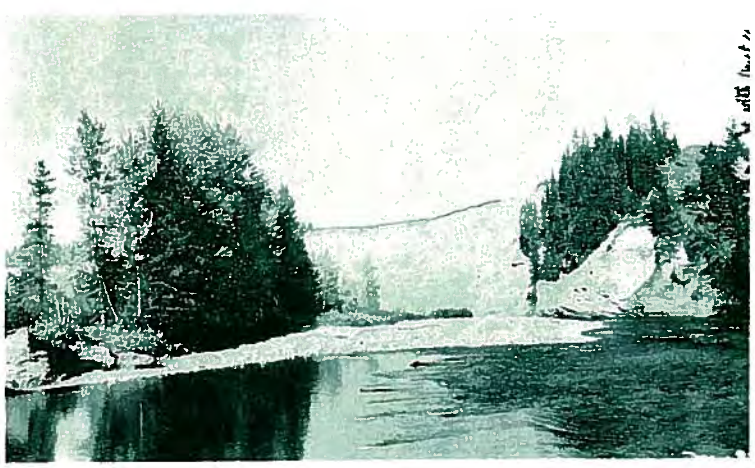

Figure 10—Pleistocene and Recent gravels on Castle river at north gate of Castlemount ranger station; Recent conglomerate along right side of stream in right middle.

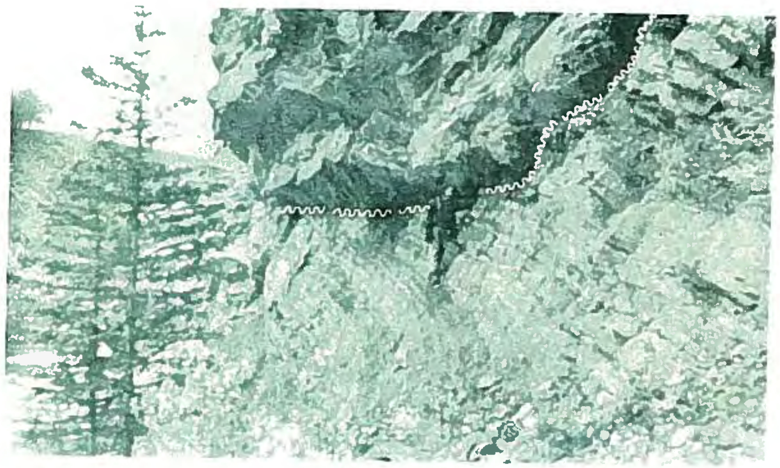

Figure 11—Blairmore strata faulted over Blairmore strata on upper Carbondale river.

Figure 12—Faulted strata at Kootenay-Blairmore contact on the north side of Maverick hill.

Figure 13—Anticlinal structure on Castle river just above its junction with the Carbondale river; folded strata is Blairmore formation. Details of anticline shown in lower photograph.

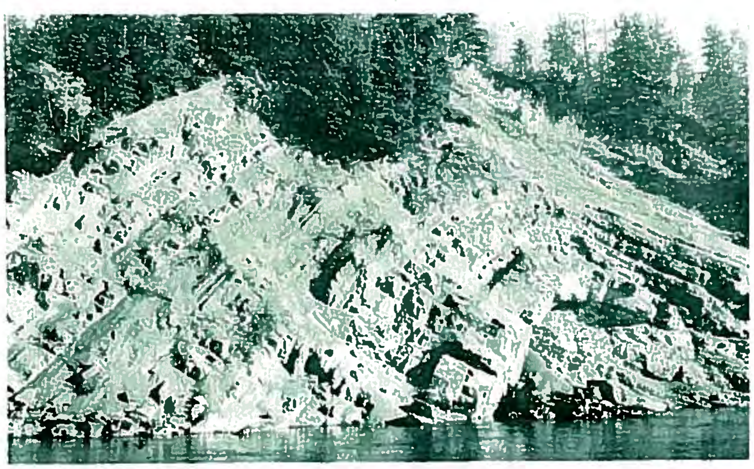

Figure 14—Faulted and folded Precambrian strata overlying Lewis overthrust; north slope of Table Mountain.

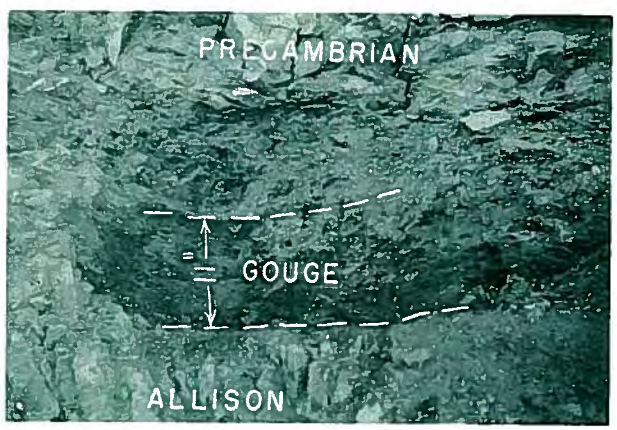

Figure 15—Lewis thrust fault contact on north slope of Table mountain; Precambrian rocks are thrust over Belly River strata.

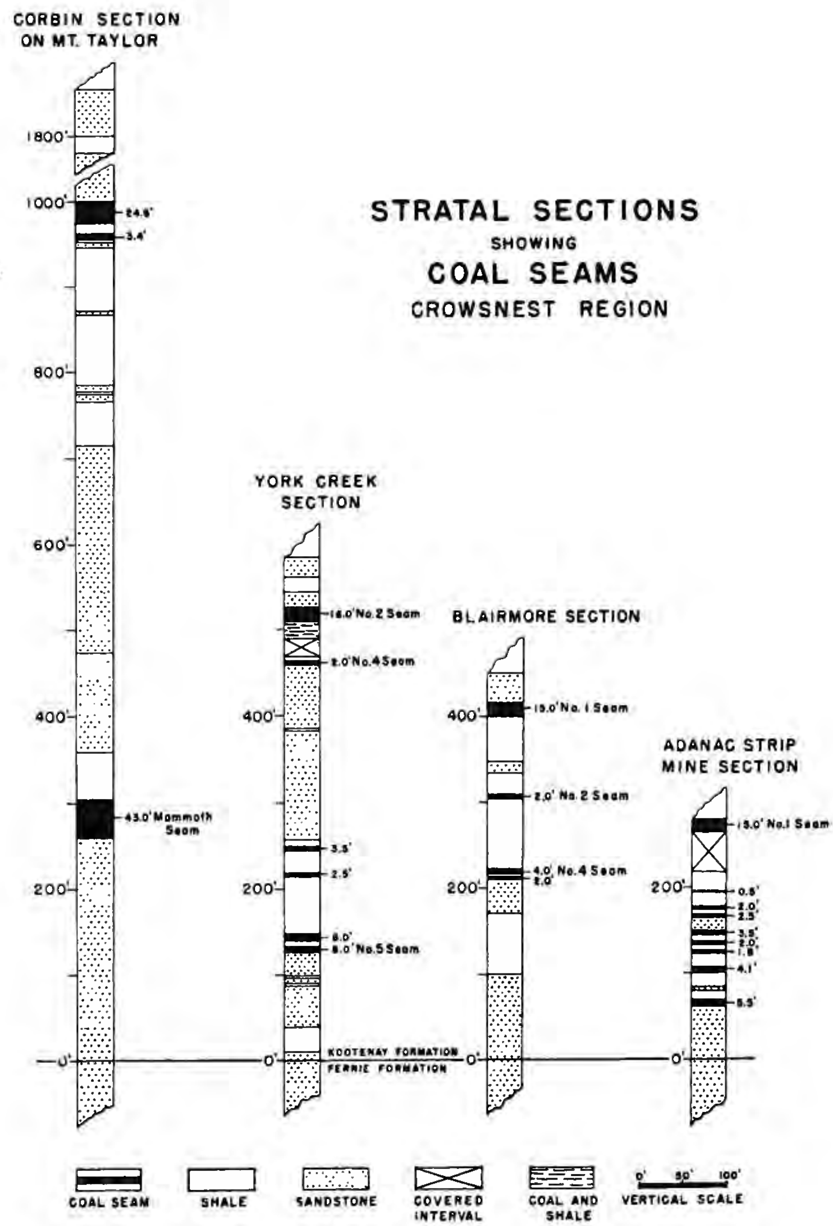

Figure 16—Diagram of stratal sections of the Crowsnest Pass region; sections given from west to east.

in the most westerly band of the map area it is of much lighter color, coarser grained and fossiliferous at the base. Moreover, this band was not so massively bedded and contains thin shale bands near the base. This quartzitic sandstone is resistant enough to form long, sharp ridges and waterfalls (Figure 9).

