BRITISH COLUMBIA DEPARTMENT OF MINES

HON. R. E. SOMMERS, *Minister* JOHN F. WALKER, *Deputy-Minister*

BULLETIN NO. 33

Geology of the Crowsnest Coal Basin

with Special Reference to

THE FERNIE AREA

By C. B. Newmarch

VICTORIA, B.C.
Printed by DON MCDIARMID, Printer to the Queen's Most Excellent Majesty
1953

Plate 1. R.C.A.F. oblique looking south across Fernie Coal Area.

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PREFACE

This bulletin dealing in particular with the Fernie coal area and in a general way with the very important Crowsnest coal basin is mainly as it was prepared by C. B. Newmarch as a dissertation for presentation to the Faculty of Princeton University in candidacy for the degree of doctor of philosophy. The bulletin includes descriptions of the Michel strip mines and of a method proposed to assist in correlation of coal seams. by use of spectrochemical analyses of the ash from coal samples.

Victoria, April, 1953.

H. Sargent,
Chief, Mineralogical Branch.

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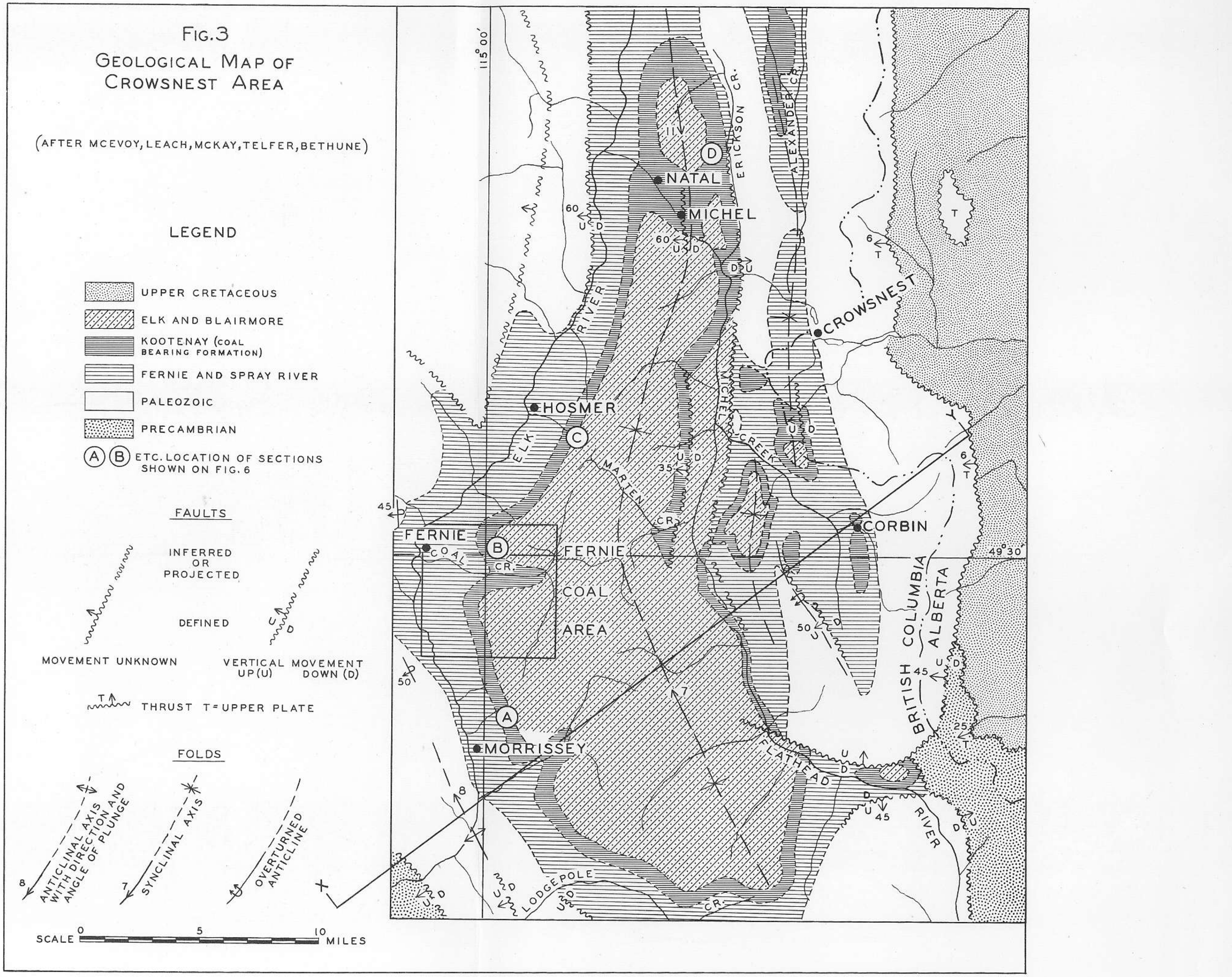

FIG. 3
GEOLOGICAL MAP OF CROWSNEST AREA
(AFTER MCEVOY, LEACH, MCKAY, TELFER, BETHUNE)
LEGEND
UPPER CRETACEOUS
ELK AND BLAIRMORE
KOOTENAY (COAL BEARING FORMATION)
FERNIE AND SPRAY RIVER
PALEOZOIC
PRECAMBRIAN
Ⓐ Ⓑ ETC. LOCATION OF SECTIONS SHOWN ON FIG. 6
FAULTS
INFERRED OR PROJECTED
DEFINED
MOVEMENT UNKNOWN
VERTICAL MOVEMENT UP (U) DOWN (D)
THRUST T = UPPER PLATE
FOLDS
ANTICLINAL AXIS WITH DIRECTION AND ANGLE OF PLUNGE
SYNCLINAL AXIS
OVERTURNED ANTICLINE
SCALE 0 5 10 MILES
115° 00'
49° 30'
NATAL
MICHEL
CROWSNEST
HOSMER
FERNIE
CORBIN
MORRISSEY
FERNIE COAL AREA
ELK RIVER
ERICKSON CR.
ALEXANDER CR.
MICHEL CREEK
MARTEN CR.
COAL CR.
FLATHEAD RIVER
LODGEPOLE CR.
BRITISH COLUMBIA
ALBERTA

CHAPTER I -- INTRODUCTION

This report presents information regarding the geology and coal resources of an area surrounding the Fernie coal mines in southeastern British Columbia. Field work on this project was carried forward under the auspices of the British Columbia Department of Mines during the field seasons of 1946, 1947, and 1948. Work done in this period may be summarized as follows:

1. The "Fernie Coal Area," comprising approximately 31 square miles centring on the Fernie coal mines; was mapped geologically on a scale of 1 inch to 800 feet. Special attention was given in both surface and underground studies to the No. 9 coal seam, in which problems of development had been encountered by the operating company.

2. Reconnaissances and detailed mapping were undertaken in the Michel area in conjunction with the exploration and development of open-cut operations.

3. Various reconnaissances were made and some prospecting was done along the western and eastern margins of the Coal Basin.

4. At Michel an extensive sampling programme of some of the seams was undertaken and the samples were analysed spectrochemically. Results of the analyses were utilized in establishing a correlation technique.

LOCATION AND ACCESSIBILITY

The area under consideration in this report is shown in Fig. 3. The town of Fernie is in the heart of the Rocky Mountains of southeastern British Columbia in Elk River valley at the mouth of Coal Creek (at latitude 49° 30' 15" and longitude 115° 03' 45"). Travel to other centres of population is facilitated by the Crowsnest branch of the Canadian Pacific Railway and by the Trans-Canada Highway which parallel one another in traversing the Rocky Mountains by way of Elk River valley and Crowsnest Pass. The valley of Coal Creek, between Fernie and the old town of Coal Creek, is served by a secondary government road and by the Morrissey, Fernie, and Michel railway, which is owned and operated by The Crows Nest Pass Coal Company Limited. Various trails, of which a few are suitable for pack-horses, lead into the hills from the principal routes of transportation. The railways, roads, and some of the trails have been shown on the map of the Fernie Coal Area (in pocket). The best trails in the map-area consist of one which follows up the valley of Coal Creek from the end of the government road, and another which branches from the aforementioned trail at the dam and follows a northerly flowing tributary of Coal Creek to its headwaters. A trail which follows southwestward along the outcrop of the No. 9 and No. 10 seams from the portal of No. 9 mine was extended in 1947 to the crest of Morrissey ridge. A trail that leads northward from the Coal Creek road from a point just west of the road bridge 2.6 miles from Fernie was found useful in reaching a prominent outcrop of the Basal Kootenay sandstone. From this outcrop various well-worn game trails may be followed to reach the higher levels on the north side of Coal Creek. The crests of the prominent ridges are generally free from underbrush, and provide additional routes for travel.

PREVIOUS WORK

F. W. Howay, (1914) mentions that, "The existence of coal deposits in East Kootenay has been known since the first Europeans saw the region." Coal was observed on the eastern flanks of the Rocky Mountains in 1811 by Alexander Henry and in 1845 Father de Smet observed "des morceaux de charbon de terre" in the Kootenay country.

CROWSNEST COAL BASIN

G. M. Dawson (1881-1885) was the first geologist to report the occurrences of coal in the vicinity of Crowsnest Pass. Dawson's early work was soon followed by a reconnaissance by A.R.C. Selwyn (1891) who described coal seams on Marten Creek, Coal Creek, and along the Elk River, and made a preliminary estimate of the tonnage of available coal in the Crowsnest Coal Basin. These early investigations suggested that more detailed work would be of great value in the development of the coal deposits. Accordingly, James McEvoy (1900) was assigned the task of geologically mapping the Crowsnest Coal Basin. McEvoy's work was supplemented the following year by investigations made by W. W. Leach (1901), and his results along with those of McEvoy, were embodied in the "Geological and Topographical Map of Crowsnest Coal Fields" (No. 767) which was published in 1902. A brief outline of the geology of the Crowsnest Coal Fields as well as an estimate of coal resources may be found in reports by D. B. Dowling, published in 1914 and 1915. The same author, in his "Coal Fields of British Columbia" (1915) assembled several reports to form a concise account of the information that was available relating to the Crowsnest Coal Fields. Subsequently, Bruce Rose (1917) extended work that he had done in southern Alberta to include the Crowsnest and Flathead coal areas.

From 1917 to 1932 no geological work on the coal deposits of the Crowsnest Coal Basin was undertaken. However, after the discovery of phosphate by W. D. Burgess and L. Telfer near the town of Crowsnest in 1925, a series of investigations of the Palaeozoic and Jurassic strata which outcrop around the rim of the Basin were made by Leo Telfer (1933).

Consequent to difficulties encountered in underground mining at Michel in 1929, B. R. MacKay (1933) undertook the geological mapping of an area of 11.4 square miles centring on the town of Michel. In addition to the map and report, The Crow's Nest Pass Coal Company was supplied with a structure-section model of the Michel area, on a scale of 1 inch to 800 feet.

During the summer of 1935 Pierre de Bethune (1936) examined coal lands in the vicinity of Flathead townsite and prepared a report dealing with the structure of that part of the Rocky Mountains adjacent to Crowsnest Pass.

In a recent report prepared for the Royal Commission on Coal, B. R. MacKay (1946) has summarized the geology of the Fernie coal basin and prepared an estimate of the coal reserves.

FERNIE COAL AREA

No geological studies, apart from the work done by James McEvoy, have been available for the Coal Creek area.

However, much useful information pertaining to the Coal Creek mines is contained in reports of the Inspectors of Mines, which are published in the Annual Reports of the Minister of Mines for British Columbia, dating from 1897. In addition, a detailed study of the "bumps and outbursts" in the Coal Creek mines was made by George S. Rice (1916) and his report has been published in the form of a bulletin. A recent report on the mining operations and a description of the preparation plant at the Elk River Colliery on Coal Creek has been made by W. C. Whittaker (1944).

FIELD WORK, BASE MAPS

When field work was initiated in the Coal Creek area in 1946 no topographical map, on a sufficiently large scale for the project contemplated, was available. However, a topographical map of the Crowsnest Coal Basin, on a scale of approximately one-half mile to the inch, with 100-foot contours, had been made by A. O. Wheeler in 1900.

Part of A. O. Wheeler's map-sheet surrounding the Coal Creek mines was enlarged to a scale of 1 inch to 800 feet as a base for geological mapping. An instrumental survey of the Coal Creek road by the Department of Public Works was utilized in checking the accuracy of the photographic enlargement. Additional checks were made possible by using a Crow's Nest Pass Coal Company survey along the No. 10 seam outcrop, a triangulation "tie" to the Canadian Pacific railroad at Cokato, and a survey of the Canadian Pacific right-of-way. For the slopes of the valley near the Coal Creek mines the contours were revised, using the numerous plans and traverses kindly provided by The Crow's Nest Pass Coal Company. A correction factor (+2856.88), established by the company was used in reducing mine elevations to sea-level elevations. As the work progressed, some other changes in the topographical map were found necessary, but for most of the area, Wheeler's topographical map, in spite of the enlargement, was found to be quite accurate. It is believed that the final base map on which geological observations have been plotted, though leaving much to be desired, is sufficiently accurate for the portrayal of the major structural features of the area.

Because of the numerous steep, brush-covered slopes in the area, difficulty was experienced in making accurate pace and compass traverses. Hence outcrops were generally located by obtaining intersecting compass bearings on two established points. Elevations of outcrops were obtained by System-Paulin altimeter readings. Hourly readings of an altimeter in the Fernie office of The Crow's Nest Pass Coal Company were kindly furnished by various officers of the company. Inasmuch as barometric elevations taken in the field were within a radius of 5 miles of these recorded hourly readings, it was possible to apply a correction for changes in atmospheric pressure. Barometric determination of elevations on traverses run between creek level and triangulation stations on the mountain tops appeared to have a limit of error of plus or minus 25 feet, whereas closed traverses at the lower levels, through a vertical range of a few hundred feet, were maintained with a limit of error of plus or minus 10 feet.

In addition to pace and compass traverses, some plane-tabling was done along the north side of Coal Creek in order to locate various trenches that had been made in several of the lower coal seams. The plane-table was also used to check the intervals between seams in a section of the Kootenay formation on the north side of Coal Creek.

Royal Canadian Air Force Vertical Aerial photographs, on a scale of approximately 1 inch to 1,500 feet, were available for that part of the map-area situated west of the mine workings. Details from these photographs were used to supplement data collected in the field.

Field work near Michel was undertaken in two small areas surrounding the Michel and Baldy strip mines. At the Michel strip mine, about 5 miles east of the town of Michel, numerous instrumental surveys and bore-hole records obtained by the operators were supplemented with attitude determinations made by the writer as mining progressed. All available data were utilized in constructing a model of the pit, on celluloid sheets at a scale of 1 inch to 50 feet. The model was to be quite useful in the early stages of the development programme. At the Baldy strip-mine prospect, located about 2 1/2 miles west of Michel, a base-line located to follow the coal seam outcrop was established with transit and chain by The Crow's Nest

Pass Coal Company. On each side of this base cross-sections and traverses were made by the writer using a chain, compass, and an altimeter. Data thus obtained were used in preparing a plan and battery of structure sections on a scale of 1 inch to 200 feet.

ACKNOWLEDGEMENTS

The writer wishes to express his appreciation of the many courtesies and services given by the officers of The Crow's Nest Pass Coal Company Limited, and especially for the provision of office facilities and assistance in the field. To Mr. H. E. Miard, former mine inspector at Fernie, thanks are due for the contribution of much useful material relating to the early mining operations of the district. Mr. H. Sargent, under whose supervision the field work was done, offered many helpful suggestions during the preparation of the report. W. A. Bell and F. H. McLearn of the Geological Survey of Canada assisted the writer by identifying fossil plants and invertebrates collected in the Fernie area. P. S. Warren, University of Alberta, identified several collections of invertebrates obtained from the Fernie shale. Research facilities were provided by the Department of Geology of Princeton University. The faculty of that Department offered many helpful suggestions; special thanks are due W. T. Thom, Jr., and E. Dorf who supervised the preparation of the manuscript. G. Cave Brown Cave (1) undertook the extensive series of spectrochemical analyses of coal ash and offered many critical suggestions that have facilitated interpretation of the results of these investigations. Able assistance in the field was contributed in 1946 by W. H. Adrian, in 1947 by F. M. Archibald, and in 1948 by W. Sparling. To all those who have aided in the preparation of this report the writer is extremely grateful.

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(1) Chief Analyst, British Columbia Department of Mines.

CHAPTER II -- GEOGRAPHY

LAND FORMS

The Fernie Coal Area is situated at the western edge of a large elliptical physiographic unit known as the Crowsnest Coal Basin. Regional structure has been a controlling influence in the production of the present topography. The varying ability of the folded lithologic units to withstand erosion and the control exerted by some of the major faults have been important factors in determining the directions of the master valleys. The coal measures in the central part of the basin have been protected from erosion by a succession of conglomerates in the Elk and Blairmore formations. The relatively resistant Palaeozoic limestone forms rugged mountains surrounding the coal basin, whereas the soft Fernie shale outcrops only in the valleys.

The Fernie Coal Area presents a maturely dissected surface with considerable relief. The rocks vary from shale in the lower part of the sequence through sandstone to conglomerate in the upper beds. From the geological map of the Fernie area it is apparent that many of the land forms are directly related to the resistance and attitude of the strata. In the western part of the area, where steep dips prevail, sandy beds in the Fernie shale outcrop as prominent strike-ridges. In the eastern part of the area, which is characterized by more gently dipping beds, the structure-contours are often closely paralleled by northward-trending surface contours.

Altitudes in the Fernie area range from 3,200 feet on the Elk River 4 1/2 miles south from Fernie, to 7,016 feet at the crest of the Morrissey Ridge. Along Coal Creek the highest ridges are approximately 3,000 feet above the valley floor.

DRAINAGE

The drainage system of the Fernie Coal Area is entirely tributary to the Elk River which occupies a broad valley that has an average gradient, near Fernie, of 15 feet to the mile. Seasonal variations in the volume of water carried by Elk River and its tributaries are pronounced. During the month of June when the snow on the mountains is melting rapidly, Elk River frequently overflows its banks, Coal Creek becomes a muddy torrent that can be crossed only with difficulty, and the smaller intermittent tributaries of Coal Creek build large alluvial fans.

Coal Creek, the largest stream in the map-area, flows westward in an open V-shaped valley at an average grade of 2 per cent. Several of the large tributaries of Coal Creek have gentle gradients in their lower reaches but have steep gradients at their headwaters. A north-flowing tributary that joins Coal Creek near the No. 1 East mine, for example, has a gradient of 9 per cent in its lower 2 1/4 miles, in the next one-half mile its grade averages 20 per cent, and in a distance of 1,000 feet at its headwaters it attains a grade of 75 per cent. The nature of the stream gradients and the narrowness of the interstream divides are evidence that the physiography of the Fernie area has approached the stage of early maturity.

Within the map-area it is observed that, with the exception of Coal Creek, the west-flowing tributaries of Elk River have had little success in cutting their channels headward into the coal basin. The alignment of the valleys of Marten Creek, Coal Creek, and Lizard Creek, therefore, suggests that the valley of Coal Creek may represent part of a superposed or antecedent drainage system.

GLACIATION

Glaciation in Fernie Coal Area has had slight effect in modifying the topography. The general absence of glacial deposits and lack of evidence of ice erosion imply that the ice disappeared from the region by ablation of an almost stationary mass.

R. A. Daly (1912) in describing glaciation in the Galton-MacDonald Mountain group, which lies about 20 miles south of the Fernie area, has noted that the upper limit of Pleistocene continental glaciation was at the 7,300-foot contour. He also mentions that there was an ice divide in the area between the Kootenay valley and the Flathead valley from which the continental ice-sheet moved both eastward and westward.

Those observations suggest that the Coal Creek area may have occupied a position near the centre of the continental ice divide, if so the absence of erosional features produced by the ice-cap within the map-area would be explained. In traversing the high ridges, on many of which bedrock is exposed, glacial grooving was nowhere observed, nor were glacial erratics seen.

The second or alpine stage of glaciation began with the melting of the continental ice-sheet. At this time the pre-glacial topography was modified somewhat. The absence of spurs and slight steepening of the walls of Elk River valley (see frontispiece) may be attributed to erosion accomplished by a valley glacier.

Two large tributaries of Coal Creek which flank the No. 1 East ridge head in steep-walled cirque-like basins, the gentle floors of which are being rapidly eroded by the present streams. The location of these basins suggests that cirque formation was confined to the highest part of the area.

Drift deposits, rarely exposed in the area, are confined to the valley bottoms. In Coal Creek and Elk River valleys thin deposits of glacial clay containing a few large boulders were observed resting on bedrock and overlain by alluvial gravel. Striae paralleling in direction the Elk valley were noted on a bedrock surface exposed in 1947 on the northwest outskirts of Fernie, on the west bank of the Elk River in excavations at the site of a new bridge on the highway from Fernie to Michel.

The following evidence suggests that glacial erosion during the alpine stage had slight effect in modifying the topography.

(1) Coal Creek and other tributaries of the Elk River have V-shaped cross-sections.

(2) Hanging valleys are not present.

(3) Bedrock sections observed in various mine entries along Coal Creek valley invariably show that both coal and roof-rock are deeply weathered.

In the Fernie area the gradients of Elk River valley and Coal Creek are both very gentle. Inasmuch as there is no evidence to suggest a greater accumulation of ice in one part of Elk valley than another, it would be expected that the ice surface of the Elk-valley glacier would conform to that of the valley floor, that the movement of the glacier would be extremely slow; and that the narrowness of the valley extending to the south of Morrissey would make stagnation of the Elk-valley glacier inevitable.

It seems likely that the gentle slope of Coal Creek would also have induced a very slowly moving valley glacier. If valley glaciers modified the shape of some of the steeply graded tributaries of Coal Creek, the actively eroding recent streams have eliminated the U-shaped profiles that may have existed.

The general absence of drift deposits in the area may be attributed in part to ineffectual ice erosion, and in part to removal of the drift by post-Glacial erosion.

CLIMATE AND VEGETATION

Precipitation in the Fernie area is heavy throughout the greater part of the year. About one-third of the annual moisture falls as winter snow which generally blankets the higher areas from early in October to late in June. During the months of July and August clear warm days may be expected. The temperature seldom exceeds 90 degrees during the day, and the nights are always cool. A table in the pocket summarizes data recorded at the weather station in Fernie, which is maintained by The Crow's Nest Pass Coal Company Limited.

Timberline is nowhere distinctly marked but above the 6,800-foot contour conifers are sparsely distributed. The more common trees noted in the area include larch (tamarack), spruce, lodgepole pine, Douglas fir, balsam, and hemlock. Poplars are sometimes confined to coal-seam outcrops and hence may be useful guides in prospecting. Forest fires have swept over extensive tracts of the Fernie area so that travel is often made difficult by an abundance of fallen trees.

Underbrush is abundant even in well-forested parts of the area. Along many of the stream channels devil's club, yellow arum, and bracken flourish, while alder and salal cloak most of the hillsides. In the open or burned-over areas raspberries and huckleberries are often found. Dumps of impure coal support a prolific growth of the common mullein.

CULTURE

Settlement within the map-area is confined to the valleys of Elk River and Coal Creek. The town of Fernie, with a normal population of 3,000 serves as a centre of supplies for the coal mines and for various enterprises along Elk River valley. Coal mining is the largest industry but activities of the East Kootenay Power Company provide employment for many local residents. Lumbering is an important industry in the vicinity of Fernie but within the map-area is restricted to small-scale operations adjacent to the Fernie-Morrissey road. Agriculture, which may take the form of mixed farming or dairying, is in evidence on the fertile bottom land and terraces of the Elk valley.

CHAPTER III -- STRATIGRAPHY

INTRODUCTION

The part of the Canadian Rockies shown in Fig. 3 contains a great thickness of essentially conformable sedimentary units of the Precambrian, Palaeozoic, and Mesozoic eras. Within the Crowsnest Coal Basin, strata ranging in age from Jurassic to Recent have been exposed, and the upturned edges of pre-Jurassic rocks are brought into view in the rugged mountains surrounding the coalfield. Only the Mesozoic succession was studied in detail, so that in the descriptions of formations which follow, the pre-Jurassic strata are given in summarized form. The general stratigraphic succession is given in the following table of formations, which serves also as a correlation chart of sections measured east or west of the axis of the Coal Basin.

DESCRIPTION OF FORMATIONS

PRECAMBRIAN

Precambrian rocks are exposed in the southwestern and southeastern corners of the area shown in Fig. 1. At both of these localities the Precambrian strata have been thrust over or against younger beds. In the vicinity of the Forty-ninth parallel Precambrian sections have been studied by Daly (1912a), and near Elko, Schofield (1922) has discussed the relationship of the Precambrian to younger beds.

PRECAMBRIAN-CAMBRIAN CONTACT

The writer examined the Precambrian-Cambrian contact at several exposures near the town of Elko. Locally the contact was marked by a few inches of hematitic conglomerate; and in all instances the contact could be sharply drawn at a smooth and regular surface. Because strata which could be regarded as equivalent to the Windermere series (which overlies the equivalent of the Galton series in the Windermere area) are not present near Elko, then it follows that at least in the Elko area the Precambrian-Cambrian contact represents a disconformity. Further east, in the Flathead area, Hume (1932, p. 6) and Mackenzie (1922) have noted an "erosional unconformity" at the top of the Precambrian.

TABLE OF FORMATIONS

System	Series	Formation: West	Formation: East
Quaternary	Pleistocene and Recent	Till and gravels generally confined to stream valleys	
		Angular Unconformity	
Cretaceous	Lower Cretaceous	BLAIRMORE 600' + of conglomerate, sandstone and vari-coloured shale	BLAIRMORE 2, 300' of conglomerate, sandstone and vari-coloured shale
			Disconformity
Mesozoic	Lower Cretaceous or Upper Jurassic	ELK 1,700 ' of conglomerate, sandstone, grey to black shale and minor cannel KOOTENAY 2, 100' of sandstone, grey to black carbonaceous shale, and coal seams	KOOTENAY 1,800' of sandstone, grey to black carbonaceous shale, and coal seams
Jurassic	Upper Middle and Lower Jurassic	FERNIE 3, 000" of grey to black calcareous shale, sandy in part	FERNIE 900' of dark grey to black thin-bedded shale, sandy in part
		Disconformity	

Mesozoic

System	Series	Formation: West	Formation: East
Triassic	Middle? and Lower Triassic	SPRAY RIVER 1,700' of quartzite, sandy shale and argillaceous dolomite	SPRAY RIVER 350' of brown to grey quartzite
		Disconformity	
	Pennsylvanian	ROCKY MOUNTAIN 1,000' of grey to brown partly calcareous quartzite	ROCKY MOUNTAIN 1,100' of grey to brown calcareous quartzite
Carboniferous	Mississippian	RUNDLE 2,500' of grey to brown crystalline limestone	RUNDLE 5,000' of grey to brown crystalline limestone
		BANFF brown to black cherty limestone	BANFF 1,100' of brown to black cherty limestone
			EXSHAW 45' of black shale, calcareous in part

Era	System	Series	Formation: West	Formation: East
Palaeozoic	Devonian	Upper Devonian	JEFFERSON? 500' + of dark-grey limestone and grey dolomite	PALLISER 900' of dense, dark grey to black limestone ALEXO 270' of grey to bluff silty dolomite. FAIRHOLME 1600' of grey to black, partly silty or shaly, limestone and dolomite.
	Silurian			UNNAMED 600' of massive limestone
			Disconformity	Disconformity
	Cambrian	Middle Cambrian	ELKO 90' of siliceous limestone or dolomite BURTON (upper part) 60' of black shale with limestone bands	FLATHEAD 300' of white to reddish quartzite

System	Series	Formation West — East
Cambrian	Lower Cambrian	BURTON (lower part) 18' of sandy limestone and micaceous shale
Disconformity		
Late Precambrian Purcell	Galton or Lewis	13,000' of metargillite, quartzite, siliceous dolomite, limestone, and basic lava.

Evidence from several areas suggests broad uplift and erosion of part of the upper Precambrian sediments prior to a widespread transgression of the Cambrian sea.

CAMBRIAN SYSTEM

Burton, Elko, and Flathead Formations

Near Elko, Schofield found that the Cambrian is represented by 168 feet of marine sediment including the Burton formation from which trilobite species have been identified as Lower and Middle Cambrian fossils. The section is represented in the following table.

Age	Formation	Description	Thickness Feet
Middle or Upper Cambrian	Elko Formation	Grey siliceous limestone and cream-coloured siliceous dolomite	90
Middle Cambrian	Burton Formation (upper part)	Greenish-black shale with thin limestone lenses	60
Lower Cambrian	Burton Formation (lower part)	Massive, grey, sandy limestone	10
		Greenish-grey micaceous shale	4
		Rubbly-weathering calcareous grit with annelid borings at top	3
		Hematitic conglomerate	1

Disconformity

Evidence from several areas suggests broad uplift and erosion of part of the upper Precambrian sediments prior to a widespread transgression of the Cambrian sea.

In the Flathead area Hume (1933) found 50 to 100 feet of white or pink coarse-grained sandstones that are "probably Cambrian in age." Near North Kootenay Pass, MacKay (1932) has used the name "Flathead quartzite" for a band 300 feet thick of white and reddish quartzite that contains trilobite remains of Middle Cambrian age.

ORDOVICIAN AND SILURIAN SYSTEMS

A major break in the sedimentary record is indicated by the absence of Ordovician strata in that part of the Canadian Rockies bordering the Crowsnest Coal Basin. Broad uplift and erosion of part of the Cambrian sediments appear to have taken place during the Ordovician period. In the Flathead area Hume (1932, p. 7) has noted 600 feet of hard and gritty massive limestones of Silurian age. However, in sections of Palaeozoic strata measured near North Kootenay Pass and near Elko (MacKay 1932, p. 29), (Schofield 1922) no Ordovician or Silurian strata have been recognized.

DEVONIAN SYSTEM

Devonian strata have been described from several areas flanking the Crowsnest Coal Basin. At Elko, Schofield (1922, p. 15) found that the "Jefferson? limestone," 500+ feet of dark grey limestone and whitish-grey weathering dolomite, disconformably overlies the Elko formation.

A well-exposed and readily accessible section of the Devonian is to be found in the railway cut along the north shore of Crowsnest Lake. This section has been described by Warren (1928, 1933) who found the total exposed thickness of the Devonian Minnewanka formation to be 2,875 feet, and by MacKay (1931) who has estimated the thickness to be 2,626 feet. The base of the section is marked by the Rocky Mountain fault (Lewis overthrust) so that a complete section of the Devonian has yet to be obtained.

The exposed section has been studied more recently by deWit (1950), who discarded the term "Minnewanka formation" and used the following units to replace it:

	Description	Thickness Feet
Palliser Formation (Costigan Member)	Grey to brownish, rubbly appearing limestone	67
Palliser Formation (Morra Member)	Grey to black limestone, cliff forming, characterized by dolomitic tracery on weathered surface	833
Alexo Formation	Grey to brown dolomite containing or interbedded with silt	268
Fairholme Formation (Upper dolomite and dark limestone beds)	Black argillaceous limestone and brown bedded dolomite	673
Fairholme Formation (Lower dolomite and limestone beds)	Grey to black limestone and dolomite, some of which carries stromatoporoids, corals, and brachiopods	924

Fossils collected from the above section have been determined to be Upper Devonian in age.

