CANADA
DEPARTMENT OF MINES
HON. LOUIS CODERRE, MINISTER; R. W. BROCK, DEPUTY MINISTER.

GEOLOGICAL SURVEY

MEMOIR 69

No. 57, GEOLOGICAL SERIES

Coal Fields of British Columbia

COMPILED BY
D. B. Dowling

OTTAWA
GOVERNMENT PRINTING BUREAU
1915

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CONTENTS.

CHAPTER III.

ILLUSTRATIONS.

PREFACE.

The coal resources of British Columbia form a subject of great interest, but although many of the coal fields have been studied and reported upon, yet much of this information is out of print or otherwise inaccessible. In the case of the areas in the Skeena River country in the vicinity of the Grand Trunk Pacific railway, studied by Mr. Leach, the early demise of this earnest worker prevented a contemplated correlation of his observations and, therefore, an attempt has been made in this volume to bring together his published writings relative to the coal fields of the Skeena valley. The volume also contains, as far as possible, extracts from all reports, except those superseded by later information, that deal with the coal areas or possible coal areas in British Columbia.

The introduction and general discussion has been made brief as the book is intended not as a report but as a collection of reports by various authors, giving their several points of view. The arrangement of the discussion is under two heads: (1) the Cretaceous coal-measures; and (2) the Tertiary. This method introduces first the deposits more important both as to relative value of the coal and extent of the mining industry. Among the fields included in the second part, are many problematical areas not thoroughly explored, but which may yet become important.

Coal Fields of British Columbia.

CHAPTER I.

INTRODUCTION.

The discovery of coal in 1835, on the British Columbia coast at Suquash and later near Nanaimo, was from information given the officers of the Hudson's Bay Company by the Indians. The coal mining industry, therefore, may be said to have grown up with the general development of the country. This at first depended almost entirely on the fur trader but later received an impetus in the excitement caused by the discovery of gold in the interior.

The first attempts at mining were made in a relatively small coal area and, had the Douglas seam at Nanaimo not been found in 1850, would have been inadequate to supply the commercial demands that sprang up after the discovery of gold. The coal mining industry gradually became centred at Nanaimo in this, the richer field, and mining at Suquash was discontinued about 1853. In a report on the Suquash area, Dr. G. M. Dawson adds a footnote in which Dr. W. F. Tolmie is credited with being the first to recognize the coal. To the locality was sent the Hudson's Bay Company's steamer, the *Beaver*, under Captain McNeil, names still preserved in the vicinity of the Suquash coal field. The fuel being tested on the steamer and found satisfactory, measures were at once taken to establish not only a mine but also a trading post and stockage. The industry languished after more profitable fields were discovered and it is quite possible that shortly after 1853 very little was left to mark the spot. Thirty-two years later when visited by Dr. Dawson and the writer, the house sites were overgrown, but a small tunnel was to be seen in the cliff behind, the handiwork of the Muirs who were brought out from Scotland to work the mine.

The report of the occurrence of coal at Nanaimo was received at Victoria in 1850, and Jos. W. McKay was sent there to find the coal. It is recorded that the Douglas seam was discovered on May 8, 1850, and much of the machinery used in opening a mine there, and many of the miners employed were brought south from Fort Rupert. For many years Nanaimo remained the principal colliery and the centre of the coal trade, until the construction of railways on the mainland brought into practical operation mines in the inland fields.

LOCALITIES AND AREAS.

(*See Map 139A*).

Several important coal-bearing areas are situated on the islands off the mainland, and in this respect are very favourably placed to compete with other coal-fields tributary to the Pacific. Inland areas of prime importance have been connected with the markets by railway, as is the case with the Crowsnest area. Other large fields such as the upper Elk River field, await the demands of a market before the construction of the connecting railway and the installation of mining machinery. The demands for transportation for other purposes may facilitate the opening of many other coal deposits, and of those listed and described, there may, in time, be many which will supply the wants of the settler, the manufacturer, or reduction works. At the present time, however, active mining is limited to the southern part of the province and to Vancouver island.

AGES OF COAL-BEARING FORMATIONS.

Coal is found in the early Tertiary and in several of the divisions of the Cretaceous. The Cretaceous coal-bearing rocks of the Rocky mountains represent portions of the Great plains coal-bearing basin and are directly correlated with the Alberta beds. The early Cretaceous, coal-bearing sediments of northern British Columbia while of about the same age as, or possibly older than, the coal-bearing strata of the Rockies, may not have been deposited in the same basin. The deposits of Upper Cretaceous time which occur in the Peace River basin, are probably of about the same age as the Belly River formation and, if so, antedate the Cretaceous beds of Vancouver and Graham islands, which are generally correlated with beds in the upper part of the Pierre overlying the Belly River formation.

The Tertiary sediments on the coast found to be coal-bearing in places are supposedly in conformable relation with the Cretaceous so that their Eocene age is generally admitted. In the interior basins, where Tertiary sediments are capped by Miocene lava flows, a coal horizon in the sediments is held to be somewhat later in age than Eocene, but from a study of the plant remains, Prof. D. P. Penhallow did not feel inclined to pronounce them later than Oligocene. Two examples of sediments later than the first or earliest lava flow are attributed to the lower Miocene. It has been pointed out that the Oligocene beds of the Coldwater group are, in places, tilted and otherwise deformed beneath the trap flows, thus showing a time interval between the Oligocene and the deposits of the lower Miocene.

TABLE OF COAL-BEARING FORMATIONS.

Tertiary	Lower Miocene	Tranquille beds	North side Kamloops lake; Stump lake south of Kamloops.
	Oligocene	Coldwater series	Kamloops; Quilchena; Horsefly river; Coal gully (Nicola valley); Tulameen; Guichon creek; Similkameen; Hat creek; Kettle river; Quesnel.
	Eocene	Unnamed series	Blackwater river; Coal brook (North Thompson); Finlay river; Omineca river.
		Puget group	Fraser River delta.
Cretaceous	Upper Cretaceous	Nanaimo formation[1]	Nanaimo; Comox; Cowichan; Suquash; Quatsino.
		Queen Charlotte formation[1]	Graham island.
		Dunvegan sandstones	Peace river.
	Lower Cretaceous	Kootenay formation[1]	Elk river; Crowsnest; Flathead river.
		Skeena series[1]	Skeena river; Bulkley river; Telkwa river; Morice river; Groundhog coal-basin.
		Tantalus conglomerate[1]	Atlin.

[1] The Nanaimo and Queen Charlotte formations are, by some, correlated and the same is true of the Kootenay, Skeena, and Tantalus formations.

CHAPTER II.

THE CRETACEOUS COALS.

GEOLOGICAL NOTES.

As may be seen from the table of formations given in the previous chapter, there are at least three Cretaceous horizons at which accumulations of vegetable matter have been preserved in the form of coal seams.

UPPER CRETACEOUS.

The highest coal-bearing strata are represented on Vancouver and Queen Charlotte islands and have been classed respectively under the names, Nanaimo, and Queen Charlotte formations. These two formations may represent the same horizon or time interval, though this has not, as yet, been definitely ascertained. Both represent beds of Upper Cretaceous age and rest on Jurassic shales. Descriptions of these formations will be found in the reports on the Nanaimo and Graham Island coal-fields and will not be repeated here.

Dunvegan Group.

The coal-bearing beds of the Peace River district, the Dunvegan sandstones, were called by Dr. G. M. Dawson the Lower sandstones and shales, in the general description published in 1879. The name Dunvegan was introduced subsequently and was used by R. G. McConnell in his report on the Athabaska district in 1890. The general description of the formation as there given,[1] is here repeated.

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[1]Annual Report Geol. Surv., Can., Vol. V, 1890-91, pp. 54-55 D.

"This name has been applied to a series of sandstones and shales, which are extensively developed along the Peace River valley, from about fifteen miles above the Smoky River Forks, up to the Cañon of the Mountain of Rocks. This part of the river was not visited during the present explorations, but was examined by Dr. Selwyn in 1875, and a description of the formation is given in the Report of Progress, Geological Survey of Canada, 1875-76. In 1879 the lower part of Smoky river was examined by Dr. G. M. Dawson, and the Dunvegan beds were found on it, underlying the Smoky River shales (Pierre), but in greatly diminished volume.[1]

"The character and age of the Dunvegan beds are fully discussed by Dr. Dawson in the report just mentioned, and but little additional information has since been obtained. They consist of greyish and yellowish flaggy and massive sandstones, often false-bedded and ripple-marked, alternating with greyish and dark shales, usually more or less arenaceous, and holding small beds of ironstone and thin seams of lignite. The thickness of the formation rapidly increases going westward towards the mountains, from 100 feet on Smoky river to 600 feet or more at Dunvegan, and nearly 2,000 feet at Table mountain. The Dunvegan beds have not been detected east of Smoky river, and probably die away soon after crossing that stream, and they are not represented, so far as known, on the Athabaska.

"The fauna of the Dunvegan formation is remarkable for its varied character, as it contains fresh-water shells like *Vivipara* and *Corbicula*, brackish water shells like *Corbula* and *Ostræa*, and such a strictly marine genus as *Inoceramus*. This assemblage of fossils, together with the general character of the beds, evidences estuarine conditions and deposition on an oscillating surface.

"The Dunvegan formation occupies nearly the same position stratigraphically, as the Belly River series of Assiniboia and Alberta, and may possibly be a continuation of it, but it differs in containing marine fossils, the fauna of the latter so far as known, being confined to fresh and brackish water species.

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[1] Report of Progress, Geological Survey of Canada, 1879-80, Part B, pp. 116-122.

It is also closely allied by its fauna to the Bear River formation of Wyoming, lately described by White and Stanton.[1] Two of the most characteristic species of the Bear River beds, *Corbula pyriformis* and *Corbicula Durkeii*, occur in the Dunvegan formation and most of the genera are alike. The position of the two formations in the Cretaceous is, however, different, as the Bear River beds are placed by the above writers below the Colorado, while the Dunvegan series overlies that formation."

LOWER CRETACEOUS.

The early Cretaceous deposits in the Rocky mountains were laid down upon Jurassic sediments of considerable thickness but generally fine grained. In the southern part of the Skeena basin they were preceded by a period of great volcanic activity and coal seams are now found in the sediments filling basins in an uneven floor of volcanics. In following these northward it is found that the floor of volcanic rocks gradually gives place to sedimentaries made up largely of tuffs and tufaceous sandstones interbedded with black shales.

Kootenay Formation.

The following general description of the Kootenay, the coal-bearing formation in the Rockies, is taken from G. S. Malloch's report on the Bighorn coal field.[2] The description of the Skeena series is by W. W. Leach.

"The name Kootenay was used by Dr. Dawson in 1885 to designate the coal-bearing series in the Cascade basin. From the palæontological evidence there is some doubt whether the formation should be assigned to the bottom of the Cretaceous or to the top of the Jurassic.

"At all points where it and the underlying formations have been studied in parallel basins in the eastern Rockies, or in the foothills, the Kootenay and these older strata thin out rapidly east-

[1] American Journal of Science, Vol. XLIII, p. 91.

[2] Malloch, G. S., Bighorn coal basin, Alberta; Memoir 9, Geol. Surv. Can.

ward. The following measured thicknesses of the Kootenay illustrate the eastward thinning, and it will be noted that in the more northerly examples, which are situated within 50 miles of the Bighorn basin, the thinning is not so pronounced as in the more southerly ones. In the Crowsnest field Mr. McEvoy measures 4,736 feet of strata, of which all but the last measurement, viz., 1,060 feet of black and brown shale, probably belong to the Kootenay. In the Frank field situated east of the Crowsnest, the thickness of the Kootenay probably does not greatly exceed 742 feet, which is the thickness of a section measured by Mr. W. W. Leach.

"Between the Bow and the Kananaskis the thickness of the Kootenay is probably about 2,900 feet, but the uppermost beds have been removed by erosion. In the foothills a short distance to the southeast, the thickness as given by Mr. Cairnes amounts to only 375 feet. In the third longitudinal valley, between Red Deer and the Clearwater, at least 2,300 feet of Kootenay strata have escaped erosion, which has removed the uppermost beds; but in the first longitudinal valley a little south of the Red Deer the total thickness of the formation is only about 1,700 feet.

Skeena Series.[1]

"This series is of great economic importance, inasmuch as all the known coal of commercial value is contained therein. The strata consists essentially of rather soft, thin-bedded shales and sandstones, the former, in places, carrying many clay-ironstone nodules and holding a number of coal seams. At the base of the series there is usually found a bed of coarse, crumbly conglomerate, but this, though fairly persistent, is not always present.

"Owing to the disconnected nature of the exposures and the seeming lack of continuity of the beds, a complete section of these rocks has never been obtained. It seems probable, however, that their total maximum thickness is in the neighbourhood

[1] W. W. Leach, Summ. Report Geol. Surv., Can., 1910, p. 94. See also discussion in report on Groundhog coal area, in present report.

of from 600 feet to 800 feet. A number of fossils (chiefly plants) collected at various times, have been determined by Mr. Lawrence Lambe and Mr. W. J. Wilson, and show the age of these beds to be Lower Cretaceous, and about equivalent to the Kootenay series of the Crowsnest pass.

"The Skeena series is apparently conformable with the Hazelton group, and the line between them must be rather arbitrarily drawn, the coarse conglomerate already mentioned being regarded as the base of the Skeena series.

"These beds occur in a number of comparatively small patches in various widely-separated localities, being folded in with the harder, underlying volcanics. These small isolated areas seem to be remnants of one or more large fields, which, owing to favourable circumstances, have escaped denudation. It is only in the valleys and low country that these rocks are now to be found, erosion having completely removed them from the higher ridges and mountains. The most important coal-bearing areas are situated on the Telkwa river and the head-waters of the Morice, which have been described in previous reports. Other important localities where they have been noted are on the Shegunia and Kispiox rivers and on the Bulkley river near the mouth of Boulder creek, about 21 miles above Hazelton, where the beds occur in the form of a shallow, synclinal basin, with a number of minor undulations, the river cutting across it diagonally. The greatest width of this trough is probably not more than 1½ miles, with a length of about 4½ miles. The only outcrops occur in the banks of the river so that it is a matter of some difficulty to define the boundaries definitely. To the north the coal-bearing beds are cut off by a granitic intrusion, while at the southern extremity there is a faulted contact with rocks of the Hazelton group. A number of small coal seams have been uncovered here and a little prospecting has been undertaken."

THE CROWSNEST COAL-FIELD.

(*See Diagram I.*)

The Crowsnest coal-field contains the most important body of coal that is being mined in the province. The coal-bearing horizon is the Kootenay formation and it occurs in synclinal form covering an area of 230 square miles surrounded by tilted lower beds. As a result of erosion the Kootenay and overlying strata form an elevated plateau-like area bordered by depressions occupied by older beds.

Most of the heavy coal seams occur in the lower 2,000 feet of the Kootenay. On Sparwood ridge, near Michel, a further thickness of 2,000 feet in the upper part of the measures contains a number of thin seams, mostly cannel or coal having a high percentage of volatile matter. The Morrissey section at the south gives a thickness of 3,700 feet of coal-bearing beds. The covering beds are mostly coarse sandstones and conglomerates and are of great thickness.

The coal content, in natural sections at a number of places, including only seams over one foot in thickness, is as follows:—

At Morrissey 23 seams give 216 feet of coal in 3,676 feet of measures.

At Fernie 23 seams give 172 feet of coal in 2,250 feet of measures.

At Sparwood 23 seams give 173 feet of coal in 2,050 feet of lower measures.

At Sparwood 24 seams give 43 feet of coal in 2,015 feet of upper measures.

The seams present in the upper measures in the Morrissey section probably thin out before reaching Fernie, but at Fernie there seems to be a possibility that there may be other, lower seams not included in the section, so that the basin appears to have a fairly constant coal content of nearly 172 feet in 23 seams, with, possibly, an additional 40 feet contained in the thin seams of the upper measures. Details of sections and a general description of the field have been given by Messrs. McEvoy and Leach, extracts of whose reports are here incorporated.

EXTRACT FROM REPORT BY J. MCEVOY.[1]

The Crowsnest coal-field is situated immediately west of the summit of the Rocky mountains on the Crowsnest pass. It is all included in the province of British Columbia, excepting a small portion in the immediate vicinity of the pass, which crosses the watershed into the district of Alberta. The area of Cretaceous rocks in the vicinity is nearly 500 square miles in extent. The coal-measures, originally deposited over the whole of the area, have been eroded away around the edges, where the rocks are crumpled and folded, and along some of the deeper valleys penetrating well into the area, so that their actual area is approximately 230 square miles. In shape, the area covered by the coal measures, like that of the Cretaceous basin itself, is, roughly speaking, a long pointed triangle, with its base to the south. Its greatest length is about thirty-five miles, north and south, and its greatest width about thirteen miles. These figures are, of course, only approximate as the work has not yet been plotted.