The shale bands resemble those of the underlying Blackstone formation. They are, in places, more sandy. The chert conglomerate band, which occurs sixty-eight feet above the base and is not always present, consists of chert pebbles one-quarter inch diameter set in a sandstone matrix.

The top of the upper band of sandstone is taken as the top of the Bighorn formation. Its thickness is from twelve feet to twenty feet. In every observed outcrop it consisted of a dark grey, very fine-grained quartzitic sandstone. The bedding is not distinct, and in fresh exposures has the appearance of numerous small lenses one-quarter inch to one-half inch thick and one-half inch to one inch long. Pyrite is scattered throughout the band.

AGE AND CORRELATION: The basal quartzitic sandstone contains numerous specimens of the pelecypod, ***Exogyra laeviuscula*** Roemer. In one locality, just above the basal shale, part of an ammonite was found. This specimen is poorly preserved, but Warren (1949) tentatively identifies it as ***Prionocyclus wyomingensis*** Meek, which is found in the Colorado shales of Montana. The above fossils are not confined to any one particular zone in the Colorado, and are not diagnostic of the Bighorn. The lithology of the strata, however, is sufficient basis for placing them in the Bighorn, for the rocks are identical with rocks of the Bighorn formation farther north.

Wapiabi Formation

NAME AND DISTRIBUTION: Malloch (1911) gave this name to the shale succession overlying the Bighorn formation in the Bighorn coal basin. It retains much of the same character from the type locality, southeastwards through the foothills, to the Carbondale River area. On various maps it may be shown as upper Benton, Colorado, or upper Alberta shale.

Throughout the map area the Wapiabi formation is faulted to the surface in a number of places. The most prominent band is that which enters the map area in the valley of Lynx creek, extends southwards through the valley of Lost creek to Carbondale river, and from there continues eastwards to the eastern margin of the map sheet. Due to the easily eroded nature of the rocks comprising the formation, outcrops are scarce, and thick sections exceedingly rare. The formation usually denotes its presence by low topographic relief.

THICKNESS AND LITHOLOGY: Wapiabi strata because of weathering, erosion, and glacial mantle and vegetative cover, does not offer continuous outcrop at any point in the map area, so the thickness was not measured. In fact, no sections of sufficient thickness to warrant measuring were observed in this survey. The calculated thickness is 1400 feet.

The Wapiabi formation is a series of thin-bedded, dark grey, marine shales with thin sandstone bands. Near the top of the formation the sandstone layers become more frequent, until at the top they grade into Belly River sandstone. No unconformity between the Wapiabi and Belly River was observed. The contact is conformable and gradational, and is placed at the base of those sandstone beds in which plant fragments first appear.

AGE AND CORRELATION: A number of fossils were found in the formation. These have been identified as ***Inoceramus exogyroides*, *Scaphites ventricosus*, *Baculites codyensis*, *Ostrea*** (?) sp., and ***Oxytoma*** sp.

The *Scaphites* zone which is near the base of the Wapiabi is of Niobrara age (Warren and Rutherford, 1928). The ***Baculites*** fauna found at the top of the formation has a Montana age. These faunal horizons are common throughout the foothills, and thus the Wapiabi section of the Carbondale area is considered as being of the same age as other Alberta sections.

Belly River Formation

NAME AND DISTRIBUTION: Some geological reports of the Crowsnest Pass area refer to the Belly River formation as the Allison. In this report the term Belly River is used, since it is commonly used elsewhere in the foothills and is applicable here.

Within the map area Belly River strata occur as one continuous broad band stretching from the northwest corner of the map sheet, along the mountain fronts to the southeast corner. Although the formation underlies a larger area than any other formation, outcrops often are disproportionally small. This paucity of outcrop is largely due to the thick glacial mantle and to the forest cover it supports.

THICKNESS AND LITHOLOGY: No complete section of the Belly River formation was found within the map area. Excepting in one locality, namely, in section 2, township 5, range 3, west of the fifth meridian, the upper beds of the formation are truncated by a fault, thereby practically precluding a direct measurement of the thickness of the formation.

At the one locality mentioned above a calculated thickness of the Belly River formation is 4300 feet. This figure compares favourably with that of 4500 feet for the area adjacent on the east (Hage, 1940). Outcrops occur sporadically, the most continuous outcrop in the area measuring 878.3 feet thick. This section is situated along Castle river in section 15, township 5, range 3, west of the fifth meridian, and is given below:

BELLY RIVER SECTION ON CASTLE RIVER

Overlying beds: Concealed by glacial deposits and forest cover.

	Thickness Feet
Sandstone, brown weathering, massive, fine-grained	7.5
Shale with sandstone bands two feet to four feet thick and at intervals of about fifty feet; shale green, black and sandy	240.0
Sandstone, massive, well indurated; fossil bed two feet thick	38.5
Sandstone, brown weathering, fine-grained, well indurated, finely banded	15.0
Sandstone, light green; friable and indurated bands; indurated bands infrequent and two to four feet thick	105.0
Sandstone, massive, light grey, fine-grained, fairly well indurated	3.0
Concealed	30.0
Sandstone, light grey, indurated, containing fossil leaf fragments and much carbonaceous matter	1.8
Sandstone, light grey, friable; indurated bands one and one-half feet thick; cross-bedded	66.0
Sandstone, medium-grained, light green weathering; well indurated	13.4
Sandstone, light green; indurated in places but mostly friable; light grey weathering	105.0
Shale and sandstone; green-grey shale with one-foot sandstone bands; indurated, slickensided; calcite crystals along fractures	185.5
Shale, black and grey bands	8.1
Sandstone, medium-grained, grey-green; slickensided; calcite crystals	1.1
Shale, mostly concealed	8.2
Sandstone, light grey, very friable	49.1
Sandstone, light grey; very thin bedding, fine-grained, friable	0.5
Sandstone, light grey, brown weathering; well indurated, medium-grained	0.6
Total thickness of section	878.3

Underlying rocks: Concealed.

The above section is typical of the Belly River strata as exposed elsewhere in the map area. In general they consist of alternate grey to grey-green sandstones and inter-bedded green shale. The sandstone beds range from friable to well indurated, and are commonly cross-bedded. The shales are green in color and sandy, and usually have a blocky habit upon weathering. Based upon fossil evidence the rocks of the formations were deposited under fresh water and brackish water conditions.

AGE AND CORRELATION: Fossils obtained from Belly River strata are *Unio minimus* **Warren**, *Unio cf. primevus*, *Unio sp.*, *Viviparus leai* Meek and Hayden, *Ostrea glabra* M. and H., *Corbula subtrigonalis* M. and H. *Corbicula subtrigonalis* M. and H.

Corbicula occidentalis M. and H., *Corbicula cytheriformis* M. and H., *Anodonta* sp., and *Melania wyomingensis* Meek. The first four specimens named had a fresh water habitat, whereas the latter group lived in brackish water. These fossils are also found in the Foremost and Oldman formations of the southern plains of Alberta.

Bearpaw Formation

One outcrop only of Bearpaw strata was observed. This occurs in section 2, township 5, range 3, west of the fifth meridian, on the second creek east of the west branch of Castle river and immediately south of Beaver Mines lake. The exposures consisted of dark grey shales, carbonaceous bands and an oyster bed. These strata may be a brackish water phase of the Bearpaw formation, but faunal evidence does not definitely identify it as Bearpaw.