CARBONIFEROUS SYSTEM

Mississippian Series

Exshaw Formation

Conformably overlying the Devonian in the Crowsnest section is a 45-foot band of dark shales which, on the basis of similar lithology and stratigraphic position, may be correlated with the Exshaw formation described by Warren (1937) from the Exshaw area, Alberta. The section consists of a lower 30 feet of hard, dark grey calcareous shale which grades into an upper 15 feet of soft, earthy, brownish-black fissile shale. Although a careful search of the section for fossils was made by the writer, none were obtained. The age of the Exshaw shale has been in doubt, the formation being originally included in the lower part of the Banff shale of Mississippian age (Warren, 1927), but later assigned to the Upper Devonian (Warren, 1937). More recently Weller (1948) has stated, on the basis of a conodont fauna described by Cooper (1943), that the Exshaw formation is lower Mississippian in age.

Banff Formation

Conformably overlying the Exshaw shale in the Crowsnest section is a thickness, according to MacKay of 1, 070 feet of dark brown and black limestone with nodules of chert. On the basis of lithology and stratigraphic position Warren has correlated this part of the section with the Mississippian Banff shale at Banff. Dark cherty limestones, resembling those exposed near Crowsnest, were seen in road cuts southwest of the tunnel on the Fernie-Elko highway, but only the upper part of the Banff section is there exposed.

Rundle Formation

Overlying the Banff shale without any apparent break in the succession is a thick unit of generally grey, crystalline, fossiliferous limestone, the Rundle formation. At Crowsnest Lake, MacKay finds the thickness of this formation to be 4, 988 feet and has estimated that a similar thickness is exposed in the Flathead range, near Corbin. However, the formation thins rapidly both eastward and westward from the vicinity of Crowsnest Pass. On the Fernie-Elko road near the tunnel the Rundle Formation is well exposed in a series of road cuts. Here a total thickness of approximately 2, 500 feet consists of alternating bands of grey to dark brown, finely crystalline limestone, with near the base, two 25- to 50-foot beds of white, apparently pure, coarsely crystalline limestone. Near the middle of the formation grey porous limestone beds have a marked petroliferous odour. Near the top of the formation a thin fossiliferous bed contained brachiopods that have been identified by R. A. Brown at Ottawa as follows:

"Rhynchopora sp.

cf. Tetracamera subcuneata (Hall)
cf. Girtyella turgida (Hall)
cf. Spirifer pellaensis (Weller)

"This faunule belongs to a fauna probably of Meramec age, occurring in the upper Rundle and basal Rocky Mountain beds in the Banff and Crowsnest areas." Fossils collected from the Rundle limestone in the Crowsnest section by Warren were all of Mississippian age, but MacKay (1931, p. 11) has reported a Pennsylvanian fauna in the uppermost beds.

Pennsylvanian Series

Rocky Mountain Quartzite

Conformably overlying the Rundle formation is a series of grey, pink, or brown-weathering quartzites, sandstones, and sandy dolomites that frequently contain nodules of grey to blue chert. This sequence, the Rocky Mountain quartzite, has a thickness, according to MacKay, of 1,118 feet near Crowsnest and 1,028 feet at Corbin. Along the west side of th Elk River at Fernie the formation has a thickness, estimated by Telfer (1933, p. 570) of 1,000 feet and includes in its upper part interbedded chert, quartzite, shale, and phosphate. The top of the formation is marked by a bed of nodular phosphate. Fossils collected from this formation near Fernie and near Crowsnest indicate a Pennsylvanian age for the Rocky Mountain quartzite.

TRIASSIC SYSTEM

Spray River Formation

An assemblage of shaly quartzites, thin-bedded sandy shales, and argillaceous dolomites, overlies the Rocky Mountain quartzite. On the basis of lithology and stratigraphic position this assemblage of sediments has been correlated with the Triassic Spray River formation of the Banff area. An erosional unconformity at the base of the formation has been noted in some parts of the present area, but is not discernible in others.

The formation thickens and becomes more calcareous westward. In the section at Crowsnest MacKay (1931, p. 17) has described a thickness of 350 feet of brown to greyish-brown quartzite. Near Fernie, Telfer (1933, p.572) has ascribed to the Spray River formation a thickness of 1,700 feet of shale and dolomitic limestone that contains fossils of probable Triassic age. West of Fernie, in a road cut at the water-supply dam on Fairy Creek, interbedded fine-grained sandstone, dark shale, and limestone of Triassic? age are exposed. The shale carries fragmentary fish remains, tiny pelecypods, and faint ammonite impressions. A 2-inch limestone band with slight intercrystalline porosity carries minor amounts of pale green light oil.

JURASSIC SYSTEM

Fernie Formation

General statement: Overlying the Spray River formation, apparently conformably in some localities but separated from the underlying strata by a disconformity of regional extent, is a sequence of black to grey calcareous shales with some sandy beds; this formation is commonly referred to as the "Fernie shale."

Early workers in the Crowsnest coalfields included the grey and black Fernie shales in their descriptions of the lower part of the Kootenay coal measures. Although the term "Fernie shale" was probably first used by McEvoy in discussing the geology of the Coal Basin in 1901 the term first appeared in the literature (without adequate definition) in a report by Leach (1902) on the Blairmore-Frank coalfields. The Jurassic age of the Fernie shale was established by Whiteaves (1903) who identified the ammonite Cardioceras in a specimen collected by James McEvoy from the upper part of the formation near the town of Fernie. More recently P. S. Warren (1934) has made a comprehensive study of the Fernie formation of the Canadian Rockies. His paper "Present Status of the Fernie Shale, Alberta" gives a clear interpretation and definition of the formational name proposed by Leach.

Distribution and Lithology: Within the area shown on Fig. 1 the Fernie formation outcrops along the bottoms and sides of the master valleys which surround the Coal Basin. Although large areas are underlain by Fernie shale, outcrops are rare, and complete sections of the formation are difficult to obtain. In many of the exposures examined the Fernie was found to be cut by numerous faults and often strongly crushed.

The formation consists mainly of grey to black shale with some beds of fine-grained sandstone or hard, sandy shale. The shales are generally calcareous along the Elk River valley, but the amount of calcareous material diminishes rapidly as the formation is followed eastward. Fossils are surprisingly scaroe in the formation and where found are generally confined to sandy calcareous beds.

A useful marker within the Fernie formation is a bed of calcareous sandstone that contains numerous belemnites. This sandstone ranges in thickness from 5 to 20 feet and occurs at an interval of from 50 to 240 feet above the base of the formation. It appears to be quite persistent, having been recognized near Morrissey, in Crowsnest Pass, and near Corbin.

A section of the Fernie shale that received careful attention by F. H. McLearn (1929) is exposed in the valley between Bluff and Grassy Mountain north of the town of Blairmore, Alta. In addition to exposures along an abandoned railway-cut, recent road building has exposed parts of the section that were formerly covered by alluvium. A section measured at this locality is as shown on page 24.

Because of the possibility of faulting beneath an alluvial cover it was not feasible to estimate the thickness of the concealed basal part of the section, and thus obtain the total thickness of the formation. However, the writer would concur with the estimate made by MacKay (1931. p. 19) of a total thickness of 900 feet for the Fernie formation at this locality.

Thickness Feet	
	Overlying bed, fine to medium-grained, brown-weathering basal Kootenay sandstone.
90	Concealed.
74	Alternating thin-bedded dark grey to black shale and fine-grained rusty-weathering sandstone. The sandstone and shale carry carbonaceous plant impressions.
80	Shale, dark grey to black, thin-bedded, with occasional concretionary bands.
100	Shale, dary grey, micaceous.
44	Shale, dark grey, with three 6- to 8-inch bentonite beds.
1	Sandstone, dark grey, calcareous, fossiliferous.
234	Shale, dark grey.
21	Interbedded dark shale and dark grey, calcareous, fossiliferous sandstone.
93	Shale, dark, with a few thin sandy beds, occasional rusty-weathering concretionary bands.
737	Total exposed thickness. Base concealed.

The type section of the Fernie formation is considered to be in the vicinity of the town of Fernie, but, because of the lack of exposures and contorted nature of the beds it has not been possible to measure more than a few hundred feet of the Fernie section in the type area. The nearest complete section has been measured by Telfer (1933, unpub. rept.) at the headwaters of Weaver Creek, a tributary of Leach Creek, about 15 miles east of Fernie and 5 miles west of Corbin. The section, which has been listed by Warren (1934, p. 60) is as follows:

	Feet	
Kootenay	143	Sandstone
	72	Sandy shale
Fernie	132	Black shale
	510	Grey calcareous shale
	60	Black shale with some calcareous shale nodules at base
	160	Black shale
	7	Calcareous sandstone with Belemnites (Rock Creek member of this report)
	50	Black shale
	1 1/2	Grey bituminous limestone
	4	Phosphate bed

Underlying beds--385 feet of thin-bedded Spray River shale.

The total thickness of the Fernie as given by Telfer is 924 1/2 feet. Comparison with other areas, however, would suggest that the 72 feet of sandy shale, assigned to the Kootenay, is more probably the upper part of the Fernie, which would make the total thickness of the Fernie approximately 1,000 feet.

Within the Fernie Coal Area, as in the above section, the Fernie formation may be subdivided into a lower black shale, a middle grey shale, and an upper black shale member. The lower part consists of black, relatively soft, thin-bedded shale which grades upward into grey, sandy, calcareous shale with occasional beds of black nodular limestone. Near the top of the formation the shale is generally dark and in places carries bands of nodular ironstone. Overlying the nodular shale is a band of dark grey, silty shale that is locally fossiliferous, and this in turn passes upward into a 35-foot interbedded sandstone and shale known as the "Ribbon Sandstone" member of the Fernie. The top of the section is marked by a massive, brown-weathering, fine-grained, calcareous sandstone, called the "Upper Fernie sandstone."

Nature of the Boundaries: The base of the Fernie formation in the vicinity of the Coal Basin is marked by a phosphate bed in the form of a phosphatic sandstone or phosphatic chert conglomerate. The basal phosphatic zone, which varies from a few inches to 15 feet in thickness, has according to Telfer (1933, p. 589) the following general characteristics.

(a) An upper yellow marker (weathered cherty limestone).
(b) A nodular or oolitic calcareous phosphate bed.
(c) A shale parting.
(d) An oolitic phosphate bed.
(e) A basal marker, usually marcasite.

Fossils are not plentiful in this phosphate but the genus Gryphaea is generally present.

The basal phosphatic zone of the Fernie rests with no discordance in dip on the underlying formation. In the vicinity of the Crowsnest Coal Basin the Fernie rests on the Triassic Spray River formation, but at Moose Mountain, Beach (1943) finds that the Fernie is separated from the underlying Mississippian Rundle limestone by an erosional unconformity. Hence it is apparent that regionally a disconformity exists at the base of the Fernie. Additional evidence of this disconformity was noted by McLearn (1915) at Turtle Mountain and by Allan and Carr (1947) in the Highwood area.

The upper boundary of the Fernie shale has been described as a gradational contact by all of the early workers who have examined the Fernie-Kootenay contact. J. D. MacKenzie (1916, p. 26) in describing the upper part of the Fernie in the Flathead valley stated "there is every reason to believe from analogies with other districts that it is not only conformable but gradational into the overlying Kootenay." The contact has been reported as gradational in the Crowsnest Pass by McLearn (1915, p. 111), by MacKay (1931, p. 20), and by Warren (1933, p. 158) and at Moose Mountain, Cairnes (1914) observed that the Fernie and Kootenay shales "gradually change into one another." Recently, however, Beach (1943) found "an erosional contact between the Fernie and the overlying Kootenay" in the Moose Mountain area. In the Highwood-Elbow area Allan and Carr (1947) mention that the upper surface of the Fernie sandstone "is gently irregular" and that "the irregularity of the contact may indicate post-Fernie erosion."

In examining the Fernie-Kootenay contact at a number of exposures within the Crowsnest Coal Basin the writer found that at some localities the contact was clearly defined, whereas at others a complete gradation was evident. In the Michel area no evidence of an unconformity at the Fernie-Kootenay contact was found. The contact was generally gradational, but at one point slight undulations in the upper surface of the Fernie sandstone were observed (see Plate 2). In the Morrissey area the contact was gradational.

In the Fernie Coal Area the top of the upper Fernie sandstone was found to be locally irregular or gently undulating. In places 1 or 2 inches of direct shale separate the upper Fernie from the basal Kootenay sandstone. A section of the upper part of the Fernie formation, measured along the road on the north side of Coal Creek, is as follows:

The overlying bed is 40 feet of sandstone, medium to coarse-grained, grey, non calcareous, with a few small lenses of bright coal--the "basal Kootenay sandstone."

Conformable contact

90 Feet	Sandstone, fine-grained, dark grey to brown, calcareous, massive, rusty-weathering, cross-bedded in part, with occasional plant fragments--the "upper Fernie sandstone."
35 Feet	Sandstone, fine-grained, calcareous--alternating light and dark-coloured thin laminae, a few plant fragments--"Ribbon sandstone" member of Fernie formation.

The underlying beds are grey, sandy, calcareous, locally fossiliferous shale.

Thin sections were made from chip samples taken a few inches above and below the contact. A microscopic study of the thin sections revealed certain differences between the Kootenay and Fernie sandstones, which are tabulated as follows:

	Upper Fernie Sandstone	Basal Kootenay Sandstone
Constituents	quartz, chert, calcite	quartz, chert, quartzite
Cement	calcite	silica
Chert	light-coloured	grey to black, oolitic in part
Grain size	0.1 to 0.3 mm.	0.1 to 0.5 mm.
Grain outlines	sharp	corroded
Rounding	grains rounded	grains subangular

The development of cross-bedding and the presence of plant remains in the sandstones at the top of the Fernie indicate shallow water, near-shore deposition at the close of Fernie time. The nature of the Fernie-Kootenay contact, being sometimes clearly defined, but generally gradational, affords no evidence of significant erosion of the Fernie sediments of the Crowsnest Coal Basin prior to the deposition of the basal Kootenay sandstone.

Thickness: Because of the often contorted nature of the Fernie shales difficulty has been experienced in many areas in determining the true thickness of the formation. In the Blairmore area, Leach (1911) gives a thickness of 750 feet for the Fernie shale, whereas MacKay (1931, p. 19) has estimated the thickness to be 900 feet. In the Crowsnest-Corbin area Telfer and Warren believe the thickness to be from 800 to 900 feet, but MacKay, on the basis of graphic determinations in the Corbin area, has estimated a thickness of 2,800 feet. In the Flathead area MacKenzie (1916, p. 26) believed the Fernie formation to be 1,000 feet thick but Béthune (1936, p. 164) has described a section of 882 feet of Fernie shale that was penetrated in a bore-hole drilled near Flathead townsite. In Fernie Coal area the thickness of the Fernie formation, as obtained graphically from cross-sections of the area, is approximately 3,000 feet.

It seems, from the evidence contained in well-exposed sections, that in the area from Blairmore to the east side of the Crowsnest Coal Basin the Fernie formation maintains a rather uniform thickness of abont 900 feet. Within that area the "belemnite sandstone" or Rock Creek member maintains an average interval of 75 feet above the Gryphaea-bearing phosphate bed at the base of the formation. On the west side of the coal basin, near Morrissey, the "belemnite sandstone" occurs at an interval of 233 feet above the basal phosphate bed. This increase from 75 to 233 feet for the lower part of the Fernie shale provides a specific example of the rapid westward thickening of Fernie sediments that must have occurred to produce a thickness of 3,000 feet of beds in the Fernie area.

Age and Correlation: The oldest fauna yet reported from the Fernie formation was recovered by Telfer from the basal phosphate bed in the Fernie and Crowsnest areas. The fauna has been described by Warren (1931) who considers it to be Lower Jurassic (Sinemurian) in age. In the Blairmore area McLearn (1929) has recognized three distinctive faunas; the *Chlamys mcconnelli* fauna near the base of the formation, the *Corbula munda* fauna which ranges from 555 to 800 feet above the base, and the Green bed fauna near the top of the formation. A Callovian age has been established for the *Corbula munda* fauna but it has not been possible to date the lower or upper zones. In western Alberta a widespread and prolific fauna of Bajocian age occurs in the Rock Creek member of the Fernie formation. Along the west side of the Coal Basin, however, the Rock Creek member carries species of *Belemnites* only.

Collections made by the writer in or adjacent to the Fernie Coal Area have added little to our knowledge of the age of the strata represented. A number of the species recovered appear to be new and hence cannot be used yet for correlation, and in addition it was seldom possible to ascertain the position in the section, of the bed from which collections were obtained. The following forms which indicate

			European Stages	West Central, and North Central Montana. (Imlay)		Southeastern B. C.
JURASSIC	Upper		Portlandian	?		
		Kimmeridgian	Bononian	Morrison Formation		
			Havrian			
			Sequanian			?
		Oxfordian	Argovian	Ellis Group	Swift Formation	Fernie Formation
			Divesian			
			Callovian		Rierdon Formation	
	Middle		Bathonian		Sawtooth Formation	
			Bajocian			
	Lower		Toarcian			
			Pliensbachian			
			Sinemurian			
			Hettangian			

Fig. 4. Correlation of Jurassic formations of southeastern British Columbia and northern Montana.

only that the strata are Jurassic, have been identified at Ottawa by F. H. McLearn.

From the lower part of the Fernie formation, on the west side of the Elk River, opposite the town of Fernie:

> Spiriferina n. sp. ?
> 'Orbiculoidea' n. sp. ?
> Pecten (Chlamys) cf. mcconnelli
> Pecten sp.
> Terebratula sp.

From the lower part of the Fernie formation, east side of Elk River, along the Fernie-Morrissey road:

> 'Belemnites' n. sp. ?
> 'Terebratula' sp.
> Ostrea sp.
> Pleurotomaria? sp.

One hundred and fifty feet below the top of the Fernie formation, underlying the "Ribbon Sandstone" member, on the Coal Creek road:

> Lima? n. sp.
> Oxytoma n. sp.

The youngest fauna yet reported from the Fernie formation was an ammonite obtained on the north side of Coal Creek valley by James McEvoy in 1900. The specimen was identified by Whiteaves (1903) as Cardioceras canadense, and is middle Upper Jurassic (Argovian) in age.

Inasmuch as no evidence of an unconformity has been observed in the section examined it is probable that the Fernie formation in the type area represents the greater part of Jurassic time, including most of the Lower, all of the Middle, and part of Upper Jurassic time.

In northern Montana, Cobban (1945) has subdivided the marine Jurassic Ellis group into three lithologic units which, in order of decreasing age, have been called the Sawtooth, Rierdon, and Swift formations. Several of the Fernie faunal zones are represented in the Montana Jurassic sections. Imlay (1945) has noted the presence of the Corbula munda fauna, which characterizes the Grassy Mountain section of the Fernie near Blairmore, in the Sawtooth formation of Montana. In the Highwood-Elbow area Allan and Carr (1947, p. 23) have recognized a zone overlying the Rock Creek member that carries Arcticoceras, Proplanulites, and Cadoceras, and have made a correlation of this zone of the Fernie with the Rierdon formation of Montana, in which Arcticoceras and Cadoceras also occur. In the upper part of the Fernie on Coal Creek and in the upper Swift of Montana the genus Cardioceras has been reported, so that a correlation of part of the upper Fernie of the type area with the Swift formation of Montana may be made. A correlation chart of the Montana and southeastern British Columbia Jurassic strata is given in Fig. 4. The age relations of the Montana section are based on information given in papers by Cobban (1945) and Imlay (1947).

UPPER JURASSIC OR LOWER CRETACEOUS SERIES

Kootenay Formation

General Statement: The coal-bearing and associated sediments of the southern Canadian Rockies were first studied and described by G. M. Dawson and J. W. Dawson (1885) in an area extending from Fernie, British Columbia to Anthracite, Alberta. An apparently conformable succession of strata that included beds now referred to the Fernie, coal measures carrying a specific or "Kootenay" flora, and possibly some of the beds now referred to as the Lower Blairmore, was designated the "Kootanie series" by J. W. Dawson. Further study of the Dawsons' "Kootanie series" by McEvoy and Leach during the years 1900 and 1901 resulted in a subdivision of the Mesozoic rocks on a lithologic basis. McEvoy (1902) referred to the lower dark shales as the "Fernie shales;" the coal measures, which "included all known workable seams" as the "Crow's Nest coal beds;" and the overlying "cherty conglomerates and gritty sandstones" as the "Elk conglomerates." Several years later W. W. Leach (1911) applied the term "Kootenay Formation" in the Blairmore area to a thickness of 565 feet of dark sandstones, grey and black shales, and coal seams. Leach included with the Kootenay an uppermost 19-foot bed of conglomerate but subsequent work by Rose (1916), demonstrated that this conglomerate, the base of which is marked by unconformity, should be included with the overlying Blairmore Formation. More recent workers who have applied the term "Kootenay" to coal-bearing sediments in other parts of the Rocky Mountains have in general used it in the restricted sense as defined by Leach and Rose. Although no type section has been designated for the Kootenay formation yet the careful study that the section at Blairmore has received, particularly the study of the Kootenay flora at this locality by Berry (1929), make the Blairmore section a convenient standard of reference. In the Fernie Coal Area the term Kootenay formation is applied to a thickness of 2,060 feet of sandstone, shale, and coal seams that is considered the lithological equivalent of the Kootenay formation at Blairmore.

Distribution: The Kootenay formation has been recognized in the eastern Rocky Mountains and foothills in a linear belt approximately 350 miles long that extends from near the Forty-ninth parallel northward to the vicinity of the headwaters of the Athabaska River. In the area immediately south of the Forty-ninth parallel the Kootenay formation has not been recognized, and to the north of the Athabaska River lithological changes in beds considered equivalent to the Kootenay have occasioned the introduction of new formational names.

Within the area shown in Fig. 1 approximately 230 square miles is underlain by the Kootenay formation in the canoe-shaped fold known as the Fernie or Crowsnest Coal basin. To the east of this basin are several small synclinal or much faulted areas of Kootenay strata. In Fernie Coal Area the valley of Coal Creek has cut deeply into the western rim of the coal basin so that the eastward-dipping Kootenay strata present a V-shaped outcrop pattern. To the north and south of Coal Creek the coal measures outcrop along the sides of Elk River valley at elevations generally above 5,000 feet. However, along Coal Creek itself all of the seams are intersected at creek level so that it has been possible to initiate mining operations at or near railroad grade.

Lithology: Within the Fernie Coal Area the Kootenay formation consists of interbedded grey to black shales, fine- to coarse-grained, often rusty-weathering sandstones, several beds of conglomerate, and twelve coal seams of commercial thickness. The dark shales are often carbonaceous and generally carry plant remains that are occasionally sufficiently well-preserved for identification. The sandstones are generally siliceous, are usually composed of subangular fragments of quartz, chert, quartzite, and argillite, are quite often cross-bedded, and occasionally show the development of ripple marks. Many of the fine-grained sandstones are calcareous but calcite has not been detected in the shales, medium- to coarse-grained sandstones or conglomerates. Dark grey to black sandstones, composed of fragments of argillite or argillaceous quartzite are quite common in the succession. Six beds of pebble conglomerate were observed in the section but only three of these, which occur at intervals of 600, 1, 200, and 1, 850 feet above the base of the formation, have more than limited lateral extent.

The most persistent and useful marker bed in the formation is the 45- to 60-foot basal Kootenay sandstone that marks the lower limit of the coal measures. This dark grey sandstone, which generally forms a prominent outcrop, (see Frontispiece) consists of medium to coarse, generally subangular grains of quartz, blue-grey to black chert, quartzite, and argillite in a siliceous cement. Limonite is generally present and carbonaceous laminae or lenses of hard, bright coal are common.

The conglomerates, which occur at several horizons within the formation, consist of pebbles of both clear and milky quartz, grey to black chert, siliceous argillite, and vari-coloured, occasionally banded quartzite, in a siliceous sandy matrix. The conglomerates are characteristically cliff-forming units and are locally useful in correlation.

On the south side of Coal Creek a section of the upper 600 feet of the Kootenay was sampled in 10-foot intervals. Examination of the samples using a binocular microscope and thin-section examination of several of the sandy beds showed that the sandstones contain the same constituents that are found in the conglomerates, and in addition the fine-grained sandstones contain calcite. The sand grains are, for the most part, subangular in outline, rounding is slight and the sphericity is low. The calcite occurs as finely disseminated particles in the matrix, or as sharply outlined or somewhat rounded rhombs. Both magnetite and limonite are a common constituent of the sandstones and a little pale green hornblende occurs in some sections. Heavy mineral separations yielded a small concentrate of particles that were too small for positive identification. Feldspar grains were not observed in any of the sandstones examined.

Throughout the Kootenay formation the beds are characteristically lenticular. The interval between the Nos. 9 and 10 seams, for example, on the north side of Coal Creek amounts to 25 feet, yet 1 1/2 miles to the south this interval has increased to 175 feet. Some of the coal seams, such as the No. 10 seam, are uniform in nature and thickness over extensive areas, whereas others such as the No. 5 seam are extremely variable in thickness and in ash content.

A section of the Kootenay formation that is typical of the Fernie Coal Area was obtained on the north side of Coal Creek. The line of the section K-K' is shown on Fig. 1. It started at a prominent outcrop of conglomerate that marks the base of the overlying Elk formation on the crest of the mountain, near triangulation station, Mine "N" (A), and extended northwestward directly across the strike of the beds to the top of the Elk River escarpment at an elevation of 6,800 feet. From this point the section was carried southwestward obliquely across the strike of the beds down the crest of a ridge to the outcrop of the basal Kootenay sandstone at an elevation of 5,000 feet.

Along this route various trenches across the carbonaceous or coaly zones that were excavated by James McEvoy in 1902 were observed. For these intervals, which are now concealed, Mr. McEvoy's descriptions have been used and are indicated in the following section by placing them in brackets with quotation marks. The grade terms used are those of Wentworth's scale as given by Twenhofel (1939). The section, which is listed in descending order, is as follows:

SECTION OF THE KOOTENAY FORMATION, NORTH SIDE OF COAL CREEK

Overlying beds are pebble conglomerate of the Elk formation.

Feet above base of Kootenay	Thickness in Feet	
2,063	64	Shale, brown to black.
1,999	8	Coal, No. "B" seam, shaly in part.
1,991	46	Interbedded dark shale and very fine-grained sandstone.
1,945	26	Sandstone, fine-grained, thin-bedded.
1,919	92	Sandstone, coarse-grained.
1,827	8	Coal, No. 10 seam, some shaly bands.
1,819	23	Shale, black, carbonaceous in part.
1,796	10 1/2	Coal, No. 9 seam, shaly in part.
1,785 1/2	8 1/2	Shale, carbonaceous.
1,777	42	("Shale, brown and black, carbonaceous at top").
1,735	18	("Sandstone, hard, grey").
1,717	45	Sandstone, fine-grained, rusty-weathering.
1,672	18	("Shale, brown and black").
1,654	4 1/2	("Coal"), No. 8 seam.
1,649 1/2	24 1/2	("Shale, brown and black").
1,625	1	("Coal"), No. 7 seam.
1,624	41 1/2	("Shale, brown to black").
1,582 1/2	2 1/2	("Coal"), No. 6 seam.
1,580	14	Shale, carbonaceous.
1,566	121	Shale, brown to black, carbonaceous in part.
1,445	35	("Shale, brown and black").
1,410	11	("Coal, dirty") No. 5 seam (upper part).
1,399	5	("Shale").
1,394	18	("Coal,dirty") No. 5 seam (lower part).
1,376	30	("Shale, brown and black").
1,346	60	Sandstone, fine-grained, dark, thin-bedded (forms the crest of the ridge at top of Coal Creek Mountain).
1,286	28	Sandstone, medium to coarse-grained, with occasional lenses of granule conglomerate.

Feet above base of Kootenay	Thickness in Feet	
1, 258	18	Shale, black, carbonaceous, coaly in part. Numerous plant fragments.
1, 240	25	Sandstone, fine-grained, shaly at top.
1, 215	40	Sandstone, coarse-grained, with lenses of granule conglomerate.
1, 175	3	Sandstone, fine- to medium-grained.
1, 172	3	Shale, black, sandy in part.
1, 169	12	Sandstone, fine-grained, dark, thin-bedded.
1, 157	17	Sandstone, very coarse-grained, with lenses of granule conglomerate (persistent cliff-forming bed).
1, 140	20	Sandstone, coarse-grained grey.
1, 120	61	Sandstone, fine-grained, dark, thin-bedded.
1, 059	7	("Shale").
1, 052	7 1/2	("Coal, upper 4 1/2 feet good").
1, 044 1/2	60	("Shale, brown and black").
984 1/2	12 1/2	("Coal") No. 4 seam.
972	18	("Sandstone, shaly at top").
954	5	Sandstone, fine-grained, thin-bedded.
949	8	Sandstone, fine-grained, shaly in part.
941	31 1/2	Shale, black, carbonaceous in part, occasional thin streaks of coal.
909 1/2	4 1/2	("Coal"), No. 3 seam (thickness variable, up to 20 feet in places).
905	8	Shale, black, sandy in part.
897	17	Sandstone, very fine-grained, dark.
880	19	Interbedded dark, sandy shale and fine-grained, thin-bedded sandstone, with rusty-weathering ironstone concretions.
861	20	Sandstone, coarse-grained.
841	27	("Sandstone, hard, grey").
814	15	("Shale, brown and black").
799	65	("Sandstone, grey hard").
734	48 1/2	("Shale").
685 1/2	4 1/2	Coal (upper part of No. 2 seam) hard, bright, clean.

Feet above base of Kootenay	Thickness in Feet	
681	6	Shale, carbonaceous.
675	25	Coal, No. 2 seam, a few shaly bands near base.
650	3	Shale, black, carbonaceous in part.
647	17	Interbedded fine-grained sandstone and dark, sandy shale, a few rusty-weathering ironstone concretions.
630	20	Sandstone, fine-grained, thin-bedded.
610	21	Sandstone, coarse-grained, with lenses of granule conglomerate.
589	2	Pebble conglomerate.
587	2	Shale, black, sandy.
585	25	Sandstone, coarse-grained, grading into granule, conglomerate in part.
560	15	Sandstone, very fine-grained, dark, shaly.
545	20	Sandstone, fine-grained, dark, shaly in part.
525	27	Sandstone, medium-grained.
498	8	("Shale, brown and black").
490	3 1/2	("Coal").
486 1/2	86 1/2	("Shale, brown and black").
400	20	Coal, No. 1 seam, top 10 feet fairly clean, remainder somewhat shaly.
380	34	("Shale, brown and black").
346	24	("Sandstone, hard and grey").
322	5	Sandstone, coarse-grained, dark-coloured.
317	20	Pebble conglomerate (coarse sandstone matrix) with some coarse-grained sandstone lenses. The conglomerate rests on an irregularly eroded surface of the dark shale that represents an erosional unconformity.
297	67	("Shale, brown and black").
230	10	Coal, shaly in part. No.0 seam (old No. 11 mine).