Coal is said to have been discovered in this part of the country many years ago. Its reported existence is alluded to in the Report of Progress of the Geological Survey for 1880-82 (p. 2 B). It is again referred to in the report for 1882-84 (p. 111 C). The coal-bearing area was approximately defined and examined in a preliminary way by Dr. G. M. Dawson in 1883. It was again visited after some prospecting had been done, by Dr. A. R. C. Selwyn in 1891[2].

The Crowsnest branch of the Canadian Pacific railway, descending Michel creek on the western slope of the mountains, crosses the northern part of the coal lands. It then follows the Elk river downward nearly along the line of the western boundary of the Cretaceous area, for a distance of about twenty-five miles. The upturned western edge of the Cretaceous rocks forms a ridge or escarpment which runs parallel to the Elk river and three or four miles distant therefrom. The height of the escarp-

[1]Summ. Rep. Geol. Surv. 1900, pp. 85A-95A.

[2]See Annual Report, Geol. Surv., Can. (N. S.), Vol. I. (1885), Part B, and Summary Report, 1891.

ment is fairly uniform, being 3,500 to 4,000 feet above the river. About halfway up the slope the coal-measures are found outcropping with dips of 30° to 40° eastward.

A search for fossils in the limestones underlying the Cretaceous rocks, resulted in the discovery of several specimens of the genus *Productus*. These rocks have been classed as Devono-Carboniferous, and for the greater part of their extent such classification must remain. The discovery of *Productus* is, however, fairly good evidence that in this part the upper member of the limestone series is definitely Carboniferous.

Notwithstanding the great lapse of time between the Carboniferous and Cretaceous deposits, wherever their relation to each other could be seen they appear to be conformable. The general attitude of the Cretaceous rocks is that of a wide flat-bottomed syncline, or rather basin, for the beds are upturned at the north and south ends of the area, as well as at each side. On the south and west borders of the area, the upturning has been accomplished without much faulting of the coal-measures and overlying beds, but the lower members of the series, consisting of the black shales and soft calcareous shales, have been badly crushed and folded. It is along or near the eastern edge of the area that the greatest dislocation has taken place. The greatest erosion, however, did not here follow the line of contact with the limestones, but is marked by a depression in the hills, running parallel to the contact, and about four miles inside the border. In some places here at the actual contact, the Cretaceous measures appear to have been tilted up bodily, without crushing, and it may be hoped that further work will discover a section where the thickness of the lower beds of the series may be obtained. Such a section could not be found on the western edge, on account of the crushed and folded state of the rocks previously mentioned.

Although in general the Cretaceous rocks are said to have assumed the form of a flat-bottomed basin, there are many places where local faults have destroyed the symmetry of this arrangement. Some of these faults are of considerable dimensions and will form an important factor to be reckoned with in the problem of systematically mining the coal.

Before attempting any detailed statement of the situation of the coal-measures, it is perhaps desirable to have an idea of the character and thickness of the Cretaceous rocks occurring in the basin. Toward the end of the season, a section was measured on the front of the escarpment, about three miles north of Morrissey siding. A steel tape was used and slopes were measured with a hand-level. The results should be fairly reliable. It is only in the adjustment necessary where there was a local twisting of the beds, that there is room for any appreciable error. The site selected for the section was on a small spur from the escarpment, where, some years ago, Mr. Fernie had excavations made on the outcrop of the coal seams. The crest of the spur has an average slope of nearly 30 degrees, and affords the exceptional opportunity of getting an unbroken section of almost 5,000 feet. Dr. Selwyn, then Director of the Survey, published in the Summary Report for 1891 a list of the seams then measured. The section which follows is given in the natural order, beginning at the top of the escarpment and running downward.

		Feet	Inches
1	Hard conglomerate	6	0
2	Grey nodular limestone in soft brown shale	3	0
3	Hard, coarse conglomerate with layers of sandstone	38	0
4	Brown shale and brown soft nodular sandstone	48	0
5	Hard conglomerate with layers of gritty sandstone	50	0
6	Covered	33	0
7	Gritty sandstone	16	0
8	Brown shale	35	0
9	Gritty sandstone and conglomerate	13	0
10	Bluish, thinly bedded sandstone	41	0
11	Brownish, shaly sandstone	30	0
12	Black shale	14	0
13	Gritty sandstone	22	0
14	Black shale	11	0
15	Conglomerate and gritty sandstone	25	0
16	Black shale	4	0
17	*Coal*	2	6
18	Black shale	20	0
19	Conglomerate	85	0
20	Black and brown shale with one layer carbonaceous shale	72	0
21	Hard grey sandstone	11	0

	Feet	Inches
22 Conglomerate	20	0
23 Hard grey sandstone	65	0
24 Carbonaceous shale. (Some coal?)	8	0
25 Black shale	6	0
26 Brownish shale	27	0
27 Fine-grained grey sandstone	24	0
28 Brownish shale; some beds of soft sandstone	84	0
29 Bluish hard sandstone	10	0
30 Black shale	8	0
31 *Coal*	2	0
32 Brown and black shale	57	0
33 Grey sandstone	96	0
34 Black and grey shale	34	0
35 *Coal*	1	0
36 Brown shale	3	0
37 *Coal*	1	0
38 Thinly-bedded bluish sandstone	14	0
39 Hard grey sandstone	133	0
40 *Coal*, including some carbonaceous shale	5	0
41 Black and brown shale	20	0
42 Hard grey sandstone with three irregular layers of conglomerate	175	0
43 Black shale	27	0
44 Coal (upper foot impure)	4	0
45 Black shale	38	0
46 Hard grey sandstone	55	0
47 Deeply covered	100	0
48 Shale, probably including some coal	107	0
49 Carbonaceous shale	8	0
50 *Coal*	7	0
51 Carbonaceous shale and coal	2	0
52 Black shale and carbonaceous shale	33	0
53 *Coal* (impure)	3	
54 Shale and soft sandstone	6	0
55 *Coal*	5	0
56 Carbonaceous shale	4	0
57 Black shale, including some carbonaceous shale and possibly some coal	150	0
58 *Coal*	3	0
59 Black shale and carbonaceous shale	100	0
60 Carbonaceous shale and coal	20	0
61 *Coal*	10	0
62 Black and brown shale and carbonaceous shale with thin seams of coal	140	0
63 *Coal* (upper ten feet impure)	36	0

		Feet	Inches
64	Brown and black shale	134	0
65	Hard sandstone	56	0
66	Black shale	4	0
67	*Coal*	1	4
68	Shale	0	5
69	*Coal*	0	9
70	Shale	0	10
71	*Coal*	6	0
72	Shale and shaly sandstone	208	
73	*Coal* (upper foot impure)	2	
74	Bluish shaly sandstone	2	
75	*Coal*	2	
76	Black shale	65	
77	*Coal*	4	
78	Shale	1	7
79	*Coal*	4	9
80	Shale	6	0
81	*Coal* (bottom two feet impure)	19	0
82	Bluish black shale	10	0
83	Bluish sandstone	35	0
84	Black shale	125	0
85	*Coal*	2	6
86	Chiefly black shale, partly covered	364	0
87	*Coal*	1	4
88	Shale	1	3
89	*Coal*	46	0
90	Black shale	16	0
91	Hard grey sandstone	60	
92	Black shale	110	
93	*Coal*	46	
94	Black shale	10	
95	Hard grey sandstone	100	
96	Black and brownish shale	1,060	
	Total	4,736	3
	Total thickness of coal	216	2

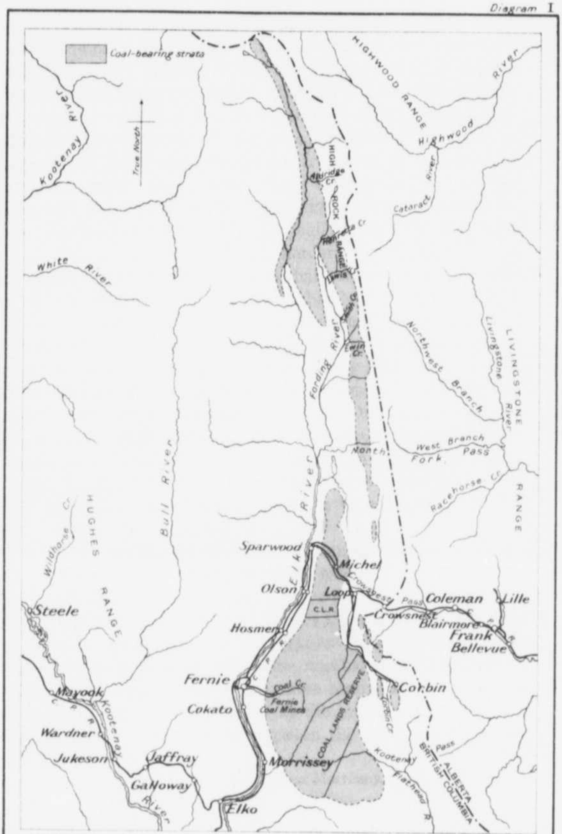
Of the above thickness of coal, the greater part, 198 feet, occurs in a thickness of measures of 1,847 feet. Besides the parts of the coal mentioned in the section as impure, there are some irregular layers of shaly material and nodular ironstone in the larger seams. Making allowance for these, and deducting some of the smaller seams that could not be profitably mined, say three feet or under, it may be safely concluded that there is a total thickness of workable coal of at least 100 feet.

Below the base of the section the rocks are disturbed and broken, but the black shales last mentioned appear to continue for some distance farther. These are succeeded by 500 feet or more of soft grey sandy argillites, fairly calcareous and occurring in thick beds. Below the argillites comes an uncertain thickness, possibly 1,000 feet of thin shaly limestone and calcareous shales. Although not seen in this place, a band of rather coarse-grained fragmental limestone belongs to this horizon. The lowest beds of the series are not exposed here, but where seen elsewhere, consist of black shales with two or more layers of hard fine-grained dark-coloured dolomitic limestone. Their thickness has not yet been ascertained, but they appear to be several hundred feet at least.

Toward the top of the section, it will be noted that the beds largely consist of conglomerate and gritty sandstone. The conglomerate especially is very hard. Its pebbles are principally of black and grey chert, embedded in a matrix so silicified that cleavage-planes cut both pebbles and matrix as if the rock were of homogeneous texture. The preservation of the coal-measures is in a great degree due to the presence of these hard beds, which prevented erosion, and by their great strength saved the more yielding beds of the underlying coal-measures from crushing and folding. The conglomerates and sandstones are false-bedded and of irregular thickness, and individual beds cannot be expected to be continuous over very large areas. The beds consisting chiefly of nodular limestone, near the top of the section, and another similar bed occurring a few feet higher up in the series, have been recognized in several places in the same relative position to the conglomerates, and may be regarded as a definite horizon for the correlation of the strata at widely separated points.

Above the top of the measured section, the overlying rocks are seen northward along the escarpment, the first succeeding bed being ten feet of soft brown shale, then the second band of nodular limestone in brown shale already mentioned, followed by 200 feet or more of alternating layers of brown shale and sand-

Diagram I



Geological Survey, Canada 1413

Crowsnest and Elk River coal-areas

Miles

To accompany Memoir by D.B. Dowling

stone, in beds of six to fifty feet thickness. Above this, although partial sections were obtained here and there, the continuity is broken. There appears to be altogether a development of 4,000 to 5,000 feet of measures above the top of the section just given. In contrast to the lower part of the series, black shales are rarely found here. Brown colours prevail throughout. The principal rocks are: soft brown friable shale decomposing easily into brown sand, brown shale weathering into angular blocks, soft grey, greenish, and yellowish sandstone weathering brown and reddish, frequently unequally and nodularly hardened. There are some beds of harder grey sandstone and conglomerate. Dark grey friable shale forms an appreciable part of the series, and an occasional band of black shale is to be seen. Toward the top of the series there is a notable bed of conglomerate, composed of well-rounded dark, cherty quartzite pebbles up to six inches in diameter, loosely held together by a matrix of soft grey sandstone. It decomposes readily, the pebbles being found in abundance in stream-beds and strewn along the hill-sides, while the rock in place, like the outcrop of coal-seams, is only to be found in certain favourable locations.

The total thickness of Cretaceous rocks deposited in the area, according to the above estimates, is from 12,000 to 13,000 feet.

It is not at all probable that a section could be found in any other part of the area that would exactly, or even closely, correspond to the one just given. A comparison of a part of this section with the beds at the mines on Coal creek, shows that there is a great difference in thickness between the measures at the two places. The coal seams numbered 61, 63, and 71, in the section, correspond to the three seams which up to the present have been chiefly worked at the mines as shown in the following table. The distance between the two places is about seven miles.

	Near Morrissey.	On Coal creek.
Coal	10 feet.	10 feet.
Intervening beds	140 "	60 "
Coal	36 "	30 "
Intervening beds	197 "	42 "
Coal	6 "	6 "

It will be seen that while there is a great diminution of the intervening beds, the coal seams are fairly persistent. This may not be the case throughout the whole of the area, but whatever change may take place, is as likely to be favourable as otherwise. The openings at Michel, sixteen miles north of the mines on Coal creek, expose three seams of coal, fifteen to seventeen feet in thickness, but there is not yet sufficient evidence to correlate them with the seams at Coal creek. What there is, however, tends to show that some of the seams at least have a greater thickness here than they have to the south.

The coal seams near Marten creek were not examined in detail, as the excavations made there, about the same time as those near Morrissey, have caved in, and re-excavation would be necessary to expose the seams. Measurements were made at this place also by Mr. Frank B. Smith, engineer for the Crow's Nest Pass Coal company, and the results are given in Dr. A. R. C. Selwyn's Summary Report for 1891. A part of this list of seams agrees fairly well with the Morrissey section, but in other parts there is a marked difference. It appears likely that the four lowest seams there given are a repetition of some of the upper ones, and are placed at the bottom, either by attempting to compile partial sections at two or more places, or because the excavations were continued downward across a line of fault which runs north-and-south, near the outcrop of the lower seams. The lowest of the large seams was not fully exposed when the list was published, and further work showed a much greater thickness of coal than was then estimated. Apart altogether from any success in correlating the individual seams in this section at Marten creek with those in the Morrissey section, there is abundant evidence to show that they are of the same horizon, and that there is only one set of coal-measures to be found in the area.

The Kootenay series of Dr. Dawson comprises the lower and middle beds of the section just given. Their age has been established as Lower Cretaceous, chiefly by the determination by Sir J. William Dawson of fossil plants contained in the beds of the coal-bearing horizon. It was remarked in this connexion that the list of plants included "some forms usually regarded as Jurassic, but that the greater number have the facies of the

Lower Cretaceous."[1] There is, however, in this section at least 3,000 feet, and probably a much greater thickness, of beds underlying the horizon from which these plants were taken. This year two specimens of Ammonites and several specimens of a Belemnite were discovered in these lower beds. They have not yet been determined, however. The rocks of the upper part of the section probably extend in to the upper division of the Cretaceous representing the Dakota group or even higher members. No fossils have yet been found in these beds.

Without the assistance of a map, it is difficult to give a clearly intelligible description of the outcrop and attitude of the coal seams, but by omitting detailed statements of distances and elevations, something further may be said. Along the front of the escarpment facing the Elk river, the coal seams begin to outcrop at elevations of 1,500 to 2,000 feet above the river. The dips are uniformly to the east at angles of 20° to 40°. Going eastward up Coal creek, these dips are seen to flatten out, until at a distance of about five miles from the Elk the beds are almost horizontal. They continue thus with slight undulations nearly to the summit between Coal creek and Marten creek, where the dips begin to be reversed. A short distance beyond, to the northeast of the summit, these dips are greatly increased and the successive beds are rapidly brought to the surface until the coal measures again appear at the crossing of Marten creek.

Marten creek is one of the sources of the south branch of Michel creek, which occupies a wide low valley running northward to the "loop" on the railway. The erosion of this valley has carried away the coal measures from a wide strip of country. The valley follows the line of what was, at one time, probably a broken anticline caused by the uplifting of the limestone floor of the basin. Two faults resulting from this movement are to be seen running parallel to the valley, one on each side. The uplift was greatest to the north where there is a protruding hummock of the limestone near the junction of the west branch. Toward the south, evidence of this movement gradually dies out, extending only a few miles to the southeast of the mouth of Marten creek.

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[1]Trans. Royal Soc. Canada, Vol. **X**, Sec. **IV.**

Beyond the valley of the south branch of Michel creek, the coal measures outcrop well up the mountain side in the same attitude and relative position to the stream that the beds on the front of the escarpment bear to the Elk river. The measures continue eastward forming another syncline, narrower than that first described, on the west side of the valley, and should outcrop again on the mountains near the edge of the Cretaceous area. Further information is, however, wanting at this point.