PLEISTOCENE AND RECENT

Extensive glaciation in the area is evidenced by numerous cirques along the fronts of the Flathead and Clarke ranges, a thick covering of glacial till in places, abundant glacial erratics, and topographic features indicative of the passage of glacial ice. The valleys of Carbondale river, Castle river, Lynx creek and Lost creek are U-shaped. Glacial erratics may be found anywhere as high as 800 feet above valley level. Most of these hills have rounded contours and resemble roches moutonnees. Certain of the higher hills of the area and some of the mountain spurs were nunataks during the Pleistocene glacial epoch. South of North Kootenay pass the ice has crossed a col at an elevation of 7100 feet. Warren (1949) believes that the ice which crossed here was an overflow from the ice sheet which occupied the adjacent areas in British Columbia.

Many river terraces of the map area are thought to have a glacial origin. During the glacial epoch the valley of Castle river was probably dammed below its junction with the Carbondale. This damming produced a glacial lake in which were deposited sediments to a great depth. When the ice dam melted the lake was drained and the bottoms remained as a flat lake bed. The varying levels of terraces are attributed to the downward and sideways cutting of the Castle and Carbondale rivers.

Gravels in the river beds are probably largely of glacial and recent origin. At several points on the Castle river and at one point on Lost creek a well consolidated recent conglomerate was noted (Figure 10). The conglomerate occurs at decreasing elevations from the mountain fronts, and consequently could not have been deposited in a lake basin. It consists largely of pebbles and cobbles derived from Mesozoic and Precambrian strata. These gravels are cemented by calcium carbonate, and the cementation took place when run-off waters were much richer in carbonates than at the present time.

Thick deposits of till occur in the valleys of the main rivers and streams. The till is apparently formed from materials of the adjacent mountain front, and has been deposited by the glaciers which at one time occupied the broad valleys. Erosive action of the streams has bared thick sections of the till. One section forty feet thick was observed on Castle river near the Castlemount ranger station (Figure 10).

Chapter IV

STRUCTURAL GEOLOGY

REGIONAL ROCKY MOUNTAIN STRUCTURE

Sub-parallel fault blocks composed of Mesozoic, Paleozoic and Precambrian rocks make up the Rocky Mountain ranges. The faults underlying these blocks usually dip westward or southwestward, but eastward dipping faults do occur. Forces arising in the west and southwest, and acting in an easterly and northeasterly direction, have raised large blocks of these strata to elevations much above their original positions.

The displacement of the faults has a wide range, the throw varying from a few feet to as much as 40,000 feet, the latter figure being the case in the Lewis and Clarke range. Net slip greatly exceeds this figure, and cannot be accurately determined. In northern Montana it has been estimated as being at least twelve miles.

The foothills are formed from rocks of Mesozoic and Tertiary age. They were folded and faulted by the forces that raised the mountains, so that they reflect the trends of the adjacent mountain fronts. The faults in the foothills are usually westward dipping, but there are some eastward dipping faults. Both thrust faulting and normal faulting occur, though the former is by far the more prevalent.

Transverse faulting is not the rule in either the foothills or mountains; however, transverse faults are not uncommon.

Warren (1938) has deduced that the main uplift of the Rocky Mountains took place at the beginning of Oligocence time. This uplift was followed by an erosional interval, during which time peneplanation took place. During Pliocene time another continental uplift occurred, and another erosional cycle initiated. From this last erosional period have resulted the present contours of the mountains.

GEOLOGICAL STRUCTURE WITHIN CARBONDALE RIVER MAP AREA

Introductory Statement

In the western, southwestern and southern parts of the Carbondale River map area, Paleozoic and Precambrian formations are thrust over Mesozoic strata. The latter have been faulted and folded into complex structures due to the forces exerted upon them during the overthrusting of the Paleozoic-Precambrian fault block. The folded and faulted blocks have been acted on by the many agents of weathering and erosion, of which frost, running water and glacial ice are the most important. Due to the great differences in the resistance of the inclined and exposed strata, ridges and valleys have resulted. The softer strata, such as the Fernie and Wapiabi shales, now occupy valleys, whereas resistant strata, which comprise a good proportion of the Crowsnest, Bighorn, Blairmore and other formations, usually stand out as hills and ridges. The Precambrian and Paleozoic rocks are the most resistant of all, and are mountain forming. The trends of the ridges and valleys in general conform to the strike of the strata. In the northern part of the area, the ridges and valleys have a trend averaging twenty degrees west of north; those in the southern parts have a trend which is fifty-five degrees west of north. Most of the faults are longitudinal, but several transverse faults occur along the upper Carbondale river and in the vicinity of Byron hill. Minor faults are very numerous throughout the area. In the less competent strata, such as fissile shales and coal seams, much of the movement has been accomplished by slippage along bedding planes.

STRUCTURE OF THE UPPER CARBONDALE RIVER AREA: This part of the map area has been examined by many geological observers from Palliser's time to the present. Hume, on his journey through North Kootenay pass, noted and made reference to the anticlinal nature of the Lewis thrust at this point (Hume, 1932). Other observers have not made particular reference to the geological structure in this vicinity, but do discuss it in general.

Kootenay strata underlie the Precambrian overthrust in this locality. Kootenay strata are faulted over Blairmore, and in turn Blairmore rocks are faulted over Wapiabi. The Kootenay and Blairmore strata are intensely faulted, and minor folds occur in them. The average dip of the beds is forty-five degrees west, but dips as low as seven degrees and as high as sixty-eight degrees were observed. The Kootenay is a slice brought up over the Blairmore band on a low angle thrust fault, which at depth is believed to join the main fault. The fault underlying the Blairmore is an imbricate and longitudinal fault. The greater part of the slippage has been in the plane, or nearly in the plane of the dip of the strata.

Lying east of this imbricate fault is a faulted and slightly overturned anticline, from which most of the crest has been eroded. In cross section C-D this anticline begins with the most westerly band of the Wapiabi formation. Eastward the Wapiabi band is succeeded in turn by Bighorn (at depth), Blackstone, Crowsnest, Blairmore, Crowsnest, Blackstone, Bighorn and Wapiabi formations, this last being faulted over younger Belly River strata. Faulting occurs on both limbs of the anticline and along the axis. On the west limb the Wapiabi formation is faulted, the apparent displacement being greater to the north where Wapiabi strata are in contact with the Crowsnest formation rather than the Bighorn. On the eastern limb the Crowsnest formation is faulted over Wapiabi shales, cutting out all the Bighorn formation, and parts of the other two formations.

The central fault of the anticline may have a large displacement. Blairmore sandstone, which overlies forty feet of the basal Blairmore conglomerate, is present on the first ridge west of Prospect hill. It lies above the conglomerate, as in the normal sequence, but the usual shale parting between the sandstone and conglomerate is missing. The absence of the shale together with the observed slickensiding denotes faulting. If this faulting were of a minor order Kootenay strata would appear along Carbondale river, thirteen hundred feet lower than the ridge. However, Kootenay strata were not observed in the valley of the Carbondale and therefore the fault must have a displacement of at least thirteen hundred feet. The faults on the east and west limbs do not have a displacement of more than four hundred feet.

It is not definitely known whether the anticline is terminated by the aforementioned faulting of Wapiabi over Belly River rocks. There is some reason for believing that the east limb of the anticline includes Belly River formation; for the calculated thickness of the Belly River formation at this locality is 6,000 feet, a figure that is abnormal for the area. However, this could not be ascertained for lack of sufficient outcrops.

Along the upper Carbondale, in sections 19 and 29, township 5, range 4, west of the fifth meridian, a transverse faulting apparently occurs. Though no faults were actually observed, probably for lack of adequate outcrops, they must be present, for it is difficult to reconcile the north-eighty-degrees-west strike of the strata south of the Carbondale with the north-thirty-degrees-west strike of the strata north of the same river without some faulting where the change of direction takes place. Evidence of this faulting is present in many outcrops, one of which is shown in Figure 11. The photograph shows Blairmore strata faulted over Blairmore, and the incompetent shales and coal of the Blairmore and Kootenay formations have absorbed most of the stresses. Consequently the displacement along the fault is greater than what it first appears to be.