Feet above base of Kootenay	Thickness in Feet	
220	25	Shale, black, sandy in part.
195	5	Coal and carbonaceous shale, thinly-banded.
190	15	Shale, carbonaceous.
175	25	Shale, black.
150	50	Sandstone, medium-grained, hard with carbonaceous laminae (cliff-forming).
100	48	Shale, black, carbonaceous at base, sandy at top.
52	12	COAL, fairly clean. No.-1 seam (Minus One).
40	40	Sandstone, medium- to coarse-grained, grey non-calcareous. It is composed of sub-angular grains of grey to white quartzite, grey to black chert, and quartz, with a little magnetite, cemented by chalcedonic quartz. Some limonite occurs along fractured surfaces. Fragments of coal or carbonaceous material and irregular carbonized wood impressions are prevalent. A generally coarse salt and pepper sandstone--the "Basal Kootenay."

The underlying beds are dark grey, fine-grained, calcareous Fernie sandstone.

Nature of the Boundaries: The gradational to locally well-defined contact at the base of the Kootenay formation within the Fernie Coal Area has already been mentioned in the section describing the Fernie formation. The upper part of the Kootenay formation grades into the overlying conglomeratic Elk formation. The upper boundary of the Kootenay has been arbitrarily placed at the base of a course conglomerate which overlies number "B" coal seam, so that all the known commercial coal seams are contained within the formation. The conglomerate which marks the base of the Elk formation appears to be generally conformable with the underlying Kootenay beds, but locally (as is shown in Plate 3) this conglomerate truncates the bedding planes of the uppermost Kootenay sandstones.

Thickness: Within the area shown in Fig. 1 significant variations in the thickness of the Kootenay formation occur. The most westerly exposures, which are located along the Elk River escarpment, show a rather uniform total thickness, that varies from approximately 2, 050 feet at Fernie to 2, 250 feet at Morrissey and Hosmer. The thickest Kootenay section occurs near the northern end of the coalfield near Michel where MacKay (1933, p. 6) measured a total of 3, 600 feet of coal measures. The increase in thickness from 2, 000 feet in the Fernie area to 3, 600 feet in the Michel area is paralleled by an increase in the number of commercial coal seams from twelve to twenty-two. Southeastward from Michel the Kootenay thins rapidly, for near Corbin (at Mount Taylor) MacKay (1930) measured a thickness of 1, 850 feet of strata which contained only two coal seams of commercial thickness. Still farther to the southeast at Flathead townsite Béthune (1936, p. 164) reports a thickness of 1, 600 feet of Kootenay beds that contain a little coal.

Variations in the thickness of the Kootenay formation along the west side of the Crowsnest Coal Basin, which are portrayed graphically in Fig. 6, are interpreted as being directly related to the total thickness of the overlying conglomeratic Elk formation. At Fernie, for example, the thinnest Kootenay section is overlain by the thickest section of the Elk formation, whereas at Michel the situation is reversed.

Elk Formation

Name: James McEvoy in mapping the sediments of the Crowsnest Coal Basin during the years 1900 and 1901 applied the term "Elk conglomerates" to a sequence of cherty conglomerates, gritty sandstones, and grey to black shales that overlie the coal measures. In a report on the Michel Area, B. R. MacKay (1933, p.5) suggested that the term

"Blairmore formation" be substituted for McEvoy's "Elk conglomerates." With this suggestion the writer cannot agree, as carbonaceous sediments carrying a Kootenay flora have been recovered from several horizons within beds mapped by McEvoy as the "Elk conglomerates." The term "Elk formation" is therefore proposed for a thickness of approximately 1, 700 feet of dark shales, sandstones, and hard cliff-forming conglomerates, which overlies the Kootenay coal measures in the Fernie area.

Distribution and Thickness: Because of its resistence to erosion the Elk formation crops out in a series of prominent ridges, with generally steep westward slopes, that mark the height of land along the western side of the Coal Basin. It has been possible to trace the formation in continuous exposures from Morrissey to Sparwood. In the few traverses made along the eastern margin of the Coal Basin it was not found possible to determine the thickness or extent of the formation because of the prevailing forest cover. Along the west side of the coalfield the formation generally crops out at elevations above 5, 500 feet and extends upward to elevations of over 7, 000 feet.

The thickness of the Elk formation reaches a maximum of 1, 704 feet at Coal Creek. At Morrissey the formation has a thickness of 1, 310 feet and at Hosmer the thickness is estimated to be approximately 1, 400 feet. The formation thins rapidly to the northeast of Hosmer, for near Michel its thickness has diminished to approximately 100 feet.

Lithology: The Elk formation consists of interbedded fine to coarse conglomerates, grey to almost black sandstones, grey to black carbonaceous shales, with near the base a few thin seams of high-ash coal some of which resembles cannel coal. At several horizons fine-grained sandstone beds from 1 to 6 feet thick carry spherical pea-sized pyritic sandstone nodules. A few of the carbonaceous layers are "needle coal," a tightly packed mass of carbonized conifer needles in a carbonaceous silty matrix. The coal seams that were found were generally lenticular, often pinching out completely when traced a few hundred feet along their outcrop. The bands of "needle coal" and the nodule-bearing sandstones are characteristic of the Elk formation.

A section, typical of the Elk formation in the Fernie area, was measured on the north side of Coal Creek directly opposite the Elk River preparation plant. The succession is as follows:

SECTION OF THE ELK FORMATION
AT COAL CREEK

Overlying beds are pebble conglomerate at the base of the Blairmore formation.

Feet above base of Elk	Thickness in Feet	
1,704	18	Partly concealed, a few exposures of fine-grained quartzose sandstone. Top of Elk formation.
1,686	35	Concealed (Talus suggests fine-grained sandstone with pyritic sandstone nodules near the base).
1,651	5	Pebble conglomerate.
1,646	40	Sandstone, fine-grained, light-coloured.
1,606	11	Pebble conglomerate.
1,595	50	Concealed interval. Talus suggests interval is mostly fine-grained sandstone.
1,545	6	Shale, dark grey to black, silty to sandy.
1,539	30	Sandstone, fine-grained, dark, thin-bedded (cross-bedded in part).
1,509	15	Sandstone, fine-grained, dark, shaly in part, with a few inches of "needle" coal.
1,494	24	Pebble conglomerate, rusty-weathering.
1,470	20	Sandstone, fine-grained, dark-coloured.

Feet above base of Elk	Thickness in Feet	
1,450	24	Pebble conglomerate.
1,426	15	Concealed, talus in sandy shale.
1,411	35	Sandstone, fine-grained, grading into carbonaceous shale and a few inches of "needle" coal at top.
1,376	15	Sandstone, fine-grained, dark-coloured, rusty-weathering.
1,361	16	Cobble conglomerate (very coarse sandstone matrix).
1,345	8	Interbedded fine- to medium-grained sandstone and granule conglomerate.
1,337	40	Partly concealed interval. Fine-grained light-coloured sandstone at base grading upward into dark silty shale.
1,297	18	Interbedded very coarse-grained sandstone and granule conglomerate.
1,279	16	Pebble to cobble conglomerate (cobbles up to 5 inches in diameter).
1,263	5	Shale, black, carbonaceous, numerous plant remains.
1,258	17	Partly concealed. Short exposed sections are fine-grained sandstone.
1,241	52	Concealed. Talus is fine-grained sandstone and sandy shale.
1,189	15	Sandstone, medium-grained.
1,174	3	Pebble conglomerate.
1,171	1 1/2	Sandstone, fine-grained, light-coloured, with pyritic sandstone nodules (one-quarter-of-an-inch in diameter).
1,169 1/2	3 1/2	Pebble conglomerate.
1,166	3	Sandstone, coarse-grained.
1,163	7	Pebble conglomerate, rusty-red-weathering.
1,156	80	Sandstone, fine- to medium-grained, rusty-weathering.

Feet above base of Elk	Thickness in Feet	
1,076	447	Concealed.
629	45	Sandstone, fine- to medium-grained.
584	20	Sandstone, fine- to medium-grained, dark coloured, rusty-weathering.
564	50	Partly concealed interval--short sections of carbonaceous shale and fine-grained sandstone.
514	13	Sandstone, medium-grained.
501	37	Pebble conglomerate with a few fine-grained sandstone bands.
464	3	Shale, black, carbonaceous, a few plant fragments.
461	2	Sandstone, fine-grained, shaly, rusty-weathering.
459	8	Shale, black, carbonaceous, a few plant fragments. (The shale is cut by a 2-inch vertical sandstone dyke that originated in the underlying sandstone).
451	62	Sandstone, medium- to coarse-grained.
389	34 1/2	Sandstone, medium- to coarse-grained, light-coloured, with several 2-foot bands of pebble conglomerate.
354 $\frac{1}{2}$	1/2	Coal.
354	45	Sandstone, medium- to coarse-grained.
309	17	Pebble conglomerate.
292	30	Interbedded granule conglomerate and medium- to coarse-grained sandstone.
262	16	Pebble conglomerate.
246	1	Sandstone, fine-grained with spherical pyritic sandstone nodules averaging one-eighth-of-an-inch in diameter, and a few ironstone concretions.

Feet above base of Elk	Thickness in Feet	
245	1 1/2	Coal, slightly shaly.
243 1/2	3	Sandstone, very fine-grained, shaly.
240 1/2	2 1/2	Coal, shaly.
238	51	Concealed.
187	2	Irregularly bedded pebble conglomerate and coarse-grained sandstone.
185	3	Shale, dark, sandy.
182	6	Sandstone, fine-grained, with numerous ferruginous nodules (Nodules are spherical, average three-sixteenths-of-an-inch in diameter, and are composed of fine-grained sandstone carrying considerable pyrite and hematite.)
176	30	Sandstone, fine-grained, thin-bedded.
146	13	Partly concealed interval--consists of black shale, carbonaceous shale, and occasional 1- to 2-foot coaly sections, occasional plant fragments.
133	2	Sandstone, black, shaly.
131	5	Sandstone, fine-grained, concretionary, rusty-weathering.
126	14	Shale, dark, sandy in part, carbonaceous in part.
112	15	Sandstone, fine-grained, thin-bedded.
97	37	Interbedded and irregularly cross-bedded pebble conglomerate and coarse-grained sandstone (cross-bedding makes angles up to 20 degrees with the normal bedding planes).
60	42	Sandstone, fine- to medium-grained, cross-bedded in part.
18	18	Pebble conglomerate, with occasional cobbles as much as 5 inches in diameter. Base of "Elk formation."

The underlying beds are brown shale at top of Kootenay formation.

Age and Correlation of the Kootenay and Elk Formations: Plant remains were collected from shaly bands of coal seams or from carbonaceous layers in both the Kootenay and Elk formations. The collection was submitted to Dr. W. A. Bell at Ottawa for identification. A list of the species determined and the horizons from which the flora were obtained is given in the accompanying chart (see Fig. 5).

Commenting on the flora from the "Kootenay" and Elk formations at Coal Creek, Bell stated "So far as I can judge there is nothing in the collection to indicate an age younger or older than that of the Kootenay formation. However, the species present in the Kootenay almost all range upward into the Blairmore or equivalent formations so that an age equivalent to the Kootenay for most of the lots is based largely on the absence of any species diagnostic of a younger age."

In a recent paper Bell (1946) assigns a Lower Cretaceous age to the Kootenay formation. He correlates the Blairmore flora with a flora in the Kome beds of Greenland and on this basis states "The close affinity of these two floras strongly suggests a Barremian or late Neocomian age for the plant-bearing part of the Kootenay formation in its type area."

In a paper, discussing the Jurassic-Cretaceous boundary in Montana and Alberta, Lammers (1939) correlates the Blairmore conglomerate with the Cloverly conglomerate, which he considers marks the base of the Lower Cretaceous. In his correlation chart Lammers assigns an Upper Jurassic age to the Kootenay formation of the Alberta foothills, which he considers equivalent to the Morrison shales plus the Kootenay coal measures. More recently R. W. Brown (1946) has compared palaeobotanical evidence from Montana and Alberta and has suggested that the Canadian Kootenay is Upper Jurassic in age. Additional evidence, which may be interpreted as suggesting a Jurassic age for the Kootenay formation, is to be found in the Hazelton and Smithers areas where Armstrong (1944) collected fossil shells of late Upper Jurassic age that "apparently lie stratigraphically above beds containing fossil plants of Kootenay age."

Plate 2. Fernie-Kootenay contact near Natal.

Plate 3. Base of Elk formation, south side of Coal Creek.

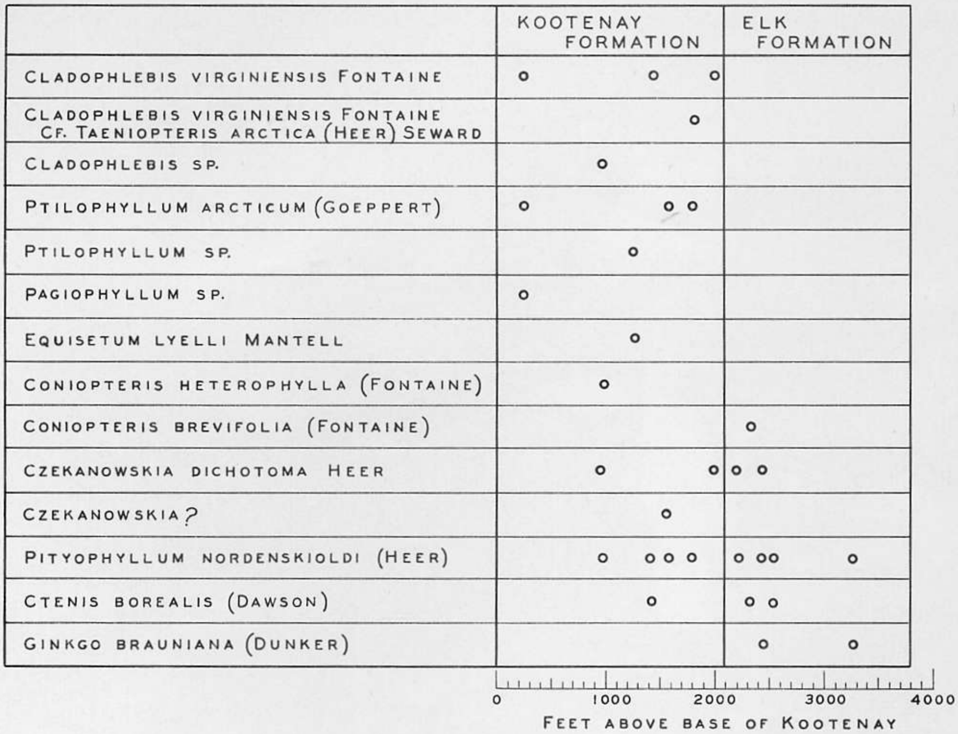

Fig. 5.

Collecting horizons of species identified in Kootenay and Elk Formations at Coal Creek by W. A. Bell.

Plate 4. Ammonite cast on a tributary of Coal Creek.

Within the Crowsnest Coal Basin evidence bearing on the age of the Kootenay formation was obtained by the discovery of a partly filled cast of an ammonite within the Kootenay sequence. The fossil locality, lies approximately 2,800 feet southwest of old No. 11 mine, and is indicated on the geological map of the Fernie area (in pocket). The cast is exposed on the west bank of a north-flowing tributary of Coal Creek and has a maximum diameter of 5 1/2 feet. and, as may be seen in the photograph (Plate 4) has suffered from erosion. The specimen is located in the section at the top of the Basal Kootenay sandstone and directly below the lowest coal seam of the Kootenay sediments.

Because of the difficulty of removing such a large cast from the bedrock for shipment to Ottawa arrangements were kindly made by Dr. W. A. Bell for a geological survey party headed by R. Douglas to visit the locality during the summer of 1949. Photographs and collections obtained during this visit were examined by Dr. J. A. Jeletzky who reports as follows:

> The photographs and few pieces of ammonoid in question are only enough to state that it seems to belong to a very large perisphinctoid (Member of the family Perisphinctidae) ammonoid, probably belonging to one of such very large late Upper Jurassis genera as _Titanites_ Buckman 1921, _Behemoth_ Buckman 1922, _Gigantites_ Buckman, _Briareites_ Buckman, etc. Any exact generic, not to speak about specific, determination is however precluded by the poor state of preservation of the specimen.
>
> As all very large genera of the family Perisphinctidae, at the present state of our knowledge, appear to be restricted to Upper Jurassic and mainly to its uppermost horizons (Kimmeridgian and Portlandian stages of European standard) it seems probable that also in this case the beds containing the specimen referred to above, would rather be of that age than of early Lower Cretaceous, where no such large perisphinctoid ammonoids are yet known to exist. However, the evidence available is not conclusive enough and the late Upper Jurassic age of the Lower Kootenay sandstone is not here considered to be established definitely by the above find.

In view of the inconclusive nature of the evidence obtained in the Crowsnest Coal Basin and because of the divergent opinions expressed regarding the age of strata that carry a Kootenay flora, the writer has included the Kootenay and Elk formations under the heading "Upper Jurassic or Lower Cretaceous Series."

Correlation of the described sections of the Kootenay and Elk formations of the Coal Creek Area with other parts of the Coal Basin has been made in the correlation chart (see Fig. 6). The 2,000 to 3,600 feet of coal measures shown in Fig. 6 are considered the lithological equivalent of the Kootenay formation of the Blairmore area. The Elk formation thins rapidly to the east and is not known to be represented in the section at Blairmore.

LOWER CRETACEOUS SERIES

Blairmore Formation

Name: The term "Blairmore formation" was first used by Leach (1911) in his mapping of the Blairmore area, Alberta. This formational name was applied in the Crowsnest Coal Basin by MacKay (1931) to a thickness of over 6,000 feet of sediments which included in its lower part strata herein referred to as the Elk formation. In the Fernie Coal Area the Blairmore formation includes all of the indurated conglomerates, sandstones, and shales overlying the Elk formation.

Distribution and Thickness: The Blairmore formation is for the most part confined to the central or upland part of the Crowsnest Coal Basin, outcrops generally occurring above an elevation of 6,000 feet. Outcrops at low elevations are encountered in several of the large transverse valleys, on the south fork of Michel Creek, and in the eastern part of the Michel area. The formation underlies the high-timbered ridges in the eastern part of the Fernie Coal Area.

Only part of the Blairmore formation has resisted erosion in the Fernie area, where its thickness seldom exceeds 1,500 feet. In the eastern part of the Michel area, however, the Blairmore attains a thickness, according to MacKay (1933), of 6,500 feet.

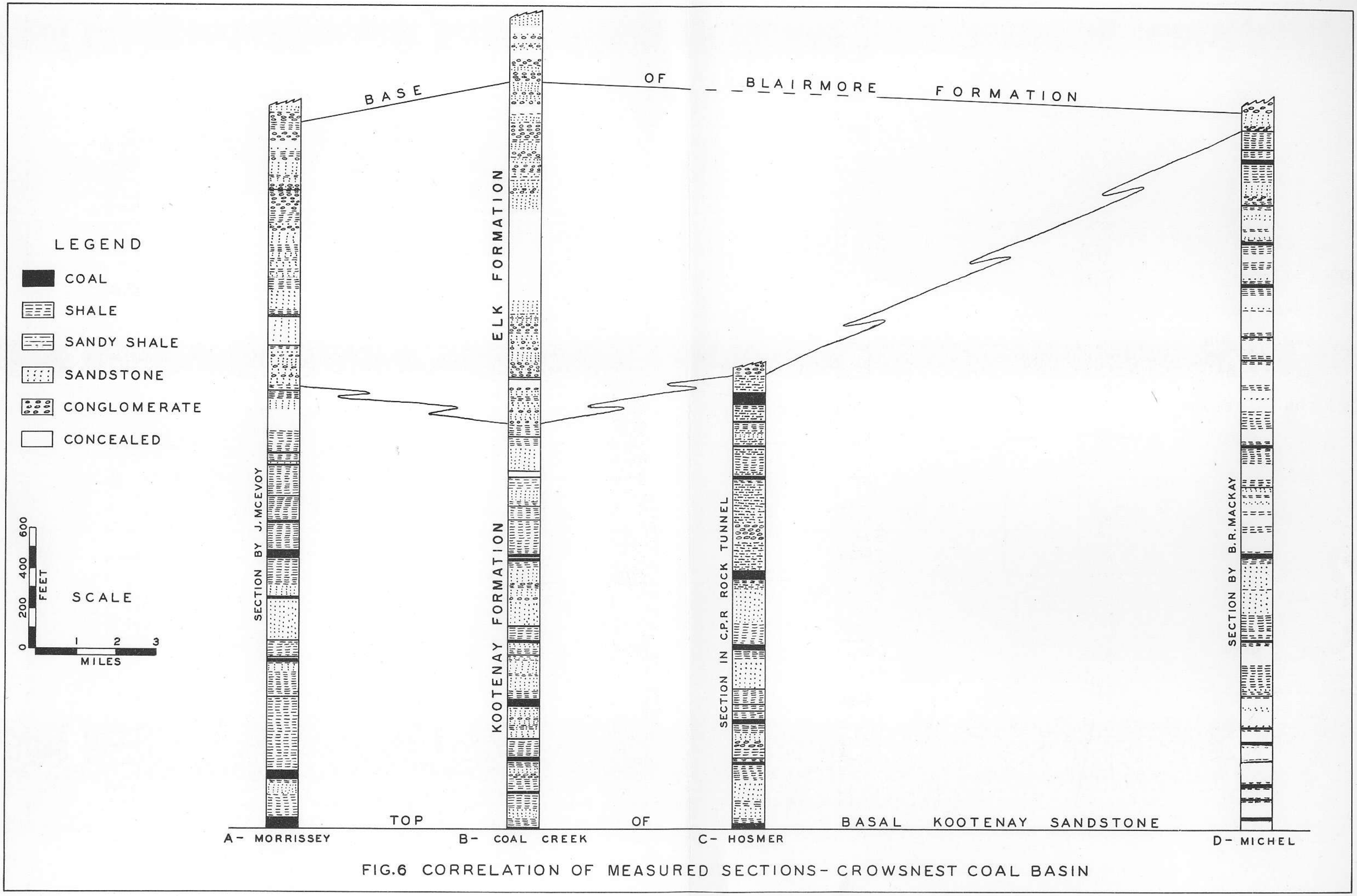

FIG.6 CORRELATION OF MEASURED SECTIONS- CROWSNEST COAL BASIN

Lithology: The writer has examined in detail only the lower part of the Blairmore formation. That part of the formation is well exposed on the north side of Coal Creek where it consists of interbedded conglomerates, light-coloured quartz-rich sandstones, and vari-coloured shales (green, maroon, yellow, and grey). The vari-coloured shales, typical of the Blairmore in its type area, provide a ready method of distinguishing this formation from the underlying Kootenay and Elk formations.

In the Fernie area the base of the formation is marked by a 45-foot bed of pebble conglomerate, consisting of well-rounded pebbles of grey and black chert, brown to white quartzite with a few greyish-green quartzite pebbles. The pebbles generally range from one-eighth-of-an-inch to 1 1/2 inches in diameter, the most common size being one-half inch. Several of the Elk conglomerates resemble the basal Blairmore conglomerate but they can usually be distinguished by having a much greater range in size than that mentioned above. Hand specimens obtained from the Blairmore conglomerate at an exposure near the Adanac mine south of Blairmore were compared with the "Blairmore" conglomerate from the Fernie area and found to be quite similar; the Fernie specimens however contained a somewhat higher percentage of dark constituents in both pebbles and matrix. In polished sections of the Blairmore conglomerate it was observed that a number of the pebbles are impressed and in some cases microstylolites have formed at the pebble contacts. These features have also been observed in conglomerates of the Elk formation and appear to be the result of differential stress and of solution (Stockdale 1922).

A section of the lower part of the Blairmore formation, measured on the north side of Coal Creek opposite the preparation plant, is as follows:

Feet above base of formation	Thickness in Feet	
605	8	Pebble conglomerate. Top of exposed section.
597	12	Sandstone, fine-grained, cross-bedded with pyritic sandstone nodules.
585	42	Sandstone, fine-grained.
543	96	Shale, pale green (purple-weathering) sandy in part.
447	2	Sandstone, fine-grained.
445	14	Sandstone, medium-grained, salt and pepper, cross-bedded.
431	39	Concealed. Talus is fine-grained sandstone.
392	14	Sandstone, medium-grained, salt and pepper, cross-bedded in part.
378	81	Sandstone, fine-grained, light-coloured, shaly in part with occasional rusty-weathering concretions.
297	20	Sandstone, fine-grained, light-coloured.
277	32	Concealed. Talus is fine-grained sandstone.
245	5	Sandstone, medium-grained, with lenses of granule conglomerate.
240	3	Cobble conglomerate.
237	9	Sandstone, fine-grained, light-coloured.
228	10	Pebble conglomerate.
218	22	Concealed, talus is fine-grained sandstone.
196	15	Sandstone, very fine-grained, light-coloured.
181	14	Granule conglomerate.
167	2	Sandstone, medium- to coarse-grained.
165	8	Sandstone, fine-grained, light-coloured with numerous soft, silty nodules which weather to produce a boxwork structure.
157	43	Concealed. A few feet of reddish shale observed in the talus.
114	30	Pebble conglomerate (cliff-forming).

Feet above base of formation	Thickness in Feet	
84	40	Concealed. Talus is mostly fine-grained sandstone with a few feet of maroon and yellow shale near the top (typical Blairmore colours).
44	44	Pebble conglomerate (cliff-forming). Base of Blairmore Formation.

Age and Correlation: No diagnostic fossils were found in the Blairmore formation of the Crowsnest Coal Basin. The formation has been assigned to the Lower Cretaceous on the basis of similarity in lithology and stratigraphic position with the Blairmore formation at its type locality in Crowsnest Pass, where its age has been established by palaeobotanical studies (Berry, 1929).

QUATERNARY SYSTEM

Pleistocene and Recent Deposits

Glacial deposits are relatively rare in the Crowsnest Coal Basin. On the northeast side of Michel Creek at the town of Michel varying thicknesses of boulder clay, some of which has been partly reworked to form a rudely stratified deposit, are exposed in road-cuts. At Fernie a 45-foot stratum of calcareous glacial-lake clay is exposed in the river bottom and on both banks at the south end of the town.

Post-Glacial gravels and sands commonly mantle the bedrock at lower levels along the principal rivers and streams in the area. Along the Elk River valley bench or terrace, gravels extend in places up the valley walls to an elevation of 4,500 feet. Deltaic deposits, often as much as 100 feet thick are common at the mouths of tributaries of the Elk River. These deltaic gravel deposits generally are low in clay and hence may be suitable for construction purposes. Along the west side of the Elk River where the gravel deposits lie close to the Palaeozoic limestone, percolating waters have precipitated calcium carbonate as a cementing agent, thus creating extensive beds of Recent conglomerate. Pebble counts of gravels along the Elk valley revealed that the constituents are entirely of local origin. Along the west side of the Elk River near some of the springs local deposits of calcareous tufa are accumulating.

CHAPTER IV -- STRUCTURAL GEOLOGY

INTRODUCTION

If a longitudinal section of the Rocky Mountains be drawn from the International Boundary northward through the Fernie, Upper Elk, and Canmore coal areas the structure appears as a series of broad undulations. Using the terminology of Bailey (1935) the high parts of these "pitch undulations" may be referred to as "pitch culminations" and the low sections as "pitch depressions." The axes of the pitch undulations trend east-northeastward, roughly at right angles to the trend of the Rocky Mountains. It is of interest to note that the major easterly flowing streams of the southern Rockies, the Oldman, Highwood, and Bow Rivers, follow a course coinciding with the projected trend of the pitch depressions.

Although the origin of the pitch undulations may be difficult to establish, their presence is of economic significance, for it is in the structurally low regions that extensive areas of the coal measures have been preserved from the effects of erosion. In the most southerly pitch depression of the Canadian Rockies about 230 square miles of the Kootenay formation have been preservied in the region now referred to as the Fernie or Crowsnest Coal Basin.

REGIONAL STRUCTURE

An attempt to portray the regional structure in the vicinity of the Crowsnest Coal Basin has been made in the plan (see Fig. 3) and the accompanying cross-section X-Y (see Fig. 7). On the plan the major fold axes and the principal faults have been shown. Where possible the plunge of the folds and the attitude and nature of movement of the faults is given.

The predominant structural trend of the region varies from north-northwest in the southern part of the map sheet to north in the area north of Fernie, with the change in strike taking place close to a line joining the towns of Fernie and Corbin. The majority of the fold axes vary from vertical to west dipping.

Most of the faults dip to the west and show relative upward movement on their west sides. Near Michel Head and west of Fernie, anticlinal folds are overturned to the east indicating that the present structures have resulted from tectonic forces that were directed towards the east or northeast.

The relative competence of the lithological units appears to have exerted a controlling influence on the nature of the structures that have developed. Broad open folds occur in the competent rocks, notably where the hard conglomerates of the Elk and Blairmore formations attain their maximum thickness, and in Precambrian quartzites and argillites that occupy the southwestern and southeastern corners of the area mapped; in these rocks faults are widely spaced and are of appreciable displacement. In contrast, the soft Exshaw and Fernie shales are invariably highly contorted and cut by numerous small faults.

STRUCTURE OF THE AREA WEST OF ELK RIVER

The structure shown in the western part of section X-Y is based on observations made by the writer along highway No. 3 between Morrissey and Elko and in traverses up several of the tributaries of the Elk River. Fault "a," near the western edge of the section, is exposed at the road bridge in Phillipps Canyon south of Elk. There the fault is marked by a zone over 200 feet wide of crushed Precambrian sediments in a clayey matrix. The fault zone strikes north 10 degrees west and dips 70 degrees to the west. From the attitudes of the beds on each side of the fault zone it appeared that the west side was downthrown, but it was not possible to establish the amount of displacement. A prominent fault-line scarp, which defines the east wall of the Rocky Mountain trench from Phillipps Canyon to the Boundary, marks the southern extension of the fault. At the Forty-ninth parallel the stratigraphic throw on the fault, as shown on Daly's (1912) cross-section, is several thousand feet. Northward from Phillipps Canyon the fault zone is concealed beneath alluvium, its position in the plane of the section being established by a strike projection.

Eastward from Elko to the Silver Springs Lakes the structure in the Precambrian is a broad northerly plunging syncline, the axis of which trends northwest. Fault "b," which has juxtaposed Precambrian and Palaeozoic sediments, strikes due north and dips west at 45 to 50 degrees. The stratigraphic throw on the fault is estimated to be 5,000 feet. Just east of the fault the Palaeozoic rocks are upturned to a vertical attitude and are cut by numerous closely spaced faults. Between this crumpled zone and the Elk River the structure is a broad anticline which plunges to the north at approximately 8 degrees. As a result of this northerly plunge Precambrian beds are exposed along the axis of the structure on Lodgepole Creek near the mouth of Wigwam Creek. Here the east limb of the anticline is cut by a high-angle west-dipping thrust. Northward from the plane of the section the dips on the east limb of the anticline become steeper until west of Fernie the east limb is overturned towards the east and the beds dip 45 to 60 degrees westward.

The structure of the area just west of the Elk River and north from Fernie has been shown in a series of cross-sections prepared by L. Telfer (1933). In general this area consists of a series of westerly dipping fault blocks that contain overturned anticlines. Relative upward movement of the beds on the west side of each of the series of northerly trending high-angle fault zones results in successively older beds being exposed as a section is followed westward.