North of Coal creek, in the area lying between the south branch of Michel creek and the Elk river, the beds do not long continue to hold the same regular form that they exhibit along Coal creek itself. A few miles north of the creek, the transition from the steep dips at the front to the horizontal position farther back is more abrupt; and, a short distance farther northward, becomes a sharp break with more or less faulting. This fault continues northward to opposite a point between Hosmer and Sparwood stations. Beyond that the beds resume a more normal attitude, such as they have near Coal creek. On the east side of the fault the rocks dip to the south at angles of 10° to 15°. The result of this is that the coal-measures are brought nearer to the surface, and they are found outcropping on the side of a deep gash in the hills made by a small stream emptying into the south branch of Michel creek, below the junction of the east fork. This stream thus causes another bay in the outline, at least of the upper part, of the coal-measures. Eastward from this place, the beds bend around gradually to join the measures at Marten creek, without any further serious dislocation. The fault above mentioned generally lies behind the front of the escarpment, but for a few miles northward from a point opposite Hosmer it cuts across the face of the hills some distance below the summit. This gives a complicated appearance which is the only exception to uniformity along the entire front.

Where Michel creek cuts through the northern part of the area, the basin is narrow, and the upper part of the coal-measures has been eroded away in the valley. The bottom of the syncline is probably a short distance to the east of Michel station, and it appears to rise gradually both to the north and the south, with the lowest point of the basin, or trough, situated a little to the south of the stream.

There are minor folds and irregularities in the rocks, and even with the help of the knowledge gained by the Coal company in their operations at this place the situation is not entirely clear.

To the north of the stream the beds continue in the form of a gradually rising syncline for a distance of about six miles. Beyond this, although Cretaceous rocks occupy the bottom of the Elk River valley for some distance, there is no sign of any coal-measures for fully twenty-five miles. For several miles of this length the Cretaceous rocks are altogether wanting and the Carboniferous limestones and quartzites are exposed to view.

On the hills to the east of the "loop" on the railway at the forks of Michel creek, thin remnants of the Cretaceous rocks are left in patches, and parts of the two lowest coal seams still remain, but for the most part the measures have been worn away.

The narrower syncline of coal-measures on the east side of the south branch of Michel creek, continues northward beyond the interruption caused by the east branch and extends for a short distance across the main watershed into the district of Alberta. The coal-measures in this extension occur in a long spur from a mountain, four or five miles southward from the Crowsnest summit on the railway. They are fairly flat-lying for the greater part, but on the west side of the spur, facing the old pack trail, a sharp fold or fault has given the rocks a dip of 60° to 70° to the northeast. Hereabouts, especially on the coal seams occurring in the steeply-dipping part of the rocks, the British American Coal company has done a good deal of prospecting. The seams have been exposed at the surface in many places, and during the last season a tunnel was commenced with the object of tapping the seams some distance below their outcrop. The point at which the tunnel is driven is 600 feet up the hill, but the seams are exposed lower down, and can no doubt be found near the base of the hill in a convenient place for shipping the coal.

In the part of the coal lands thus described, there is no very great area intact, and as there are several points from which the measures may be conveniently attacked, no excessive underground haulage will be necessary. The coal seams do not reach any great depth, being almost entirely above the level of the Elk river.

The measures lying south of Coal creek occupy a practically unbroken block of country twelve miles or more in width and of somewhat greater length. Along the front by the Elk river, the beds continue to hold uniform easterly dips and behave in the same way that they do at Coal creek. Morrissey creek, ten miles south of Coal creek, makes a slight indentation in their outline and affords a good site for mining operations. Southward from Morrissey creek, the escarpment or rim of the basin begins to bend to the east and continues curving around along the southern limit of the measures by Lodge-pole creek, finally turning northward as far as the Flathead river at the southeastern corner of the area. Here the escarpment ends. The rocks all the way around dip regularly inward. They gradually flatten out to a more or less horizontal position a few miles from the edge, without any noticeable fractures, but in so doing, in this southern part of the area, they are carried to a greater depth than they are to the north. A section eastward from Morrissey creek would show that the coal-measures, after first bending to a horizontal position, rise a little in a gently swelling anticline and then slope steadily downward until they reach the lowest depth in the whole area. This point of greatest depth is only three or four miles from the eastern edge of the basin. The rocks at the surface are the highest beds of the section previously given and they still dip to the east. A low drift-covered valley lies between this point and the eastern edge, where the lowest beds of the series are upturned against the limestone mountains. It is probable that this rapid transition has been assisted by faulting. Owing to the depth of the measures in this eastern interior part, it is doubtful whether the coal can be profitably extracted. For the greater part, however, the conditions for mining are favourable enough. Coal creek, Morrissey creek, and Lodge-pole creek are all suitable places to commence operations, and a part of the area can be reached from the south branch of Michel creek.

The mines of the Crow's Nest Pass Coal company at Coal creek, already referred to, were started when the Crowsnest branch of the Canadian Pacific railway was built. On this line, near the crossing of Coal creek, the town of Fernie has sprung up. It is a good example of rapid western growth. The mines are reached from Fernie by a spur from the main line running four and a half miles up the creek. The good quality of the coal is now so well established that further mention in that respect is unnecessary. The output is increasing rapidly of late and is now well over 1,000 tons a day. About one-half of this is converted into coke, 360 bee-hive ovens being in constant operation at Fernie. The coke produced is of superior quality and preparations are being made to increase the number of ovens.

In addition to the mining on Coal creek the company has recently commenced work on the seams at Michel and is already turning out coal for shipment. Material is on the ground for the construction of coke ovens and this point promises shortly to equal Fernie in importance.

Although the extent of the coal lands in the area can as yet be only somewhat roughly estimated, the estimate (230 square miles) should be near enough to the truth to be used as an argument for the calculation of the total available coal supply. The thickness used in the calculation is the minimum already given of 100 feet of workable coal.

Total area of coal lands		230 square miles.
		= 147,200 acres.
One acre with 100 feet of coal would yield	153,480	tons of 2,240 lbs.
50,000 acres would yield	7,674,000,000	" "
147,200 acres would yield	22,595,200,000	" "

SECTIONS ON SOUTH FORK OF MICHEL CREEK.[1]

(Extracts from report by W. W. Leach.)

The coal measures outcrop in the valley of the South fork of Michel creek, at a point about $10\frac{1}{2}$ miles above the "loop"

[1]Summ. Rep. Geol. Surv., 1901, pp. 76A-78A.

of the Crowsnest Branch of the Canadian Pacific railway, and at an elevation of about 900 feet above the railway. This valley would thus afford a comparatively easy grade for a branch line, and, as it is fairly wide and flat-bottomed, there would be ample room for coke ovens and other necessary structures. As stated by Mr. McEvoy, there are two faults running parallel to the valley, one on each side; the eastern being the most important. This fault was not traced northwards farther than the branching forks of the South fork. To the south, it continues nearly parallel to the stream about a mile to the eastward, to near the summit, when the valley swings round to the east, meeting the line of fault which continues across the summit and down the valley of a branch of the Flathead river. This fault is probably an overthrust from the east, the rocks to the west of it in the valley being chiefly conglomerate and gritty sandstones with some beds of brownish and yellowish arenaceous shales, characteristic of the beds overlying the coal measures.

The western fault lies generally below the outcrop of the coal seams on the face of the escarpment, and dies out about one mile and a half south of Marten creek. The structure here is difficult to trace out as the hillsides are heavily drift-covered and densely timbered, exposures being very scarce. However, it is possible that this is also an overthrust fault, the movement in this case being from the west. If so, the area lying between these two faults in the valley-bottom must be underlain by the coal measures, but further information is necessary before the attitude of these beds is made entirely clear.

The section given below was measured at a point on the west side of the creek, about two miles and a half south of the mouth of Marten creek. The lower seams are not included, as they outcrop in the valley-bottom where the covering of drift is so deep that it was impossible to uncover them in the time available. The strike here is generally about N. 9° W., dip about 25° to the west, gradually flattening towards the west. This dip remains fairly regular to the north for about a mile, when the western fault mentioned above is met with. To the south the coal seams gradually disappear beneath the bed of the creek, which is here rising rather rapidly, until the summit is reached, when they are cut off by the eastern fault and do not outcrop again for some miles down the Flathead river.

The section which follows, measured by Mr. Denis, is given in descending order:—

		Feet
1	Grey arenaceous shale with occasional narrow bands of black shale	46·2
2	Sandstone	61·5
3	Grey shale	24·9
4	Coal	4·2
5	Grey shale	30·0
6	Black shale	3·2
7	Coal	2·8
8	Black shale	3·2
9	Grey shale with narrow bands of black shale	89·3
10	Grey shale	9·2
11	Black shale	10·0
12	Sandstone	0·7
13	Grey and black shale	8·4
14	Grey shale	47·5
15	Coal	2·0
16	Grey shale with narrow bands of carbonaceous shale	5·7
17	Grey shale	82·7
18	Coal with shale parting	3·6
19	Grey shale	9·4
20	Black shale	3·0
21	Grey shale	7·7
22	Coal	0·8
23	Grey shale	64·7
24	Coal with shale parting	7·3
25	Grey and black shale with a little coal	8·7
26	Grey shale	25·0
27	Coal	1·5
28	Black shale	4·6
29	Grey shale	7·2
30	Coal	13·0
31	Black shale	0·8
32	Arenaceous shale with thin beds of sandstone	31·0
33	Grey shale with a little coal	73·5
34	Carbonaceous shale and coal	1·6
35	Grey shale	8·2
36	Coal	2·1
37	Shale	16·1
38	Covered	32·0

		Feet
39	Sandstone..	8·2
40	Arenaceous shale with narrow bands of black and carbonaceous shale....................................	32·0
41	Black and carbonaceous shale with thin seams of coal....	24·4
42	Coal with shale partings..............................	7·1
43	Black shale with thin seams of coal......................	24·4
44	Dark greyish shale..................................	15·6
45	Coal with shale parting...............................	25·2
46	Black shale with thin seams of coal.....................	10·0
	Total...	921·8
	Total thickness of coal...........................	69·6

A comparison of this section with that measured by Mr. McEvoy at Morrissey, gives the following results:—

On South fork of Michel Creek		Near Morrissey	
Seams numbered	Feet	Seams numbered	Feet
24 Coal with partings.....	7·3	50 Coal..................	7·0
Intervening beds........	47·0	Intervening beds........	35·0
30 Coal..................	13·0	53 and 55 Coal with partings	14·0
Intervening beds........	115·1	Intervening beds........	154·0
36 Coal..................	2·1	58 Coal..................	3·0
Intervening beds........	112·7	Intervening beds........	120·0
42 Coal with partings......	7·1	61 Coal..................	10·0
Intervening beds........	61·7	Intervening beds........	140·0
45 Coal with partings......	25·2	63 Coal (upper part impure)	36·0

It will be seen from the above table that the coal seams are fairly persistent, considering the fact that these two points are about ten miles apart. The intervening beds, however, show a wider variation with a decided tendency to thin out in the lower part of the section at least.

THE MINES.

The following extracts from Guide Book No. 9 prepared for the Twelfth International Geological Congress deal with the mining activities of the district and the seams mined. They were prepared by Mr. W. W. Leach.

Corbin.

At Corbin an outlying remnant of the coal-measures is being exploited by the Corbin Coal and Coke company. This company is operating two mines; No. 1 being opened near the valley level by means of a tunnel along the strike of the seam, while No. 2 mine is situated nearly 1,000 feet above the floor of the valley. The geological relationship of these two openings has not as yet been worked out, and it is possible that the same is represented at both places. At No. 1 mine the seam is nearly vertical and varies greatly in size, from a minimum thickness of 10 feet (3 m.) to a maximum of nearly 250 feet; this great difference may be due to compressed monoclinal folding. At the upper mine the coal has been stripped near the top of the hill, and shows the coal in a synclinal basin about 370 feet in width; the thickness of the coal near the centre of the syncline having been proved by drilling to be over 100 feet.

The upper mine is reached from the valley by means of a switch-back railway and the coal is worked in open-cuts with a steam shovel. The output in 1910 from No. 1 mine alone amounted to about 142,000 tons.

Michel.

At Michel, near the centre of the trough, the Crow's Nest Pass Coal company is operating an extensive colliery and coke-making plant. The company has developed seven seams in all, four on the south side of the valley and three on the north side; of the former the seams designated upper No. 3, No. 3, No. 4, and No. 5, have the following respective widths: 10 to 12 feet (3 to 3·6 m.), 4½ to 5½ feet (1·3 to 1·6 m.), 6 to 8 feet (1·8 to 2·4 m.), and 6 to 8 feet (1·8 to 2·4 m.); while on the north side, No. 7 seam is about 11½ feet (3·5 m.) thick with a 2½ foot (0·76 m.) parting; No. 8 is from 8 to 14 feet (2·4 to 4·2 m.) and No. 9 is about 10 feet (3 m.) thick. No. 9 seam has not been worked for some years. All the mines at Michel, with the exception of No. 3, are worked by the pillar and stall method.

Hosmer.

At Hosmer the colliery of the Department of Natural Resources of the Canadian Pacific railway is situated. A rock tunnel, across the measures, has been driven at a point 600 feet above the railway for a distance of 4,931 feet, which has cut ten coal seams of the following dimensions:—

No. 1	seam,	18 feet.
No. 2	"	12 feet.
No. 3	"	22 feet.
No. 4	"	4 feet.
No. 5	"	5 feet. 10 inch parting. 13 feet coal.
No. 6	"	8 feet, 8 inches.
No. 7	"	4 feet.
No. 8	"	5 feet.
No. 9	"	8 feet.
No. 10	"	large seam.

Of these seams Nos. 2, 9, and 10 are at present being worked and it is probable that Nos. 9 and 10 correspond to seams Nos. 2 and 1, respectively, of the Coal Creek colliery. The lowest seams, first cut in the tunnel, have easterly dips of 65 degrees, the dip flattening from there on to a minimum of about 25 degrees. In addition to the tunnel seams, the company is operating a mine on the outcrop of the coal where No. 2 seam is being worked by means of a slope; this point being several hundred feet higher than the tunnel entry.

From the tunnel the coal is lowered to the tipple level by a seam-actuated, double-track incline, and thence hauled to the tipple by air locomotives. The tipple, of steel construction, is equipped with screens and picking belts, and has storage bins with a capacity of 2,600 tons of coal and 2,400 tons of slack. The slack coal is treated in a Robinson washer of 400 tons daily capacity, the washed product being utilized in the manufacture of coke in a battery of 240 beehive ovens.

Coal Creek.

Coal creek is a tributary of the Elk river from the east, which occupies a comparatively deep valley cut through the Cretaceous rocks, thus affording a suitable railway grade to the point where the valley floor rises to meet the easterly dipping coal measures. Here the mines are situated. The coal seams strike approximately at right angles to the valley, thus enabling tunnels to be driven on the seams on each side of the creek, while, as this point is approaching the centre of the basin, the seams dip at much lower angles (12 to 18 degrees) than at their outcrop along Elk River escarpment. The company is working five seams here, while several others have been prospected to some extent. The seams being worked with their several thicknesses, are as follows:—

No. 1	Average	thickness	10 feet.
No. 2	"	"	$4\frac{1}{2}$ feet.
No. 5	"	"	12-14 feet.
A	"	"	8 feet.
B	"	"	$3\frac{1}{2}$ feet.

Seams Nos. 1, 2, and 5 are the ones most extensively worked; Nos. 1 and 5 being opened on the north side of the valley, while three mines are being operated on No. 2 seam, viz., No. 9 mine on the north side and Nos. 2 and 3 on the south side of the valley. The coal from all the seams except No. 2 is mined by the pillar and stall method, whereas, in the mines on No. 2 seam, the longwall system is in use. Inside the mines, haulage is by horses and air locomotives, while all the coal from the various mines is hauled to the same tipple from the several entries, by steam or electric motors. The tipple, a steel structure 840 feet in length, which bridges the valley, is of the Heyl and Patterson revolving side dump pattern, and is capable of handling 4,000 tons daily. It is electrically driven and equipped with the necessary screening and picking appliances. The slack coal is stored in large bins at Fernie and is utilized there in making coke, 452 beehive ovens being in operation.

Morrissey.

The Carbonado collieries have been idle for some years, although at least nine seams have been worked at different times, and a large plant, including 240 coke ovens, installed. The extremely gaseous nature of the coal at this point, resulting in a number of serious outbursts of gas, has caused it to be considered expedient to abandon this colliery for the present.

NORTH FORK OF MICHEL CREEK.[1]

(Extracts from report by W. F. Robertson.)

Crown Coal and Coke Company.

The following notes on the holdings of the Crown Coal and Coke company, situated on the north fork of Michel creek, have been extracted from a report on the property by Chas. L. Hower, mining engineer, of Johnstown, Pa., and were kindly supplied the Bureau.

LOCATION OF THE PROPERTY. The property of the Crown Coal and Coke company consists of certain coal lands situated in southern British Columbia near the Alberta line (long. 114° 25′ W., 49° 45′ N.). It is about forty-eight miles north of the International Boundary, and its southern extremity is six miles north of the Canadian Pacific railway, where it crosses the Continental Divide via the Crowsnest pass at an elevation of 4,425 feet above sea-level. This pass is one of the lowest in the Rocky mountains.