South of the Carbondale river three unusual relationships in the strata underlying the Precambrian overthrust are noted. One of these is that the nose of Precambrian rock jutting out between

Macdonald creek and Carbondale river, faults out the Kootenay formation leaving Blairmore strata underlying the overthrust. Secondly, on the northwest side of this ridge, a narrow slice of Fernie is brought up with the Kootenay strata. This slice is the finely banded sandstone of the upper Fernie, consequently it has not been displaced a great deal further than the Kootenay underlying it. Lastly, on the north slope of Mt. McCarty and underlying it, two additional bands, one Blairmore, the other Kootenay, are present. The strata underlying the overthrust in this latter locality is a slice of Kootenay strata. This is faulted over Blairmore which in turn overlies Kootenay. The contact between the two formations was not observed, and it is assumed to be normal. This lower Kootenay band, overlying the Blairmore, is faulted and overturned. This is probably a section of the east limb of the anticline described above. The Kootenay coal measures overlie the basal Blairmore conglomerate, which here is fifty feet thick.

The band of Blairmore underlying the conglomerate is overturned. It is faulted over the underlying volcanics, which in turn is faulted over the Blackstone.

STRUCTURE AT THE HEADWATERS OF LYNX AND LOST CREEKS: The structure on the north branch of Lost creek and the west branches of Lynx creek is a continuation of the upper Carbondale river structure. Here Kootenay strata are faulted over the Blairmore (Figure 4), and underlie the overthrust Precambrian rocks. However, this band of Blairmore is not the one underlying the overthrust in the upper Carbondale River district, but is the east limb of the anticline which plunges northward from Prospect hill, partially disappearing under the main overthrust fault.

A slice composed of upper Fernie and basal Kootenay strata has been brought along the thrust fault, and is exposed on the ridge lying between Lynx and Lost creeks.

Belly River strata are included in the east limb of the Prospect Hill anticline. They are faulted along the axis of the adjoining syncline and eastwards are folded into another broad anticline and syncline. This interpretation is based on both topographic expression of the formation and the attitude of the strata. A northwestward trending ridge is located in the northeast quarter of section 18, township 6, range 4. Eastward dips occur along the top and east side of this ridge and indicate the trough shown in section A-B.

STRUCTURE OF THE MESOZOICS SOUTH OF CARBONDALE RIVER AND UNDER THE MAIN OVERTHRUST: It has been noted above that south of the Carbondale river the Precambrian overthrust fault changes from a direction of west of north to one of south of east. On upper Gardiner creek a thin band of Kootenay underlies the main thrust fault. The Kootenay strata are underlain by the normal but overturned and faulted sequence of Blairmore Crowsnest, Blackstone, Bighorn and Wapiabi formations. These comprise the east arm of the Prospect Hill anticline and the east arm of the broad syncline. The anticline is not plunging out as is the case north of the Carbondale river, but is gradually faulted out eastwards by the overthrust Precambrian rocks.

The slice of Kootenay rocks under the Precambrian overthrust wedge out on upper Gardiner creek; and immediately east of this same creek, the Blackstone formation is faulted out. Between the two branches of the Castle river the Precambrian rocks lie directly on those of the Belly River formation. This condition persists eastward throughout the remainder of the map area.

WILLOUGHBY RIDGE AND CHERRY HILL: Willoughby ridge enters the map area in section 27, township 6, range 4. The formations comprising the ridge are, from west to east, Crowsnest Volcanics, Blairmore and Kootenay. On its eastern slope at the north end the Kootenay formation is faulted over Wapiabi shales. The ridge has a general trend of north-twenty-five-degrees west, and terminates in Cherry hill. The ridge throughout its length has a double crest, one formed by the Crowsnest formation on the west and the second formed by Kootenay and basal Blairmore sandstones. Forces exerted upon the ridge have caused the strata to be squeezed so that proceeding south the distance between the crests narrows, and furthermore the Kootenay strata on the eastern side are completely faulted out.

Cherry hill offers a complicated structural condition. Along Willoughby ridge north of Cherry hill there is a regular sequence of formations from Belly River to Kootenay. Immediately north of Cherry hill two small faults repeat thin sections of Blairmore and Crowsnest rocks. Relationships of the formations and faulting are shown on the accompanying map. These formations are exposed in almost continuous outcrop along Lynx creek. Cherry hill however, is structurally dissimilar to the remaining part of Willoughby ridge. The eastern part of it is a broad block of Blairmore strata which is anticlinal on the west and synclinal on the east. Both of these folds have a fifteen-degree plunge southward. The fault underlying Cherry hill dips westwards at a relatively small angle, and has carried Blairmore strata over the anticline on the east.

Cross section C-D shows the anticlinal-synclinal feature observed on the surface of Cherry hill also occurs at depth. The two outcrops of Bighorn strata along Carbondale river in section 1, township 6, range 4, indicate that this structure also is anticlinal. It is therefore concluded that this local folding of the strata has carried to some depth. The bands of Kootenay and Crowsnest rocks north of Cherry hill have been folded, and plunge out beneath Cherry hill.

MAVERICK HILL AND MAVERICK HILL FAULT: Maverick hill lies east of the axis of the Turtle Mountain anticline, and is a part of the east limb of that structure. The hill has considerable interest not only on account of its complex structure, but also because of its economic prospects, for on it occurs the Kootenay band which is mined at the Adanac underground mine. This mine is situated just outside the map area in section 31, township 6, range 3, west of the fifth meridian.

The major part of the disturbance in Maverick hill has centred around a north-south striking fault having an easterly dip. It was not possible to discover exactly where this fault began on the north side of the hill, but a mile south of the northern boundary of the map area the fault is very pronounced. At this place the fault has an eastward dip, and passes through strata at the Kootenay-Blairmore contact. As the fault continues southward, the dip becomes vertical and ultimately dips slightly westward.

The strata on the west side of Maverick hill and about halfway down are eastward dipping, and the Kootenay strata lie in a normal manner on the Fernie. About two-thirds of the way up the hill and still on the west side the faulting begins, and stratal dips are much steeper though inclined eastward. At the top of the hill the strata are badly faulted and folded, and in general are vertical. An exception to this is a broad band of sandstone which has been faulted into a horizontal attitude along the southern summit of the hill. On the east side of the hill the dips become westward, and Blairmore strata are overturned. To sum up, from north to south on Maverick hill there is a change from normal lying strata to vertical strata and finally to overturned strata. In Figure 12 are shown the beginning of the faulting and some of the basal Blairmore strata, which have an attitude of sixty-eight degrees east, north nine degrees west.

Coal seams and shale beds have here, as in many cases throughout the area, served as a lubricant for the movement of rock masses. Indications of coal at the surface are present as thin seams and small pockets. It would seem that the thicker seams have either been faulted out by more competent strata, or have been squeezed into lenticular bodies of which only the thin edges are discernable in outcrop. It is thought that by careful plotting of the attitude of horizons adjacent to the coal seams, their depth could be accurately determined. For instance, it was noted that the minor unconformity which is described in the discussion of the Blairmore formation lies about three hundred feet above the Blairmore-Kootenay contact above Adanac mine. On the southeastern portion of Maverick hill this unconformity is overturned along with strata of the Blairmore formation and lies 300 feet below the main fault line. The position of this outcrop, with respect to the coal seam, is known at Adanac mine and therefore offers some evidence of the location of coal in Maverick hill.

The strata of Maverick hill have been subjected to two or more compressional forces, each acting at different times. Evidence supporting this conclusion is seen in a heavy basal band of Blairmore sandstone present on the south end, which has been pushed from the south as well as the east. As observed from the valley of the Carbondale river, this band, which is thirty feet thick, has been folded and faulted into an S-shape.

CARBONDALE HILL STRUCTURE: Carbondale hill lies south of Maverick hill and between the confluence of Carbondale and Castle rivers. It is composed principally of rocks belonging to the Blairmore and Crowsnest formations.

The southwest peak, which is the highest point of the hill, is formed by a ridge composed of Crowsnest formation. This ridge is a continuation of the same band which lies immediately east of George creek. However, the strike has changed from north twenty-five degrees west to north fifty degrees west. These volcanic rocks are a part of the west limb of the Turtle Mountain anticline. East of the volcanic ridge the dip of the Blairmore strata changes from west to east. This is the southernmost expression of the Turtle Mountain anticline.