STRUCTURE OF THE CROWSNEST COAL BASIN

The broad open fold shown on section X-Y between the Elk River and fault "c" is typical of the known regional structure of the Coal Basin. Although the general shape of the Coal Basin has been established by the reconnaissance mapping of McEvoy and others, structural details of the central part of the Basin are not fully known, partly because of its inaccessibility and heavy forest cover, and partly because the area lacks economic interest. In view of the structural complications that have been discovered in the Fernie and Michel areas where detailed work has been done it may be that the structure of the Basin, as shown in the plan and cross-section, represents an over-simplification.

In the southern and wider portion of the Basin the main synclinal axis is estimated, from observations of subsidiary folds in the Morrissey area, to plunge northward at approximately 7 degrees. At the north and narrow end of the Coal Basin, structure contours on coal seams that have been mined show a southerly plunge of the structures averaging 11 degrees. Along the sides of the Basin the beds generally dip inwards at angles varying from 20 to 45 degrees. In the Michel area the synclinal structure is cut by a series of north-trending, west-dipping, high-angle faults. These faults, shown on cross-sections prepared by B. R. McKay (1933), dip westward at angles of 60 to 70 degrees, and generally show relatively small upward movement on their west sides, but evidence of normal displacement has been observed on several of the faults. The only high-angle thrust-fault shown on the plan (see Fig. 3) is one on which several hundred feet of displacement occurred. This fault, generally referred to as the "MacKay fault," marks the eastern edge of mining operations on the south side of Michel Creek.

For much of its length the eastern edge of the Crowsnest Coal Basin is marked by a northerly trending fault zone, that may be referred to as the "Erickson fault." For part of its length this fault follows the valley of Erickson Creek (see Fig. 3) and separates vertically dipping palaeozoics from strongly folded Kootenay beds. At no point is the fault exposed although its position may be estimated to within a few feet in exposures along Michel Creek southeast of the mouth of Erickson Creek. The fault can be traced southward along the east side of Michel Creek to where it dies out in an anticlinal fold just south of the plane of the cross-section. Although the dip could not be established, observations of the surface trace of the fault and of drag relationships suggest that the fault is an east-dipping underthrust, as shown at "c" on section X-Y, Fig. 7.

A thrust fault that may be termed the "Marten Creek fault" is exposed on Marten Creek west of the northerly flowing part of Michel Creek (see Fig. 3). The fault strikes due north and dips west at 35 degrees, the dip decreases downward so that it appears as if the fault merges with the bedding at depth. Displacement on this fault is such that only the upper few hundred feet of the Kootenay formation are exposed in the Marten Creek area. Between the Erickson and Marten Creek faults the sediments, which form a depressed wedge, are very tightly folded.

STRUCTURE OF THE AREA EAST OF THE COAL BASIN

The structure shown on section X-Y, Fig. 7, between fault "c" and Corbin is based on traverses made in the vicinity of Michel Head. Fault "d" and the tight overturned anticline above it are well exposed in a northwesterly trending valley that separates the coal measures at Michel Head from the Palaeozoic rocks to the southwest. The fault strikes north-northwest and dips to the west at approximately 45 degrees. The syncline between faults "c" and "d" represents the southward extension of the north-trending Mount Taylor syncline. Between Michel Head and Corbin outcrops within the Fernie shale are infrequent so that the structure may well be more complex than that shown. East of Corbin the structure shown on section X-Y is taken from a cross-section made by B. R. MacKay (1932). The high-angle thrust, "e," is shown by MacKay to trend north-northwest and dips to the west at 80 degrees. The underthrust fault, "f," strikes almost due north and dips east at 80 degrees. East of Corbin the westward dip of the Lewis thrust is shown at 6 degrees in accordance with the results obtained by MacKay in the Crowsnest Pass area. West of Corbin the increased dip on the Lewis overthrust is inferred by projecting to the plane of the section the 25-degree dip of the Lewis obtained by Béthune at North Kootenay Pass.

The synclinal axis extending northward from Tent Mountain and along Alexander Creek is based on observed dips on Tent Mountain, in Crowsnest Pass, and along Alexander Creek. Cutting through the crest of Tent Mountain is a high-angle west-dipping thrust that can be traced northward as far as Glacier Creek but it is concealed beyond that point. On Tent Mountain this fault strikes nearly due north and dips west at 70 degrees.

The structure shown in the Flathead area is based on mapping done by Béthune (1936). The writer spent several days traversing in the vicinity of Flathead townsite and was able to check the location of the faults shown on the plan. However, because of the thick forest cover in the area and the scarcity of outcrops, it was not possible to confirm the dips of many of the faults or the relations of the faults to one another. The eastward dip of the Flathead fault seems reasonable because in its extension into northern Montana Clapp (1932) finds the fault to be east-dipping. The time relationships of the several faults of the Flathead townsite area suggested by Béthune's cross-sections are as follows:

1. The east-dipping and north-trending Flathead fault formed early in the structural history of the area and has been folded by later movements.

2. The north- to northwest-dipping and northeast-trending Pitons fault, which separates the Palaeozoic rocks from the Mesozoic just north of Flathead townsite, truncates the Flathead fault.

3. The south-dipping and east-trending Townsite fault, on which the Palaeozoic sediments have overridden the Mesozoic sequence just south of Flathead townsite, cuts both of the abovementioned faults and is shown as being only slightly folded.

STRUCTURE OF THE FERNIE COAL AREA

The structure of the Fernie Coal Area has been shown on the geological map of the area (see Fig. 1, in pocket) and by the two cross-sections A-B and C-D (see Fig. 2, in pocket). The structure of a small area that was studied in detail on Castle Mountain ridge is illustrated by the cross-section A-B (see Fig. 2). In the eastern part of the map-area, where extensive mining operations provide adequate contrcl, the structure has been shown in plan (see Fig. 1) by structure contours (in red) drawn on the top of the No. 10 coal seam.

The area mapped is on the west limb of the Crowsnest Basin and the prevailing structural trend is an easterly regional dip that in general ranges from 35 degrees along the Elk River escarpment to almost zero at the eastern edge of the mine workings. Within the area underlain by mine workings, the cross-sections show that a series of gentle undulations are superimposed on the regional dip. To the west of the actively mined area Fernie shale crops out and in that unit the structure becomes increasingly complex; evidenced by strong folds and numerous faults.

Plate 5. Low-angle overthrust near the top of Castle Mountain.

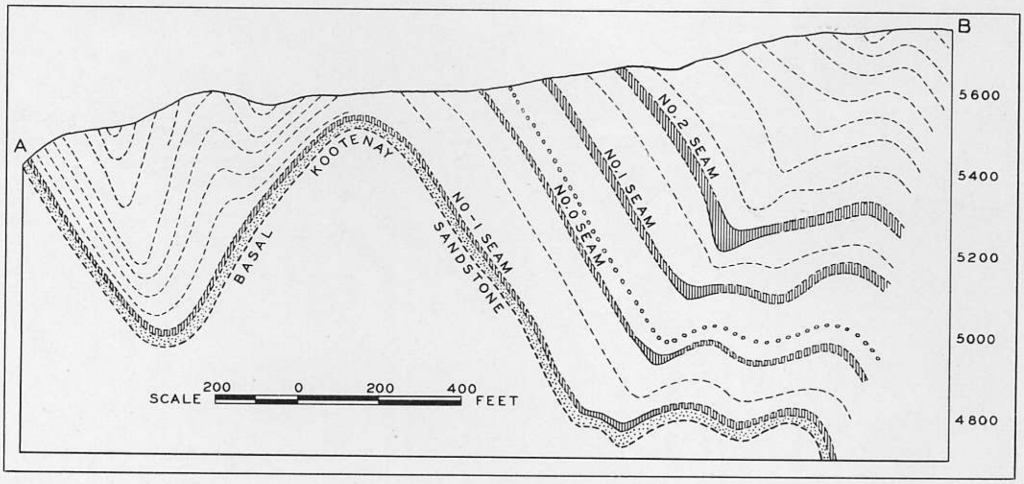

Fig. 8.

Structure of Lower Kootenay Formations, vertical section of Castle Mountain Ridge.

FOLDS

The prevailing trend of the fold axes varies from north in the southern part of the area mapped, to east of north in the northern part of the area, with a rather sharp bend in the fold axes taking place along Castle Mountain ridge. The intensity of folding appears to be directly related to the competency of the rock units that have been involved. Folds that are tight in the incompetent Fernie formation, die out upward in the lower few hundred feet of the Kootenay formation, as illustrated in section A-B, Fig. 2. In the more competent upper Kootenay, Elk, and Blairmore formations, only the slightest reflection of the strong folds observed lower in the section is apparent. For the most part the plunge of the folds is gentle, but on Castle Mountain ridge where the structures bend sharply to the east the folds plunge northward at angles up to 25 degrees.

The upward diminution of intensity of folding is of economic significance. In almost all exposures of the lower Kootenay formation along the west side of the Coal Basin the lower few hundred feet of the coal measures were tightly folded. In general the folding has become moderate about 800 feet above the base of the formation, but below this horizon the folding is such that underground mining could be done only with great difficulty. It is of interest to note that at the unsuccessful ventures at Morrissey and Hosmer the primary effort was made in exploring the lowest coal seams of the section. By contrast, the operations at Coal Creek and Michel were initiated in the upper part of the Kootenay where folding is normally gentle. However, it should be noted that where barren cover is not too thick, seams thickened in folds may be strip-mined, see pages 74 to 76.

FAULTS

Within the Fernie formation faults are numerous and often closely spaced, are generally northerly trending, and usually dip at high angles. Unfortunately, lack of continuity of outcrops made it impossible to trace any of the faults for appreciable distances. A low-angle fault within the Fernie formation is well exposed encircling the top of Castle Mountain (see Plate 5). The fault plane is folded so that at the west side of Castle Mountain it dips gently east and at the east side the dip is approximately 10 degrees to the west. Slickensides on the fault surface indicate a relative easterly movement of the upper plate of the fault.

Within the Kootenay formation only one fault of large displacement, the east-dipping underthrust shown on section A-B (see Fig. 2, in pocket), was recognized in the field. This fault separates nearly vertical lower Kootenay beds from gently dipping strata to the east, and dies out upwards below the No. 2 coal seam. In the mines of the area faults are encountered quite frequently but are generally of small displacement and usually have affected only one seam. For the most part the faults strike north to east of north, dip eastward, are high-angle, are generally slightly folded, and show relative upward movement on their east sides. Faulting is more frequent in coal seams lying close to a bed of conglomerate or coarse sandstone, and seams underlain or overlain by incompetent strata tend to undulate with consequent variations in thickness. The prevailing upward movement on the east sides of the faults is believed to be the result of a tendency for the upper beds of the section to slide outward from the axis of the Coal Basin during compression. As the compressive forces are believed to have acted from the west, the east-dipping thrusts of the Fernie area are considered to be high-angle underthrusts.

In addition to the underthrust faults referred to above, high-angle normal faults are occasionally encountered in the underground operations. They are usually of small displacement and vary widely in strike.

The folding of the low-angle thrust on Castle Mountain and of many of the faults observed underground suggests that much of the faulting of the area took place over a long period of time, with renewed movement occurring on old lines of weakness. No evidence, to date the period when faulting or folding occurred, was obtained within the area mapped. However, in the Flathead area the folding and faulting visible in the Eocene Kishinena formation implies that the main mountain building forces were of Eocene or later age.

SUMMARY

Considering the region as a whole the major structural pattern shows many high-angle west-dipping thrusts, a few east-dipping underthrusts, a good many folded faults, and only a few normal faults. The structures bear a direct relation to the competency of the beds involved. The age of the folding is believed to be Eocene or later.

In the Fernie area tight folding of the incompetent Fernie shales dies out upward into the Kootenay formation in which faults are rare and mainly are east-dipping underthrusts.

CHAPTER V -- ECONOMIC GEOLOGY

The mineral and fuel resources of the Crowsnest Coal Basin include bituminous and cannel coal, phosphate, limestone, building stone, clay and shale, gravel, and surface and underground water. Of these, coal is at the present the most important economic resource and supports the major industry of the region. The reserves of minable coal have been estimated by MacKay (1947) to be approximately six billion tons. Assuming only half of this tonnage is recoverable, then, at the present rate of production, the reserve could support the industry for 3,000 years. Next to coal in importance, surface and underground water play a major role in the development of electric power. The remainder of the industrial minerals listed above have not yet achieved economic significance.

COAL

HISTORICAL OUTLINE

According to Rickard (1942) Michael Phillipps was the first man to discover and prospect coal in the Crowsnest Pass. During the years 1873 and 1874 Phillips prospected coal outcrops on Morrissey and Coal Creeks and carried word of the immense coal reserves to Fort Steele. Because of the lack of transportation, little interest was taken in Phillipps' reports or in reports of the Geological Survey of Canada from 1880 to 1883 substantiating Phillipps' reports. However, in 1887, William Fernie, an experienced miner, began prospecting in the coal basin. He found such promising showings of coal that he was able to interest Colonel James Baker and Arthur Fenwick in financing prospecting in the area. This work was continued for eight years and as a result, a syndicate, formed at Victoria, obtained a charter to build a railroad and with the charter obtained a grant of land surrounding the coal prospects.

In 1897 The Crow's Nest Pass Coal Company Limited was organized and acquired a major interest in the Fernie-Baker syndicate. In this same year mining was commenced on Coal Creek with twenty miners from Cape Breton. By 1898 a branch line, constructed by the Canadian Pacific Railway

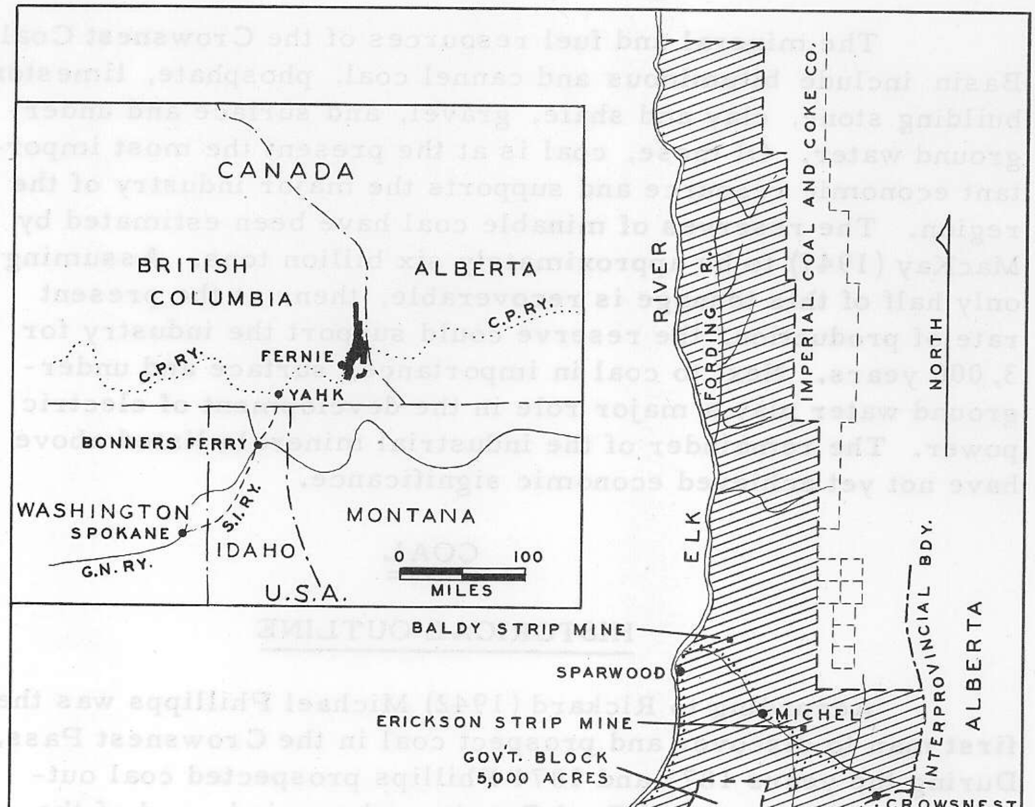

Fig. 9.

Plan showing property of The Crow's Nest Pass Coal Company Limited, and subsidiaries.

from Fort McLeod, reached Fernie, and in the following year a rail link between Fernie and Coal Creek was completed by The Crow's Nest Pass Coal Company Limited. Development at Coal Creek proceeded rapidly under the guidance of W. R. Wilson, who was appointed general manager in 1899. Between 1898 and 1903, Nos. 1, 2, 3, 4, 5, and 9 mines were opened and developed. In 1901, the Great Northern Railway Company, having acquired a substantial interest in The Crow's Nest Pass Coal Company Limited, financed the construction of the Crow's Nest Southern Railway from Gateway through Fernie to Michel. This branch line connected with the main line of the Great Northern Railway and provided ready access to an important market.

The Crow's Nest Pass Coal Company Limited undertook development at Michel and at Morrissey not long after the Coal Creek colliery was brought into production. The Michel colliery was brought into production in 1899, and the Morrissey or Carbonado colliery in 1902. Coke production was begun in Fernie in 1899, in Michel in 1902, and at Morrissey in 1903.

The town of Fernie was almost completely destroyed by fire in 1908, and on July 31, an extensive bump forced the abandonment of Coal Creek No. 2 mine. This was followed in 1909 by severe outbursts at Morrissey that resulted in the Carbonado colliery being abandoned. In 1911 the No. 1 East mine, on Coal Creek, the largest producer to date, was opened, increasing the output substantially so that in 1913 the Coal Creek production reached an all-time record of 924, 200 short tons.

In 1906, the Canadian Pacific Railway Company, which had acquired 6 square miles of coal land on the western edge of the Crowsnest Coal Basin, 8 miles north of Fernie, opened Hosmer mines. These mines were opened with great optimism and were equipped with extensive surface plant and with coke ovens. However, numerous sharp folds and faults complicated mining, causing suspension of operations, and the colliery was finally shut down in 1914.

At Corbin, southeast of Michel, a colliery served by a branch railway some 14 miles long, began producing in 1908. The colliery was operated each year until 1935. The coal at

Corbin is in thick seams that have been thickened by folding. An open pit was opened at the Big Showing, in 1913 and although it could not be operated during periods of deep snow, the open pit contributed substantially to the colliery output until 1920 and again between 1926 and 1935. The Corbin colliery was re-opened in 1943 and since then has been operated in several years. The production in 1943 and in subsequent years has been from the open pit. The branch railway was torn up after the shut-down in 1935 and the coal produced subsequently has been trucked to McGillivray on the Canadian Pacific Crowsnest Pass line. A mine on Tent Mountain in the same area began producing in 1950. It is on a seam that crosses the Alberta-British Columbia boundary dipping into British Columbia. The mine is an open pit operated by Hillcrest Mohawk Collieries Limited of Bellevue, Alberta.

The annual production from Crowsnest Pass area exceeded 1,000,000 short tons of coal in 1909, 1910, 1912, and 1913, but declined in the early years of World War I, and in the next twenty-six years production reached 1,000,000 tons only in 1927 and 1928. Since 1941 the gross output has exceeded 1,000,000 tons each year except 1945 and 1946. The yearly production is tabulated on table facing this page.

To the end of 1951 The Crow's Nest Pass Coal Company Limited has produced 40,597,873 tons of coal. In 1926 W. R. Wilson was succeeded as general manager of that company by his son, H. P. Wilson, who was succeeded in 1944 by T. H. Wilson. In spite of serious competition from oil, the company has maintained a substantial output for many years. The quality of the coal and the fact that several of the seams yield coal suitable for making metallurgical coke have been important in maintaining the market. For many years the need of railways, notably the Great Northern Railway, for steam coal, provided an important market. Sales of coal in the United States have been of importance from 1899, but from 1923, with the conversion of the Great Northern locomotives to burning oil, the export of coal to the United States has been less important and sales in Canada have been twice to twenty times the sales in the United States. The importance of coke production is indicated by the quantities of coal used in the making of coke (see table facing this page). A substantial part of the coke made has been sold

COAL PRODUCED AT COLLIERIES OF THE CROWSNEST COAL BASIN
(In Short Tons)

	CORBIN COLLIERY		MICHEL COLLIERY			HOSMER COLLIERY			COAL CREEK AND ELK RIVER COLLIERIES (2)			MORRISSEY-CARBONADO COLLIERY			
Year	Total Sales Tons	Gross Output Tons	Total Sales Tons	Used for Coke Tons	Gross Output Tons	Total Sales Tons	Used for Coke Tons	Gross Output Tons	Total Sales Tons	Used for Coke Tons	Gross Output Tons	Total Sales Tons	Used for Coke Tons	Gross Output Tons	Total Gross Output Tons (1)
1898	-	-	-	-	-	-	-	-	10, 454	526	11, 148	-	-	-	11, 148
1899	-	-	438	-	438	-	-	-	69, 819	42, 865	114, 922	-	-	-	115, 498
1900	-	-	3, 455	7, 483	11, 162	-	-	-	109, 546	107, 912	220, 457	-	-	-	231, 619
1901	-	-	15, 639	36, 005	52, 763	-	-	-	202, 209	166, 456	372, 114	-	-	-	424, 877
1902	-	-	68, 314	55, 898	127, 515	-	-	-	129, 864	131, 318	267, 429	40, 961	-	46, 292	441, 236
1903	-	-	130, 997	125, 757	263, 589	-	-	-	83, 931	147, 618	241, 686	143, 427	6, 122	155, 400	660, 675
1904	-	-	85, 155	171, 350	263, 487	-	-	-	160, 178	213, 435	387, 409	76, 296	8, 223	91, 311	742, 207
1905	-	-	116, 824	217, 799	346, 646	-	-	-	241, 839	211, 698	476, 552	83, 670	16, 070	108, 566	931, 764
1906	-	-	121, 546	172, 807	306, 317	-	-	-	285, 433	167, 723	478, 008	20, 476	-	22, 578	806, 903
1907	-	-	168, 804	208, 599	396, 175	-	-	-	398, 668	153, 016	585, 517	241	-	246	981, 938
1908	4, 604	4, 604	207, 899	231, 082	461, 647	706	613	2, 942	285, 367	171, 786	493, 924	25, 291	-	26, 072	989, 189
1909	67, 415	68, 123	232, 753	176, 114,	437, 318	13, 040	39, 508	67, 562	200, 119	193, 697	425, 565	35, 243	-	36, 161	1, 034, 729
1910	139, 854	142, 073	315, 633	164, 790	512, 491	60, 590	77, 228	177, 098	529, 628	132, 644	697, 272	-	-	-	1,528, 934
1911	88, 964	91, 524	72, 827	45, 139	128, 110	12, 320	22, 025	44, 127	167, 526	50, 051	231, 343	-	-	-	495, 104
1912	133, 507	136, 935	146, 546	115, 316	284, 325	103, 956	81, 291	210, 832	492, 746	247, 927	780, 466	-	-	-	1,412, 558
1913	78, 744	81, 523	106, 440	113, 299	242, 171	107, 762	110, 658	243, 631	619, 888	261, 313	924, 207	-	-	-	1,491, 532
1914	80, 588	83, 229	111, 577	93, 882	225, 236	36, 195	66, 444	114, 764	364, 654	237, 790	646, 575	-	-	-	1,069, 804
1915	65, 968	70, 049	146, 340	145, 939	311, 499	-	-	-	294, 619	238, 771	573, 332	-	-	-	954, 880
1916	72, 018	77, 302	76, 141	176, 216	273, 413	-	-	-	369, 585	218, 014	637, 427	-	-	-	988, 142
1917	105, 494	113, 193	35, 096	89, 718	142, 380	-	-	-	195, 011	128, 068	362, 388	-	-	-	617, 961
1918	110, 049	138, 868	83, 788	126, 539	231, 181	-	-	-	276, 406	138, 125	450, 759	-	-	-	820, 808
1919	98, 577	89, 317	101, 489	76, 080	193, 612	-	-	-	291, 922	19, 943	342, 934	-	-	-	625, 863
1920	160, 073	169, 136	161, 822	113, 847	296, 343	-	-	-	444, 653	-	483, 597	-	-	-	949, 076
1921	67, 005	76, 083	190, 200	95, 921	311, 697	-	-	-	414, 338	-	463, 146	-	-	-	850, 926
1922	59, 905	51, 545	164, 027	68, 877	242, 668	-	-	-	304, 916	-	326, 672	-	-	-	620, 885
1923	48, 890	54, 058	167, 204	100, 536	289, 440	-	-	-	445, 290	-	485, 897	-	-	-	829, 395
1924	25, 069	31, 011	104, 591	52, 026	165, 541	-	-	-	93, 819	1, 742	109, 788	-	-	-	306, 341
1925	69, 065	77, 069	264, 462	78, 083	360, 119	-	-	-	428, 792	51, 579	519, 829	-	-	-	957, 017
1926	77, 749	132, 831	289, 975	99, 799	407, 450	-	-	-	322, 148	60, 180	409, 981	-	-	-	950, 262
1927	130, 405	145, 731	289, 771	91, 429	399, 500	-	-	-	383, 394	54, 096	471, 191	-	-	-	1,016, 422
1928	165, 356	200, 752	317, 612	66, 780	402, 693	-	-	-	443, 912	36, 940	518, 261	-	-	-	1,121, 706
1929	133, 903	188, 450	295, 060	70, 190	383, 200	-	-	-	362, 681	45, 292	421, 460	-	-	-	993, 110
1930	201, 729	239, 021	219, 274	60, 883	297, 429	-	-	-	176, 725	49, 072	235, 493	-	-	-	771, 943
1931	262, 703	288, 067	206, 948	59, 885	277, 217	-	-	-	117, 312	50, 335	175, 513	-	-	-	740, 797
1932	270, 630	314, 375	200, 626	31, 076	240, 022	-	-	-	81, 790	16, 565	104, 024	-	-	-	658, 421
1933	206, 529	243, 277	215, 889	9, 447	231, 382	-	-	-	56, 746	-	60, 339	-	-	-	534, 998
1934	229, 953	273, 267	262, 917	53, 641	327, 070	-	-	-	99, 175	-	102, 596	-	-	-	702, 933
1935	10, 840	11, 170	300, 110	41, 639	347, 489	-	-	-	93, 696	-	97, 304	-	-	-	455, 963
1936	-	-	349, 272	12, 918	424, 436	-	-	-	99, 596	-	102, 642	-	-	-	527, 078
1937	-	-	288, 846	71, 838	389, 616	-	-	-	116, 971	3, 912	124, 617	-	-	-	514, 233
1938	-	-	266, 673	86, 615	367, 732	-	-	-	114, 983	-	118, 424	-	-	-	486, 156
1939	-	-	383, 023	87, 615	513, 613	-	-	-	112, 606	-	115, 780	-	-	-	629, 393
1940	-	-	562, 819	99, 028	730, 862	-	-	-	135, 055	-	138, 839	-	-	-	869, 701
1941	-	-	721, 246	140, 887	953, 389	-	-	-	192, 278	-	195, 791	-	-	-	1,149, 180
1942	-	-	750, 245	143, 854	972, 250	-	-	-	197, 177	-	201, 189	-	-	-	1,173, 439
1943	34, 131	39, 762	591, 251	130, 463	772, 264	-	-	-	219, 845(2)	-	226, 754(2)	-	-	-	1,038, 780
1944	153, 468	185, 528	544, 719	126, 623	728, 665	-	-	-	311, 406	-	340, 952	-	-	-	1,255, 145
1945	-	-	497, 166	100, 600	660, 494	-	-	-	285, 949	-	313, 510	-	-	-	974, 004
1946	1, 294	1, 294	462, 880	106, 122	649, 256	-	-	-	280, 767	-	315, 640	-	-	-	966, 190
1947	98, 856	98, 856	551, 162	175, 665	848, 712	-	-	-	323, 341	-	354, 349	-	-	-	1,301, 917
1948	150, 638	150, 638	573, 077	154, 342	844, 690	-	-	-	266, 815	-	293, 857	-	-	-	1,289, 185
1949	-	-	533, 461	228, 792	899, 677	-	-	-	309, 518	-	338, 899	-	-	-	1,238, 576
1950	-	-	525, 894	213, 218	808, 696	-	-	-	277, 641	-	304, 943	-	-	-	1,138, 389
1951	-	-	532, 352	236, 871	851, 458	-	-	-	282, 355	-	312, 860	-	-	-	1,249, 501
	3, 603, 973	4, 068, 661	14, 132, 275	5, 752, 722	21, 605, 545	334, 569	397, 767	860, 959	13, 575, 102	3, 750, 409	18, 505, 571	425, 605	30, 415	486, 626	45, 638, 430

Note: Gross output includes material discarded as washery waste, coal used in making coke, and coal burned at colliery.

(1) Total Gross Output includes: from Erickson Colliery, 138 tons in 1899; from the Hillcrest Mohawk Colliery, 24,750 tons in 1950, and 85,183 tons in 1951.

(2) 1943 and subsequent years, production credited is from the Elk River Colliery.

in the United States. Coke production was begun in Fernie in 1898, Coal Creek coal being used; coke production in Michel was started in 1900. Except in 1937, no coke has been made in Fernie since 1932. Coke sales have increased in recent years but have not yet reached the peak of more than 260,000 short tons reached in 1905. Until 1939 all coke had been made in beehive ovens but in that year a battery of Curran Knowles by-product ovens was brought into operation at Michel. The by-product oven installation has been increased from time to time, most recently in the autumn of 1952, and at the end of that year the entire coke output was produced in by-product ovens. Tar is recovered for sale and coal gas is used to heat the ovens and steam boilers, and to supply other needs for heat at the colliery.

Coal is prepared in modern preparation plants at Michel and at the Elk River colliery. An entirely new surface plant was provided at Coal Creek in 1953, and with the mines now operated there, is known as the Elk River colliery.

FERNIE COAL AREA

As indicated on the stratigraphic section on pages 36 to 39, there are within the Kootenay formation in the Fernie area thirteen coal seams of commercial thickness. The majority of these seams are sufficiently low in ash as to warrant their being mined. To date only six of these seams, Nos. 3, 4, 5, 9, 10, and B, have been extensively mined, although several of the other coal beds have been prospected actively.

Prior to 1942 mines were operated on both the north and south sides of Coal Creek, production being handled at the Coal Creek tipple. The seams were developed by main haulage roads following the strike of the coal and driven into the mountainside roughly at right angles to the trend of the creek valley. From the haulage level inclines and slopes were driven up and down the dip, roadways were driven paralleling the main haulage and the coal was extracted by pillar-and-stall or a modified longwall method of mining. By these methods, the workings in ten mines, of which only the No. 1 East mine is still in operation, developed or partially extracted the coal in the extensive area shown in Fig. 10 (in pocket).

In the more recent underground operations, which were confined to the south side of Coal Creek, rather frequent severe bumps and outbursts occurred. Because of these occurrences and in view of the large virgin coal area lying to the west of the old workings under moderate cover, it was decided to open a new colliery three-quarters of a mile west of the Coal Creek tipple. This project, the Elk River colliery, shown in Plate 6, was completed in November 1943, and now handles the production from five mines, the Nos. 3, 4, 9, 10, and 1 East, mines.

The location and extent of the underground workings on Coal Creek shown on the mine plan (see Fig. 10) and in part on the two cross-sections map (Fig. 2, in pocket). For a description of the mining methods used in the Fernie area the reader is referred to a recently published paper "Mining Pitching Seams in Northwest Canada" by T. H. Wilson (1949). The operations at Elk River colliery have been described by W. C. Whittaker (1944).