DESCRIPTION OF PROPERTY. The entire property is on the watershed of the north fork of Michel creek, a tributary of the Elk river. For a distance this creek is the approximate western boundary, and the property lies on the western slope of the Sentinel range of the Rocky mountains.

In most places nature has stripped the softer measures away to the hard rocks and limestones which now comprise the crests and headlands of the great Rocky Mountain ranges,

[1]Report Minister of Mines, B.C., 1911, pp. 123-125.

and only in extremely favoured locations, in narrow belts nestling against the great ranges and parallel to them, have the coal-bearing Cretaceous rocks been preserved from destruction.

GEOLOGY OF PROPERTY. Crown mountain is one of the survivors, the cap of hard conglomerate overlying the coal-measures indicating one of the reasons they were not destroyed. In the vicinity of the Crown Coal and Coke company's property is Crown mountain, an upturned block of strata, exposing the raw edges of the Kootenay series (the coal-bearing Cretaceous rocks) on its eastern escarpment and disappearing under the limestone range to the west.

PROSPECTING. The prospecting-work on the property has been almost entirely confined to the four Crown-granted sections on Crown mountain. During the past four years this part of the property has been most exhaustively examined, fixing the value of the property as a coal-depository and disclosing the natural mining features.

On this portion of the property two camps have been built and the prospecting-work carried on in thorough and systematic manner. A complete section of the measures has been uncovered, disclosing eight workable seams, and the continuity of the measures has been established by tracing seam "C" around the mountain for a distance of over three miles.

No coal has yet been developed on the southern claims.[1] The lay of the coal, if present there, is such that it is not as easily uncovered as in the northern part of the property. Should further prospecting-work disclose that this part of the property is barren, the various claims, now held on leases, should be relinquished, unless the timber is of sufficient value to justify the expense of Crown-granting them.

COAL-MEASURES ON PROPERTY. The Kootenay coal-measures outcrop on the western side of the creek, opposite the southern end of the property. They follow up nearly parallel with the stream and cross the west branch at a point

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[1]Information supplied the Geological Survey by Mr. B. L. Thorne shows that south of the forks several seams have been found on the west side of the valley indicating a possible narrow coal-field about two miles wide. D.B.D.

about 2,000 feet above the forks. From this point the outcrops swing around the southern end of Crown mountain and outcrop in its eastern escarpment. The measures gradually rise to the north, and on the Crown property they are about 2,000 feet above the eastern branch of the creek.

The coal-bearing rocks are about 500 feet thick and contain at least eight workable seams of coal with a combined thickness of 65 feet. As before stated, one of the seams has been traced through the entire property and the continuity of the measures thus established.

The only evidence of disturbance in the field is along the eastern escarpment of the mountain, where there are indications of a break in the strata near the outcrop of the same; also, near the point where Crown mountain joins the main range to the north, a "wrinkle" has broken the measures, almost at the northern boundary of the property. The general dip is 28 degrees and to the west.

Amount and Quality of Crown Coal. The following tabulations indicate the quality of the coal in the Crown-granted part of the property:—

Coal-contents, Crown Mountain (owned) Sections.

Workable seams	Thickness		Acreage	Amount (Net tons)
	Ft.	*in*		
A	6	0	800+	7,200,000
B	5	0	900+	6,750,000
C	16	5	1100+	26,400,000
D	6	5	1200+	11,500,000
F	5	5	1300+	11,200,000
H	12	0	1400+	25,200,000
K	8	0	1500+	18,000,000
New seam	6	0	1600+	14,400,000
Total thickness	63	3		
Total of workable coal known				120,650,000

Analyses of Coal-seams, Crown Mountain.

Elements	Seam C.	Seam D.	Seam G.	Seam H.	Seam I.	Seam J.	Seam K.
Moisture.........	7·9	5·2	6·7	8·3	7·5	5·6	4·4
Volatile..........	23·00	22·00	21·60	22·20	23·55	19·60	18·80
Fixed carbon.....	71·55	74·50	69·00	69·30	70·90	74·65	73·40
Ash.............	5·45	3·50	9·40	8·50	5·55	5·75	7·80
Sulphur..........	0·10	0·59	0·22	0·30	0·55	0·59	0·51

The above analyses were made by Wm. H. Stowell, of Spokane. The samples were taken from the various prospects on the property. Most of these were merely shallow holes on the crop, and as a result the coal contained an excess of moisture and some surface impurities. Under mining cover the coal will not contain above 2 per cent moisture.

Correcting for excessive moisture, the following is an average of twenty analyses of all the seams on the property:—

Average Analyses of all Seams, Crown Mountain.

Moisture..................................	2·00	per cent
Volatile combustible........................	21·08	" "
Fixed carbon..............................	72·12	" "
Ash......................................	6·80	" "
British thermal units.......................	14,212	

ELK RIVER COAL-FIELD.

(See Diagram I.)

North of the wide syncline in which is found the Crowsnest coal-field, the mountains are disposed in ridges corresponding to the axes of narrow parallel fault blocks, with a general north and south alignment. The eastern boundary of British Columbia follows the upturned eastern edge of one of these blocks from the Crowsnest pass northward to the head of Elk river, and the rocks exposed on its westward slope consist of limestones and quartzites of Carboniferous and Permian age. On the lower slopes, a shale series containing beds ranging in age possibly from Triassic to upper Jurassic, are seldom seen although probably present. The character of the topography indicates that the Lower Cretaceous sandstones, containing the coal-bearing beds of the Kootenay formation, form a long narrow strip in the valley to the west of the summit range, and where the denudation has not been excessive may also be found projected high up the westward slope of the range. Of these beds there are in places a thickness of upwards of 1,800 feet, and in them as many as 22 seams of coal are found with several that are very valuable both on account of thickness and quality. The coal area thus formed is limited on the west by the upraised rocks of the continuation of the Crowsnest syncline, near the western edge of which the Elk river flows northward to a point about 38 miles north of Sparwood where this syncline is fractured obliquely by a cross fault and is overridden on the northwest by a more elevated block which continues northward into Alberta. The northern portion of the Crowsnest syncline, where overridden by the next fault block to the west and north, is probably bent over in a close anticline and is depressed so that the coal-bearing Cretaceous beds again appear and are brought into contact with the same measures in the fault block to the east.

Toward the centre the basin is thus seen to be much widened as it includes the same measures capping an easterly-dipping contiguous block to the west, known as the Green Hills area, thus forming apparently a wide syncline. To the north the measures are probably in a monoclinal block; to the south there is some evidence of a syncline especially at its termination on North Michel creek, but its axis is probably near the line of fault.

The northern end of the field is drained by the headwaters of the Elk river and sandstones and conglomerates of the Kootenay formation are found dipping west on both sides of the stream to the foot of the escarpment on the west side. The eastern side is generally occupied by the lower part of the coal-bearing measures. Several small coal seams are found near the height of land between the Elk and Kananaskis rivers, but farther south near Aldridge creek where the Elk river is nearer the western edge of the valley, a greater proportion of the measures occur on the eastern side and quite a large area is there found that would be mineable above drainage level. Between the valleys of Weary creek and Aldridge creek, one such block occurs and in this the prospectors working on this area in 1905 uncovered about 22 seams on the eastern slope of a ridge formed of the Cretaceous beds. The section is merely estimated and although the seams were fairly well exposed by trenching, it may include some surface float coal.

Section on east side of ridge north of Aldridge creek in descending order, estimated:—

Measures with 4 small seams at top of ridge.

	Feet	*Inches*
Coal, fairly clean	9	0
Barren measures	120	0
Coal, with streak of shale in centre	11	0
Barren measures	78	0
Coal	18	0
Barren measures	65	0
Coal	27	0
Barren measures	90	0
Coal	6	6
Barren measures	90	0
Coal	7	6
Barren measures	45	0
Coal	11	0
Barren measures	68	0
Coal	18	0
Barren measures	90	0
Coal	8	0
Barren measures	80	0
Coal	14	0
Shale	3	6
Coal	5	3
Shale	22	0
Coal	6	0
Barren measures	130	0
Coal	17	0
Barren measures	68	0
Coal	3	6
Shales	32	0
Coal	7	0

	Feet	Inches
Shale	10	0
Coal	2	0
Shale	2	0
Coal	5	0
Sandstone at base of measures		
Esitmated section	1,169	3
Coal reported in above section	175	9

Several of these seams have been probably prospected in the exposures on Aldridge creek and later reports on this work will be found included under extracts from W. F. Robertson's report. Analyses[1] were made (1) of sample of the coal in a tunnel at Aldridge creek on what appeared to be a 7-foot seam; (2) of surface sample from 6-foot seam east of Elk lake; and (3) of surface sample of 13-foot seam on height of land, Alberta boundary.

	(1)	(2)	(3)
Moisture	1·60%	4·90%	9·10%
Volatile combustible	32·47	30·06	21·00
Fixed carbon	63·44	56·60	57·00
Ash	2·49	8·44	12·90

The following reports refer to areas held by various companies. These are, in general terms, to be understood as comprising the following portions of this coal-field.

Northern Coal and Coke Company, from the Alberta boundary south to Aldridge creek.

Canadian Pacific Railway Company, from Aldridge creek to Henretta creek and including the Green hills.

The Imperial Coal and Coke Company, from Henretta creek south to Grave creek, all tributary to Fording river.

The Crown Coal and Coke Company, at headwaters of North Michel creek.

Information on several of these areas is compiled from engineers' reports and supplemented by an examination by the Provincial Mineralogist, from whose report the following is taken.

[1]Report on Analyses, F. G. Wait, Mines Branch, Publication No. 59.

Extracts from Report by W. F. Robertson.[1]

The[2] Cretaceous coal-bearing formation of this area occupies a depression between limestone ranges. On the east side of the area they rest conformably upon the limestones; on the west the limestones have been overthrust upon the sharply folded Cretaceous rocks.

Between the two limestone ranges lie the valleys of the Elk river and its tributary, the Fording river. Between the Elk and Fording rivers are two prominent topographical ridges, the Green hills, formed by the Cretaceous rocks.

The general structure of the Green hills is that of a broad synclinal basin, the southern range of the Green hills forming one limb of the syncline and the northern range the opposite limb; the topographical depression between the ridges is a synclinal trough with its axis running in a northwest to southeast direction. West of the Elk river, near the southern boundary of the area, there is evidence of the existence of an anticlinal fold whose axis lies east of the river, the arch of which has been worn away. This anticline thus lies between the main synclinal basin and the overthrust limestone range on the west.

The coal-measures, so far developed, all lie to the east of the Elk river, with the exception of a relatively small area near the south end of the field which is probably on the anticlinal fold already mentioned, and which, as yet, has not assumed much importance. It is possible, however, that in the upper reaches of the Elk river, near its source, coal may be developed to the west of the river for a short distance.

The base of the coal-bearing measures is well marked by a persistent massive sandstone which outcrops on both edges of the synclinal basin, and underlies several hundred feet of barren shales. The rocks of the coal-measures are coarse and fine sandstones, massive clay shales, and thick bedded shales, on top of which is a band of conglomerate, which has, however, been eroded away in the southern Green Hills range. The

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[1]Report of Minister of Mines, B.C., 1909, pp. 176-183.

[2]From private report by Prof. A. W. G. Wilson, McGill University, Montreal. Kindly loaned by Mr. W. H. Aldridge.

total thickness of the coal-measures is approximately 1,800 feet.

The coal-field so far as known is held chiefly by companies or syndicates, viz., the syndicate represented by Mr. W. H. Aldridge, and known locally as the Canadian Pacific Railway syndicate; the Imperial Coal and Coke company; and the Northern Coal and Coke company.

Canadian Pacific Railway Syndicate Area.

The southern end of this coal area is included in lot 4,588, which belongs to the Canadian Pacific railway, acquired through the British Columbia Southern railway.

Immediately north of this lot and extending fourteen miles up the Elk River slope of the Green Hills range, the coal outcrops are found to be from 1,500 to 2,500 feet vertically higher than the river, but towards the northern end of this group of claims, at Aldridge creek, the coal outcrops come down to the valley level.

On the southern tier of claims held by this syndicate, on lot 3,422, prospecting work has exposed the outcroppings of some twenty-one seams of coal, dipping to the northeast at angles of about 35 degrees. These outcrops are at an altitude of about 7,000 feet, or 2,000 feet higher than the valley of the Elk river, and as they are, therefore, not as favourably located for present development as certain other claims held by the syndicate, they have been only roughly prospected, but sufficiently to prove the existence of the seams here and their general regularity.

About three miles farther north, on the C. H. Gill claim, lot 6,047, Dr. Wilson has marked the outcrops of some eleven seams of coal, of which he gives the analyses of the coal from seven seams, including seams of thickness of from 8 to 20 feet. These seams are located at altitudes of from 6,000 to 6,500 feet, or from 900 to 1,500 feet above the level of the river at this point. These seams are also dipping to the northeast at angles of about 28 degrees, and doubtless further prospecting will reveal quite as many seams as on lot 3,422, while various intermediate cuts vouch for their continuity between the two points. These exposures are seen on the hillside just above the company's cabin and storehouse—known locally as C.P.R. Headquarters—to which point there is a wagon-road from Michel, over which supplies are taken in by a two-horse team, the time occupied by the trip inward, loaded, being three days and the return trip, light, two days.

A mile farther north from Headquarters, on lot 6,048, what are presumably the same seams have been exposed by a series of test-pits, showing the seams dipping to northeast.

The Green hills in all this distance have an average maximum altitude of about 7,000 feet, although the occasional peaks rise as high as 8,000 feet over a limited area, which would represent a maximum cover over the seams of about 2,000 to 3,000 feet.

Proceeding northward from Headquarters, outcroppings of coal are found on the hillside for ten miles; for the first five miles the dips are to the northeast, after which they are found to be southwest, indicating that at the point of change the basin of the anticlinal fold is crossed, and that the coal found northward is a part of the eastern leg of the anticlinal basin previously referred to.

At Abbott creek, on lot 6,823, about nine miles north of Headquarters, and at Aldridge creek, on lot 6,825, a number of seams have been prospected and proved.

On the former creek Dr. Wilson shows some eight seams of coal as developed within a vertical height of 400 feet, that is between elevations of 5,800 and 6,200 feet, of which he gives analyses. These seams are found to strike northwest and southeast, with dips to southwest of from 43 to 62 degrees at the outcrops.

On Aldridge creek, on lot 6,825, Dr. Wilson gives analyses from some seven seams, the outcrops of which are cut by the valley of the creek. (See Schedule of Analyses, samples Nos. 60 to 66).

Aldridge creek is practically the northern boundary of the group of claims held by this syndicate, although it holds one claim, lot 6,826, covering the river valley for a mile farther north.

The seams at Aldridge creek are, unquestionably, those most readily accessible and the ones that can be opened up and made productive with the least expenditure of money or time, and are, as far as can be judged by the present, the seams which promise the lowest mining costs; consequently, it is at this point that the development of late years has been chiefly done. Mr. Dowling, of the Geological Survey, in his report, places the total thickness of coal at 163 feet, but does not mention the number of seams that go to make up this total thickness.

The management at Aldridge creek reports some twelve known seams as having been partly developed; the lowest four of these seams have been developed on the property of the Northern Coal company (as on the Canadian Pacific Railway property they are probably covered), and in the flatter lands, and will eventually be reached by shafts.

The next five seams are those most readily available for immediate opening-up, and on these the syndicate has done the most serious development work.

The writer inspected these five seams this past summer, and found them to have a respective thickness of 14 feet 2 inches, 19 feet 9 inches, 9 feet, 3 feet 4 inches, and 10 feet. Analyses of coal from these seams will be found in the Schedule of Analyses accompanying this report, samples Nos. 35 to 38.

Above these five developed seams are three others having thicknesses of 10 feet, 15 feet, and 4 feet, respectively.

These five developed seams outcrop on the south bank of Aldridge creek from a quarter to half a mile above the flat benchland formed in the valley of the Elk river, and along this bench it is probable railway connexion would be made.

The openings have all been made at, practically, the same elevation, just sufficiently high above the creek level to allow for suitable tipple height above a spur line of railway to be built up the creek from the river valley.

The following represents the conditions in which these five seams were found in August, 1909:—

No. 1 tunnel was driven in 153 feet on a seam of coal 14 feet 2 inches thick, in a S. 10°E. (astro.) direction, which represents the strike of the seam; the dip is 45 degrees to the west.

The seam is free from serious shale partings, and was sampled by the writer completely across the face. The analysis is given in Table of Analyses as No. 1. The pavement under the coal-seam is sandstone, while above the coal is 1 foot 2 inches of clod, or hard shale, and then a sandstone roof. The coal will make a good coke.

No. 2 tunnel was in 154 feet on a seam having the same strike, and a dip of 41 degrees to west. The seam has a sandstone pavement or foot-wall, on which lies 4 feet of good coal, then a shale parting of 9 inches in thickness, and then 14 feet of coal, above which there is 1 foot of clod, or shale, and then a sandstone roof. The 14 feet of coal was sampled at the face by the writer, and the analysis is given in Table of Analyses as No. 2.