The anticlinal attitude of the strata may be observed from Carbondale river to the crown of the hill. In the core of the anticline Jurassic strata occur with both east and west dips in accordance with the limb it is on. The Kootenay and Blairmore strata also exhibit both east and west dips.

As is the case in Maverick hill, the strata of the east limb of the anticline on Carbondale hill are greatly distorted. From the point where the eastward dips begin, to the eastern side of the hill, the Blairmore rocks are folded and faulted. The axes of the folds and the strike of the faults trend in a direction of about north ten degrees west.

Observance of the north-south trend of the strata at the top of Carbondale hill would lead to the conclusion that the compressional forces on Carbondale hill were from the west acting east. However, there is along the north side and adjacent to Carbondale river a fault with a southwest trend. The fault line may be observed along the river bed. Movement along this fault line has been northeastwards, and has thrust the Blairmore and Kootenay strata of Carbondale hill over the north-south trending folds of Blairmore, Crowsnest, Blackstone and Bighorn formations north of the Carbondale river. This fault may best be observed in the north half of section 9, township 6, range 3. Here the Kootenay strata have a general east-west strike and the underlying formations over which they are thrust, strike in a general north-south direction.

Further evidence of this northward thrusting is seen on the southern flank of Carbondale hill. Here both transverse and longitudinal faulting of the anticline occur. The transverse faulting here, and also similar faulting east of Castle river, are the result of a thrust acting in a north-south direction. Transverse faulting may continue northward through Carbondale hill and across the Carbondale river, but verification is lacking owing to scarcity of good outcrops.

GINGER HILL ANTICLINE: Ginger hill is located north of the junction of the Carbondale and Castle rivers. It is structurally an anticline with a southeastward plunge of close to five degrees. The east limb of the anticline is not very apparent since vegetation covers most of the outcrops; and furthermore its structure is complicated by a fault on the east limb of the anticline. This fault brings to the surface the igneous pebble conglomerate, which occurs seven hundred feet stratigraphically above the base of the Blairmore. However, the rocks exposed on the hilltop are but two hundred feet higher stratigraphically than the conglomerate, so the displacement has not been very great. The fault varies in attitude from steeply eastward dipping to vertical, and strikes in the same direction as the anticline.

The southward extension of the anticline is exposed on both the Carbondale and Castle rivers. Both of these streams are antecedent to the anticline, and therefore expose a cross section of it. The cross section is best observed on the south bank of Castle river immediately south of its junction with the Carbondale. Here the Blairmore forms the core of the anticline (Figure 13), which is flanked successively on each side by Crowsnest, Blackstone and Bighorn strata.

The fault cuts across the strata of the east limb. On the top of Ginger hill it brings Blairmore over Blairmore strata; on the Carbondale river Crowsnest volcanics are thrust over Blairmore rocks, and along the Castle river Bighorn and Wapiabi strata overlie Blairmore sandstone and shale.

BACKUS MOUNTAIN THRUST FAULT: The name Backus Mountain thrust fault is given to denote a major overthrust of Mesozoic strata over Mesozoic. The thrust begins along Carbondale river immediately north of Carbondale hill; and, in influencing the structure of that hill, is the fault that thrust Kootenay strata northwards over southward trending folds. At the east end of Carbondale hill the fault trace swings abruptly southeastwards, the direction of the fault trace varying from east forty-five degrees south to east twenty-five degrees south. The dip of the fault plane has been calculated to average about twenty-five degrees southwards.

The fault, as observed throughout its course in the map area and also in the Beaver Mines map area adjacent to the east, strikes normal to the trend of most faults and folds in the area north of it. That it is a thrust fault and not a transverse fault is quite evident, for none of the structures north of the fault can be traced south of it. All traces of these structures have been obliterated by the overriding thrust sheet.

The force causing this thrust must have come from the south, a direction almost at right angles to that which produced the north-south trending folds of the area. This appears to be another expression of the northward acting force, which was previously mentioned.

In the eastern part of the map area and both north and south of the trace of the Backus Mountain thrust, numerous slice faults occur. These are especially evident in sections 6 and 7, township 6, range 2; sections 1 and 12, township 6, range 3; and sections 26, 27, 28, 33, 34 and 35, township 5, range 3, all west of the fifth meridian. The slicing was probably caused by northward acting forces. The faults involved in the slicing are not exposed.

TURTLE MOUNTAIN ANTICLINE: The axis of the Turtle Mountain structure, which is an anticline, enters the Carbondale map area in section 25, township 6, range 4, west of the fifth meridian. As the anticline first appears in the northern extremity of the map area it has a trend of north five degrees east; but this soon changes to north twenty degrees or more west. The plunge of the anticline is about six degrees southwards. The structure cannot be traced south of Carbondale hill.

Paleozoic strata of the eastern limb are exposed along the crest of the anticline where it first enters the map area. The Paleozoic rocks of the west limb are concealed by forest cover. The dip of the east limb here is about sixty degrees east. Along the crest southwards Paleozoic rocks are succeeded by those of the Fernie, Kootenay and finally Blairmore formations. A noteworthy feature of the anticline is the large area covered by Fernie shales, which extend from the east boundary of section 24, township 6, range 4, west of the fifth meridian to section 5, township 5, range 3, west of the fifth meridian.

Both the east and west limbs of the anticline are faulted. Faulting on the east limb has been discussed in connection with the structure of Maverick hill. Faulting on the west limb has brought Kootenay rocks to the surface on the west slopes of Hastings ridge. This fault apparently dies out on Carbondale hill in section 5, township 6, range 3, west of the fifth meridian on the northern slopes of Carbondale hill.

LEWIS AND COLEMAN THRUST FAULTS: The most pronounced fault in the map area is that which brings Precambrian and Paleozoic rocks over rocks of Mesozoic age. It roughly parallels the western, southwestern and southern margins of the map area. Within the map area the trend of the surface trace of the fault changes from a north-south direction on the west to a southeasterly direction on the south. The actual fault contact is covered by glacial debris and talus in most of the area, but it was observed in a few places, namely in section 13, township 6, range 5, west of the fifth meridian, on the ridges at the headwaters of Lynx creek; in section 24, township 5, range 5, on the southeast slope of Kootenay North; and in section 2, township 5, range 3, west of the fifth meridian on the northern slope of Table mountain. At the outcrop on upper Lynx creek, the Precambrian limestones are thrust over coal-bearing Kootenay strata. No gouge is present. The Kootenay strata strike north twenty degrees west, and dip fifty degrees west. No accurate attitude could be obtained for the Precambrian strata because of their being intensely folded and faulted. The exposure of the contact at Kootenay North revealed Precambrian overlying Kootenay sandstone, but in this instance there is six inches of black gouge. The gouge is very fine grained and consists largely of pulverized carbonaceous matter. The fault plane at this and the first location strikes north fifteen degrees west, and dips twenty degrees west. The exposure on Table mountain reveals black Precambrian argillite overlying green sandstones belonging to the Belly River formation. The Precambrian rocks are faulted and intricately folded (Figure 14). The gouge here is eleven inches thick (Figure 15). The fault plane at this point strikes north eighty-five degrees west, and dips twenty-one degrees south.

The strata a few feet above and below the fault were observed at a number of other places, but the actual contact is not exposed. It was not possible at these outcrops to determine the strike and dip of the fault plane.

The average dip of the fault plane within the Carbondale map area is twenty degrees, but the strike is quite variable. The measured strike on Table mountain is north eighty-five degrees west; on the mountain front between the branches of Castle river it is north seventy degrees west; in the valley of Gardiner creek it is north eighty degrees west, and on the north slopes of Mt. McCarty it strikes north eighty degrees west. On Kootenay North the strike has changed to north twenty degrees west, an attitude that persists to the northern boundary of the map area.

It was noted that along a large part of the thrust fault, Kootenay strata are associated with the thrusting. Hume has pointed out that not only are coal beds very incompetent, but they seem to act as a lubricant (Hume, 1932). Coal seams underlying the overthrust were noted along upper Lynx creek (Figure 4), along upper Carbondale river and on Mt. McCarty.