Pertinent data relating to the mines and coal seams of the Fernie area have been summarized in the following table on pages 67, 68, and 69.

Production

The annual production of the Coal Creek mines is given in the table on page 70.

Character of the Coal

The nature and quality of the Coal Creek coals, which are medium-volatile bituminous coking coals, is indicated in the table of analyses on page 71. Many of the analyses given are of channel samples across the seam outcrop taken in surface trenches from 4 to 10 feet in depth. It is likely that considerable improvement over the quality listed here would be expected had it been possible to sample a selected minable interval beyond the zone of surface weathering.

Tabular Summary

DATA ON COAL SEAMS, COAL CREEK AREA

Mine No.	Seam No.	Thickness of seam in feet: From	To	Average Worked	Nature of Coal	Nature of Roof	Year Opened	Year Closed and Reason for closing	Outbursts or Bumps	Method of Mining
B-N	B	4	6	5	Fairly Hard	Fairly good shale	1912	1923, operating difficulties	None, one explosion	Pillar-and-stall
Old No. 1	10	6	10	7	Soft	Hard sandy shale	1897-98	1911, worked to a fault	Moderate bumps occasionally, no serious accidents	Pillar-and-stall
No. 1 N	10	10	15	12	Soft, friable	Coaly shale	1908	1923, worked to a fault, and operating difficulties	None	Pillar-and-stall, small areas by longwall
No. 1 S	10	12	20	16	Soft, friable	Fairly strong shale overlain by conglomerate	1908	1930, roads were hard to maintain, marketing difficulties	Very few, several fires	Pillar-and-stall
No. 1 E	10	6	50	20	Friable, top 2 feet was hard	Sandy shale outside, conglomerate inside	1910		Numerous, both	Pillar-and-stall and modified longwall

DATA ON COAL SEAMS, COAL CREEK AREA (Cont'd)

Mine No.	Seam No.	Thickness of seam in feet: From	Thickness of seam in feet: To	Average Worked	Nature of Coal	Nature of Roof	Year Opened	Year Closed and Reason for Closing	Outbursts or Bumps	Method of Mining
No. 10	10	6	15	9	Friable, high ash	Soft shale	1945		None	Pillar-and-stall and modified longwall
No. 2	9	5	16	8	Fairly hard	Sandy shale overlain by conglomerate	1897-98	1932, marketing difficulties	Bumps in outer workings	Pillar-and-stall, minor longwall
Old No. 3	9	3	7	5	Fairly hard, high quality	Sandy shale	1900	1905-08, flooded after tipple fire, 1933 marketing difficulties	Numerous bumps along main entry	Pillar-and-stall and longwall
Old No. 9	9	4	9	5	Hard, good quality	Strong shale, a 2-inch clod in roof caused caves	1904	1913, operating difficulties, faults	Very few, no outbursts	Longwall and pillar-and-stall
New No. 9	9	2	14	8	Hard, low ash	Hard sandy shale, conglomerate locally	1942		None	Pillar-and-stall and modified longwall
No. 8	8	5	6	5 1/2	Hard, good quality	Strong shale	1931	1932, marketing difficulties, faults	None	Development

DATA ON COAL SEAMS, COAL CREEK AREA (Cont'd)

Mine No.	Seam No.	Thickness of seam in feet: From	To	Average Worked	Nature of Coal	Nature of Roof	Year Opened	Year Closed and Reason for Closing	Outbursts or Bumps	Method of Mining
No. 6	6			7	Fairly good	Shale	1906	1907, band of rock in middle of seam	None	Development
No. 5	5	5	16	12	Rather soft	Moderately strong shale, overlain by conglomerate	1904	1915, faults and operating difficulties	None	Pillar-and-stall
Old No. 4	4	12	16	14	Soft, fairly high ash, poor coking	Moderately strong shale	1904	1906, coal did not coke well	None	Development
New No. 4	4	6	13	8	Friable and high ash	Hard shale subject to caves	1942		None	Pillar-and-stall and modified longwall
New No. 3	3		15	11	Friable, clean	Hard shale	1946		Occasional outbursts	Pillar-and-stall
No. 12	1		25		Fairly hard, high ash	Sandy shale	1906	1908, encountered a fault	None	Development
No. 11	0	7	12	10	Hard, low ash	Soft shale overlain by hard, sandy shale	1906	1908, worked to a fault	None	Development

GROSS PRODUCTION OF COAL CREEK MINES

In Short Tons

Year	Old No. 1	No. 2	Old No. 3	Old No. 4	No. 5	Old No. 9	No. 1N	No. 1S	No. 1E	B-N	New No. 4	No. 9 & No. 10	New No. 3
1904	152,057	143,413	25,423	3,315	45,307	17,895							
1905	120,203	143,925	6,194		77,488	77,418							
1906	65,346	167,680		4,407	103,885	136,690							
1907		239,282			144,160	198,090							
1908		158,880			228,726	84,793	11,918						
1909		68,359			234,719	41,496	71,879	9,112					
1910	49,383	133,273	27,112		213,879	46,405	146,604	77,677	1,177				
1911	23,135	29,688	13,684		49,959	6,797	36,160	5,514	1,734				
1912		103,027	70,725		171,650	29,400	132,751	82,739	190,175				
1913		38,150	66,412		159,722	22,595	161,885	140,153	299,452	32,393			
1914		42,076	41,221		92,400		21,144	105,099	254,231	82,331			
1915		55,565	54,390		38,949		30,014	96,724	261,948	25,204			
1916		65,047	63,172				39,693	100,601	307,151	61,763			
1917		46,578	21,708				32,186	101,040	106,791	51,176			
1918		54,402	33,478				61,811	114,435	121,186	58,604			
1919		42,240	66,948				45,193	71,367	72,446	28,652			
1920		70,852	85,980				67,780	95,981	114,785	48,221			
1921		72,673	76,647				53,368	91,514	119,363	49,582			
1922		50,781	59,113				30,108	63,289	82,777	35,974			
1923		74,404	85,970				22,675	104,750	150,410	47,687			
1924		19,745	22,603			3,669		17,079	31,793				
1925		95,801	108,956					115,939	199,135				
1926		79,734	87,323					87,291	155,633				
1927		79,608	97,994					65,214	228,373				
1928		98,110	105,098					74,286	240,767				
1929		91,657	87,125					59,414	183,264				
1930		57,701	53,212					3,140	121,441				
1931		48,679	32,178						94,656				
1932		21,178	21,824						61,023				
1933			3,665						56,628				
1934									102,595				
1935									97,304				
1936									102,643				
1937									124,616				
1938									118,424				
1939									115,779				
1940									138,840				
1941									195,790				
1942									201,189				
1943									206,211		11,164	6,961	
1944									153,924		50,234	111,995	
1945									125,133		24,821	139,940	
1946									114,327		31,393	139,291	
1947									107,139		89,420	95,623	
1948									94,301		116,751	59,253	
1949									98,620		117,287	97,367	
1950									78,095		112,344	90,888	
1951									66,988		137,667	81,644	

PROXIMATE ANALYSIS OF THE PRINCIPAL SEAMS OF THE COAL CREEK AREA

Seam No.	Nature of Sample	Basis	Moisture	Volatile Matter	Fixed Carbon	Ash per cent	S	B.T.U per lb.	Fuel Ratio	Lab. No. or Source of data
"B"	Channel of outcrop	R	8.4	23.3	38.9	29.4		7,660	1.67	1425M
10	2,100 lbs. of No. 1E mine run coal	R	1.0	27.1	63.1	9.8	0.3	14,130	2.32	Swartzman, Rept. No. 61, 1939
9	1,990 lbs. of No. 9 mine run coal	R	1.3	23.4	60.4	16.2	0.5	12,965	2.58	Swartzman, Rept. No. 91, 1944
7 & 8	Channel of outcrop	R	9.8	22.5	42.8	25.9		8,050	1.90	1264M
6	Channel of outcrop	R	10.7	21.7	43.6	25.8		8,110	2.01	1265M
5	Channel of outcrop	R	9.8	20.9	29.1	31.5		7,430	1.87	1267M
4	1,956 lbs. of No. 4 mine run coal	R	1.1	20.7	61.9	17.4	0.5	12,705	2.99	Swartzman, Rept. No. 92, 1944
3	No. 3 mine, sample taken 670 feet from portal, main entry	D	0.46	18.9	71.2	9.5			3.77	C.N.P.C. Co.
2	Channel of outcrop	R	7.7	25.9	52.7	13.7			2.04	C.N.P.C. Co.
1	Channel of outcrop	R	9.8	18.2	29.3	42.7		5,360	1.61	1491M
0	Channel at old No. 11 mine portal	R	1.3	17.9	69.6	11.3		13,440	3.89	1266M
-1	Channel of outcrop	O	5.2	24.6	49.4	20.8		6,970	2.01	1817M

No. 9 Mine

During the months of July and August, 1947, the field work was concentrated on the examination of the upper part of the Kootenay formation on the south side of Coal Creek. The work was undertaken with the hope of finding a solution to problems of development that had arisen in the underground workings of the No. 9 mine. In the up-dip workings of this mine a pinch-out of the seam had been encountered. This pinch-out was met at successively lower elevations as the workings were extended southward, so that it became apparent that the pinched-out area would cross the line of the projected main level some 3,800 feet from the portal. Hence it appeared that development of the seam by extending the existing main level might well be impossible.

In the underground workings, the pinch-out of the seam was found to be a gradational one. The seam thins gradually up the dip, its place being taken by a fine-grained sandstone or sandy shale. On the surface it was found possible to trace the No. 10 seam southward for several miles from the mine portal. Using the No. 10 seam as a reference datum it was possible to locate the No. 9 seam or horizon by trenching down the hillside. The trenches were carried well down the hillsides and exposed several seams below the No. 9 horizon. In this way an attempt was made to delimit roughly the "want" area in No. 9 seam and to examine several sections of the upper coal seams.

The results of the surface and underground work done are shown in the plan and cross-sections (see Fig. 10). In working along the outcrop it was observed that from station 5 to station 36 the No. 9 seam was thin (1 foot) or absent. South of station 36, at point "E," the No. 9 coal was clean and had a thickness of 11 feet. From point "E" southward the seam maintained this thickness for at least one-half mile, but was covered by overburden still farther to the south.

It seems likely, then, that within a crescent-shaped area, shown on the plan by diagonal ruling, that the No. 9 seam is very thin or absent. The main level of the mine has now been extended, in spite of considerable expense for a rock tunnel, and apparently has skirted the "want" area to reach what promises to be a widening area of good quality coal.

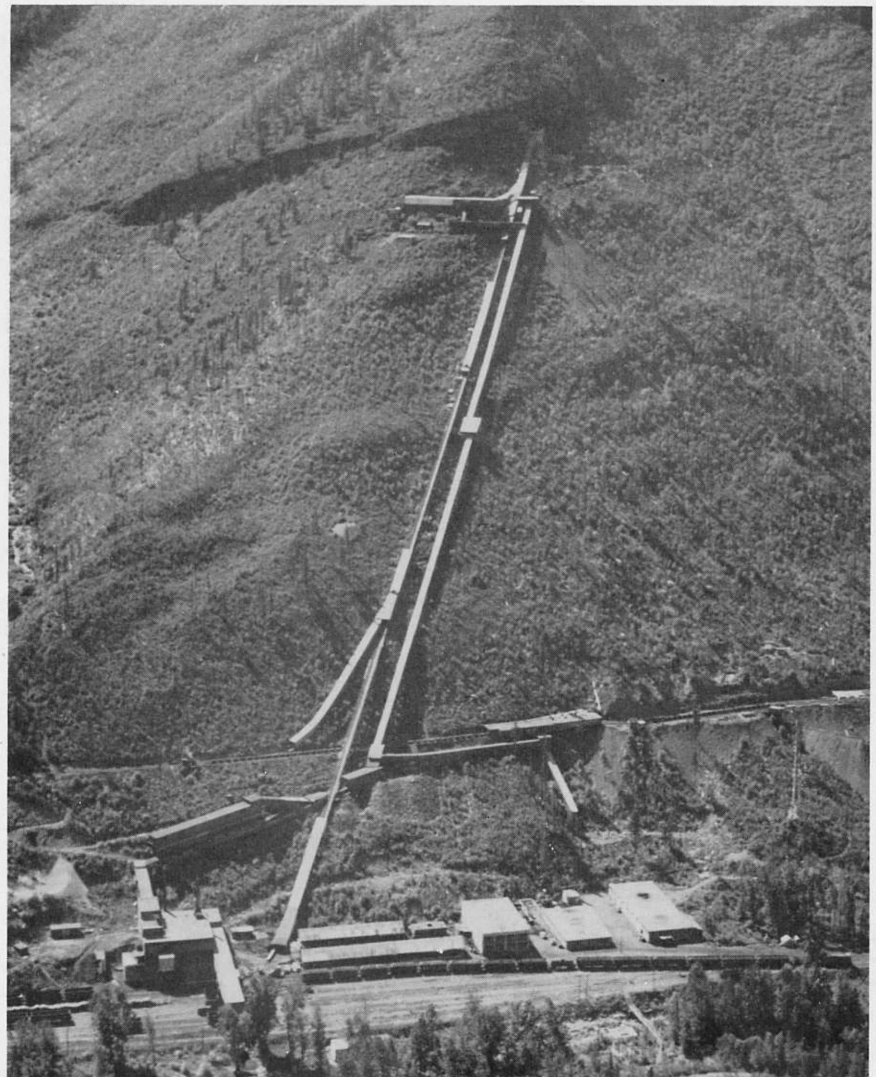

Plate 6. Elk River Colliery on Coal Creek.

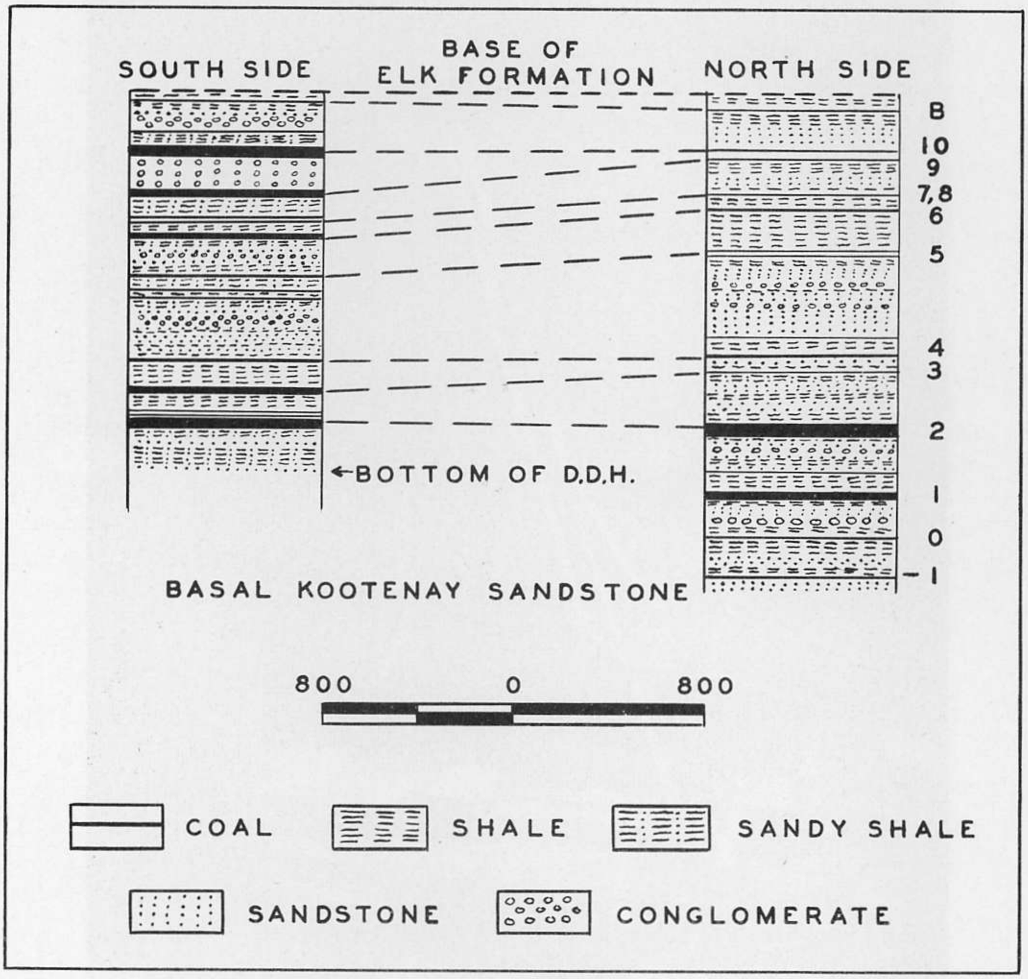

Fig. 11.

Correlation of sections of Kootenay Formation on Coal Creek.

Variation in Seam Thicknesses and Intervals Between Seams

The sections of Fig. 10 illustrate the rapid lateral variations in thickness of the coal seams and in the thickness and nature of the enclosing strata. Between sections A and B, for example, in a distance of 410 feet the interval between No. 9 and No. 10 seams increases from 30 feet to 100 feet, and the thickness of No. 6 seam decreases from 12 feet to 2 feet. The interval between No. 7 seam and No. 9 seam, a predominantly shaly unit in section A, is largely sandstone in section C. Further evidence of the variable conditions of deposition that prevailed during the accumulation of the coal measures is afforded in the comparison of sections from the north and south sides of Coal Creek given in Fig. 11. Rapid lateral variations of the sediments, such as those described above, make the problem of correlation of coal seams, even within limited areas, a difficult one. It seems unlikely that on the basis of stratigraphic position or thickness of seams that any dependable correlation could be established between the sections at Coal Creek and those at Morrissey or Hosmer, 8 to 10 miles distant.

MORRISSEY AREA

The coal measures at Morrissey may be reached by following the main highway south from Fernie for 9 miles, then crossing the Elk River on the government bridge by Morrissey station, thence southward along the old road grade for 2 1/2 miles continuing by a poor motor-road that leads eastward up Morrissey Creek valley. This road roughly parallels an old abandoned railroad grade for 2 miles and ends about one-quarter mile beyond the Chudik residence near a prominent outcrop of the Basal Kootenay sandstone.

Because of the thick forest cover the best exposures of the Kootenay formation are found along an old tram-grade on the north side of the creek just above the road. The lower several hundred feet of the Kootenay formation is strongly folded into tight anticlines and synclines that have nearly vertical axial planes, striking north-northwest. The limbs of the folds are steep, dipping as much as 80 degrees. The folds plunge from 7 to 10 degrees to the north. East of the strongly folded zone the beds dip to the east at more gentle angles with the dip decreasing up the creek till at a point 1 mile upstream from the end of the road the beds are nearly flat.

Inasmuch as violent outbursts of gas had forced the abandonment of the rather extensive underground operations on the creek in 1909, the writer's field work was undertaken with the hope of locating an area that might support a stripping operation. Because the tight folding and local thickening was confined to the lower part of the section, attention was focused on the lowest seams. By trenching several of the seams it was found that the lowest seam, directly overlying the Basal Kootenay sandstone, had the thickest section of clean coal. This seam had a thickness of 48 feet, with a 6-foot shaly zone 20 feet above the base. Along the axis of a syncline, which crosses Morrissey Creek just west of the Chudik home, the coal was found to be thickened appreciably, but no area was located where stripping might profitably be undertaken. A proximate analysis of a channel sample across the outcrop of the seam (excluding the 6-foot shaly section) yielded the following results:

Moisture Per Cent	Volatile Per Cent	Fixed Carbon Per Cent	Ash Per Cent	Coking Properties
1.2	14.2	75.0	9.6	non-coking

As field work was done only on the north side of Morrissey Creek it was not established whether stripping possibilities along this seam exist to the south of the creek. Viewed from a distance the structures to the south looked worthy of investigation.

MICHEL AREA

The geology and coal deposits of the Michel area have been described by B. R. MacKay (1932). As a result of the writer's field work, supplemented by the results of bulldozer trenching and diamond drilling done by The Crow's Nest Pass Coal Company, two coal areas, now known as the Erickson and Baldy strip mines, were discovered. The location of these areas is shown on the index map (see Fig. 9).

Erickson Strip Mine

At the start of the exploration programme on Erickson ridge bulldozer trenching had exposed a 25-foot coal seam which may be correlated with that mined at the old No. 9 mine, striking almost due north and dipping west at 45 degrees in the same direction as the hillside. Diamond drilling west of the outcrop revealed a deep syncline

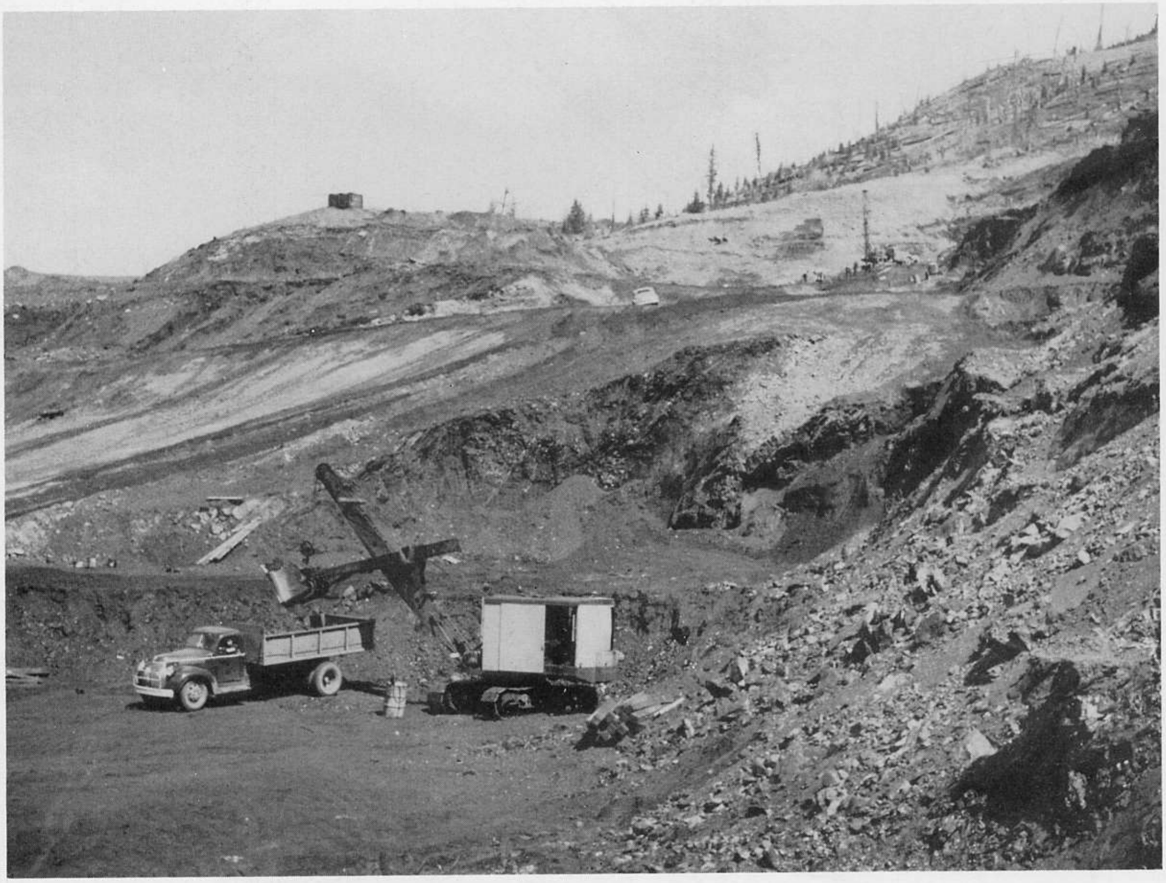

Plate 7. Erickson strip mine.

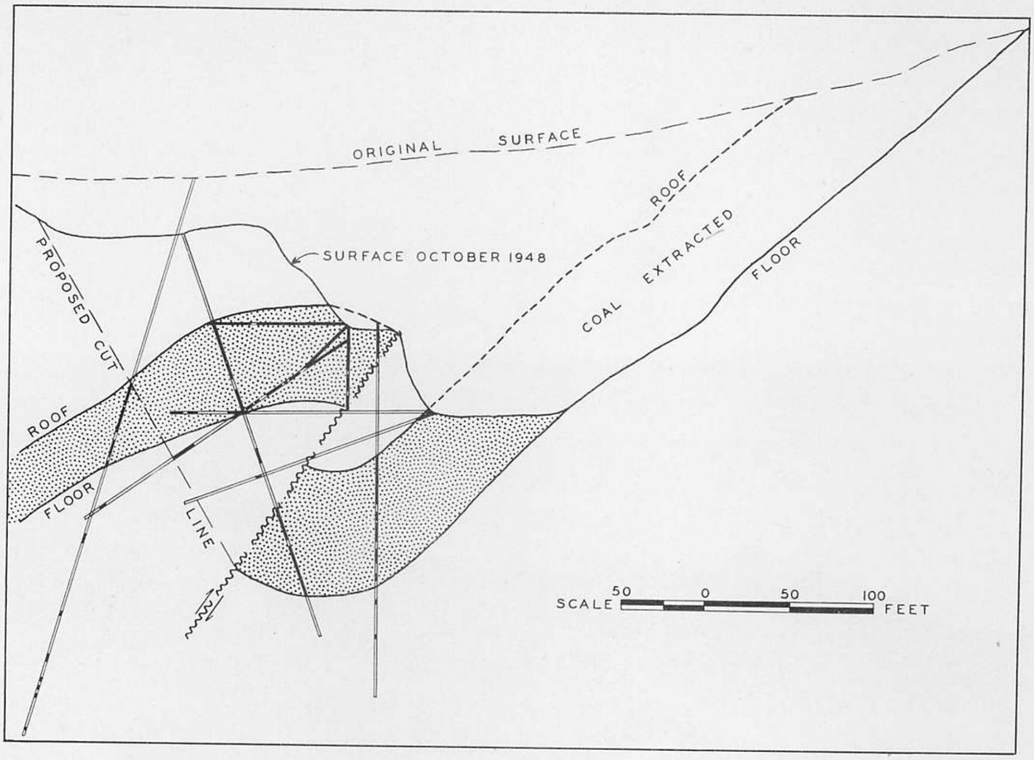

Fig. 12.

Erickson Strip Mine, typical section.

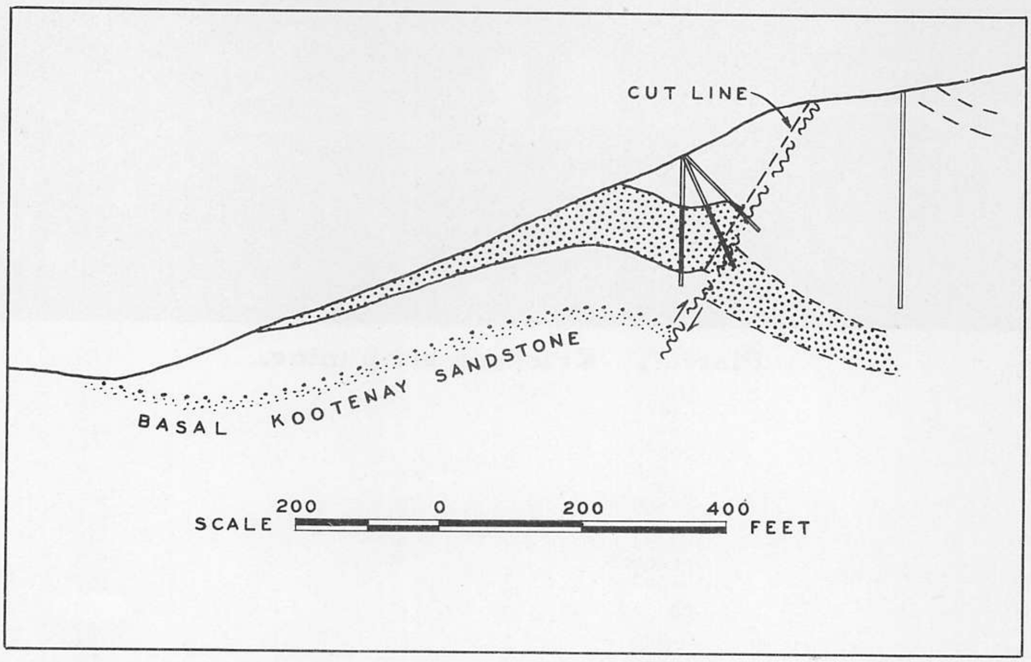

Fig. 13.

Baldy Strip Mine, typical section
near site of pit, 1950.

in which the coal was thickened to as much as 150 feet beneath a relatively shallow cover. The drilling also showed the presence of a high-angle west-dipping reverse fault truncating the western limb of the syncline, and a thickened area of coal on the crest of the anticline just west of the fault zone.

Figure 12 is a cross-section near the centre of the pit and is typical of the structure encountered. The trend of the folds is close to astronomic north with a slight southerly plunge of the axes. Although some coal was removed from the crest of the anticline most of the mining was confined to the bottom and east limb of the syncline (see Plate 7). The hard sandstones and sandy shales overlying the coal were shattered by drilling and blasting, and removed with a 1 1/2 yard shovel, bulldozers, scrapers, and Euclid trucks. The coal was removed in 15-foot "lifts" with the power-shovel and transported 5 miles by road to the Michel tipple in 13-ton trucks. Approximately 700,000 tons of coal was removed before it became necessary to abandon the pit because inferior quality coal was encountered at the south end of the stripping.

The coal, having attained an abnormal thickness by a combination of repeated thrusting and flowage folding, was soft and slickensided but generally of satisfactory ash content. In places irregular lenses of shale were encountered which were removed prior to loading out the surrounding coal. A 15-foot channel sample of the coal in the upper part of the seam gave the following analysis:

Moisture Per Cent (As received)	Volatile Per Cent	Fixed Carbon Per Cent	Ash Per Cent	Coking Quality
10.2	24.8	52.5	12.5	Good

Baldy Strip Mine

The Baldy Strip Mine was discovered in 1947 as a result of the traverses carried out through the lower part of the Kootenay formation in a 6-mile long area centring on the town of Sparwood. On the Elk River escarpment about 3 miles south of Sparwood a seam of coal 35 to 45 feet thick and 70 feet stratigraphically above the Basal Kootenay sandstone had been discovered. Followed northward this seam was found to outcrop along a gently sloping hillside above the old quarry just north of the junction of the No. 3 highway with the Upper Elk road. At this locality the topography was such that stripping possibilities were believed to exist.

Surface trenching followed by diamond drilling in 1948 showed that the seam was strongly folded above the high-angle thrust fault. Along the crest of an anticline just west of the fault the coal attains a thickness of 90 to 110 feet, and for considerable distances the west limb of the anticline, where the coal has a thickness of 45 to 70 feet, parallels the slope of the hillside. The cross-section (see Fig. 13), near the centre of the operation, shows the nature of the folding and the favourable stripping conditions.