No. 3 tunnel had been driven in 160 feet on the same strike, while above it, and separated by a 40-foot pillar, a counter level had been started away and was then in 35 feet. The seam has a dip to the west of about 70 degrees, and a sandstone pavement or floor, above which is 3 feet of coal, then 2 feet of shale parting, and then 9 feet of coal, above which is a hard sandstone roof. The 9 feet of coal was sampled, and the analysis is given, No. 3 in Table of Analyses herewith.

No. 4 tunnel had been driven in for 93 feet in a S. 35°E. direction on the strike of the seam; the dip of the seam was 58 degrees, and to the west. The pavement was sandstone, above which was 7 feet of dirty coal—coal and shale mixed; this part of the seam is not good enough to mine. Above this was 4 feet 3 inches of unusually hard, firm coal; while above this coal was 1 foot 3 inches of clod, or hard shale, overlain by a sandstone roof.

No. 5 tunnel had been driven in 91 feet on the strike of a coal-seam which dips at an angle of 37 degrees to the westward. The pavement of the seam is sandstone, on which lies 10 feet of coal, with above it 1 foot 6 inches of hard shale and then a sandstone roof. The coal of this seam as seen at the face is particularly hard and clean; its analysis is given on an average sample across the face, as No. 4 in the Table of Analyses.

As already stated, the syndicate has, at its headquarters camp, substantial log buildings, to which point supplies are brought in by wagons.

From Headquarters to Aldridge Creek camp there is only a pack-trail as yet, which, however, with a little work could be made into a good sleigh-road.

At Aldridge creek there has been erected a comfortable office for the local superintendent, a good log bunk-house and cook-house, a blacksmith-shop, having at one end a dry-room and wash-room for the miners; it is at this point that the most advanced preparations have been made for the actual opening-up of the seams.

From Headquarters a trail leads over the Green hills to their eastern slope in the valley of Fording river, where the syndicate had established a camp which, in August, 1909, was still under canvas, but two substantial log buildings were then approaching completion; a third had been begun, and all should have been completed before snow fell in the autumn. These buildings will serve as office and superintendent's house, cook, and bunk houses, and will be the headquarters for prospecting this part of the field.

The mining done here is entirely prospecting and of a nature only to demonstrate the field, and it is not expected that this location will be developed until after the Aldridge Creek camp is fully opened up.

Several outcrops of coal have been located here, dipping to the southwest, and these are considered as marking the eastern outcrop of the synclinal fold, which has been more fully developed on its western outcropping in the Elk River valley.

The most northerly opening seen in this camp was near the northern part of lot 6,647, the Jane L. Gill claim, where a tunnel had been driven for a distance of 55 feet, disclosing a seam of coal some 14 feet thick, having a strike of about S. 60°E. (mag.), and dipping to the southwest at an angle of about 45 degrees.

The seam promised well, but, as far as had then been developed, the coal was very soft, as it was near the weathered outcrop.

Table of Analyses of Coal from the Canadian Pacific Railway Syndicate's Elk River Seams. Sampled by Provincial Mineralogist. Analysed by Provincial Assayer.

No.	Sample obtained from	Moisture	Vol. comb.	Fixed carbon	Ash	Coking qualities
		%	%	%	%	
1	No. 1 seam, Aldridge cr. C. P. R. Synd..........	1·1	23·3	69·0	6·6	Good
2	No. 2 seam, Aldridge cr. C. P. R. Synd..........	1·0	23·9	65·9	9·2	"
3	No. 3 seam, Aldridge cr. C. P. R. Synd..........	0·9	22·4	64·4	12·3	"
4	No. 5 seam, Aldridge cr. C. P. R. Synd..........	0·9	18·9	67·4	12·8	"
5	10-ft. seam, J. R. Wilson claim, Elk River Headquarters...............	0·9	17·9	73·7	7·5	Fair

Northern Coal and Coke Company Area.

In the Elk River valley, immediately adjoining on the north the lands held by the Canadian Pacific Railway syndicate, there are a number of coal-areas held by the Northern Coal and Coke company.

The development of these areas was in charge of Mr. F. Gardiner, but at the time the property was visited he was away temporarily, the work being left in charge of a foreman—McDonald—who was not very conversant with the affairs of the company, outside of the work he had in hand, which he was prosecuting with the aid of three men.

As far as could be learned, the holdings of this company began at the north bank of Aldridge creek, extending northward about eight miles, and are said to include some thirty-eight square miles of territory.

The men employed in the development were found at work on the fourth block above Aldridge creek, where they were engaged in driving a crosscut prospecting tunnel through sandstone 5 feet by 7 feet, very lightly timbered. The barometric altitude of the tunnel mouth was 5,550 feet, or about the same as the Aldridge Creek outcroppings. On August 9 this tunnel was in 84 feet in a N. 60° E. direction, and had not at that time struck coal—in fact, the coal for sharpening drills was packed on men's backs from Aldridge creek; it is since reported that coal was eventually struck. The hill to the east of the Elk river here is gently rolling, the measures all dipping to the west at an angle of about 44 degrees.

Some 200 yards to the south and 100 feet higher up than the tunnel, there is, in a small gulch, an outcropping seam of coal, on which no work has been done, but which has been stripped by the spring flow of water off the side-hill.

As best could be measured, this seam has from 20 to 25 feet thickness of coal, overlain by 2 feet of shale with a sandstone roof.

The outcrop was naturally soft, broken, and dirty, but a sample from the surface of the outcrop gave, upon analysis: water, 8·6; volatile combustible matter, 20·5; fixed carbon, 54·7; and ash, 16·2. This sample was non-coking.

It was reported that on these properties tunnels had been driven in from Aldridge creek on seams of coal, but these tunnels had been allowed to cave in, and nothing could be seen in them.

While the development done on the property by this company is, as yet, of little importance, the work done by the Canadian Pacific Railway syndicate on the south side of Aldridge creek, and the geological plans prepared, show that, beyond doubt, many of the coal-seams developed on the Canadian Pacific Railway property must continue under the areas held by the Northern Coal and Coke company; there is no doubt but that they will eventually be found and proved on several of the areas immediately to the north of Aldridge creek, at no great depth, and so conveniently located as to be easily and cheaply opened up.

Imperial Coal Company Area.

The property held by this company comprises about ninety lots on the east side of Fording river and between that river and the British Columbia-Alberta boundary line. The company's holdings adjoin, on the south, the holdings of the Canadian Pacific railway east of Fording river, and extend from Henretta creek southward for about twenty-six miles. The area included in these claims covers the Cretaceous strata lying to the westward of the limestone ranges of the Rocky mountains and nearly down to the valley of Fording river within the distance mentioned. Several large streams flowing from the mountains westward into Fording river have cut deep and, in some cases, wide flat-bottomed valleys across the coal-measures, by which valleys access to the coal-seams so cut can readily be had. Each creek valley might, therefore, be said to develop a separate coal-field for mining purposes, some eight in number, which might appropriately be designated by the creek through the valley of which they are accessible. These are Henretta creek, Clode creek, Lewis creek, Smith creek, Ewin creek, Grace creek, Line creek, and Grave creek.

Henretta creek has a wide valley and rises very gradually from the river valley so that it could serve for railway lines to the various coal-outcrops. The Imperial company holds two and a half areas near the mouth of the creek, lots 6,711, 6,709, and fraction 6,719. On these the measures are found dipping to the southwest, at a very low angle on the western portion of the claims, but at an angle of about 45 degrees on the eastern border.

Clode creek is very narrow and steep, and it is probable that it would not be used as a starting point for workings through which coal would be extracted, as these seams could better be worked by drifting along them from Henretta creek on the north, or Lewis creek on the south.

The valley of Lewis creek is flat-bottomed and would give access by railway on very easy grade, the seams outcropping in the hills on either side of the valley. Eagle mountain, which forms the north side of the valley of this creek, has a synclinal structure; on the west the seams dip to northeast at an angle of 20 degrees, on the east they dip 40 degrees to the southwest; while in the middle, two miles east of Fording river, the seams are for some distance nearly horizontal. Some eight seams of good coal are reported as developed, one of which is 31 feet thick and of very good quality[1]. In Castle mountain, which forms the southern side of the valley, the formation is the same as in Eagle mountain. It would appear that the best point to attack the seams in either mountain would be along the axis of this syncline.

This creek gives access to the seams on the south end of Castle mountain and in the north end of Grouse mountain, although it is probable that these seams could be reached, respectively, from Lewis creek on the north and Ewin creek on the south, by drifting on the seams, along their strike, although this would entail a maximum length of underground haulage of about four miles.

Ewin creek has a broad flat valley rising by an easy grade from the river valley and offers excellent ground and space for a large colliery. This is, probably, the most available point for opening up the seams in this company's properties, and here the most active developments have been carried on. The company has erected here a substantial headquarters camp consisting of an office, storehouse, cook-house, and dining-room, with a couple of good large bunk-houses, divided into various rooms, all built of logs, etc.

In Grouse mountain to the north, accessible from this creek, six good seams of coal are partly developed, dipping to the west at angles of about 45 degrees, which can all be mined by drifting in on the seams on their strike[2].

On Bear mountain, lying to the south of the creek valley, some nine seams of good coal have been proven—the details of which are given later; these seams dip to the west at angles of approximately 40 degrees and can all be mined by drifting in on the seams along their strike. The development work noticed in August, 1909, consisted of a series of tunnels, driven in from a contour level which would permit of a belt line of railway conveying the coal to a common tipple.

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[1]See Note 1.

[2]See Note No. 2.

The following seams were examined and measured, commencing at the exposure farthest up the creek, the lowest seam, and proceeding westward:—

Seam A.—Tunnel in 150 feet. Altitude 5,625 feet. Seam consists of 10 feet of coal, then a parting of clay for a few inches, above which is 2 to 3 feet of coal and a shale roof. The coal is bright and clear and cokes well, but the seam is rather "dirty" from shale partings.

Seam B.—About 200 feet north of Seam A, at an altitude of 5,550 feet. Tunnel in about 100 feet. It is caved so that the thickness of the seam could not be obtained. The coal on the dump is good and cokes well.

Seam C.—Is about 300 yards to the northwest of Seam B; altitude 5,525 feet. The tunnel is in about 150 feet, but was caved at the face. The seam dips to the west and is at least 6 feet thick. The coal evidently cokes well in an open fire.

Seam D.—This seam is about 150 feet northwest of Seam C, and is about 3½ feet thick, of good coal. A tunnel had only been started and was just "faced up". No sample was taken for analysis.

Seam E.—This seam shows about 4 to 5 feet of clear coal, below which is 3 feet of dirty coal and above is 1 foot of dirty coal with a shale roof. The dip of the seam is 35 degrees to the west.

Seam F.—This seam is horizontally about 250 feet northwest of Seam E, and on it a tunnel has been driven in for 220 feet. The seam dips at an angle of about 35 degrees to the west, and shows about 6 feet of clean coal, above which is from 2 to 3 feet of loose shaly coal.

Seam G.—Is 165 feet west of seam F, and, on its strike, a tunnel was in 240 feet, showing the seam to dip at 35 degrees to the westward, with from 5 to 6 feet of good coal with a band of 2 feet of shaly coal.

Seam H.—Lies about 150 feet west of G and is indicated, but not developed.

Seam I.—Lies 420 feet west of G and near the edge of the property. The tunnel on this, at an altitude of 5,600 feet, is in about 65 feet, showing the seam to dip to westward; there is on the bottom 8 feet of good coal, above which lies 6 inches of sandstone parting, then 2 feet of coal, above which is shale.

Analyses of Samples Taken by the Provincial Mineralogist, Imperial Coal Company's Seams.

	Water	Vol. C.M.	Fixed carb.	Ash	Coking qualities
Seam A........	1·4	19·1	70·1	8·1	Good
Seam B........	0·9	21·6	69·5	8·0	"
Seam C........	2·8	22·8	69·4	5·0	"
Seam E........	4·4	22·2	62·5	10·9	Non-coking
Seam F........	1·4	23·1	64·2	11·3	Good
Seam G........	1·3	24·7	62·8	11·2	"

Possible Railway Development.

The Canadian Pacific railway and the Great Northern railway both have substantial railway lines constructed as far up the Elk river as Michel prairie, at the mouth of Michel creek. From this point north the configuration of the country demands that a main line must follow up the Elk River valley, and there is no difficulty in so doing—in fact, a line has been surveyed as far north as Aldridge creek, a distance of forty-eight miles; it has been found that a road may be constructed to this point on a one per cent grade, and, as it follows the river valley, the work would be very light and inexpensive. As the coal-measures all lie to the east of the Elk River valley, short spurs, of a mile or so, would have to be run in from the main line to the points at which it may be decided to open up the coal. From Aldridge creek the railway might be continued northward, up the Elk river to its headwaters, and, crossing the summit, follow the Kananaskis river down so as to make a junction with the Canadian Pacific main line, near Kananaskis station.

A railway to reach the coal areas on Fording river would not be quite so simple, since the lower portion of the Fording river, a few miles above its junction with the Elk river, is in a canyon, and very rapid, the fall being too great to permit of its being followed by a railway grade. Above this canyon, the Fording River valley can be traversed anywhere by a grade of less than 1 per cent, so that when this upper valley is once reached the problem is practically settled. To reach this valley of the upper Fording river, a branch line has been surveyed, and found quite practicable, leaving the main line in the Elk valley near Elk prairie, circling eastward on to the Green hills, and southward round the southern end of these hills into the Fording valley. The work on this branch, until the valley of the upper Fording is reached, would be heavy and expensive, but on an easy grade. From this main line and branch lines, spurs from one to four miles long, with workable grades, can be put into any of the coal-exposures.

Extracts from Report by G. Sundberg.

Note No. 1.

On Eagle mountain; Group No. 1.

Prospect No. 22:—3,000 feet north of Lewis creek and up the mountain 1,600 feet; seam, 5 feet 6 inches; good quality coal.

Prospect No. 23:—150 feet east and 25 feet above No. 22; seam 19 feet 6 inches; very fine coal.

Prospect No. 24:—500 feet above No. 23; seam, 5 feet 7 inches; fairly good coal.

Prospect No. 25:—50 feet above No. 24; seam 7 feet 6 inches coal.

Prospect No. 26:—250 feet north of No. 25; seam, 6 feet 6 inches; good coal.

Prospect No. 27:—225 feet above No. 26; seam, 8 feet 3 inches; good coal.

Prospect No. 28:—150 feet above No. 27; seam, 17 feet; dirty coal.

Prospect No. 29:—200 feet above No. 28; seam, 1 foot 4 inches coal.

Prospect No. 30:—50 feet above No. 29; seam, 1 foot 6 inches; fairly good coal.

Prospect No. 31:—200 feet above No. 30; seam, 1 foot 5 inches; good coal.

Prospect No. 32:—150 feet above No. 31; seam, 31 feet; coal of very fine quality. In this seam there occurs about 9 inches bone and 1 foot of shale. This is a remarkable showing, being by actual measurement from wall to wall on the surface 91 feet.

Prospect No. 33:—250 feet north of No. 24; seam, 2 feet 6 inches; coal.

Above No. 32, and up to the summit, occur several small seams of very high grade coal.

The dip of the seams on Eagle mountain is about 20 degrees to the northeast.

North of Eagle mountain, and across a valley about half a mile wide south of the northern boundary of this property, there are two enormous croppings of coal plainly visible, apparently a continuation of two of the seams, probably the same as Nos. 23 and 32.

To the south of Eagle mountain, and across the valley of Lewis creek, on Castle mountain, the coal croppings are noticeable in a number of places, although this slope is quite heavily timbered.

Note No. 2.

On Grouse Mountain; Group No. 2. (About six miles south of Eagle mountain.)

Prospect No. 1:—500 feet above the valley of the west slope of Smith creek; seam, 7 feet; dirty coal.

Prospect No. 2:—52 feet east on No. 1; seam, 2 feet 2 inches; clean coal.

Prospect No. 3:—About 300 feet west of No. 1; 16 feet of coal blossom; of this 6 feet 6 inches is clean coal, the balance mixed.

Prospect No. 4:—Above No. 3 is 10 feet of bone, adjoining which there is 9 feet 3 inches of clean coal blossom.

Prospect No. 5:—About 500 feet above No. 4; seam 22 feet 8 inches; fine coal. There is a very fine showing here.

Prospect No. 6:—100 feet west of No. 5; heavy croppings, 8 feet 6 inches.

Prospect No. 7:—Above sandstone dyke, 200 feet above No. 6; seam, 2 feet 10 inches; very hard coal.

Prospect No. 8:—About 150 feet west of No. 7 appear good croppings of seam coal, 3 to 4 feet.

Prospect No. 9:—On the west slope, about 550 feet west of No. 8; seam, 2 feet; very hard blacksmith's coal.