The main overthrust fault in the Crowsnest Pass area has been considered to be the northern extension of the Lewis thrust. This thrust is a prominent geological feature in Montana, and has been studied in some detail there. In Montana the thrust has a northwest trend, and dips southwest at angles of three to eight degrees (Willis, 1902). Willis also noted that the fault plane was warped. Hume (1932), in commenting on the structure in North Kootenay pass area, notes that the attitude of the fault changes from south eighty degrees west with a southerly dip of fourteen degrees to a strike of north twenty degrees west on Kootenay North and a dip twenty degrees west. He suggest that this may be due to warping of the fault plane subsequent to faulting.

In the foregoing pages of the discussion of structure, it was noted in several instances that the forces acting upon the strata were not always from the same direction. Attention is drawn to the following cases. The regional trend of the ridges changes within the area to a more northerly direction, the difference of strike being as much as twenty-five to thirty degrees. The strata on the south end of Maverick hill has been subjected to a north-south stress which has folded it into an S-shape. Also surface trace of the Backus Mountain thrust fault has an east-west direction and a northward thrust is necessary to explain it. Moreover this thrust has overthrust other strata and structures which have a north-south strike. In the Carbondale River valley north of Mt. McCarty the faulting is more intense than was observed elsewhere. Slickensiding indicates that movement was towards the northeast.

In general, north of the Carbondale river evidence of this northward force has disappeared, and the active force came from the west or slightly south of west. It would appear then that a definite change in the direction of the stresses has occurred in the North Kootenay Pass area.

Since the Lewis thrust fault begins in Montana, where faulting is caused by pressures acting in a northerly to northeasterly direction, it is herein proposed that the term "Lewis thrust" be applied in Alberta only where the force had that direction, namely east of North Kootenay pass and along the northern front of the Clarke range. It is further proposed that the extension of the Lewis fault north of North Kootenay pass to Crowsnest pass and underlying the Flathead range be named the Coleman fault.

Although no actual discontinuity in the fault was seen, there is a fault zone in the vicinity of North Kootenay pass where the abrupt change in the strike of the Lewis fault plane to that of the Coleman fault plane occurs.

It is concluded that the Lewis and Coleman thrusts are the result of two forces which were not contemporaneous. It is to be noted that the north-south trending structures north of Carbondale river are overridden by the Backus mountain fault block both in the vicinity of Backus mountain and also north of Carbondale hill. It is therefore obvious that the northward thrusting took place at a later date than the eastward thrusting, consequently the Lewis thrust as here defined is in part a younger thrust than the Coleman thrust, which is that lying north of North Kootenay pass.

Chapter V

ECONOMIC GEOLOGY

COAL

History of Coal Investigations in the Crowsnest Pass Region

G. M. Dawson in his early reports made mention of coal seams in the Crowsnest Pass area (Dawson, 1885: 1886). However, it was not until 1902 that the coal producing possibilities of the area were investigated in detail. In that year and again in 1911 and 1912 the Geological Survey of Canada assigned W. W. Leach to study the geology of the area. His work was continued in 1915 by B. Rose. The geological work of Leach and Rose was combined in the Blairmore map, published in 1920. B. R. MacKay (MacKay, 1932, 1933, 1934) investigated and reported in some detail on the coal measures of the area.

The area included in the Carbondale River map is part of a large tract which was investigated in 1912 in a reconnaissance manner, by J. D. MacKenzie.

Prospecting for coal by private individuals and companies is evidenced by the numerous pits and entrances dug or driven in the Kootenay strata throughout the Carbondale River map area.

Kootenay Outcrops of the Region

In the Crowsnest Pass area folding and faulting of the strata have produced numerous repetitions of the Kootenay formation. An east-west line drawn approximately through the town of Frank, which is situated about ten miles north of the Carbondale River map area, would transect at least eight bands of Kootenay strata. All of these bands do not contain the whole of the Kootenay formation. The bands diminish in number southwards and only the four most westerly bands are continuous into the map area. These bands have been given local names, which are used in this report. From west to east these bands are the Coleman outcrop or series, the Mutz outcrop, the Greenhill or Blairmore outcrop, and lastly the Adanac outcrop. The Coleman outcrop supports the mines about the town of that name; the Mutz outcrop is not presently producing; the Greenhill outcrop is mined at Blairmore and at localities several miles north of the town, and at one locality south and within the map area, viz., the Adanac strip mine; and the Adanac outcrop supports several mines. The Coleman, Mutz and Greenhill bands of Kootenay enter the map area in sections 27, 26 and 25 respectively of township 6, range 4, west of the fifth meridian. The Adanac comes into the map area in section 30 of the same township but of the range adjacent on the east. None of the above bands extends very far into the map area. The Coleman and Mutz outcrops are faulted out after a few miles; and the two other easterly bands, which lie on either flank of the Turtle Mountain anticline, unite immediately south of Carbondale river. This joint outcrop then plunges from view underneath Carbondale hill.

Figure 16 shows sections throughout the Crowsnest district and one section in the Corbin coal field. The Corbin section is included to illustrate the thickening of the coal measures and the Kootenay formation to the westward.

The York Creek Kootenay strata includes six coal seams, four of which have received attention as to the possibility of commercial development. Number one seam is not thicker than three feet and occurs sporadically. Number two and Number four seams are the only two that have been mined economically.

There are four seams in the Blairmore section. Number one seam is the only one suitable for economic development. This seam corresponds to Number two of the York Creek section, while Number two seam is the equivalent of Number four of the York Creek section.

The section measured at the Adanac strip mine has nine seams. Only the top seam which underlies the conglomerate is of suitable quality to be mined. This seam is being stripped by West Canadian Collieries.

Coal of the Carbondale River Kootenay Bands

BANDS UNDER THE OVERTHRUST: The most westerly bands of Kootenay occur under the main overthrust fault, and contain coal seams. Of the coal occurrences, two are worthy of mention. One of these is located in legal subdivision 12, section 13, township 6, range 5, west of the fifth meridian, immediately below the overthrust. At this place the Kootenay strata have been folded into a small anticline. This is the seam shown in Figure 4. The trench shown in Figure 4 crossed fifteen feet of dirty coal with two shale partings. The inaccessible location of the prospect and the quality of coal do not favour development at this time.

The second outcrops were those noted immediately under the overthrust on the north shoulder of Mt. McCarty. One seam outcrops in legal subdivision 15, section 17, township 5, range 3, west of the fifth meridian. It is immediately under the overthrust, and because of its unfavourable location was not prospected in detail. Another occurs in legal subdivision 2, section 20, township 5, range 3, west of the fifth meridian. Here the strata are overturned, for the coal seam lies above the conglomerate, which at this location is thirty feet thick. The seam consists largely of shale and a very little coal. The seam has an attitude of north eighty degrees west, nine degrees west. Structural conditions as they appear at the surface do not favour development of this outcrop.

COLEMAN OUTCROP: The Kootenay band which is mined in the Coleman district, namely the Coleman outcrop, extends southward into the Carbondale River area. This is the band which occurs along the eastern slopes of Willoughby ridge in township 6, range 4. Kootenay beds are exposed on Lynx creek in legal subdivision 16, section 10, township 6, range 4, west of the fifth meridian. South of this locality the band is faulted out under Cherry hill.

The Kootenay section is as follows:

Overlying beds: Blairmore sandstone, shale and conglomerate.

Contact conformable

	Thickness Feet
Sandstone, thin-bedded, platy, grey, fine-grained, dark weathering, well indurated	5.9
Sandstone, hard, blocky, grey; reddish-brown weathering, fossil plant fragments	8.4
Shale, sandy, very finely bedded, weathers to a grey-black, traces of coal, fossil plant fragments	29.4
Concealed	24.7
Sandstone, grey, well indurated, brown weathering, cross-bedded, blocky to massive	33.8
Concealed in part, mostly Kootenay shale; mine dump shows shale with some coal	47.8
Sandstone, ferruginous, fine- to coarse-grained; massive fossil plant fragments	36.0
Concealed	90.0
Total thickness of Kootenay beds	276.0

Fault

Underlying beds: Blairmore shale and sandstone.

No important coal seams were observed in the above section. The absence of the five seams which occur at Coleman may be due to non-deposition, faulting or thickness of cover. Faulting may account for the absence of several seams, for the coal seams have served as gliding planes and consequently they pinch and swell. Test drilling might reveal sizeable pockets of coal.