The length of the strippable coal is approximately 1 1/2 miles, and it is hoped that several million tons of coal will be extracted. The coal varies from soft and friable to hard and blocky, has generally a high vitrain content, is low in ash and rather low in volatiles, and varies from non-coking to fair-coking. A channel sample of 25 feet of coal near the site of the present pit gave the following analysis:

Moisture (Air dried) Per Cent	Volatile Per Cent	Fixed Carbon Per Cent	Ash Per Cent	Heat Value British Thermal Units	Sulphur Per Cent	Coking Quality
1.0	17.3	73.2	8.5	14,040	0.2	Non-coking

The completion in June, 1949, of a 3 1/2-mile road to the deposit has permitted a daily production of 1,200 to 1,500 tons.

CANNEL COAL

Within the Elk formation, which overlies the Kootenay coal measures, there are several thin seams of coal that from visual inspection resemble cannel. These coals are very hard, shiny, and break with a conchoidal fracture. The coal can be ignited with a match and when burned on the campfire gave off quantities of dense black smoke and very little heat. The few samples analyzed were all over 30 per cent in ash. The seams were invariably thin (3 feet being the maximum) and lenticular, often pinching out completely in a short distance. At present these coals do not appear to have a commercial use, unless they might possibly prove suitable for cutting and polishing into ornaments.

PHOSPHATE

During the period 1926 to 1933 The Consolidated Mining and Smelting Company of Canada Limited prospected the phosphate horizons from the International Boundary as far north as Jasper. The most promising-looking deposits were found in the Fernie-Crowsnest area where extensive surface stripping and trenching and considerable underground development were done on three properties:[1] the Lizard Creek showing, situated at 4,500 feet elevation, 5 miles west of Fernie; the Crow or Crowsnest deposit, at 4,600 feet elevation on Alexander Creek three-quarters of a mile north of the railway at a point 2 miles north-west of Crowsnest station; and the Marten deposit at 4,400 feet elevation on the south fork of Michel Creek, 5 1/2 miles south of McGillivray station. In 1933 some 2,000 tons of phosphate rock was shipped from the Crow deposit to the company's fertilizer plant at Trail. Since then no work has been reported at the phosphate deposits. The company imports its phosphate rock from deposits in the state of Montana.

The East Kootenay phosphate horizons are within a sedimentary sequence ranging in age from Mississippian to Jurassic. Several of the phosphate horizons are at formational contacts. Telfer (1933) lists the known horizons as follows:

1. Near the base of the Mississippian (Banff Shale).
2. Near the top of the Pennsylvanian (Rocky Mountain Quartzite).
3. At the base of the Jurassic (Fernie Shale).
4. In the Jurassic (Fernie Shale).

LIMESTONE

Limestones and dolomitic limestones form the greater part of the Devonian and Mississippian strata that outcrop in the high mountains surrounding the Coal Basin. Relatively pure high calcium limestones have been recognized only in the Mississippian Rundle formation, and particularly in the upper part of this formation.

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(1) See Minister of Mines, B. C. Ann. Repts., 1926 to 1933 inclusive.

Limestone of high quality is being quarried from the upper part of the Rundle formation at the Summit Lime Works on Crowsnest Lake. Light-coloured pure-looking bands were noted in road-cut exposures of the Rundle near the "Loop" east of Michel and southwest of the tunnel on the No. 3 highway near Fernie. Samples of material from these two locations gave the following analyses:

Location	CaO Per Cent	MgO Per Cent	Insolubility Per Cent	Fe_2O_3 Per Cent	Ignition Loss Per Cent
Road cut near "Loop" east of Michel	48.90	3.8	4.86	0.12	41.94
Road cut near tunnel No. 3 highway near Fernie	45.78	6.09	4.90	0.010	42.60

Although neither of the above stones is suitable for the production of either lime or cement it is possible that rather pure stone could be located in these areas by further sampling.

BUILDING-STONE

Within the Coal Basin the only stratum that has been extensively quarried for building-stone is the Basal Kootenay sandstone, a hard fine- to medium-grained siliceous sandstone. Quarries have been opened in the Basal Kootenay at Morrissey, at the "Rock Cut" near Elk River colliery, at Hosmer, and near Natal. The stone, which is highly resistant to weathering, has been used in the construction of colliery buildings and in various fireproof establishments in Fernie and Michel. Although satisfying most of the requirements of a building-stone the Basal Kootenay has a rather drab, pale brown or grey colour. Material of brighter hues that should make a satisfactory building-stone is found in exposures of green to maroon Precambrian siliceous argillites east of the town of Elko.

CLAY AND SHALE

Clay and shale form an important part of the sedimentary sequence in or adjacent to the Crowsnest Coal Basin. Although many exposures were examined and sampled, in only one instance was material found that is considered well suited to the production of common brick and tile. Material of possible commercial value was found at the following two localities.

A. Lizard Creek Exposures--Dark grey to brown shale of the Fernie formation is exposed in road-cuts along the steep logging road on the south bank of Lizard Creek opposite an abandoned sawmill 4.3 miles from the Fernie-Elko highway. A channel sample of 15 feet of beds believed to be typical of the outcrop was tested by the Ceramic Section, Mineral Dressing and Metallurgy Division of the Bureau of Mines at Ottawa with the following results:

Locality--Lizard Creek.
Nature of material--light brown shale.
Amount of sample--3 1/2 pounds.
Water required to temper stiff plastic state--33.3 per cent.
Working properties--good plasticity, works well.
Drying behaviour--small surface cracks in rapid drying.
Average drying shrinkage--7.1 per cent.

Firing Behaviour

Cone	Fire Shrinkage Per Cent	Absorption Per Cent	Colour	Remarks
06	5.7	11.5	Dark Salmon	Hard
03	10.7	0.5	Dark Red	Steel hard near vitrification

Softening point (Pyrometric Cone Equivalent) 9.

Approximate temperature 2,310° Fahrenheit.

Economic considerations--should be suitable for common brick and tile, some face brick might be obtained by sorting.

B. Elk River Exposures--A deposit of buff-coloured plastic clay is exposed along the west bank of the Elk River for a distance of approximately one-half mile near the junction of the Lizard Creek road with the main highway. The clay has an exposed thickness of 20 feet, contains no visible sandy lenses, is thinly bedded (varved), and appears to be of lacustrine origin.

It is reported that in 1902 Mr. Mutz and Mr. Todd operated a brick factory near the above exposures. The locally made brick is said to have been used in a number of buildings in Fernie including the Canadian Bank of Commerce and the old Methodist Church. The brick in these buildings is a pale yellowish buff and appears to have weathered only slightly.

On the east bank of the Elk River and just upstream from the south of Coal Creek, a similar deposit of clay is exposed. Here the clay has an observed thickness of 33 feet, is quite clean except for the top 5 feet where a few thin carbonaceous partings occur. A channel sample of the full thickness, tested by the Bureau of Mines at Ottawa, gave the following results:

Locality--East bank of Elk River at Coal Creek.
Nature of Material--highly calcareous light-grey clay.
Amount of sample-- 6 1/2 pounds.
Water required to temper stiff plastic state--26.5 per cent.
Working properties--slightly flabby, fair workability.
Drying behaviour--small surface cracks in rapid drying.
Average drying shrinkage--6.5 per cent.

Firing Behaviour

Cone	Fire Shrinkage Per Cent	Absorption Per Cent	Colour	Remarks
03	0.7	22.0	Cream	Very soft
1	4.5	13.5	Yellowish cream	Fairly hard

Softening point (Pyrometric Cone Equivalent) 4.

Approximate temperature 2,150° Fahrenheit.

Economic considerations--very short firing range, not recommended for the manufacture of clay products.

GRAVEL AND SAND

Sand and gravel suitable for construction purposes is present in the valley bottoms and terraces of the Elk River and its tributaries. In general the gravel or sand contains a considerable clay fraction so that it is usually necessary to wash the material to obtain a satisfactory product.

PETROLEUM AND NATURAL GAS

Evidence of petroleum in or adjacent to the Crowsnest Coal Basin was observed at the following horizons or localities.

(a) Within the Fernie Formation.

Belemnites from the "belemnite bed," 50 to 240 feet above the base of the formation, give off a strong petroliferous odour when crushed.

(b) At the Base of the Fernie Formation.

The dark phosphatic sandy or shaly beds at the base of the Fernie formation have a noticeable petroliferous odour.

(c) Within the Triassic.

Light-green oil was seen to issue from small calcite-filled vugs in a bed of calcareous shale exposed in a road-cut on Fairy Creek near the water supply intake. The beds are tentatively referred to the Triassic on the basis of lithology and fragmentary fossil content.

(d) Within the Devonian.

Minor amounts of oil were noticed in a porous zone in the lower part of the Devonian limestones in the railway-cut exposures at Crowsnest Lake.

(e) In the Flathead Valley.

Some sandstones of the Tertiary Kishinena formation where exposed on Burnham and Couldery Creeks have a strong odour of petroleum and are locally oil-stained. Oil-seeps issuing from Precambrian strata (described by Hume, 1932) may be seen on Sage and Kishinena creeks.

Porous zones which might act as reservoir rocks were seen only in the Mississippian Rundle formation and in the lower part of the Devonian (excepting the Kishinena formation which is not present within the Crowsnest Coal Basin).

The writer believes the region is an unfavourable one in which to drill for petroleum or natural gas because of:

(a) The excessive drilling depth to reach Mississippian or Devonian beds.

(b) The necessity of penetrating at least 1,000 feet of very hard Rocky Mountain Quartzite to reach porous horizons.

(c) The apparent lack of major unfaulted anti-clinal structures.

CHAPTER VI -- THE CORRELATION OF COAL SEAMS

INTRODUCTION

A method enabling the ready recognition or correlation of coal seams has long been sought by coal operators and geologists throughout the world. Many techniques have been devised but most of the methods have a restricted use or may be regarded as furnishing only additional evidence that may be helpful when used in conjunction with other criteria.

In the Crowsnest area within the Kootenay formation it appears that the coal seams are the most persistent stratigraphic units. Because of the relatively rapid changes in both the thickness of the seams and the interval between seams, difficulty has invariably been experienced in attempts at correlation. Even short-range correlations by able geologists who have worked in the Crowsnest Coal Basin have been questioned by the operating companies. It was apparent, therefore, that a more dependable correlation technique was needed so that stratigraphic and structural studies could be of greatest value.

EVALUATION OF ESTABLISHED METHODS

A survey of the literature showed that the following methods have been used with varying success in the correlation of coal seams.

1. Lithology and Stratigraphy

    (a) Cyclothems (Wanless, 1932)
    (b) Marine bands
    (c) Continuous tracing

2. Plant Remains

    (a) Distribution of Flora
    (b) Spore identifications
    (c) Cellular plant debris

3. Non-marine fossils
4. Inherent characters of the seam
5. Fuel Ratio
6. Coking characteristics

An attempt was made to apply or evaluate the effectiveness of each of these methods in the Crowsnest area. Unfortunately none of the above methods provided a firm basis for correlation.

1. Lithology and Stratigraphy

Comparison of carefully measured and described sections of the coal measures in the Coal Creek area showed a rapid lateral variation of the sediments. Examination of samples of the Kootenay sediments under a binocular microscope failed to reveal useful marker horizons to which the coal seams could be related. However, several of the conglomerates were found to be useful marker beds within limited areas. Attempts to separate heavy minerals from several of the Kootenay sandstones yielded residues that were too small for a satisfactory identification. It was not found possible to study the roundness or sphericity of sand grains because of the tendency for the sandstones to break through rather than around the grains.

(a) Cyclothems

In the central and eastern United States Wanless (1932) made effective use of cyclical repetition of strata in the correlation of coal seams. Comparable conditions were not found to be present in the Crowsnest Coal Basin.

(b) Marine bands

With the possible exception of the Basal Kootenay sandstone, strata that could be regarded as marine were not discovered in the Kootenay formation.

(c) Continuous tracing

In both the Fernie and Michel areas it was found possible to follow a few of the seams from one area to another by walking along the outcrop. Unfortunately this positive method of extending known data was seldom practicable because the outcrops were often concealed by overburden or vegetation.

2. Plant Remains

(a) Distribution of flora

In the Nova Scotian coal field Bell (1945) has used variations in number and variety of plant species collected from the roof shales of coal seams to establish a useful method of correlation. In the Fernie area plant remains were collected from coal seams throughout the Kootenay formation. The collections, which were identified by Dr. Bell at Ottawa, were found to contain only long-ranging species, none of which could be regarded as useful for correlation. Attempts to estimate the percentage distribution of species in several seams failed to give consistent or useful results.

(b) Spore studies

In England Raistrick (1933, 1934) and in the United States Thiessen (1924) have developed successful methods of correlation based on studies of the nature and distribution of microspores and megaspores in the coal seams. An attempt was made to apply the described methods to the Fernie and Michel coals.

Polished sections of cubes of coal from four of the Fernie coals were prepared for microscopic examination. A study of both polished and etched surfaces did not reveal the presence either of spores or of significant textural differences such as those described by Williams (1926).

Maceration of samples of coal from a number of the seams in both the Fernie and Michel areas was undertaken following a procedure suggested by Dr. L. R. Wilson at Amherst College. Two and one-half grams of the finely broken coal was mixed with an equal weight of potassium chlorate. The mixture was covered with 50 cubic centimetres of concentrated HNO_3 and allowed to stand. The coal was allowed to stand in the oxidizing mixture (Schulze solution) for varying lengths of time, ranging from 12 hours to several weeks. A period of 6 days appeared to yield the most satisfactory results. The beaker containing the solution was then filled with water, stirred, and allowed to settle before decanting. The residue was covered with concentrated NH_4OH, stirred and allowed to stand for a day. The mixture was then diluted with water, stirred and let stand till it had settled. The liquid was poured off, a little water was added and the mixture stirred. A few cubic centimetres of this solution were then centrifuged until the odour of ammonia had disappeared. After centrifuging, a few drops of the solution were placed on a glass slide and examined under the microscope for the presence of spores. In some instances a one per cent solution of saffranine was added to the solution after primary centrifuging. The excess saffranine was removed with cellosolve and further centrifuging.

Some fifty samples of coals from the Fernie and Michel areas were macerated and studied.

Only a small percentage of the coal appeared to be disintegrated after it had been subjected to the above procedure and perhaps because of this very few spores were obtained. Experiments with various oxidizing agents other than Schulze solution, and attempts to soften the coal by presoaking in pyridine, were unsuccessful. For most of the samples no spores were isolated but in a few cases two or three spores per microslide were obtained. It was apparent, therefore, that the method could not be successfully used as a basis for correlation of these Kootenay coals.

I. W. Jones (1936) in his study of Kootenay coals of Alberta concluded that few spores are present, and the writer's investigations suggest that this is also the case in the Crowsnest Coal Basin. In this regard it is interesting to note that Fanshawe (1930) has observed that coking coals in general have a noticeably low spore content. A survey of North American literature revealed only one reference by E. L. Miner (1935) describing Lower Cretaceous (Kootenai) microspores. Because the spores observed in this study differed from the three species described by Miner, a brief description of them is given here.

Microspores from Coal Creek Coals

Number 9 Coal Seam

No. 1--The exine is round, brown in colour, with no surface markings (psilate), and has a diameter of 20 microns.

No. 2--The exine is round, greyish-brown in colour, with a granular surface and a diameter of 15 microns.

No. 3--The exine is shield-shaped with thickened walls, pale brown in colour, psilate, with a length of 14 microns.

No. 4--The exine is prolate, brown in colour, psilate, with a long axis of 22 microns and short axis of 8 microns.

Number 4 Coal Seam

No. 5--The exine is round, pale grey-brown in colour, 20 microns in diameter, with a granular central nucleus 10 microns in diameter, surrounded by fine radial markings.

No. 6--The exine is round, almost colourless, psilate, 7 microns in diameter.

Species No. 1 was found to be present in several of the Coal Creek seams, species No. 3 was found in both No. 9 and No. 4 seams.

(c) Cellular plant debris

Cellular plant material was readily recognized in the polished section and maceration studies. None of the material noted appeared to characterize any one coal seam.

3. Non-marine fossils

The few non marine invertebrates that have been found in the Kootenay formation are long-ranging species that are apparently of little value for purposes of age, determination, or correlation.

4. Inherent characters of the seam

Such properties of the coal seam as its thickness, the nature of the roof or floor, character of the coal (e.g. the relative amounts of bright and dull coal), the nature and number of shale partings, may be of considerable aid in seam identification within limited areas. Unfortunately these characteristics are subject to rapid lateral variation, so that where such data are used as a basis for correlation the method is subject to an error that usually increases with the distance of projection involved.

5. Fuel Ratio

In a report on the Michel Coal area B. R. MacKay (1933) has used as a basis for correlation the fuel ratio of several of the seams as well as the interval of the seams to a conglomerate marker bed. Because the interval to the marker bed was subject to variation, the fuel ratio became the deciding factor in the identification made.

Numerous proximate analyses of several of the Coal Creek seams were available for reference at the offices of The Crow's Nest Pass Coal Company. Some of them were tabulated in order to see what variations might be expected within a given seam and between several seams. The seams investigated are: No. 10, No. 9, and No. 5.

The variation both of individual values and of averages of several samples within one seam is such as would exclude the possibility of seam identification in the Coal Creek area being based on the determination of fuel ratios. However, it is interesting to note that the tabulation of proximate analyses indicated an increase of fuel ratio in the direction of the lower seams, which one would expect from Hilt's law.

The more easterly and more deeply covered part of No. 10 seam, represented by the samples from the No. 1E mine, has the highest fuel ratios. A similar eastward increase exists in the No. 9 seam where the No. 3 mine is east of and down dip from the two other sampled areas. It appears that the variation in the load supported by the seams here considered has resulted in a situation where a part of the uppermost seam has a fuel ratio (2.80) that differs but slightly from the fuel ratio (2.82) of a seam several hundred feet lower in the section. Inasmuch as comparable conditions may exist in other parts of the Coal Basin, it seems unlikely that correlations based on fuel-ratio determinations could be made successfully.

6. Coking characteristics

In the Coal Creek and Michel areas many of the coals studied had similar coke-forming properties, and for that reason that characteristic has little chance of being helpful in identifying seams.

NEW TECHNIQUES

Two additional methods were studied in the hope of developing a correlation technique applicable in this coalfield. The methods studied involve:

A. Determination of the radioactivity of samples of coal from several seams.

B. Semi-quantitative spectrographic analyses of the ash from samples from several coal seams.

1. Radioactivity Measurements

Six 30-gram coal samples from each of four of the seams at Michel were tested with the Geiger-Mueller counter at the Department of Mines laboratory. Each of the twenty-four samples was left in the counter for a period of 150 minutes, and the radioactivity count (less the background) was recorded.

It was found that when the values obtained were plotted on a graph of radioactivity versus ash content, that a direct relationship existed. The higher ash samples showed correspondingly larger radioactive values. The results obtained, therefore, were considered useless for purposes of correlation.

2. Spectrographic Analysis of Coal Ashes

Introduction--It had been noted that the ash from certain seams in both the Michel and Fernie areas appeared to have a colour that was distinctive. For instance, the ash from some samples was quite red; from some pure white; and from others cream or maroon-coloured. These colours could be attributed to the iron, silica, or alumina content of the ash.

As may be seen in the following table, determinations by Swartzman (1940) showed differences in the fusion point and chemical composition of the ash of two of the Michel coals.

Seam No.	SiO_2	Fe_2O_3	Al_2O_3	CaO+ MnO	MgO	K_2O	P_2O_5	TiO_2	SO_3	Total
"A"	51.3	4.4	35.5	2.4	1.3	0.8	0.1	1.5	2.5	99.8
"B"	47.3	19.1	20.2	3.8	1.6	1.9	0.9	0.7	4.5	99.9

Seam No.	Ash Fusion Point Initial Deformation
"A"	2, 650-2, 850+° Fahrenheit
"B"	2, 040-2, 850+° Fahrenheit

Note: The samples were of 0- to 4-inch run of mine coal.

It was felt that semi-quantitative analyses of the ash from various coal seams should indicate whether certain elements might be present only in one seam, or might be present in unusual concentration. Moreover, the use of spectrographic analyses as an aid to correlation of stratigraphic sections had been recently demonstrated in a paper by Sloss and Cooke (1946), to which the reader is referred for a more extensive treatment of analytical technique and theory than will be given here.

It was decided, therefore, to undertake a sampling and ash analysis programme. The Michel area was selected for two reasons. (1) A problem of seam identification had arisen in the underground operations at the Michel colliery, and (2) accessible underground workings at Michel are the most extensive in the coalfield.

Previous Work

A rather extensive study of the rare elements present in coal ash has been made by V. M. Goldschmidt (1933). In his report

Dr. Goldschmidt observed that various rare elements have been concentrated in coals and suggests that the most important processes are:

1. Concentration processes during the life of the plants.

2. Concentration processes after decay of the plant parts concerned, and during the rotting and decomposition of plant substance.

3. Concentration processes resulting from the circulation of aqueous solutions through the beds of coal.

Goldschmidt believed that a tenfold to one hundredfold increase above the average content was principally produced by the leaching of rotting and decaying plant parts. For germanium, however, both Goldschmidt and Egorov (1940) have suggested that the concentration is due to the chemical effect of the coal on solutions circulating next to it. Goldschmidt observed that the content of some of the rare metals is high in the ash from low-ash coals, particularly germanium.

Use of the metal content of coal ash to correlate seams in the Charleroi Basin in France was attempted by Legraye and Coheur (1944). These authors detected the presence of aluminium, magnesium, iron, silica, calcium, copper, sodium, potassium, manganese, nickel, chromium, titanium, lead, zinc, tin, cobalt, strontium, vanadium, and beryllium in the ashes studied, but concluded that no element or group could serve to characterize any one bed. The spectrographic analyses made were on a qualitative basis only, so that variations in amount of the elements present was not observed.

Sampling Programme

At the start of the investigation twelve samples from each of the two most extensively mined seams in the Michel area were obtained (see Figs. 14, 15, 16, 17). Semi-quantitative spectrographic analyses of the ash from these samples of "A" and "B" seams showed that considerable differences existed in the amount of some of the elements present in the two coals. It was decided, therefore, to obtain an additional twelve samples from each of these seams at points as far distant from the original areas sampled as was possible. In addition samples were obtained from two of the lower coal seams, upper No. 3 (U3) and lower No. 3 (L3) seams. A seam encountered near the face of the Michel rock tunnel, and believed to be either U3 or L3 seam, was also sampled with the hope that a positive identification could be made. This seam and the samples from it were given the designation U3?. Attempts to identify this seam based on determination of stratigraphic intervals had yielded inconclusive results because of local complex folding of the strata.

All of the samples taken were full channel samples of the coal seams. The face of the coal was first cleaned of visible impurities, such as rock dust, and a channel several inches wide and a few inches deep was cut through the coal. The chips of coal thus obtained were quartered on a sampling cloth, placed in bags, and transferred to the grinding room at the Michel Colliery. Here each sample was ground to minus 20 mesh, coned and quartered, and a representative amount placed in a pint glass sealer for shipment to the laboratory. The locations of the areas sampled are shown on the accompanying plans and cross-section (Figs. 14 to 17 inclusive). The relative stratigraphic positions of the seams that were sampled are approximately as follows:

TOP

"B" seam--6 feet thick
    120-foot interval
"A" seam--22 feet thick
    260-foot interval
Upper No. 3 seam--10 feet thick
    150-foot interval
Lower No. 3 seam--7 feet thick

Analytical Technique

The analyses were made by the Chief Analyst of the British Columbia Department of Mines on an A.R.L. Dietert spectrograph using an aluminized grating with a dispersion in the first order of 7 Angstroms per millimetre. Only the ultra-violet spectra were obtained. "Super pure"-grade graphite electrodes, one-quarter inch in diameter were used, operating on a 10-ampere 220-volt direct-current source.

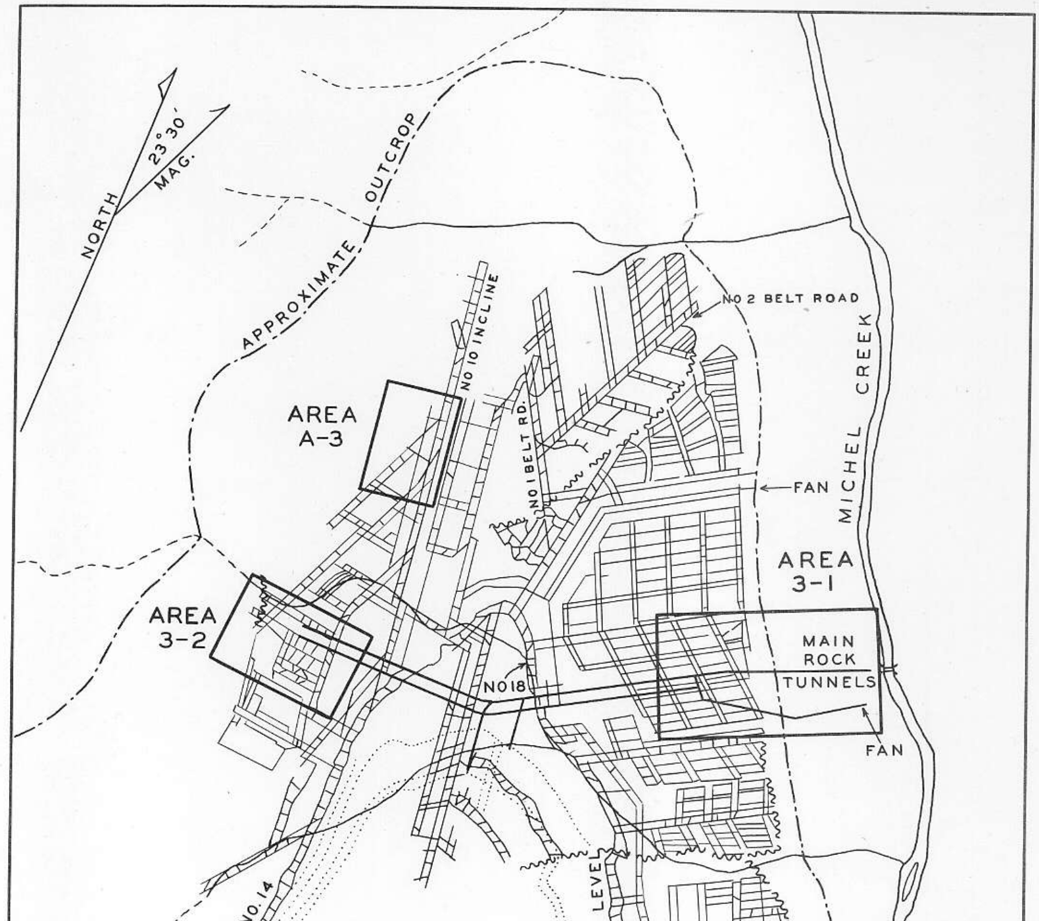

Fig. 14.

Sampled areas, A, U3, L3 seams, Michel Colliery.

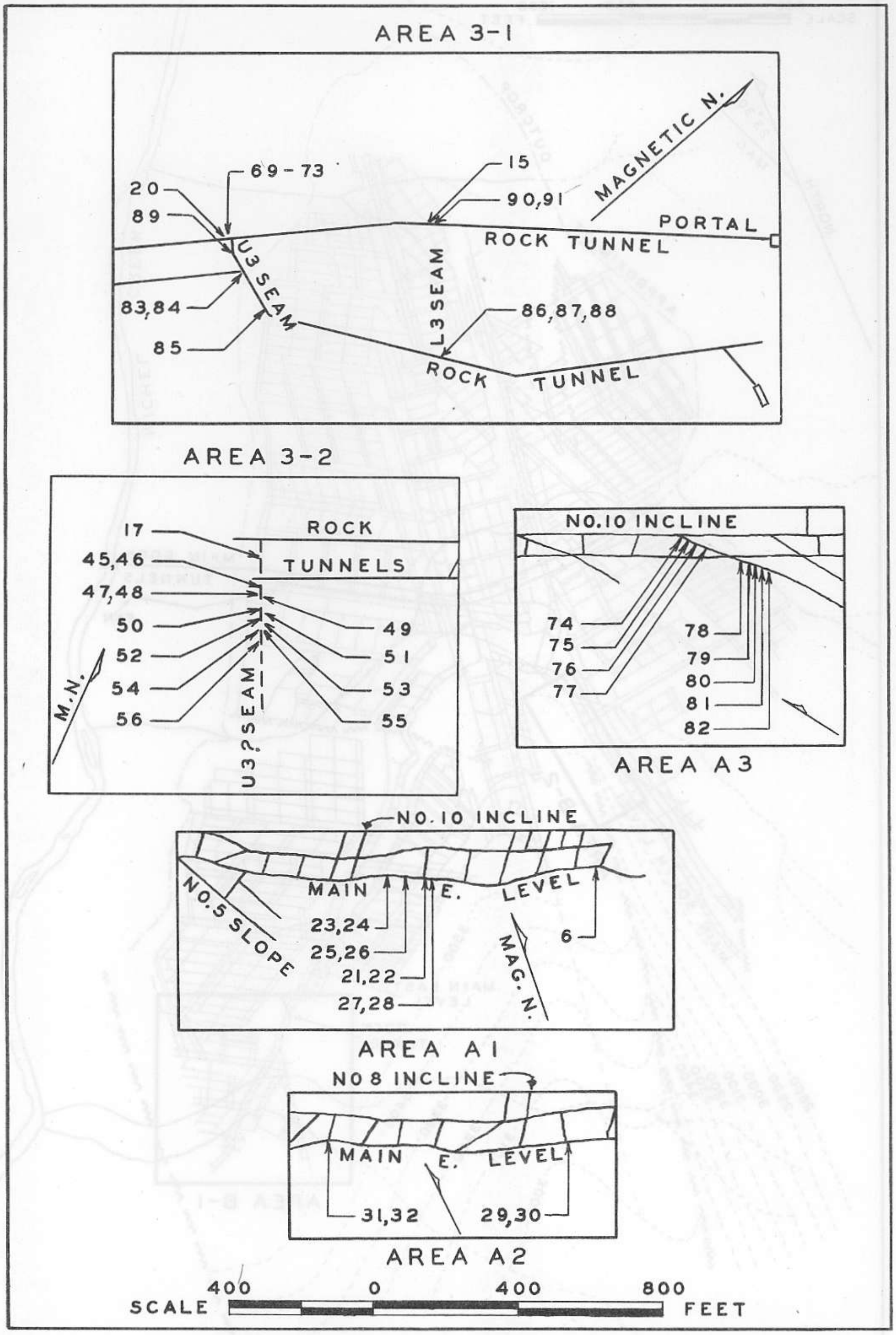

Fig. 15.

Location of channel samples, seams A, U3, and L3, Michel Colliery.