Prospect No. 10:—100 feet west of No. 9, on the crest of the slope; seam of extra hard and very fine coal, 8 feet wide. The solid coal is exposed on the surface at this point, and this seam also outcrops in the same manner on Bear mountain, at a point two miles south.

Prospect No. 11:—About 50 feet west of No. 4; seam of extremely hard coal, from 18 inches to 2 feet.

Above No. 8 to the summit appear to be several other seams of unknown width.

The dip of all the seams on Grouse mountain is 45 degrees to the west.

FLATHEAD COAL AREA.

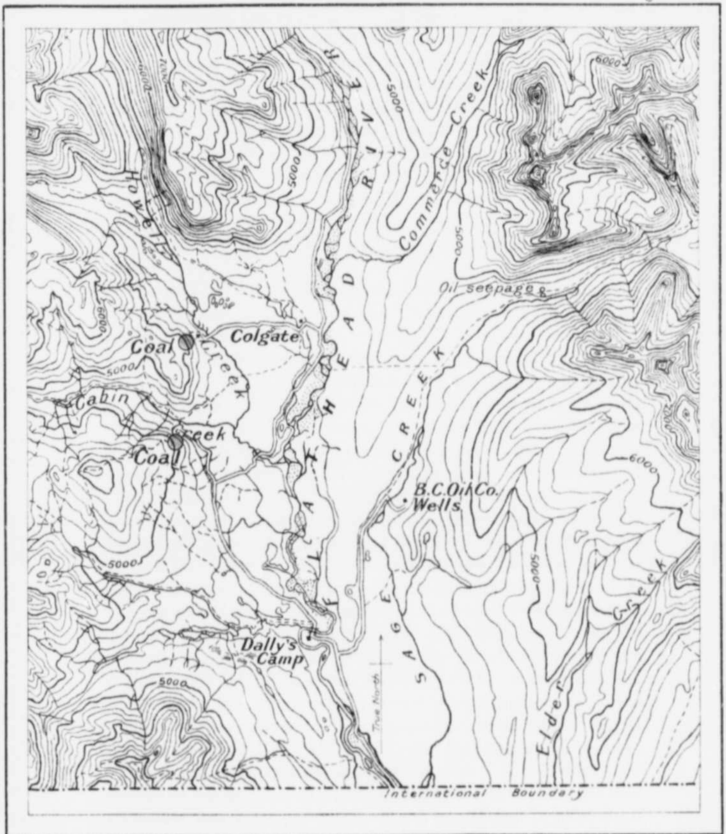
(*See Diagram II.*)

The upper waters of the Flathead river drain from the southern part of the large coal area called the Crowsnest coalfield. To the east and south, three small blocks of the coal-bearing rocks are found in the valley apparently isolated within fault blocks consisting mainly of Devono-Carboniferous limestones. The first area is about due south of Corbin at the mouth of Squaw creek, and just west of North Kootenay pass. The Flathead, here, turns almost at right angles and seems to be following in its upper course, a structural valley, formed by an east and west fault with downthrow on the south side. The downtilted block is of Carboniferous limestone with reddish tinted upper beds that may be Permian and Triassic in the higher members. At the point of lowest depression near the fault line, a remnant of Cretaceous has been found. This contains several coal seams that may be of economic value. Considerable prospecting has been carried on and several seams exposed. The block near the fault line has been somewhat deformed so that the exposures give the impression that it is bent up in trough form near the fault. These exposures were examined by Mr. W. F. Robertson, Provincial Mineralogist, while freshly made, and the following notes were published by him in the Report of the Minister of Mines, B.C., for 1909, page 175.

"The work done during 1909 consisted chiefly in proving the continuity of the coal seams by means of tunnels and incline shafts. There are four seams of bituminous coal on this property. No. 1 seam, 6 feet thick, has been opened by tunnel and incline shafts at six different points, one tunnel being run in on the coal for nearly 200 feet. Seam No. 2, 8 feet thick, has one tunnel run in on the coal for about 75 feet. Seam No. 3, 10 feet 3 inches thick, is the best seam on the property, the coal being exceptionally clean, with a high percentage of fixed carbon; one tunnel was run in on this seam for about 70 feet, at which point an incline shaft was sunk on the coal for 40 feet, where the coal is hard and firm; about 700 yards from this point an incline shaft was sunk on the same seam for a depth of 50 feet, showing the quality and thickness of the seam to be the same as in the original location. Seam No. 4, 16 feet thick, has been opened in several places with open-cuts, and an incline run down on the coal, for 50 feet, where the coal is hard and firm. The distance between each of the seams is about 300 feet; the coal seams trend east by north, west by south, and pitch north at an angle of 40 degrees."

The area is restricted to a narrow strip running westward from the North Kootenay pass, its western extremity has not been determined but is not far past Squaw creek.

Flathead river here turns southward and follows a probable line of fractures or sharp rolls. About 5 miles south of this bend on the west side of this valley, a block of Cretaceous rocks is



Geological Survey Canada

1414

Flathead coal-areas

Miles

To accompany Memoir by D.B. Dowling

found standing on edge; whether a fault block or a downward bend in the beds, was not learned. In this, the exposed rocks consisted of a ridge of conglomerate striking about north and south. West of this by trenching several seams of coal have been found. The extent of the block is at least two miles along the strike of the rocks. At Donald Cate's location the coal seams so far found west of the conglomerate, probably occur in a group about 250 feet from the conglomerate, and consist of two six-foot seams and a four-foot seam, then a large forty-foot seam and two others between 6 and 10 feet thick. The trenching had not been deep enough to penetrate the weathered coal so that it was all quite disintegrated and its character could not be judged.

Howell and Cabin Creek coal areas are of larger proportions and are farther down the Flathead, 8 and 6 miles respectively, north of the Boundary line.

The valley here is wide and floored with river and glacial debris, lying on the planed surface of late Tertiary beds with which the valley was partially filled. On the east these deposits are lying against the flanks of Cambrian and Pre-Cambrian rocks. On the west, Devono-Carboniferous rocks protrude in bare ridges near the Boundary line and again north of Howell creek. Between, there is an area occupied by wooded hills rising 1000 feet above the river plain. These show along the eastern escarpment sandstones and other soft rocks of Cretaceous age. Coal seams have been found at two localities on the face of these hills in apparently advantageous places for mining. The one examined at our visit was near Howell creek a western branch of the Flathead. The wooded hill which here forms the western edge of the valley, rises steeply for nearly 700 feet and in a slight gully on its face, Mr. Butts, who was in charge of the prospecting, has constructed several short tunnels into the various seams exposed. The measures here strike nearly east and west and dip 25° south. Six large seams have been exposed and some excavation done on each. No. 1 seam near the top of the gully, is reported as being not far below the conglomerate and is 25 feet thick. No. 2 has 31 feet of solid clean looking coal between the walls. This is probably the finest appearing seam in the southern part of the mountains and should mine a large percentage of lump coal. No. 2 seam is 16 feet thick, No. 4, 10 feet, and No. 5, the big seam, is somewhere near 50 feet thick, but where opened appeared quite friable and easily crushed. This seam is near the bottom of the hill and probably easy of access, but seam No. 2 will probably be the first mined from its apparent good quality.

At the foot of the hill another seam was found, but from its position it was suspected that there had been a slide and that it was displaced. This one was about 11 feet in thickness.

The river flat appeared favourable for the construction of a railway but to gain connexion with other Canadian lines, a summit must be climbed.

COWICHAN AND NANAIMO COAL AREAS.

(Extracts from Reports by C. H. Clapp.)

(*See Diagram III.*)

INTRODUCTION.[1]

The unmetamorphosed sedimentary rocks of Mesozoic, and possibly lower Cenozoic (Eocene) age in southern Vancouver island, belonging to at least two unconformable formations, cannot be distinguished lithologically, or at present structurally, and are, therefore, grouped together provisionally under the general name of Cowichan group.[2] The larger part of the group doubtless belongs to the Nanaimo formation or series as defined by Richardson, Whiteaves, and Dawson.[3]

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[1]C. H. Clapp, Southern Vancouver island. Memoir 13, Geol. Surv. Can., pp. 124-127.

[2]C. H. Clapp. Summary Report, 1909, Geol. Survey, Canada, p. 89.

[3]James Richardson. Report on the Coal Fields of Nanaimo, Comox, Cowichan, Burrard inlet, and Sooke, B.C. Rept. of Progress, 1876-77, Geol. Survey, Canada, pp. 160-192.

J. F. Whiteaves. Mesozoic Fossils, Vol. 1, Part 2, Geol. Survey, Canada, 1879, pp. 93-190.

G. M. Dawson. The Nanaimo group, Am. Jour. Sci., Vol. 39, 1890, pp. 180-183.

The Cowichan group occurs in three principal areas and basins, which were outlined by Richardson,[1] and called by him the Comox, Nanaimo, and Cowichan basins. The boundaries of the Comox and Nanaimo basins are about as Richardson describes .. ..The Cowichan basin is much larger than Richardson supposed, as he did not trace it inland. All three basins occur along the east coast of Vancouver island. The Comox basin is the northern one........The Nanaimo basin is separated from the Comox basin by an axis of Vancouver volcanics which occur to the north and south of Nanoose harbour. The Nanaimo basin on Vancouver island extends southeast from Departure bay, north of Nanaimo, to Crofton, a distance of about 30 miles. Its greatest inland extent, south of Nanaimo, is about 10 miles. It extends, however, much farther east and southeast, comprising the northern part of Saltspring island, and the islands to the east and north; extending still farther southeast to the islands of the State of Washington. Its greatest exposed length and width in Canadian territory is 55 and 15 miles respectively. The Cowichan basin occurs to the south of the Nanaimo basin, being separated from it by a narrow axis of crystalline rocks of the Sicker series, south of Crofton; and extends northwest from the east coast at Cowichan bay, where the basin is 8 miles wide, to the west end of Cowichan lake, a distance of about 40 miles. In the western portion it is divided into two parts by an axis of the underlying rocks forming a ridge between the Cowichan and Chemainus valleys. The Cowichan basin extends some 20 miles to the southeast from Cowichan bay, being exposed on the northern end of Saanich peninsula, and on several of the small islands between Saanich peninsula and the islands of the State of Washington.

A small basin occurs in the upper portion of Koksilah valley, 10 miles west of Shawnigan lake, in the Malahat district; and a much larger basin, separated from the Comox basin, to the east, by a wide axis of Vancouver volcanics, occurs in the vicinity of Alberni, underlying the wide Alberni valley.

The rocks of the Cowichan group, being less resistant than the underlying crystalline rocks, were greatly eroded during

[1]Ibid.

the pre-Glacial cycle, and lowlands have been developed on them. These lowlands were covered by drift during the Pleistocene period, and the rocks are, therefore, rather poorly exposed, except along the shore, and river beds. North of Cowichan bay and Cowichan valley, and on Saltspring island, thick, gently northeastward dipping basal conglomerates form low mountains with steep obsequent scarps, such as Mount Prevost in Somenos district, and Mount Tzouhalem in Cowichan district........

The rocks of the Cowichan group consist of conglomerates, sandstones, and shales, the sandstones predominating near the coast, and the shales in the interior. The shales are arenaceous, and many of them carbonaceous, especially in the lower part of the group; and coal occurs near the base of the Nanaimo formation. Distinctly calcareous rocks are rare.

The conglomerates usually consist of fairly well rounded, water-worn fragments of the underlying crystalline rocks of the vicinity, in a sandy matrix. They range from very coarse basal conglomerates to fine-grained phases, and from phases in which there is very little matrix, to those in which the matrix is dominant. The conglomerates of the farther inland portions of the Cowichan basin are commonly green coloured, and consist almost entirely, both fragments and matrix, of detritus of the volcanic rocks of the Vancouver group; which detritus has apparently been formed by mechanical rather than chemical disintegration. More rarely, as on the south slope of Mount Sicker, the conglomerates consist of angular to sub-angular fragments, which are not clearly stratified.

The sandstones are yellowish (especially the upper members of the Nanaimo basin) to grey or greyish green in colour, and many of the sandstones of the Cowichan basin are dark olive green. Quartz is the most abundant constituent, and occurs with other minerals and even small rock fragments, in angular to sub-angular grains with an argillaceous matrix. The other minerals present are, in about the order of their relative abundance, feldspar, chiefly plagioclase, muscovite, biotite, chlorite, epidote, and more rarely serpentine, magnetite, and other iron oxides, and calcite. Ilmenite altering to leucoxene occurs in the sandstones near the gabbro-diorite porphyrites of the Sicker series.

The sandstones are commonly massive, forming with conglomerates thick-bedded strata. They grade into arenaceous shales through thin-bedded shaly sandstones, and the arenaceous shales are very commonly interbedded with thin beds of sandstones, a few inches thick, which are very numerous, seldom more than a foot or two apart. Fine-grained, laminated sandstones occur, but as a rule the ordinary sandstones are quite uniform in composition, and no colour lamination is seen. The sandstones are commonly concretionary, the numerous concretions ranging from an inch to several feet in diameter. The cement of the concretions is ferruginous and calcareous. Sun cracks and ripple marks are rarely seen.

The shales are commonly dark, olive grey or drab coloured, seen on microscopic examination to consist of small angular quartz grains in a fine argillaceous groundmass, which is brown from the presence of carbonaceous matter. The carbonaceous matter occurs in microscopic, rounded clouds, which are darker near the centre. Calcite is frequently present, sometimes as veinlets, although rarely in large amounts. Muscovite occurs in small quantities.

The shales have very seldom a well developed shaly parting, but are relatively massive; although the finer grained, less arenaceous shales weather into small flakes. The shales, far more commonly, weather concentrically; and where calcite is fairly abundant in the groundmass, rapidly, to a light brown clay. Sandstone concretions are very numerous, and in the fine-grained shales, associated with the coal, small rounded calcareous concretions also occur.

In the small basin of the upper portion of Koksilah river, associated with an argillaceous sandstone, is a dark coloured, almost black, homogeneous rock, which consists of fine, rounded calcite or limestone grains in a carbonaceous and argillaceous matrix. Other calcareous rocks, which are, however, highly fossiliferous, occur near the base of the Nanaimo formation, in the northern part of the Nanaimo basin.[1]

[1]James Richardson, Rept. of Progress, 1876-79. Geol. Survey, Canada, p. 172.

COWICHAN BASIN.[1]

The Cowichan basin cannot at present be subdivided lithologically into general divisions, as it consists of rapidly alternating beds of conglomerates, sandstones, and shales which grade laterally as well as vertically into beds of different texture, the individual beds being, therefore, lens-like in shape; and it also contains at least two unconformable formations, which have not as yet been distinguished. The lower formation where recognized consists chiefly of shales and sandstones. In the upper formation, which is largely or entirely part of the Nanaimo formation, there is a tendency for the rocks to grow finer grained upwards, and the basal conglomerate is, in places, very thick. No estimate as to the thickness of the lower formation can be made, but the upper formation is at least 6,000 feet thick........

The apparent structure of the eastern part of the Cowichan basin........is, briefly, a southern close-folded syncline, with a strike of N. 70° W., which is slightly overturned to the southwest, with the northern limb broken by an overthrust fault, which brings up the underlying Sicker series against the folded rocks of the Nanaimo formation. The Sicker series are overlain by the basal members of the Nanaimo formation, which form the southern limb of another parallel syncline, which also is broken by an overthrust fault—the northern boundary of the basin.....

A small basin occurs in the upper part of the Chemainus valley, and it seems as if it was originally a part of the southern limb of the northern syncline of the Cowichan basin, once continuous with the easterly portions, but now separated by erosion.

A similar area occurs in the upper part of the Koksilah valley; but in this instance all other evidence of a large downfold to the south of Cowichan valley has been removed by erosion.

Coal at present is the chief source of mineral wealth of Vancouver island. The coal mined is a high grade bituminous variety, and is obtained near the base of the Nanaimo formation

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[1]C. H. Clapp, Southern Vancouver island. Memoir 13, Geol. Surv., Can., pp. 128-136, and pp. 194-195.

of the Cowichan group. It is mined in large amounts along the east coast from the northern part of the Nanaimo basin and from the Comox basin.

Other basins of sedimentary rocks of the Cowichan group have been considered as possible sources of coal, because of the frequent indications of coal which have been found, and on account of their proximity and lithological similarity to the coal-bearing measures of the Nanaimo and Comox basins. A large part of the rocks of the Cowichan group belong to the Nanaimo formation, but an exact correlation of the coal horizon in the various basins cannot be made at present. Although the rocks are well exposed, no thick or extensive seams are known; but small lens-like seams are exposed in the southern part of the Nanaimo basin and eastern part of the Cowichan basin. They are rarely more than a foot thick, although beds of impure, sandy and shaly coal occur from 3 to 6 feet thick. Fossil coal plants and thin seams of coaly material, seldom more than one-quarter of an inch thick, are found in the western part of the Cowichan basin and in the minor basins exposed in the upper Chemainus and Koksilah valleys.