Adits have been driven in two places one near the middle of the above section and the other below the Blairmore conglomerate at the top of the section. Very little coal shows up in the mine dump, but whether this is due to the thinness of the seams or to the coal having been transported as mined could not be ascertained.

TURTLE MOUNTAIN ANTICLINE: Three bands of the Kootenay formation are present on the Turtle Mountain anticline. Two lie on the west flank, and one on the east flank.

The western bands are the southward extension of the Mutz and the Greenhill bands of the Blairmore area. The most westerly the Mutz band, is not worked in the area. It has been prospected and does not appear to have workable seams. One cut, opened by a bulldozer, had coal showings. It is believed that the intensity of orogenic pressures has caused the seams to be quite lenticular. The Greenhill band enters the Carbondale river map area in section 25, township 6, range 4, west of the fifth meridian. In legal subdivision 10, section 24, township 6, range 4, west of the fifth meridian, Number one seam is strip mined by West Canadian Collieries. The measured section for this location is detailed on Page 24, and is illustrated in Figure 16. At this locality the seam directly underlies the basal Blairmore conglomerate, and is apparently separated from it by an erosional unconformity. Since the top of the Kootenay formation has been subject to varying degrees of erosion, some differences might be expected in the thickness of the Number one seam. Moreover the section at Blairmore is 470 feet thick and at the Adanac strip mine it is but 280 feet. The loss of the lower workable seams then may be attributed to a marginal position in the depositional basin. The stripping process requires the removal of the heavy basal Blairmore conglomerate and a shale band which lies next to the conglomerate. The shale band has thickened at depth. The footwall is a well indurated sandstone.

The Mutz and Greenhill outcrops converge as the Turtle Mountain anticline plunges towards Carbondale hill. Inspection of the outcrop of these bands along Carbondale river did not show any coal seams. A property has been developed and abandoned at legal subdivision 7, section 8, township 6, range 3, west of the fifth meridian. Recovery in this attempt was principally black shale for no coal is present in the dump.

The eastern Kootenay band, the Adanac outcrop, is an extension of the band mined at Adanac mine near Byron creek just north of the area. The band outcrops along the top and western side of Maverick hill. The structure of this hill is discussed in Chapter IV. The coal seams probably continue into Maverick hill but have been buried in the very intense faulting. Discovery of mineable coal on this hill will depend on careful plotting of the horizons adjacent to the coal seams and determination of their relationships to the main faults. The lower part of the Kootenay formation and the underlying Fernie, which lie at the base of the west side of Maverick hill, have escaped most of the intense faulting and folding, but this part does not generally contain workable seams. Preliminary observation of the outcrop leads one to doubt that strippable coal seams will be found in this hill. However, by the methods suggested above, followed by a drilling program, it is possible that accumulations of coal will be discovered at depth.

A prospect that appears to hold some promise was observed at the lower end of the Adanac outcrop along Carbondale river in legal subdivision 6, section 8, township 6, range 3, west of the fifth meridian. The thickness of the seam explored could not be determined since the adit had long since caved in, but considerable coal is present in the dump. Some of the coal is blocky. The strata containing the coal seam dip to twenty degrees east. The thickness of the overburden at this place is not over fifteen feet, and consequently the prospect offers possibilities as a stripping proposition.

The three Kootenay bands of the Turtle Mountain anticline are converged in the nose of the anticline in section 5, township 6, range 3, west of the fifth meridian. Prospecting along the nose has not yielded mineable coal.

Along the base of Carbondale hill, part of the Kootenay formation is concealed beneath the Backus Mountain overthrust. No coal was observed in the outcrops along Carbondale river. The presence of some finely banded Fernie sandstone in this faulted wedge led to the conclusions that much of the strata in the faulted section is lower Kootenay, and therefore would not contain number one seam. An old prospect was observed where the Kootenay band crosses the Castle river in legal subdivision 7, section 10, township 6, range 3, west of the fifth meridian. No coal or carbonaceous shale was seen in the diggings.

EASTERN BAND: This band comes to the surface just north of the mapped area, and enters it in section 25, township 6, range 3, west of the fifth meridian. It outcrops on the Castle river, where it has been prospected, apparently without success.

SUMMARY: The intense faulting and folding in the Carbondale River area have resulted in the Kootenay coal horizons being faulted out at depth in many instances. The seams which are mined north of the map area are mostly unproductive at the surface in the south. Drilling in selected localities may reveal seams and accumulations at depth.

PHOSPHATE

Phosphate in the Canadian Rockies has been investigated in considerable detail and reported on by Telfer (1933).

Only one phosphate bed is known in the Mesozoic strata of the Carbondale River area. This bed is at the base of the Jurassic formation and lies disconformably on Carboniferous limestone. It was observed only at the outcrop on the Adanac Strip Mine road (Figure 3). At this locality it is a sandstone containing disseminated phosphatic nodules and accretions. Analysis of the rock shows that it contains 7.07 percent of phosphate (P_2O_5).

BUILDING STONE

The Paleozoic rocks outcropping in the map area do not appear to offer any good building stones. The limestone beds are hard and badly fractured, and consequently do not lend themselves to quarrying and facing.

The Spray River formation is not exposed in the map area. In the vicinity of Banff the formation furnishes a fine building stone.

According to Parks (1916) some sandstones of the Blairmore and Kootenay formations are a possible source of building stone for rough work such as foundations and coke ovens.

Possible sources of ornamental stone are the Crowsnest formation and the Precambrian formations. The Crowsnest formation includes colorful porphyries with large red crystals of analcite (Figure 8) and pink feldspar. These stones weather a drab color and fracture very unevenly but may take a good polish. The Precambrian sills of the Kintla formation are of two kinds, diorite sills and porphyry sills, the latter being associated with amygdaloidal basalt. These sills are exposed on Kootenay North. The lower, a diorite sill, is a dense, crystalline rock twelve feet thick. This rock when polished would be quite attractive. The upper sill is eight feet thick, and consists of a very dense, finely crystalline, blue-grey matrix with numerous lath feldspars two or three inches in length scattered through it. This rock has a good appearance in outcrop and in erratic boulders.

GRAVELS

The best gravels of the area occur in the river channels, where they are well sorted and very clean. However they occur in quantity only along the Castle river. There they may be suitable for local use.

The glacial deposits often contain gravel lenses one to two feet in thickness interbedded with rock flour. The deposits appear to be too impure to have any commercial use. The river bank illustrated in Figure 10 is thirty feet high and consists of glacial clays and gravels. It does not contain any gravel lens of apparent economic value.

OIL AND GAS

Two wells have been drilled for oil and gas within the region. One of these is along the west branch of Castle river, just south of the map area. No drilling records for this well could be located. The other well, known as the Kelly well, is located in section 16, township 5, range 3, west of the fifth meridian, very close to the Castlemount ranger station. This well was completed at 1500 feet and drilled Belly River strata throughout its entire depth. It obtained a small gas flow in rocks considered to be near the base of the Belly River formation (MacKenzie, 1912).