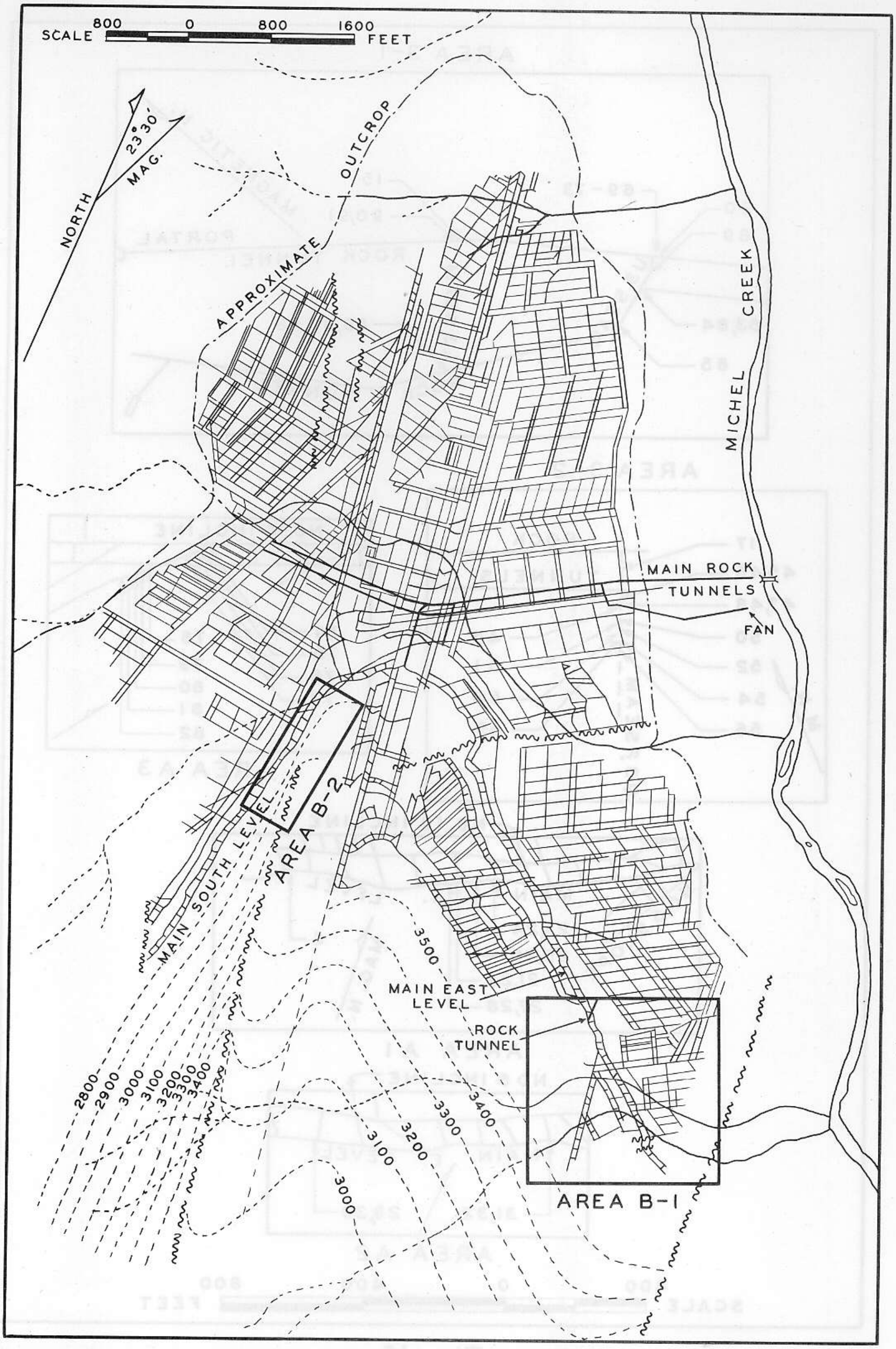

Fig. 16.

Sampled areas B seam, Michel Colliery.

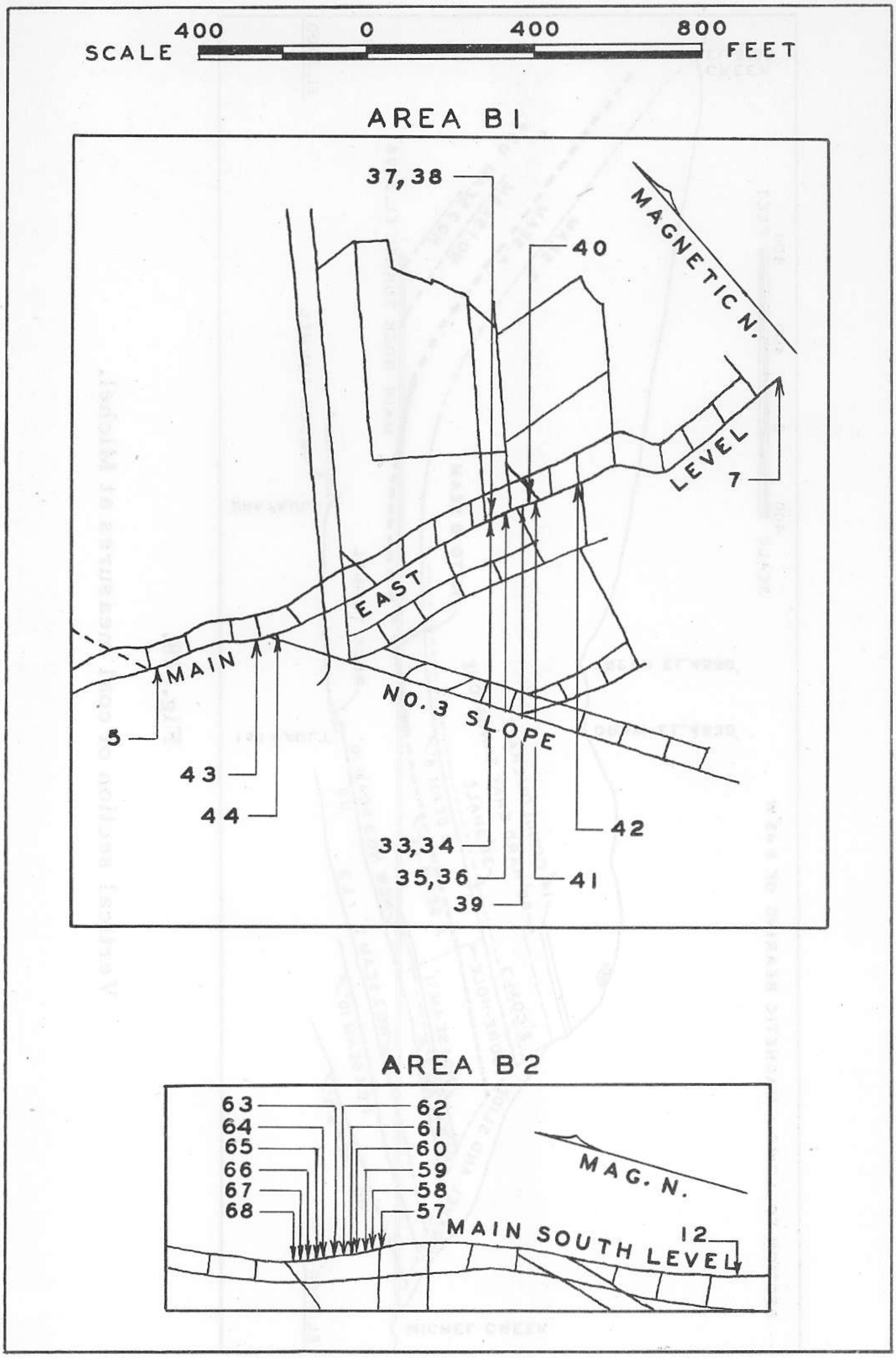

Fig. 17.

Location of channel samples, B seam, Michel Colliery.

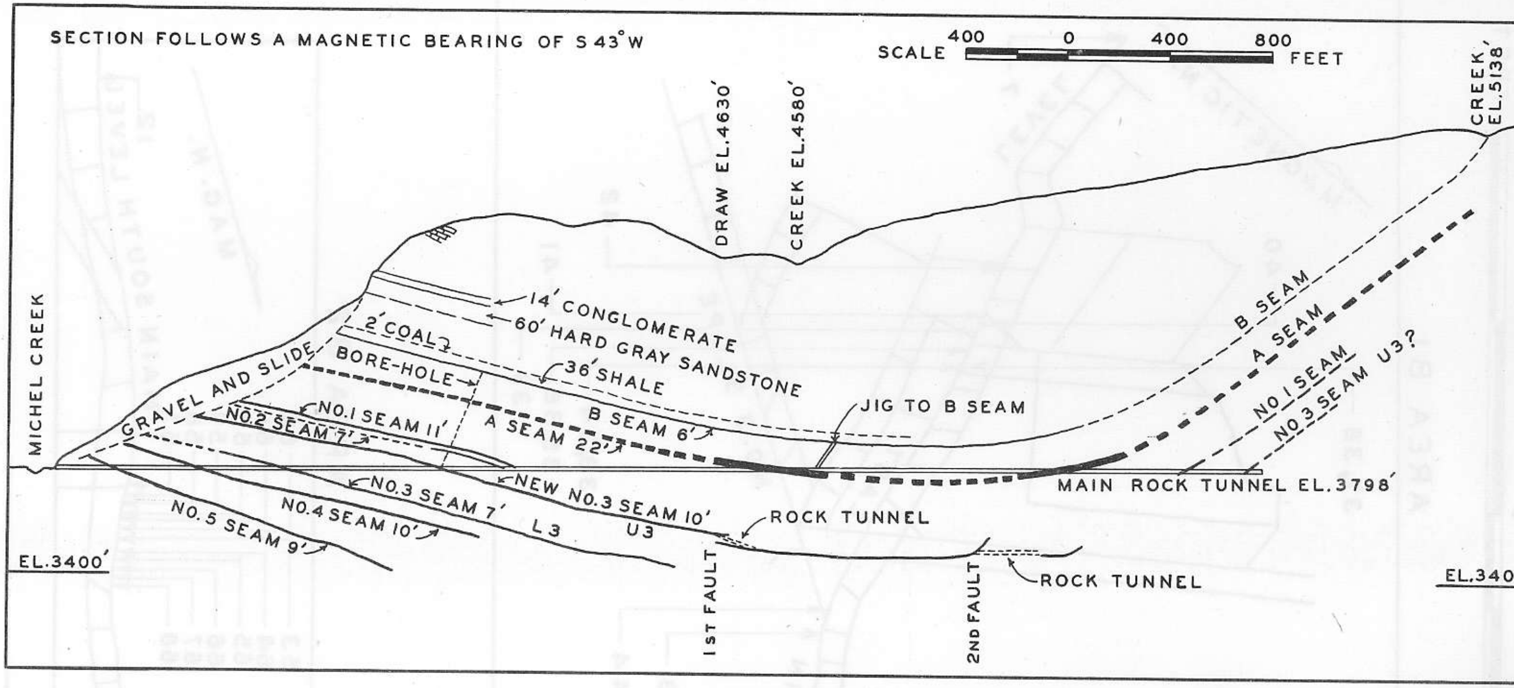

Fig. 18.

Vertical section of coal measures at Michel.

The coal was further ground to minus 60 mesh, ashed at 750° Centigrade[1] and after thorough mixing a 50-milligram sample was arced directly. With the arc burning, a piesector was caused to rotate in the light beam thereby reducing the incident intensity to 30 per cent. After a 20-second exposure under these conditions the camera was racked with the arc still burning, and a 130-second exposure made using a 10 per cent sector. The camera was again racked and the spectrum photographed with a 10 per cent sector until the remainder of the sample had been completely vaporized (approximately another 130 seconds). The full procedure was repeated, sometimes several times, to provide a eheck on the values obtained. For each of the elements detected the relative content, indicated by the intensity of the spectral line, was recorded by densitometer readings which were converted to intensity numbers by means of an emulsion calibration curve. These values were scaled down to numbers between 1 and 10 for ease in comparison.

The spectrochemical procedure is not strictly quantitative and the values have not been converted to percentages. For any selected element the values tabulated may safely be taken as a measure of the amount of that element present in the various samples but may not be used to compare the content of different elements in the same sample or in different samples.

Results Obtained

The following elements were detected in the ash from many of the samples: silicon, boron, phosphorus, iron, magnesium, manganese, lead, titanium, chromium, gallium, calcium, aluminium, germanium, barium, molybdenum, vanadium, silver, ytterbium, sodium, zinc, zirconium, nickel, cobalt, strontium, copper, potassium. In addition beryllium, scandium, antimony, neodymium, lanthanum, bismuth, and tin were present in a few of the samples. The elements found to be most useful in correlation include sodium, barium, silicon, vanadium, and magnesium. Variations in the nickel, strontium, and aluminium content were also helpful. It is interesting to note that the eight elements found useful in the correlation of

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[1] For the exact quantitive analyses of coal ash, 500° Centigrade would be chosen for the ashing temperature, in order to minimize the possibility of partial volatilization of certain elements.

coal seams include magnesium, strontium, and aluminium, the three elements found most dependable by Sloss and Cooke (1946, p. 1897, Fig. 3).

The spectrographic results of the coal ashed analysed are given in Table I. The results are arranged to facilitate a comparison between the pairs of seams "A" and "B" and also the comparison of samples from U3 and L3 seams with each other and with samples from Area 3-2, believed to represent either U3 or L3 seam and termed U3?. Average values for the areas sampled within each seam, as well as averages for the whole seam are given, and are repeated as a group at the bottom of the table to permit a ready comparison of the average values. For each of the elements listed the wave length at which the determinations were made is given in Table I. The two columns at the right of the table represent combinations of values for elements that are useful in identifying L3 and "B" seams.

Effect of Ash Content

An attempt was made to determine what relationship, if any, exists between the ash content of the coals and the element content of the coal ashes. Table I shows that the element germanium is recorded in few of the analyses. However, it is present in half of the samples from area B-2 (samples 57-68, see Figs. 16 and 17) which were the lowest ash coals studied. This concentration of values may be regarded as corroborating Goldschmidt's observation that germanium tends to be concentrated in the low-ash coals.

With regard to the atber elements present, no direct relationship between ash content and trace-element content was discerned. The analyses given here were arranged in order of increasing ash content for each of the coal seams, and graphs of ash content versus element content were constructed. No definite trend was apparent. However, high values in nickel were generally in the ash from coals carrying less than 6 per cent ash, but in coals containing more than 6 per cent ash a diminution of nickel values with increasing ash was not apparent. Average values of some of the elements regarded as useful for correlation purposes for several of the seam areas, arranged in order of increasing ash content, are given in the following table:

Average Values* for Selected Elements

Seam No.	Area	No. of Samples	Ash Per Cent	Si	V	Mg	Na	Ni	Sr	Al	Ba	Zn
B	B-2	12	4.4	3.4	4.6	3.3	6.3	6.7	5.8	4.8	-	5.5
U3	3-1	9	7.5	3.9	4.7	3.2	-	5.8	2.9	6.6	5.4	2.9
U3?	3-2	12	9.8	3.8	4.1	3.1	-	2.0	2.4	4.8	5.3	2.2
A	A-3	9	11.3	5.8	5.4	3.4	-	1.1	0.9	8.0	-	2.9
A	A1-2	12	12.5	2.7	3.7	2.8	0.3	1.3	1.4	4.2	-	4.5
B	B-1	12	16.7	5.0	5.6	3.8	3.9	3.2	2.0	3.3	0.1	3.3
L3	3-1	5	25.9	7.0	8.2	5.6	-	2.6	0.4	5.6	2.0	5.4

* The value tabulated, for an element in a sample, is not the percentage of the element present, but is a number that is roughly proportional to the percentage. The number 10 is the highest rating used (see p. 93). The same number used for two different elements does not imply that the elements are present in the same amount or percentage.

Effect of Ash Content--Editor's Note

It should be noted that the presence of a particular element or the content of a particular element in a sample of coal may be characteristic either of the coaly matter or of the extraneous matter in the coal seam. The extraneous matter consists of rock grains or other mineral matter rather than of plant remains. Usually the extraneous matter contributes the major part of the ash, and variation in the proportion of extraneous matter is the principal reason for variation in the percentage of ash between different samples from the same coal seam. Some of the variations in the content of the elements in different samples of coal are probably traceable to variations in the proportion of extraneous matter and accordingly to variations in the ash content, rather than to variations in the element content of the coaly matter.

With these thoughts in mind an attempt was made to separate the coaly matter from the non-coaly matter of a sample. This phase of the investigation was limited by the fact that the samples had already been finely ground and when the separation was attempted only about 10 per cent of the sample was retained on a 150-mesh screen. The separation was made on this "plus 150-mesh" material because it was considered that the very fine material would not react according to the specific gravity of the grains.

The sample studied consisted of 5.1 grams of -100 and +150 mesh coal from sample No. 88 from seam L3 which had an ash content of 35 per cent. A separation into two fractions was effected using a heavy liquid (carbon tetrachloride and benzine) having a specific gravity of 1.31. The float fraction weighed 1.9 grams (a yield of 37 per cent clean coal) and had an ash content of 2.1 per cent. The sink fraction weighed 3.2 grams and had an ash content of 40.9 per cent. The results of spectrographic analyses of the two fractions rated in a manner similar to the rating of the other spectrochemical results follow:

Element	Sink	Float	1881M
Silicon	8	2	10
Barium	9	6	8
Phosphorus	1	10	1
Iron	1	1	1
Magnesium	6	3	6
Manganese	1	2	1
Lead	1	2	1
Titanium	1	10	5
Chromium	4	5	4
Gallium	2	10	5
Calcium	0	4	-
Aluminium	6	3	6
Germanium	0	5	-
Barium	-	-	-
Molybdenum	1	5	-
Vanadium	1	10	7
Silver	1	5	-
Ytterbium	1	7	-
Sodium	-	-	-
Zinc	1	4	-
Zirconium	1	10	5
Nickel	1	10	2
Cobalt	1	8	-
Strontium	1	4	-
Copper	2	3	3
Potassium	5	0	5

The spectrographic analyses of the ash and of the sink and float fractions represent analyses of the ash of only part of the original sample. It is unlikely that this 10 per cent was truly representative of the original sample. However, the differences between the analyses of the sink and float products indicate that similar treatment of coal samples might have an important bearing on the usefulness of the method proposed by Mr. Newmarch.

This phase of the investigation was not undertaken until shortly before Mr. Newmarch left the services of the Department of Mines and for that reason was not pursued further. Editor.

An examination of the average values in Table I* shows that few of the elements detected are found only in a single seam. However, sodium and barium are significant exceptions to this general tendency, and hence provide a convenient basis for correlation. On referring to Table I, it may be seen that sodium is present in all samples from "B" seam but is absent from all samples of the other seams with the exception of sample No. 30. Barium is absent from the samples of "A" and "B" seams (with one exception) but is present in almost all of the samples from U3 and U3? seams and in three of the five samples from L3 seam. From this distribution it follows that an ash analysis could be recognized as being from "B," "A," or U3 seam with the following criteria:

Presence of sodium--Sample is from "B" seam.
Absence of both sodium and barium--Sample is from "A" seam.
Presence of barium--Sample is from U3 seam.

The three samples Nos. 35,30, and 73, exceptions to the foregoing rules, represent a small percentage error inherent in applying the above criteria.

The investigation was undertaken with the thought that it might lead to results such as have been outlined. In studying the results of the spectrochemical analyses it became apparent that the validity of the conclusions should be investigated by statistical analysis. This statement is particularly true for the argument that follows, in which the thought is advanced that in addition to considering the presence or absence of one

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* In pocket

or several particular elements, we may also consider that for one element or for several elements a range of values established by experiments may be characteristic of a particular coal seam.

For example, for some of the elements present in all four of the seams, the values may be notably high or low in one of the coal seams. On referring to Table I it may be seen that the average value for nickel in "B" seam is much higher than in the other seams represented. A high value for strontium and a low value for aluminium also characterize "B" seam. The average values for silicon, vanadium, and magnesium are distinctly higher in L3 seam than in the other three seams.

To determine definitely whether or not such differences in element content constitute a reliable basis for seam identification would require a rigorous statistical analysis of all the results obtained from the analyses of the writer's samples, and probably also a more searching and extensive sampling programme. The writer did not make a rigorous statistical analysis of the problem and discussion of such an analysis is outside the scope of this bulletin.[(1)] However, the writer believes that variations in the values for certain elements may be useful in identifying particular coal seams, especially if the data are analysed statistically, provided that for each one of several elements, a definite value or range of values can be established for a particular seam and that it is different from the value or ranges of values in other seams in the same coalfield. The writer believes that a sum of the values for a selected group of elements may be taken as characteristic of a definite seam, and that similarly such a sum reduced by the value for one or more other elements may be used in the same way. The writer selected

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(1) The problem is outlined and an approach to statistical analysis is discussed in a paper, The Correlation of Kootenay Coal Seams, by Charles B. Newmarch, C.I.M.M. Trans., Vol. LIII, 1950, pp. 91-98.

eight elements as most useful in the effort to identify the coal seams being considered. The values for seven of these elements were combined as indicated in the next two paragraphs.

This technique may be used to identify L3 seam. On referring to Table I it will be seen that the average values for silicon, vanadium, and magnesium are noticeably higher in L3 seam than in any of the other coal seams. When these average values for silicon + vanadium + magnesium (Si + V + Mg) are combined a value is obtained that is approximately twice as high for L3 seam as it is for each of the other seams. This value has been oomputed for each ash analysis in Table I (see second column from the right) and the results have been shown graphically in Fig. 19. On referring to this graph it can be seen that the values of silicon + vanadium + magnesium for L3 seam are 18 or greater, and that the values for samples from the other seams are less than 18 with the exception of two samples from "A" seam.

The recognition of "B" seam may be accomplished by use of the combination Na + Ni + Sr – Al. As can be seen from Table I this combination of elements is effective because the values for sodium, nickel, and strontium are highest, and the aluminium values are lowest, in "B" seam. The combined values for each sample and for the averages are given in the right-hand column of Table I, and are shown graphically in Fig. 19. On the graph it is evident that all the values for "B" seam lie above a value of +2, whereas values from the other seam samples are all below the +2 line. Coal-seam identification on the basis of a single ash analysis may be accomplished with the following criteria.

1. If Si + V + Mg is less than 18--the sample is from "B," "A," or U3 seam.
2. Presence of sodium--sample is from "B" seam.
3. Absence of sodium and barium--sample is from "A" seam.
4. Absence of sodium and presence of barium--sample is from U3 seam.
5. Si + V + Mg is 18 or greater--sample is from L3 seam.

The average values for those elements considered useful for correlation may be portrayed in the form of a histogram, which should have a distinctive shape for each coal seam. This has been done in Fig. 19, each seam being represented by a 3-column diagram. The value for sodium is plotted in column 1, the barium value in column 2, and the Si + V + Mg in column 3. The marked similarity of the diagrams for U3? and U3 samples suggests that the coal seam termed U3? may be correlated with U3 seam.

Conclusions

The preliminary results here presented suggest that correlation of coal seams may be possible by statistical analysis of the composition of the ash. For dependable correlations, ash analyses of an adequate number of samples from each seam must be available. Quantitative spectrographic or chemical analyses may be of particular value in making correlation possible in areas where other known methods yield inconclusive results.

Because this investigation was limited to an area of only 8,000 feet by 4,000 feet many more analyses will be needed to ascertain whether the method can be applied in larger areas. It should also be determined whether the method will be useful where many more coal seams are involved, and whether it can be applied in other coalfields.

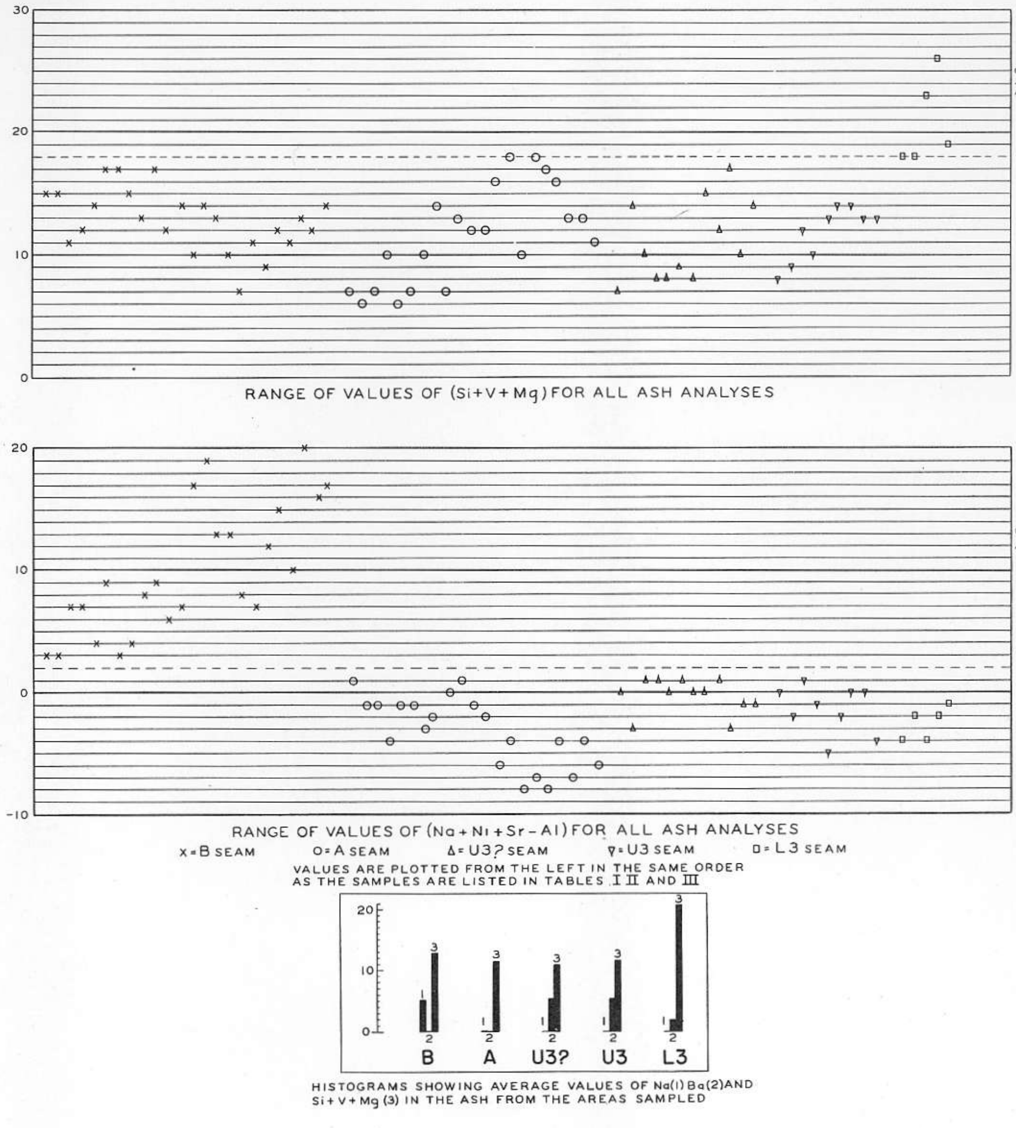

Fig. 19

Graphs representing ranges of values for certain elements in ash from coal samples, Michel Colliery.

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WEATHER RECORD, FERNIE, BRITISH COLUMBIA, 1914-1947

Precipitation in Inches				Total Snowfall, etc.							
Year	Rain	Snow	Total	Winter of	Snow Inches	Zero Days	Coldest Day	Year	Latest Frost in Spring	Earliest Frost in Fall	Warmest Day
1914	29.93	125.94	42.52	1914-1915	71.5	28	Jan. 27-14.5°	1914	May 7-28°	Sept. 29-31°	Aug. 1-91.2°
1915	20.72	136.70	34.39	1915-1916	201.6	37	" 12-35°	1915	Apr. 25-29.5°	" 11-32°	" 7-88.0°
1916	27.04	156.18	42.66	1916-1917	123.77	45	" 31-27.5°	1916	June 12-32°	Aug. 20-31°	July 13-87°
1917	20.95	158.70	36.82	1917-1918	135.15	34	" 31-29.0°	1917	" 4-29°	Sept. 29-27°	" 17-90°
1918	26.56	85.50	35.11	1918-1919	98.80	14	Feb. 24-28.5°	1918	" 4-30°	Aug. 28-31°	" 19-93°
1919	17.27	100.40	27.31	1919-1920	99.50	37	Dec. 12-32°	1919	" 12-29°	Sept. 22-29°	" 16-93°
1920	33.55	88.05	42.35	1920-1921	120.33	10	Feb. 6-10.5°	1920	" 26-31°	" 7-32°	" 18-90.5°
1921	32.47	130.80	45.55	1921-1922	95.10	35	" 24-23°	1921	May 29-32°	" 2-30.5°	" 20-88.2°
1922	24.87	113.30	36.20	1922-1923	140.60	37	Dec. 14-35°	1922	" 23-28°	" 25-32°	Aug. 2-9-89.0°
1923	23.76	135.10	37.27	1923-1924	86.40	16	Jan. 1-37°	1923	" 29-30°	" 6-32°	July 23-24-90°
1924	25.49	121.30	37.62	1924-1925	160.30	24	Dec. 18-34°	1924	" 30-30°	Aug. 30-31.5°	" 1-96°
1925	25.11	92.10	34.32	1925-1926	50.90	0	Jan. 22-+0.5°	1925	" 26-31°	Sept. 20-26°	June 28-94°
1926	27.95	83.80	36.33	1926-1927	171.30	24	" 21-36°	1926	June 10-21°	" 5-32°	July 1-93°
1927	31.89	213.50	53.24	1927-1928	141.80	32	Dec. 31-35°	1927	" 1-32°	" 9-32°	" 25-89.5°
1928	32.37	71.20	39.49	1928-1929	80.10	37	Jan. 23-31°	1928	May 14-32°	Aug. 28-30°	" 27-91.0°
1929	20.10	100.50	30.15	1929-1930	83.60	33	" 16-28°	1929	June 23-31°	" 25-31°	Aug. 1-90.5°
1930	22.62	61.20	28.74	1930-1931	75.10	7	" 8-3°	1930	May 26-31°	Sept. 1-28.5°	" 10-91.0°
1931	23.78	130.60	36.84	1931-1932	189.0	36	Feb. 2-24.5°	1931	" 22-32°	" 16-31°	July 10-25-89.0°
1932	35.44	191.70	54.61	1932-1933	184.60	31	" 10-38.5°	1932	" 26-26°	" 2-30.5°	" 29-90°
1933	36.39	188.80	55.27	1933-1934	147.10	9	Dec. 16-11.5°	1933	" 28-30°	" 8-29.5°	June 15-97°
1934	26.39	125.80	38.97	1934-1935	192.20	24	Jan. 20-39°	1934	June 4-32°	" 20-18°	July 28-95.5°
1935	21.28	165-40	37.82	1935-1936	156.10	44	Feb. 15-34°	1935	" 6-32°	" 18-30°	" 13-91°
1936	16.78	158.70	32.65	1936-1937	161.30	52	Jan. 20-35°	1936	May 18-32°	Aug. 29-30°	" 20-94°
1937	26.69	175.80	44.27	1937-1938	152.70	20	" 30-20°	1937	" 31-31°	" 29-30°	(June 29-92° (July 24-92°
1938	22.24	137.10	35.95	1938-1939	131.20	21	Feb. 10-40°	1938	" 20-29°	Oct. 7-31°	July 14)-93° July 15)
1939	26.20	101.40	36.34	1939-1940	57.10	12	Jan. 21-11°	1939	June 2-30°	Sept. 7-30.5°	July 27.95°
1940	26.36	99.80	36.34	1940-1941	96.85	15	Nov. 12-18°	1940	May 27-32°	Oct. 5-31°	" 12-93°
1941	35.40	59.15	41.31	1941-1942	58.00	17	Jan. 7-18°	1941	" 10-30°	Sept. 8-29°	" 16-94°
1942	29.88	118.90	41.77	1942-1943	170.70	34	" 17-30°	1942	" 19-31°	" 18-28°	" 3)-88° " 6)
1943	24.73	102.30	34.96	1943-1944	55.00	17	Feb. 22-9°	1943	" 18-30°	" 3-32°	" 21)-87° " 22)
1944	19.94	70.20	26.96	1944-1945	109.6	17	Mar. 18-18°	1944	" 4-30°	" 18-27°	" 28-89°
1945	27.30	154.80	42.78	1945-1946	175.8	11	Jan. 26 & 27-12°	1945	June 15-32°	July 19-32°	Aug. 7-90°
1946	26.44	181.70	44.61	1946-1947	129.5	37	Feb. 1-20.5°	1946	May 21-31°	Sept. 19-28°	July 21-88°
1947	34.98	91.50	44.13	1947-1948	113.9 until Mar. 1	28	" 6-21.0°	1947	June 21-32°	Sept. 6-32°	July 14-90°
1948								1948			
1949								1949			
1950								1950			

Heaviest Rainfalls on record (July 26, 1921--3 p.m. to 5.p.m. 1.91"
(Oct. 25-26, 1922 4.16")
(Dec. 1-2, 1941 4.18") in 24 hours

Coldest Day on record--Feb 10, 1938 40° below zero
Hottest " " " --June 15, 1933 + 97°

Heaviest Snowfall on record--Dec. 10, 1922 25"
" 9, 1922 5"

Highest Barometer Jan. 4, 1924. 27.298
Lowest " Dec. 6, 1923.)
Jan. 11, 1932) 25.500

Latitude 49° 30' 15"
Longitude 115° 03' 45" Height above sea-level 3305'

Average Snowfall 1914-1945 Inc. 123"

Data compiled by the Fernie weather-recording station, maintained by The Crows Nest Pass Coal Company Limited.