The coal, so far as known, occurs near the base of the Nanaimo formation. Since it is known that the rocks of the Nanaimo formation were deposited on a surface of considerable relief, and that sedimentation probably first began in the down-warped area off the east coast, it seems probable that part of the area now covered with the rocks of the Nanaimo formation was above the depositional level during the period of coal formation. The Nanaimo formation and conformably overlying formations are very thick—6,000 to 10,000 feet; and since the rocks of the southern part of the Nanaimo basin and of the Cowichan basin have been closely folded, the coal horizon, occurring as mentioned near the base of the Nanaimo formation, must occur chiefly at great depths. The folding and faulting increases the difficulty of prospecting, and in the southern Nanaimo and Cowichan basins is so extensive as to preclude mining.

Considerable prospecting has been done and some attempts at mining have been made, especially in the eastern portion of the Cowichan basin, as yet without success. The probability of finding coal which could be mined profitably, in the southern Nanaimo, Cowichan, and minor basins, with the exception of the Alberni basin, is slight.

NANAIMO COAL-FIELD.

GENERAL GEOLOGY.[1]

The character and age of the coal-measures of the Nanaimo district were known and described as early as the late fifties, but little work of a general and correlative nature was done and no maps were published until the seventies. Then Richardson worked for five years on the coal-fields of the east coast of Vancouver island, his results being published in the Reports of Progress of the Geological Survey for the years 1871-72, 1872-73, and 1876-77. His last report summarizes his work, and is accompanied by a map on a scale of 4 miles to an inch. During Richardson's examination a great many fossils were collected, and these, with many others collected since that time, have been described, chiefly by Whiteaves. Much prospecting has been done and many private examinations have been made since Richardson's reports were published; but of the extensive information thus collected very little has been made public. In 1905 H. S. Poole collected some of the data, which appeared in the Summary Report of the Geological Survey for 1905. During the writer's previous work on Vancouver island little attention was given to the Nanaimo coal-field, and in his reports very little was published concerning it. A large part of the data collected in the district is in the hands of Mr. W. J. Sutton, geologist of the Canadian Collieries (Dunsmuir) company, and he has very kindly co-operated with the writer in the present examination.

The crystalline rocks upon which the sedimentary rocks of the Nanaimo series unconformably rest consist of metamorphic volcanics, which belong to the Vancouver group, and of intrusive

[1]General Geology from Summary Rept. Geol. Surv., Can., 1911, pp. 91-102.

batholithic rocks. They occur in three low ridges extending east from the crystalline rock highland to the west of the Nanaimo area. The first ridge occurs in the northwestern part of the area, north of Departure bay, and is the northern boundary of the Nanaimo basin. The second ridge is the east flank of Mt. Benson and is situated west of Nanaimo. The third ridge occurs along the southern boundary of the area and is the southern boundary of the Nanaimo basin. The first two ridges are composed entirely of Vancouver volcanics and the southern one consists largely of batholithic rocks, although a small area of metamorphic volcanics does occur in its western part.

Lying unconformably upon the crystalline rocks are the thick series of sedimentary rocks of Upper Cretaceous age which contain the coal seams of the Nanaimo district. The lower members of this series are fossiliferous, and have been designated by Dawson[1] as the Nanaimo series (group). The entire series of conformable sediments is, however, generally known as the Nanaimo series or Nanaimo formation. As the upper fossiliferous member (Gabriola sandstones) is very unlike the Eocene sandstones near the city of Vancouver, being much more indurated, it is very doubtful that it is of Eocene age as Dawson[2] suggests it might be. It seems best, therefore, to enlarge the scope of the name Nanaimo so as to embrace the entire conformable series of sedimentary rocks. None of the lower members of the Cowichan group[3] occur in the area.

The Nanaimo series may be subdivided solely on lithological grounds, since all of the lower formations contain an identical fauna, while the upper formation is unfossiliferous. The various subdivisions or formations are more or less characteristic and well defined..
.............and their distribution and lithological characters are described below in order of age, the lowest or oldest formation being described first.

[1]G. M. Dawson. "The Nanaimo group," Am. Jour. Sci., Vol. 39, 1890, pp. 180-183.

[2]G. M. Dawson. Bull. Geol. Soc. Am., Vol. XII, 1901, p. 79.

[3]C. H. Clapp. Summary Report, 1909, Geol. Surv., Canada, p. 89.

The Benson formation is the basal conglomerate of the series. It is exposed and apparently developed only locally, chiefly around the north flank of the east spur of Mt. Benson and in the extreme southwestern portion of the area; it is well exposed on Haslam creek. It occurs also on the shore of Departure bay. The basal conglomerate varies from a typical coarse conglomerate composed of large rounded fragments of the underlying rocks, where it occurs lying in hollows in the Vancouver volcanics along the north shore of Departure bay, to a rather fine-grained conglomerate, composed chiefly of rounded volcanic fragments, interbedded with arkose sandstones, which grade upward into interbedded arkose and shaly sandstones characteristic of the base of the overlying Haslam formation. The maximum thickness of the Benson conglomerate is about 400 feet.

Overlying the Benson conglomerate, and sometimes resting directly on the underlying crystalline rocks, is the Haslam formation. It consists chiefly of fine-grained shaly sandstones and sandy shales. Even the shaly sandstones are locally called shales on account of their pronounced difference from the prevailing coarse-grained sandstones of the Nanaimo series. The formation is locally called the "marine shales" on account of the marine fossils which are occasionally found in it. The Haslam formation extends along the western border of the area in an irregular belt from one-fourth of a mile to 3 miles in width, and also underlies three narrow anticlines in the south central portion of the region. The shales are carbonaceous, being usually light to dark grey in colour. Interbedded with the typical sandy shales are thin beds of light grey, fine-grained, and often fairly siliceous sandstones. These sandstones average less than a foot thick, but sometimes occur in large numbers. Toward the base of the formation the interbeds of sandstone, although not more numerous, are thicker and usually of much coarser grain. They grade into a coarse arkose which, although interbedded with shale, shows an abrupt transition into the Benson basal conglomerate, or lies directly upon the underlying crystalline rocks. Along the north shore of Departure bay the Haslam formation is composed of broken shells mixed with a large amount of sand; such a rock, composed of shell-sand, or limestone fragments, is known as calcarenite, although in this instance the rock is an impure calcarenite. The thickness of the Haslam formation appears to be fairly uniform and averages about 600 feet.

The upper portion of the Haslam shales almost invariably grades upward into, or is limited by a uniform, fine to medium-grained and rather flaggy sandstone, called the East Wellington sandstone. The sandstone varies from about 25 to 50 feet in thickness, and sometimes contains thin interbeds of sandy shales, identical with the underlying Haslam shales. More rarely the sandstone is coarse-grained and contains interbeds of fine to medium-grained conglomerate.

The East Wellington sandstone is the floor of the Wellington coal seam. The seam is overlain by the Extension formation, and in places has a roof of sandy shale and in others a conglomerate roof.

The Extension formation consists chiefly of a very characteristic conglomerate. The formation underlies a broad belt extending entirely across the area with a N. 30° W. strike. The belt averages somewhat over a mile in width, except in the central part, where, on account of a repetition of the beds by folding and faulting, it is 2½ miles wide. The conglomerate is medium to coarse-grained, the fragments averaging about three-fourths of an inch in diameter. The fragments are sub-angular to sub-rounded and are composed almost entirely of quartz, having been derived from quartz veins and from the very fine-grained siliceous rocks of the Sicker series that resemble cherts, and are locally so called. Fragments of the normal metamorphic volcanics of the Vancouver group are rare. The fragments occur in a coarse, sandy matrix which, ordinarily, is in large amount, and the typical conglomerate grades into coarse-grained and pebbly sandstone. There are also a few horizons of sandy shales or shaly sandstones, in the Extension formation, the thickest being about 80 feet. The shale horizons are usually associated with thin coal seams or lenses. Neither the shale horizons nor the coal seams are persistent over large areas. In the central and southern parts of the belt underlain by the Extension formation sandstones and shales are confined to relatively thin interbeds in the typical massive conglomerate. In the northern part of the belt, however, in the vicinity of East Wellington, the lower 300 feet of the formation consists largely of sandstones and shales, and the upper 400 feet consist almost entirely of massive conglomerate. The thickness of the Extension formation varies from 700 to 1,500 feet, the greatest thickness being reached only in its southern part.

The Cranberry formation overlies the Extension formation, and occupies a belt which averages about half a mile in width, with a maximum width in the central part of over a mile on account of repetition due to folding and faulting. The formation consists chiefly of dark green shaly sandstones and more rarely sandy shales. In the central part of the belt, west of South Wellington, there are one or more thick horizons of conglomerate resembling the Extension conglomerate, although there are a larger number of fragments of volcanic rocks present. In this portion the Cranberry formation is not well defined, and grades downward into the Extension formation and upward into shales, characteristic of the overlying Newcastle formation. In its northern part it is fairly well defined and represents a very characteristic period of deposition. Its thickness varies from 150 feet to a maximum of 500 feet in its southern part.

The upper limit of the Cranberry formation is the Newcastle coal seam, or, as it is sometimes locally called, the Lower Douglas seam. The seam is overlain by the rocks of the Newcastle formation. It is well defined in the northern part of the area of the Nanaimo map-sheet and persists through the central part, but is poorly defined or absent in the southern part.

The Newcastle formation, which directly overlies the Newcastle coal seam, contains the Douglas coal seam. The formation underlies a belt extending across the area of the Nanaimo sheet, from northern Newcastle island through the city of Nanaimo and town of South Wellington to Ladysmith. The formation, although having determinative characteristics, varies in different parts. In certain portions it consists of a fine conglomerate and coarse gritty sandstone with interbeds of dark green sandy shales. The conglomerate is distinguished by its fineness and by its well-rounded fragments, which are chiefly derived from the Vancouver volcanics. In other portions, practically the entire formation consists of dark green sandy shales or shaly sandstones, composed largely of detritus of volcanic rocks. Interbedded with these shales are, however, lenses of the characteristic fine conglomerate and gritty sandstones. The formation varies in thickness in its northern part from 250 feet, where it is chiefly conglomerate, to 150 feet, where it is composed chiefly of sandy shales; but in its extreme southern portion, although apparently composed chiefly of shales, it is approximately 400 feet thick.

The Douglas seam occurs in the Newcastle formation. Its floor and roof vary from fine conglomerate to sandy shale, corresponding more or less closely to the similar variation in the lithological character of the Newcastle formation. The former conditions prevail in the vicinity of Nanaimo and the latter at South Wellington, the two centres where the Douglas seam is mined. The seam lies from 25 to 100 feet above the Newcastle seam. It is well developed from northern Newcastle island to south of the Nanaimo river, the outcrop of the seam crossing the river near the Esquimalt and Nanaimo Railway bridge at Cassidy siding. Indications of the seam also occur as far south as Bush creek, a mile north of Ladysmith.

The Newcastle formation is overlain by a characteristic horizon of sandstone, which is the best horizon marker in the Nanaimo series. The horizon is called the Protection formation from its typical development on Protection island. It underlies a belt extending from Newcastle island to Ladysmith, 1 mile to 1½ miles wide in its northern portion and narrowing to less than one-fourth of a mile in width in its extreme southern portion where the dips are very high. The formation consists largely of a white or greyish sandstone, composed chiefly of rounded quartz grains with a coating of white kaolin. Associated with the sandstones are frequent interbeds of shaly sandstones and carbonaceous, siliceous, sandy shales. The formation contains also numerous small coal lenses, none of which are of commercial value. The formation varies from 600 to 750 feet in thickness.

Overlying the Protection sandstone is a formation of dark ferruginous sandy shales with a large number of interbeds of coarse-grained sandstone. This formation, which is one of the less resistant formations, underlies a wide valley extending almost north and south from the mouth of Nanaimo river to Ladysmith harbour. The larger part of the valley is in Cedar district, and the formation is, therefore, given the distinctive geographic name of Cedar district.[1] This formation is fairly uniform throughout its entire thickness, which is about 750 feet with a maximum thickness of 1,000 feet in its southern portion. A peculiar feature of this formation is the large number of sandstone dykes which cut the shales. These dykes, which have a maximum thickness of 3 to 4 feet, usually protrude from the interbeds of sandstone and are irregular and branching following joints in the shales.

Overlying the Cedar District shales, with a transition zone 100 to 200 feet thick, is a thick and uniform horizon of sandstones called the DeCourcy formation from its typical development in the group of islands known as the DeCourcy group. The DeCourcy formation extends from Jack point, a long narrow point east of Nanaimo, to the high range of hills on the east side of Ladysmith harbour. On account of a number of open folds the outcrop of the formation has a maximum width in its southern part of about 4 miles. The formation consists chiefly of a grey, rather coarse-grained sandstone usually weathering to a yellowish brown. It contains also thin horizons of shaly sandstone and carbonaceous sandy shales, with which are associated thin lenses of impure coal, none of which are of commercial value. The thickness of the DeCourcy formation averages about 800 feet, but in its southern part has a maximum thickness of about 1,400 feet.

The DeCourcy formation is limited by an overlying, persistent horizon of shales. These shales are similar to the Cedar District shales; but in their upper portion, both in vertical and lateral directions, grade irregularly into or, more strictly,

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[1]The name Cedar has already been used to designate a formation of Juratriassic age in California.

are replaced by sandstones and coarse conglomerates composed of a great variety of fragments. This formation, consisting of shales, sandstones, and coarse heterogeneous conglomerates, is called the Northumberland formation, and is exposed chiefly to the northeast of Northumberland channel along the southwest shore of Gabriola island. The Northumberland shales are exposed also along the northeast shore of Gabriola island, showing the presence of a syncline which extends through the island. The thickness of the formation varies from about 1,100 feet to about 1,200 feet.

Overlying the Northumberland formation and separated from it by a more or less persistent horizon of shales is a very thick series of fairly uniform, massive sandstones, which since they compose the larger part of Gabriola island are called the Gabriola formation. This formation is the uppermost of the Nanaimo series. The sandstones are medium to coarse-grained, rather siliceous, and characteristically concretionary. The concretionary structure and soluble cement causes them to be eroded into fantastic forms or "galleries" where they are subject to solution by saltwater spray and by wind and wave erosion. The formation is about 1,400 feet thick in the area of the Nanaimo map-sheet, but increases in thickness to the southeast to a maximum of over 3,000 feet.

The rocks of the Nanaimo series have as a whole a general northwest-southeast strike and a prevailing dip to the northeast. At the northern rim of the basin, in the vicinity of Departure bay, the general strike turns to the northeast and east, while the dip is to the southeast and south. With the exception of the major fold which outlines the basin, the entire series is not involved in any large single fold. There are, however, many smaller folds involving one or more formations. Of these, the largest and most important are an anticline whose axis underlies Extension valley, another anticline pitching to the northwestward, whose axis underlies Trincomali channel, and a syncline on Gabriola island. The two anticlines may be called the Extension anticline and the Trincomali anticline, and the syncline the Gabriola syncline. Along the axis of the extension anticline the Haslam shales are exposed, with the East Wellington sandstone, Wellington coal seam, and Extension conglomerate exposed on either side in the ridges fronting the anticlinal valley. The axis of the Trincomali anticline is largely under water, but the Protection sandstone is exposed on a small island, called Round island, near the axis. The DeCourcy islands along the northeast flank of the anticline and the shore of Vancouver island along the southwest flank are underlain by Cedar District shales and DeCourcy sandstones.

Minor faults, seldom more than sharp rolls with a very small actual displacement, are common. In the west central part of the basin are two large reversed or compression faults. These two faults, which occur to the southwest of Extension, have northwest-southeast strikes and steep dips to the northeast. Along the larger fault, the northeastern, the Haslam shales on the southwestern and upthrown side of the fault are in contact with Extension conglomerate on the northeastern and downthrown side. The throw of the fault is about 300 feet. The Wellington coal seam also is brought to the surface on the upthrown side of the fault. The smaller fault is, as stated, of the same character—the southwestern side upthrown. The throw decreases from about 100 feet, where the fault is first recognized near the old No. 1 mine of the Wellington Collieries company, to nothing, about a mile to the southeast. The faulting has been traced in the underground workings of the No. 3 Extension mine.

ECONOMIC GEOLOGY.[1]

The Nanaimo coal-field occurs at the northwestern end of the Nanaimo basin,.........The productive area is only about 65 square miles, but the area virtually known to be underlain by workable coal seams is somewhat larger. The coal occurs chiefly in the lower part of the Nanaimo series in three seams, the Wellington, the Newcastle, and the Douglas. The lowest seam, the Wellington, lies at the base of the Extension formation and rests on the East Wellington sandstone, and is about 700 feet above the base of the Nanaimo series. The Newcastle

[1] Memoir 51, Geological Survey, Canada, pp. 96-116.

seam occurs at the base of the Newcastle formation, and overlies the Wellington seam by about 800 to 1,000 feet. The Douglas seam is contained in the Newcastle formation, from 25 to 100 feet above the Newcastle seam. As already described, the associated measures are moderately disturbed and have a general monoclinal structure with a low dip to the northeast. There are a few rather larger open folds and many smaller ones. There are also many minor faults and in the southwestern part of the field, affecting the Wellington seam only, are at least two and possibly four, reversed, strike faults with throws of 100 to 500 feet.