Chapter VI

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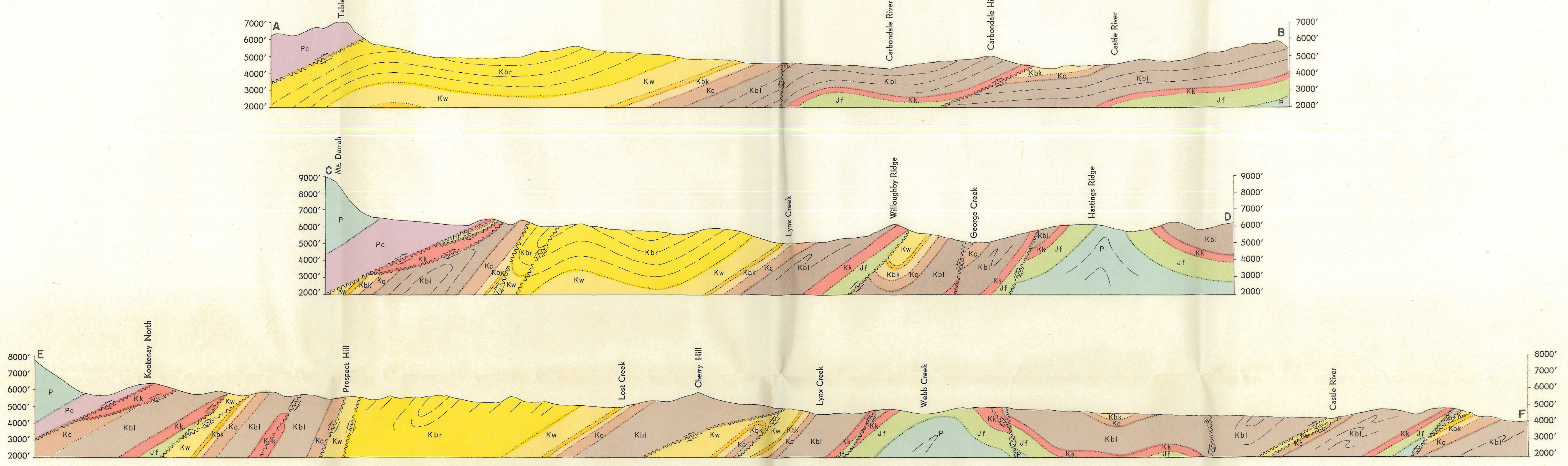

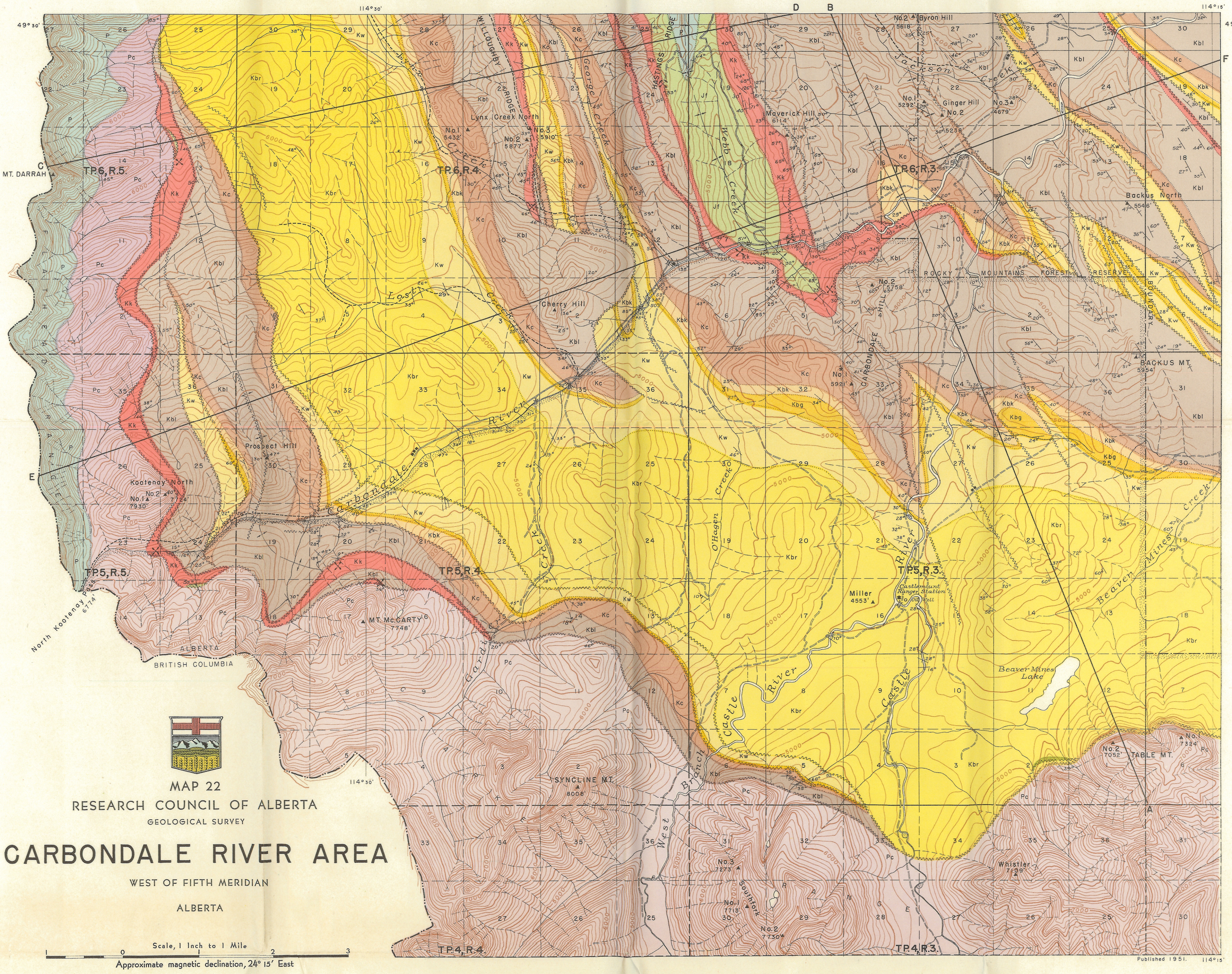

MAP 22

RESEARCH COUNCIL OF ALBERTA

GEOLOGICAL SURVEY

CARBONDALE RIVER AREA

WEST OF FIFTH MERIDIAN

ALBERTA

Scale, 1 Inch to 1 Mile

1 0 1 2 3

Approximate magnetic declination, 24° 15′ East

LEGEND

MESOZOIC

CRETACEOUS

UPPER CRETACEOUS

Kbp — **BEARPAW FORMATION:** dark grey, sandy shales; carbonaceous layers; shell beds; marine and brackish water.

Kbr — **BELLY RIVER FORMATION:** soft, greenish grey sandstone and shale; fresh and brackish water.

Kw — **WAPIABI FORMATION:** dark grey and black, sandy shales; nodules; brown, sandstone bands; marine.

Kbg — **BIGHORN FORMATION:** grey, quartzitic sandstone; dark grey shales with conglomeratic lenses; marine.

Kbk — **BLACKSTONE FORMATION:** medium grey and dark grey, arenaceous shales; nodules; marine.

LOWER CRETACEOUS

Kc — **CROWSNEST FORMATION:** tuffs, agglomerates, breccias and bedded ash.

Kbl — **BLAIRMORE FORMATION:** green, grey and maroon shales; green, grey, and greenish-grey sandstone; fresh water limestone; non-marine.

Kk — **KOOTENAY FORMATION:** brown, dark grey and black shales; coarse to fine-grained, grey sandstone; coal seams; non-marine.

JURASSIC

Jf — **FERNIE FORMATION:** black shale; grey and brown, arenaceous shale; brown, finely bedded sandstone; marine.

PALEOZOIC

P — **UNDIVIDED:** green shale; light grey dolomite; brecciated zone; grey limestone; calcareous shale; marine.

PRECAMBRIAN

Pc — **UNDIVIDED:** buff weathering limestone and sandstone; red and green argillite; lava flows and sills.

Geological boundary (approximate)
Bedding (inclined, vertical, overturned)
Fault
Anticlinal axis
Synclinal axis
Coal Mine
Coal prospect

Road well travelled
Road not well travelled
Forestry trail
Bridge
Forestry cabin
Lookout station
Buildings
Forest Reserve boundary
Game Preserve boundary
Township boundary (surveyed)
Township boundary (unsurveyed)
Section line (surveyed)
Section line (unsurveyed)
Waterfall
Intermittent stream
Sand or gravel

Contours (interval 100 feet) — 5000
Height in feet above mean sea-level — 7025′
Triangulation and Camera Stations — ▲

Geology by W. H. A. Clow and M. B. B. Crockford, 1949.

Base map compiled from topographic maps of the Department of Interior.

Map 22, to accompany Report 59.

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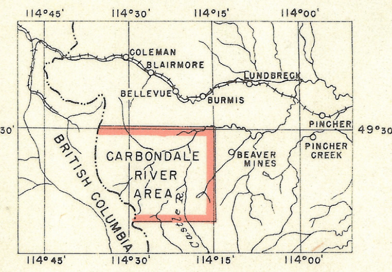

SCALE, 1 INCH TO 20 MILES