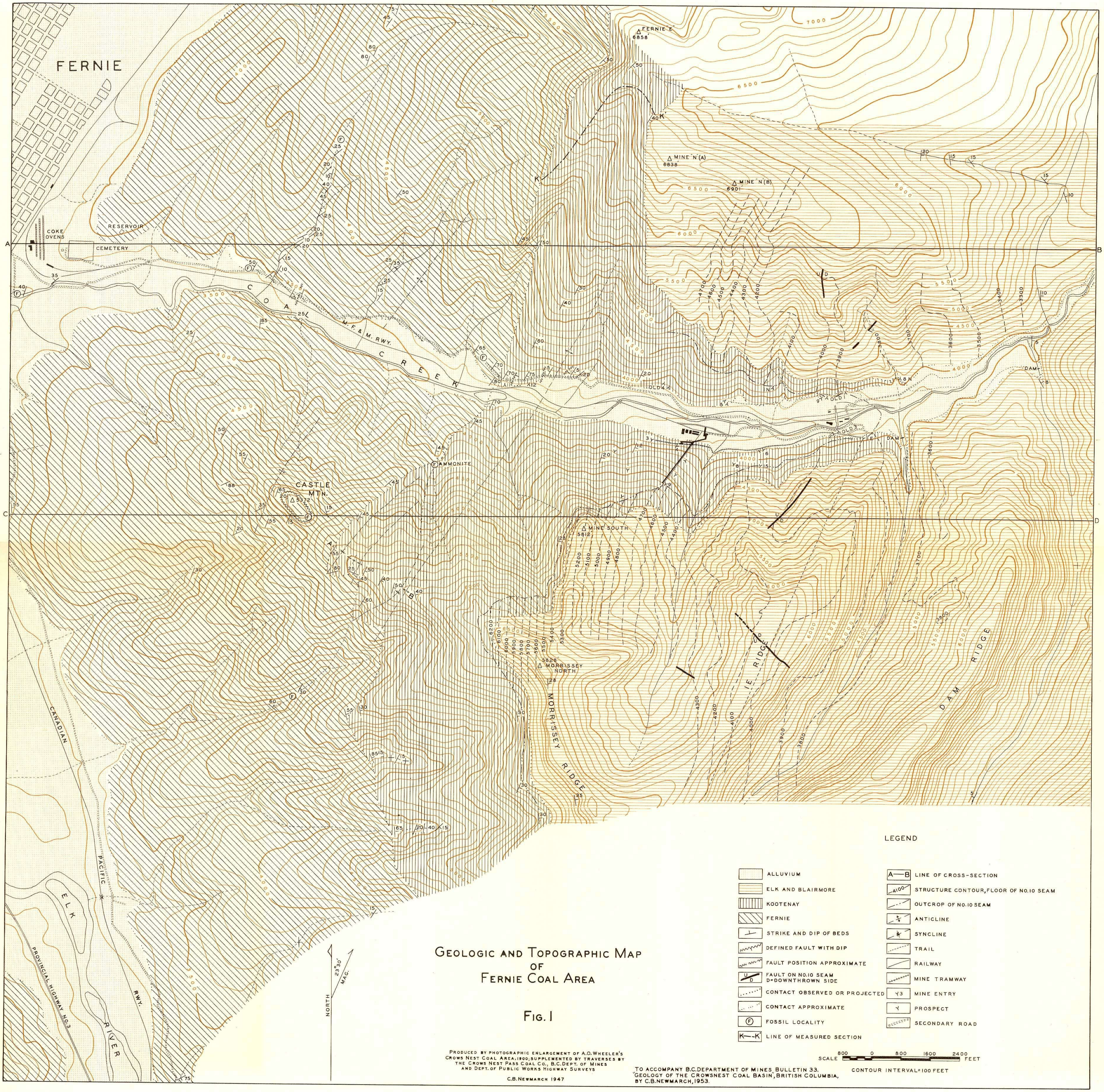
TABLE I. SPECTROGRAPHIC ANALYSES OF ASH OF MICHEL COALS

RELATIVE VALUES SEE NOTE BELOW TABLE ON PAGE 95

				Wave Length (Angstroms)	2438.8	2497.7	2553.2	2628.3	2776.7	2801.1	2833.1	2841.9	4254.5	2943.6	3006.9	3050.1	3039.1	3071.59	3132.5	3183.4	3280.7	3289.2	3303	3345	3392	3414.8	3453.5	3464.5	3273.9	4044.1		
Seam No.	Area	Field No.	Lab. No.	Ash Per Cent	Si	B	P	Fe	Mg	Mn	Pb	Ti	Cr	Ga	Ca	Al	Ge	Ba	Mo	V	Ag	Yb	Na	Zn	Zr	Ni	Co	Sr	Cu	K	Si+V+Mg	Na+Ni+Sr-Al
B	B-1	33	1159M	21.8	5	6	1	1	4	1	1	3	7	1	1	4	-	-	-	6	-	-	4	1	4	2	-	1	2	6	15	3
B	"	34	1160M	18.5	6	6	1	2	3	1	1	2	6	1	1	3	-	-	1	6	1	-	3	3	2	3	-	-	3	6	15	3
B	"	35	1161M	15.6	4	5	2	1	2	1	1	2	7	2	3	3	-	1	3	5	1	-	3	6	3	5	-	2	3	5	11	7
B	"	36	1162M	18.5	5	7	4	1	3	1	2	3	4	5	3	3	-	-	2	4	2	-	1	6	3	3	-	6	3	4	12	7
B	"	37	1163M	22.5	6	5	1	1	3	-	1	3	5	4	1	3	-	-	-	5	1	-	3	3	4	2	-	2	2	4	14	4
B	"	38	1164M	16.5	5	6	1	1	5	1	7	5	8	7	4	3	-	-	5	7	2	-	9	2	5	3	-	-	3	10	17	9
B	"	39	1165M	17.9	5	5	1	1	4	1	1	3	10	4	2	4	-	-	3	8	1	-	4	3	4	3	-	-	3	6	17	3
B	"	40	1166M	15.3	5	5	1	2	5	1	1	3	6	3	2	3	-	-	1	5	1	-	3	1	5	3	-	1	2	6	15	4
B	"	41	1167M	7.0	6	4	1	1	3	-	2	3	3	4	1	2	-	-	1	4	2	-	6	-	3	3	-	1	3	3	13	8
B	"	42	1168M	13.3	5	5	2	1	4	1	1	5	7	6	4	6	2	-	4	8	1	-	5	3	8	4	-	6	3	4	17	9
B	"	43	1169M	16.1	4	5	3	8	5	6	1	3	4	2	3	3	-	-	5	3	2	-	2	7	3	4	-	3	3	3	12	6
B	"	44	1170M	17.5	4	6	3	10	4	7	1	2	4	4	1	3	-	-	5	6	2	-	4	5	4	4	-	2	3	6	14	7
B	B-1	Average		16.7	5.0	5.4	1.8	2.5	3.8	1.8	1.7	3.1	5.9	3.6	2.2	3.3	0.2	0.1	2.5	5.6	1.3	-	3.9	3.3	4.0	3.2	-	2.0	2.8	5.2	14.4	5.8
B	B-2	57	1850M	5.0	4	6	8	4	4	7	8	4	4	5	9	5	10	-	3	2	5	-	10	10	7	.5	4	7	5	2	10	17
B	"	58	1851M	3.3	4	6	2	8	5	9	10	6	6	7	8	6	2	-	10	5	9	10	10	4	10	10	10	5	4	-	14	19
B	"	59	1852M	4.0	4	5	6	5	4	6	8	4	7	10	10	6	4	-	6	5	4	6	7	10	7	6	3	6	3	-	13	13
B	"	60	1853M	3.0	3	5	6	4	3	5	7	4	3	1	8	5	-	-	5	4	2	6	8	3	7	7	4	3	4	-	10	13
B	"	61	1854M	5.8	3	4	5	3	1	3	4	4	2	3	4	3	-	-	4	3	1	-	4	2	6	4	-	3	5	-	7	8
B	"	62	1855M	4.5	5	5	5	2	2	3	4	5	6	8	5	5	2	-	2	4	2	6	4	4	8	5	-	3	6	-	11	7
B	"	63	1856M	5.6	2	5	10	4	4	6	3	3	1	2	9	3	-	-	2	3	3	-	3	7	4	4	2	8	4	-	9	12
B	"	64	1857M	3.8	4	4	3	1	2	1	7	6	10	2	5	7	2	-	2	6	10	7	9	5	10	8	-	5	5	-	12	15
B	"	65	1858M	5.5	3	4	3	2	3	3	3	5	8	1	5	3	-	-	10	5	1	-	4	2	8	5	-	4	3	2	11	10
B	"	66	1859M	3.8	3	4	6	4	2	5	3	5	2	4	4	3	4	-	10	8	6	6	7	8	8	9	4	7	5	-	13	20
B	"	67	1860M	5.1	3	4	2	5	5	8	5	4	6	3	7	7	-	-	7	4	4	4	5	8	5	8	3	10	4	-	12	16
B	"	68	1861M	3.7	3	8	7	2	5	3	1	3	7	2	9	5	-	-	8	6	1	4	4	3	4	9	1	9	4	-	14	17
B	B-2	Average		4.4	3.4	5.0	5.3	3.7	3.3	4.9	5.3	4.4	5.2	4.0	6.9	4.8	2.0	-	5.8	4.6	4.0	4.1	6.3	5.5	7.0	6.7	2.6	5.8	4.3	0.3	11.3	14.0
B	B1+2	Average		10.6	4.2	5.2	3.6	3.1	3.6	3.4	3.5	3.8	5.6	3.8	4.6	4.1	1.1	-	4.2	5.1	2.7	2.1	5.1	4.4	5.5	5.0	1.3	3.9	3.6	2.8	12.9	9.9
A	A-1	21	1136M	13.7	2	3	7	2	1	2	1	4	1	1	5	4	-	-	-	4	7	-	-	7	4	2	1	3	10	-	7	1
A	A-1	22	1137M	12.4	2	5	3	1	1	2	1	4	2	2	3	3	-	-	-	3	1	-	-	9	5	1	-	1	5	1	6	-1
A	A-1	23	1138M	14.5	2	2	3	4	3	9	1	4	1	1	4	4	-	-	1	2	-	-	-	-	5	-	-	3	2	-	7	-1
A	A-1	24	1139M	12.8	4	5	1	-	1	1	1	8	2	2	2	5	-	-	-	5	1	-	-	3	6	-	-	1	4	-	10	-4
A	A-1	25	1140M	11.1	1	4	4	5	2	3	2	4	1	2	4	4	-	-	2	3	1	-	-	2	6	1	-	2	5	-	6	-1
A	A-1	26	1141M	10.0	2	3	6	5	4	6	2	3	1	3	6	4	-	-	1	1	2	-	-	6	3	1	-	2	5	-	7	-1
A	A-1	27	1142M	9.7	2	3	4	5	4	6	1	5	1	2	3	5	-	-	1	4	-	-	-	4	6	1	-	1	4	-	10	-3
A	A-1	28	1143M	11.7	4	5	1	2	5	2	2	10	3	5	4	5	-	-	4	5	1	-	-	3	8	2	-	1	5	2	14	-2
A	A-2	29	1144M	10.1	2	4	4	3	1	4	2	6	1	4	8	5	-	-	3	4	1	-	-	8	5	2	2	3	4	-	7	0
A	A-2	30	1145M	11.0	3	4	2	7	6	7	1	6	3	2	5	4	-	-	3	4	1	-	3	7	6	2	4	-	7	3	13	1
A	A-2	31	1146M	15.8	4	5	1	1	3	1	1	4	6	2	2	3	-	-	1	5	3	-	-	3	4	2	-	-	4	4	12	-1
A	A-2	32	1147M	15.8	5	4	1	1	3	1	1	5	3	1	1	4	-	-	1	4	-	-	-	2	5	2	-	-	4	3	12	-2
A	A1+2	Average		12.5	2.7	3.9	3.1	3.0	2.8	3.7	1.3	5.3	2.1	2.3	3.9	4.2	-	-	1.4	3.7	1.5	-	0.3	4.5	5.3	1.3	0.6	1.4	4.9	1.1	9.2	-1.2
A	A-3	74	1867M	12.3	7	8	1	1	3	1	1	6	6	4	2	9	-	-	1	6	-	5	-	4	7	1	-	2	4	2	16	-6
A	"	75	1868M	9.0	8	10	1	2	3	1	10	7	3	4	3	8	-	-	2	7	3	-	-	3	9	2	-	2	4	3	18	-4
A	"	76	1869M	15.7	6	4	2	1	1	1	1	5	5	4	2	10	-	-	2	3	-	4	-	3	6	1	1	1	2	-	10	-8
A	"	77	1870M	9.6	6	7	1	1	5	1	1	9	5	5	3	9	-	-	2	7	-	5	-	2	9	1	1	1	4	1	18	-7
A	"	78	1871M	12.6	7	8	1	1	5	1	1	7	2	5	3	9	-	-	1	5	-	-	-	2	8	1	1	-	4	-	17	-8
A	"	79	1872M	8.9	4	7	1	1	5	1	3	6	6	4	3	5	-	-	2	7	2	6	-	2	9	1	2	-	4	2	16	-4
A	"	80	1873M	12.2	5	6	1	1	3	1	1	5	3	3	3	8	-	-	2	5	-	3	-	3	8	1	-	-	3	1	13	-7
A	"	81	1874M	10.2	5	9	1	1	3	1	1	4	3	2	4	6	-	-	2	5	-	4	-	3	6	1	-	1	3	1	13	-4
A	"	82	1875M	11.0	4	5	1	1	3	1	1	6	3	1	2	8	-	-	2	4	2	-	-	4	5	1	-	1	3	2	11	-6
A	A-3	Average		11.3	5.8	7.1	1.1	1.1	3.4	1.0	2.2	6.0	4.0	3.6	2.8	8.0	-	-	1.8	5.4	0.8	3.0	-	2.9	7.5	1.1	0.6	0.9	3.4	1.3	14.6	-6.0
A	A1+2+3	Average		11.9	4.1	5.3	2.2	2.2	3.1	2.5	1.7	5.6	2.9	2.9	3.4	5.8	-	-	1.6	4.4	1.2	1.3	0.1	3.8	6.3	1.2	0.6	1.2	4.3	1.2	11.6	-3.3
U3?	3-2	45	1838M	10.7	3	2	4	2	2	1	4	2	2	1	3	3	-	5	1	2	1	-	-	-	3	1	-	2	4	3	7	0
U3?	"	46	1839M	10.5	5	4	2	2	5	1	7	5	3	1	-	5	-	-	3	4	1	-	-	-	6	2	-	-	4	4	14	-3
U3?	"	47	1840M	8.4	3	2	6	1	3	2	6	4	2	2	5	5	-	4	4	4	2	-	-	2	7	2	-	4	5	2	10	1
U3?	"	48	1841M	9.1	3	2	4	1	2	1	3	4	2	4	3	4	-	8	3	3	-	-	-	5	5	2	-	3	4	2	8	1
U3?	"	49	1842M	10.1	3	3	4	1	2	1	6	3	3	2	3	5	-	5	2	3	1	-	-	-	5	2	-	3	3	3	8	0
U3?	"	50	1843M	9.3	2	2	4	3	3	5	4	3	3	1	10	3	-	7	2	4	1	-	-	2	4	2	-	2	5	-	9	1
U3?	"	51	1844M	8.7	2	3	7	2	2	2	1	3	3	3	6	4	-	7	1	4	1	-	-	2	5	2	-	2	5	2	8	0
U3?	"	52	1845M	9.2	4	3	6	1	4	2	6	4	6	8	1,	6	-	5	6	7	10	-	-	7	7	3	3	3	4	6	15	0
U3?	"	53	1846M	9.5	3	3	4	1	4	1	7	3	6	3	3	5	-	10	4	5	1	-	-	2	5	2	-	4	4	3	12	1
U3?	"	54	1847M	10.3	7	4	3	1	5	3	6	5	6	3	2	8	-	9	3	5	1	-	-	3	7	2	-	3	8	3	17	-3
U3?	"	55	1848M	9.2	5	3	5	2	2	3	4	3	4	1	3	5	-	3	2	3	-	-	-	-	7	2	-	2	4	1	10	-1
U3?	"	56	1849M	10.0	6	4	3	1	3	1	2	3	6	1	2	4	-	-	2	5	2	-	-	3	6	2	-	1	3	2	14	-1
U3?	3-2	Average		9.8	3.8	2.9	4.3	1.5	3.1	1.9	4.7	3.5	3.8	2.5	3.4	4.8	-	5.3	2.8	4.1	1.8	-	-	2.2	5.6	2.0	0.3	2.4	4.4	2.6	11.0	-0.4
U3	3-1	69	1862M	7.4	3	6	3	2	2	3	1	3	6	1	4	4	-	6	2	3	-	-	-	3	4	2	-	2	1	4	8	0
U3	"	70	1863M	8.7	2	5	2	3	3	5	1	3	7	2	5	4	-	5	6	4	-	-	-	5	1	1	1	1	2	1	9	-2
U3	"	71	1864M	6.1	4	6	5	1	3	1	-	5	4	3	5	5	-	8	3	5	-	-	-	-	6	3	1	3	4	1	12	1
U3	"	72	1865M	9.4	3	5	2	2	3	3	1	4	2	3	4	4	-	2	1	4	-	-	-	3	6	2	2	1	3	3	10	-1
U3	"	73	1866M	7.2	6	5	6	1	2	4	1	5	3	5	3	9	-	-	5	5	-	6	-	3	10	2	1	2	4	1	13	-5
U3	"	83	1876M	7.3	5	4	7	2	4	5	3	6	4	2	5	9	-	10	6	5	1	-	-	6	7	3	-	4	3	1	14	-2
U3	"	84	1877M	5.8	4	6	7	1	4	2	2	3	6	2	5	8	2	6	3	6	1	4	-	4	6	4	-	4	3	2	14	0
U3	"	85	1878M	9.4	3	6	2	2	4	4	10	2	5	5	5	7	-	8	6	6	2	-	-	2	5	5	-	2	4	5	13	0
U3	"	89	1882M	6.4	5	4	6	7	4	10	1	6	6	2	9	9	-	4	5	4	-	4	-	-	7	4	1	1	4	-	13	-4
U3	3-1	Average		7.5	3.9	5.2	4.4	2.3	3.2	4.1	2.2	4.1	4.8	2.8	5.0	6.6	0.2	5.4	4.1	4.7	0.4	1.6	-	2.9	5.8	2.9	0.7	2.2	3.1	2.0	11.8	-1.5
L3	3-1	86	1879M	28.2	5	5	1	1	5	2	2	3	3	-	2	6	-	-	2	8	-	-	-	7	5	2	-	-	3	2	18	-4
L3	"	87	1880M	18.7	4	3	1	1	5	1	2	7	5	8	2	6	-	4	3	9	6	5	-	3	5	3	2	1	2	6	18	-2
L3	"	88	1881M	35.0	10	8	1	1	6	1	1	5	4	5	-	6	-	-	-	7	-	-	-	-	5	2	-	-	3	5	23	-4
L3	"	90	1883M	26.4	9	10	6	1	7	2	1	3	10	1	2	5	-	3	2	10	1	-	-	7	3	3	-	-	4	7	26	-2
L3	"	91	1884M	21.2	7	6	2	1	5	2	1	4	4	2	3	5	-	3	2	7	-	-	-	10	6	3	-	1	3	7	19	-1
L3	3-1	Average		25.9	7.0	6.4	2.2	1	5.6	1.6	1.4	4.4	5.1	3.2	1.8	5.6	-	2.0	1.8	8.2	1.4	1.0	-	5.4	4.8	2.6	0.4	0.4	3.0	5.4	20.8	-2.6

AVERAGE VALUES

Seam No.	No. of Samples	Ash Per Cent	Si	B	P	Fe	Mg	Mn	Pb	Ti	Cr	Ga	Ca	Al	Ge	Ba	Mo	V	Ag	Yb	Na	Zn	Zr	Ni	Co	Sr	Cu	K	Si+V+Mg	Na+Ni+Sr-Al
B	24	10.6	4.2	5.2	3.6	3.1	3.6	3.4	3.5	3.8	5.6	3.8	4.6	4.1	1.1	-	4.2	5.1	2.7	2.1	5.1	4.4	5.5	5.0	1.3	3.9	3.6	2.8	12.9	9.9
A	21	11.9	4.1	5.3	2.2	2.2	3.1	2.5	1.7	5.6	2.9	2.9	3.4	5.8	-	-	1.6	4.4	1.2	1.3	0.1	3.8	6.3	1.2	0.6	1.2	4.3	1.2	11.6	-3.3
U3?	12	9.8	3.8	2.9	4.3	1.5	3.1	1.9	4.7	3.5	3.8	2.5	3.4	4.8	-	5.3	2.8	4.1	1.8	-	-	2.2	5.6	2.0	0.3	2.4	4.4	2.6	11.0	-0.4
U3	9	7.5	3.9	5.2	4.4	2.3	3.2	4.1	2.2	4.1	4.8	2.8	5.0	6.6	0.2	5.4	4.1	4.7	0.4	1.6	-	2.9	5.8	2.9	0.7	2.2	3.1	2.0	11.8	-1.5
L3	5	25.9	7.0	6.4	2.2	1	5.6	1.6	1.4	4.4	5.1	3.2	1.8	5.6	-	2.0	1.8	8.2	1.4	1.0	-	5.4	4.8	2.6	0.4	0.4	3.0	5.4	20.8	-2.6



GEOLOGIC AND TOPOGRAPHIC MAP OF FERNIE COAL AREA

FIG. 1

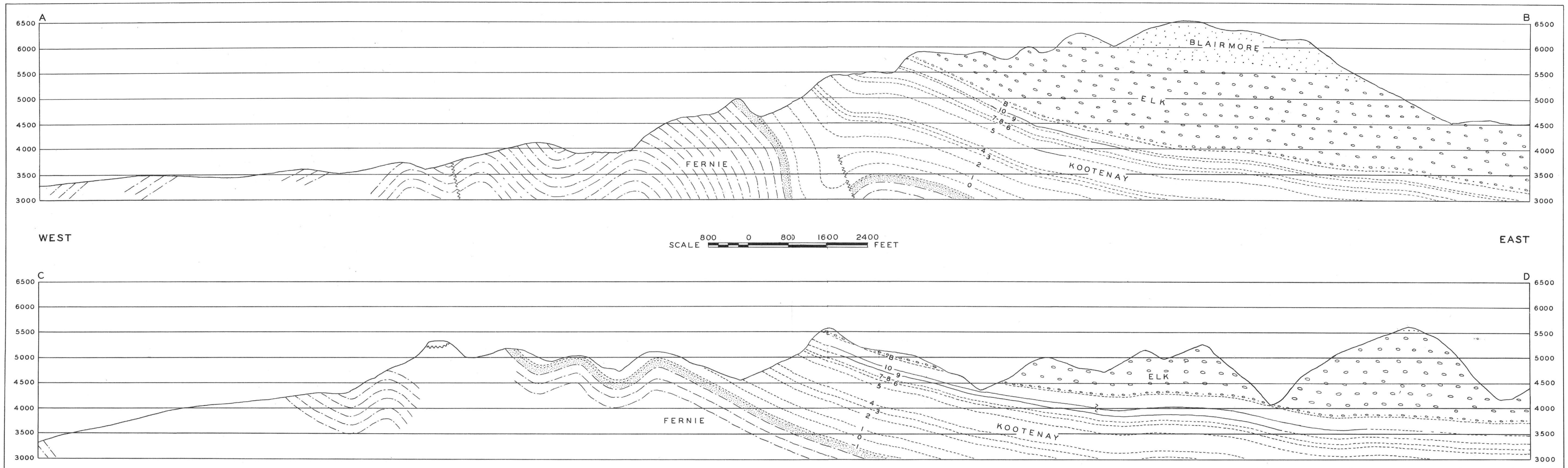


Fig. 2 Sections A-B and C-D

To accompany B.C. Department of Mines Bulletin 33, "Geology of the Crowsnest Coal Basin," British Columbia, by C.B. Newmarch, 1953.

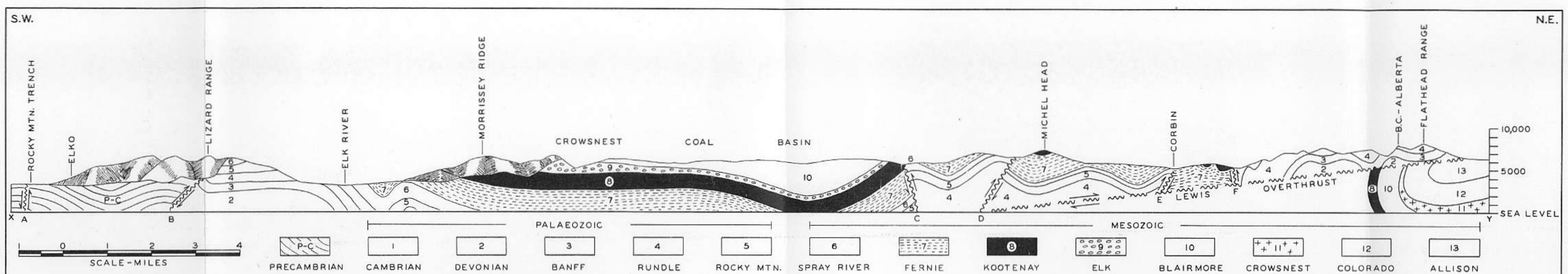


FIG. 7 SECTION X–Y FROM ELKO THROUGH CORBIN TO THE FLATHEAD RANGE

TO ACCOMPANY B.C. DEPARTMENT OF MINES BULLETIN 33, "GEOLOGY OF THE CROWSNEST COAL BASIN," BRITISH COLUMBIA, BY C.B. NEWMARCH, 1953.

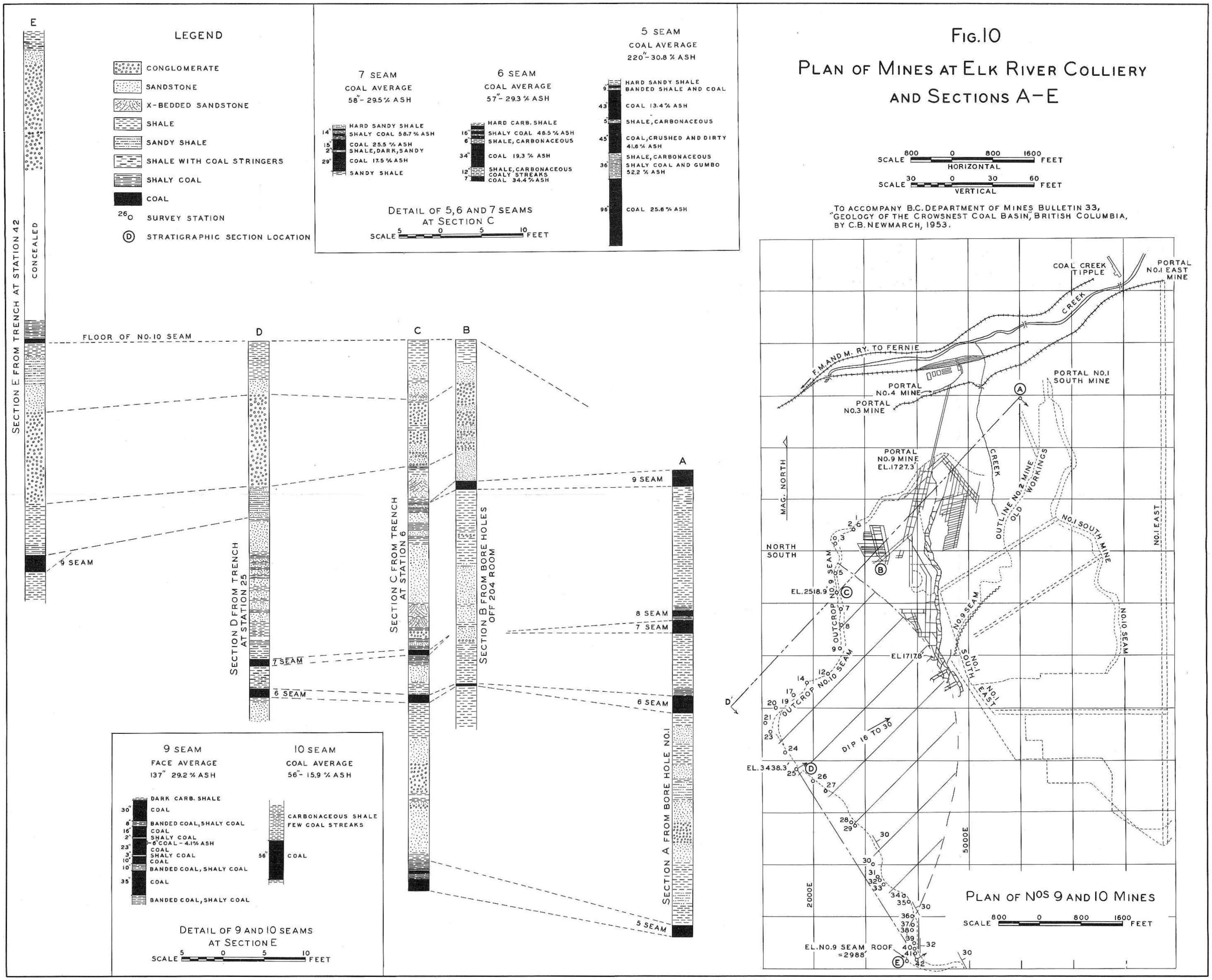


Fig. 10

Plan of Mines at Elk River Colliery and Sections A–E