The three seams are remarkably persistent considering the great variability of the associated rocks, but vary greatly in thickness and quality. In places a variation, as great as from 2 or 3 feet of dirty slickensided coal or "rash" to 30 feet of clean coal, occurs within a lateral distance of 100 feet. It seems as if this extreme variation is due to a folding of dirty or silty coal seams, when at least the clean coal was in a plastic or pasty condition permitting it to flow away from the bends where an increased vertical pressure was developed, to the limbs of the folds where there was a corresponding decrease of pressure. There are also large, barren places in the seams owing to silting or similar causes. The coal seams are displaced also by small faults, although an actual break seldom occurs, the coal having been forced along the plane or zone of dislocation. Rarely the seams fold or wrinkle without any appreciable variation in thickness.

The coals of the various seams are, as a whole, much alike, and are high volatile bituminous coals of fair quality. The amount of fixed carbon in the best quality ranges from 45 to 60 per cent and the ash from 5 to 10 per cent. The coals, especially that from the Wellington seam, coke readily. The following are the available analyses of coals from the Nanaimo field.

Analyses of Coals from the Nanaimo Field.

	Wellington			New-castle	Douglas	
Proximate analysis	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
Moisture.........	1·65	1·16	1·1	1·9	1·6	1·54
Volatile c'bustible	43·25	40·47	39·3	39·4	39·7	33·30
Fixed carbon	45·52	50·04	49·2	45·7	47·7	56·23
Ash.............	9·24	7·80	10·0	11·7	10·1	8·44
Sulphur..........	1·24	0·53	0·4	1·3	0·9	0·49
	100·00	100·00	100·0	100·0	100·0	100·00
Coke............	55·38	58·11	67·5	57·4	57·8	64·91
Its character.....	Firm, coherent.	Firm, coherent.	Good commercial.	Non-commercial agglomerate	Poor commercial to non-commercial agglomerate.	Firm, coherent.
Fuel ratio........	1·05	1·23	1·25	1·16	1·20	1·69
Ultimate analysis.						
Carbon..........	72·80	75·53	72·1	67·7	71·0	74·46
Hydrogen........	5·17	5·13	4·7	4·7	4·9	5·42
Nitrogen........	0·88	1·19	1·2	1·2	1·2	1·37
Oxygen..........	10·67	9·82	11·6	13·4	11·9	9·82
Sulphur..........	1·24	0·53	0·4	1·3	0·9	0·49
Ash.............	9·24	7·80	10·0	11·7	10·1	8·44
	100·00	100·00	100·0	100·0	100·0	100·0
Carbon hydrogen ratio..........	14·1	14·7	15·3	14·5	14·5	13·7
Calories (by determination with dry coal).......	....	....	7310	6930	7130	....
B. T. U. (by determination with dry coal)	....	....	13160	12470	12830	....
Calories, by calculation from ultimate analysis............	730	7450	6980	6530	6930	0747

No. 1. "Run of mine," East Wellington No. 1 mine, Vancouver-Nanaimo Coal Mining Co., C. H. Clapp, collector, F. G. Wait, analyst.

No. 2. "Run of mine," Nos. 1, 2, and 3 Extension mines, Canadian Collieries Co. C. H. Clapp, collector, F. G. Wait, analyst.

No. 3. Regular sample of commercial coal, 1½ inch screen and picking belt. Extension mine, Wellington Collieries Company (Canadian Collieries Company) Edgar Stansfield, Dept. of Mines, Mines Branch, Coals of Canada, Vol. II, Table LXVIII. Recalculated to an air-dry basis.

No. 4. Regular sample of commerical coal, over 2 inch screen and picking belt. No. 1 mine, Western Fuel Co., No. 1 North level, lower seam. Edgar Stansfield, Dept. of Mines, Mines Branch, Coals of Canada, Vol. II, Table LXVIII. Recalculated to an air-dry basis.

No. 5. Regular sample of commercial coal, over 2 inch screen and picking belt. No. 1 mine, Western Fuel Co., Upper seam or south side coal. Edgar Stansfield, Dept. of Mines, Mines Branch, Coals of Canada, Vol. II, Table LXVIII. Recalculated to an air-dry basis.

No. 6. "Run of mine," South Wellington mine, Pacific Coast coal mines. C. H. Clapp, collector, F. G. Wait, analyst.

The following proximate analyses are from Dowling's compilation of analyses in Publication No. 1035, Geological Survey, Canada, 1909.

Proximate Analyses of Coals from the Nanaimo Field.

	Moisture	Volatile combustible	Fixed carbon	Ash	Sulphur	Fuel ratio	Calorific value B.T.U.
Wellington coal.							
[1]Wellington mine........	2·75	38·03	52·64	6·58	.....	1·38	12567
[2]Wellington mine........	8·57	25·30	56·40	9·52	0·21	2·22	....
[3]Wellington mine........	4·14	36·85	46·16	12·85	0·56	1·25	....
[4]Harewood mine........	1·58	33·84	52·17	11·85	0·56	1·53	12238
[4]Extension collieries.....	1·44	31·40	46·18	20·65	0·33	1·47	11401
[4]Extension collieries.....	1·52	35·27	57·04	5·85	0·32	1·61	13416
[4]Extension collieries.....	1·24	36·49	53·72	8·20	0·35	1·47	13261
[4]Extension collieries.....	1·28	35·26	55·83	7·30	0·33	1·58	13199
Newcastle coal.							
[4]Nanaimo colliery No. 1 shaft................	2·86	35·84	54·79	5·5	1·01	1·53	12951
Douglas coal.							
[1]Newcastle island........	1·57	38·14	50·84	8·63	0·82	1·33	....
[4]Nanaimo colliery No. 1 shaft................	1·88	33·27	54·67	9·40	0·70	1·64	12672
[4]Southfield colliery No. 5 shaft................	2·08	35·78	56·26	5·60	0·28	1·57	13261
[2]Southfield colliery No. 5 shaft................	2·06	34·07	56·94	6·67	0·25	1·67	....

References:—

[1]Reports of Geological Survey of Canada to Vol. XVI.

[2]Report on the efficiency of various coals used by the United States ships, 1893-95, Bureau of Equipment, Washington, 1895.

[3]Report on the efficiency of various coals used by the United States ships, 1896-98, Bureau of Equipment, Washington, 1899.

[4]Reports of Minister of Mines, B.C., 1902.

A small seam averaging about 2 feet thick, called the Little Wellington, overlies the Wellington locally in the extreme northwestern part of the basin, at a distance of 20 to 60 feet. It was mined at the Old Wellington collieries, within the Nanaimo map-area at the old No. 1 shaft, and it is reported to have been mined at the old East Wellington colliery, also within the Nanaimo map-area. Another small seam occurs 80 to 100 feet above the Wellington seam near the Nanaimo river south of Extension. The seam as exposed at "Jacks" prospect on the north bank of the Nanaimo river, three-quarters of a mile above the Extension collieries railway bridge, is about 10 feet thick and consists of a carbonaceous shale with lentils of bony coal, and occurs as an interbed in the Extension conglomerates and sandstones. A thousand feet to the east, apparently the same seam is exposed, and consists of 3 feet of bony coal with partings of sandstone and conglomerate. There appears to be still another small seam with a maximum thickness of 2 or 3 feet, in the Extension formation from 200 to 250 feet above the Wellington seam. This has been found in several boreholes in the vicinity of Extension, and less than half a mile to the northeast of Extension, near the old railway grade, is a small prospect on what is apparently the outcrop of this seam. There it consists merely of carbonaceous shale with coaly lentils.

Besides the small seams in the Extension formation there are numerous lenses or lentils of coal in the Protection, Cedar District, and DeCourcy formations. Most of the lentils are only a few inches thick, but a few are 2 to 4 feet thick. Several of them have been prospected, but none of them, however, so far as known, are more than a few feet in lateral extent, or are of any commercial value.

The Wellington seam has been mined at Wellington, Northfield, East Wellington, Harewood Plains, and Extension, and is at present mined by the Vancouver-Nanaimo Coal Mining company at East Wellington and by the Canadian Collieries (Dunsmuir) company near Extension. The Newcastle and Douglas seams are usually worked together and have been mined extensively in the vicinity of Nanaimo. The mines there are operated by the Western Fuel company. There has also been a large production from the Douglas seam south of Nanaimo, notably at Chase River, Southfield, and South Wellington. There is only one mine producing at present in this district, namely the South Wellington colliery operated by the Pacific Coast Collieries. Very recently the Douglas seam has been reached by two new shaft mines—by the Reserve mine of the Western Fuel company on the Indian Reservation near the mouth of the Nanaimo river, at 1,064 feet, and by the Morden mine of the Pacific Coast Collieries between South Wellington and the Nanaimo river, at 610 feet.

Coal was first produced from the Nanaimo coal-field in 1852, the production before the close of 1853 amounting to 2,000 tons. Since that time the production has shown a continuous although fluctuating increase. In 1875, the annual production first passed the 100,000 long tons mark, and in 1900 a production of over 1,000,000 tons a year was reached. The maximum production was attained in 1911 when it amounted to 1,184,719 long tons valued at over $4,000,000. This amounts to more than one-third of the entire production of British Columbia which during the last few years has averaged over 3,000,000 long tons a year, although during 1911 it was considerably less owing to labour troubles in the East Kootenay district. The total production of the field to December 31, 1912, is approximately 24,500,000 long tons, about three-fifths of the total coal production of British Columbia.

The future of the coal industry is very promising, although thinner and deeper coals will have to be mined in the near future. As already stated, two new shaft mines have reached the Douglas seam in depth. Owing to the great variability of the seams and to the lack of public information, no figures can be given for the actual coal reserve at Nanaimo. But granting a moderate extension in depth and area, the probable reserve of the Nanaimo field, including the seams of 1 foot or over to a depth of 4,000 feet, is conservatively estimated as 1,340,000,000 long tons. This estimate is based on the assumption of 3 seams, with a total average thickness of 10 feet, and a total area, largely within the Nanaimo map-area, of 181 square miles, none of the seams, however, extending over the entire area, and of 1,000,000 tons per square mile-foot.

The Wellington seam, which as stated rests on the East Wellington sandstone and the Extension formation, outcrops along the western border of the field. It is well developed in the northern part of the map-area in the vicinity of East Wellington where the seam averages 3 to 6 feet in thickness and consists almost entirely of clean coal, there being no persistent partings. The outcrop can be seen in the northern area at only one place, at the old Jingle Pot slope to the northwest of the New East Wellington colliery. The outcrop bends around the east flank of Mt. Benson, although the position of the outcrop and the character of the seam are unknown in this vicinity. Farther south the outcrop is well located at Harewood plains where there are three or four old slopes on the seam, In this locality the seam although attaining a thickness of 10 feet, contains many thick partings of carbonaceous or coaly shale and the amount of clean coal in places is less than a foot. The seam outcrops along both sides of the Extension valley in the limbs of the Extension anticline, and the seam pitches below the Extension conglomerates, at the southeast end of the anticline, nearly 1½ miles south of Nanaimo river. The seam is exposed at a few places along both sides of the anticlinal valley. It averages in thickness along the Extension valley from 6 to 10 feet, but in many places, especially in the northeastern limb of the anticline, it contains thick partings of carbonaceous shale and bony coal. The southwest limb of the anticline is broken by two reversed strike faults with throws of 500 and 150 feet respectively. The seam for nearly 4 miles outcrops a few yards to the southwest of the northeastern and larger fault, in the upthrown side. Farther southwest, the seam outcrops in the northeastward dipping limb of the shallow syncline southwest of the faults. The seam is not actually exposed until it crosses the Nanaimo river, but its position has been fairly well determined by underground mining. At Nanaimo river, south of Berkley creek, about 4 feet of clean coal is exposed for a distance of 25 yards. The seam also outcrops along the Nanaimo river in the limbs of the sharp anticline southeast of the Extension anticline. On the outcrop of the southwest limb of the anticline is an old prospect, now caved, but in the dump are fragments of good coal. South of the Nanaimo river, except in the limbs of the Extension anticline, the further continuation of the seam is problematical, but the position of the western outcrop of the horizon has been fairly well determined. Because of the thick mantle of Colwood sands and gravels of the Nanaimo delta, the extent of the anticline southeast of the Extension anticline, and the position of the outcrop of the seam horizon is only assumed. Since the seam is so well developed where it crosses the Nanaimo river, both at its western outcrop and in the northeastern limb of the Extension anticline, the continuation of the seam for some distance south of the Nanaimo river is very probable. South of Haslam creek the seam horizon outcrops in the valley to the northeast of Mt. Hayes ridge in the northeastly and steeply dipping monocline of this vicinity. The seam was not seen by the writer; but coal is reported to have been found in Bush creek where crossed by the outcrop of the seam horizon. The eastward extent of the seam is unknown, but it doubtless extends with a variable thickness beyond the outcrop of the Newcastle and Douglas seams, at a depth of 800 to 1,200 feet, and may extend considerably farther.

The thickness of the Wellington seam varies where mined, from virtually nothing to nearly 30 feet, and has perhaps an average thickness of 4 to 7 feet. This extreme variation is best described further by considering the structure of the seam and associated measures.

The floor of the seam is virtually always the firm, but thin-bedded to flaggy, East Wellington sandstone. In places, there are lentils of shale between the seam and the floor, and interbeds of shale in the sandstone floor. Less commonly certain beds in the sandstone are pebbly and pass into conglomerate. The roof, on the contrary, varies in character. Most commonly it is a sandy shale, carbonaceous and even coaly in places. It varies in thickness from nothing up to 20 or 25 feet, and near East Wellington is overlain by sandstone, but near Extension by the typical Extension conglomerates. Near Extension, the conglomerate itself is in many places the roof of the seam. In a few places the roof is sandstone.

Near East Wellington the seam contains no persistent partings. In places, usually in the swells, the seam consists entirely of clean coal with only a very few small bony lentils or partings of soft dirty coal or "rash," an inch or less in thickness and seldom of a lateral extent of even 10 or 15 feet. In other places, usually in the pinches, the seams consist entirely of rash. Near Extension the more undisturbed portions of the Wellington seam do contain more or less persistent partings. There the seams frequently consist of three benches of coal separated by rash.... Other portions of the seam show the three benches of coal separated by rash, but also thick partings of shale. The character of the rash is indicated by the following proximate analysis by F. G. Wait of the Mines Branch, Department of Mines, of a sample of rash collected by the writer from the Wellington seam at Extension:—

Moisture	1·59
Volatile combustible	24·15
Fixed carbon	19·29
Ash	54·97
	100·00

Other impurities besides the partings and the dirty broken coal are of little consequence. The coal contains more or less pyrite, especially the bony coal and rash, and very thin veinlets or films of calcite traversing the irregular joints of the coal are numerous, but probably do not increase the ash content greatly.

The most conspicuous feature of the seam is its variability in thickness caused chiefly by minor faults, folds, or bends usually in the roof, while the floor is fairly regular and even, although a few sharp rolls do occur in it. These features are well illustrated at East Wellington where the seam in places pinches gradually to virtually nothing and then suddenly thickens to 10 or 12 feet. Although the floor may be nearly smooth, the roof in passing from the thin to thick portion of the seam rolls sharply, and often irregularly upward. In some places the roof is even overturned, at least 25 feet in one place.

These sharp rolls are locally called "faults." Invariably at the thin places or "pinches" the coal is dirty and slickensided, while in the thick places, or "swells" it is clean, black in colour, with a sub-brilliant lustre, and broken only by a few irregular joints. Rash is usually found near the top and bottom of the swells, and only rarely, as described, in thin, non-persistent partings near the centre. In some places the coal is clean and unfractured against the upturned roof, but more commonly it is somewhat slickensided and even contorted. The roof at the rolls is always contorted and slickensided. The strike of the rolls corresponds with the strike of the measures, that is northwest to west, and the pinches occur in the northeast or north side of the rolls, with the corresponding swells on the opposite side. Where the seam is overlapped, the overlap is to the northeast or north.

Near Extension, although the seam has even greater extremes in thickness, from 5 feet to 26 feet, the rolls in the roof are, as a rule, not so abrupt, although a few abrupt rolls of 3 or 4 feet do occur. Instead at the bends of some of the larger folds affecting the entire seam, the seam pinches and is in places composed almost entirely of rash. On the limbs of the folds, the roof rolls gradually and irregularly upward forming a swell, where the seam consists, except for the rash at the top and bottom of the seam, chiefly of clean, bright, irregularly, but not greatly fractured, coal.

The coal of the Wellington seam where relatively undisturbed is black with a sub-brilliant lustre. In places it is finely laminated or bedded and in other places it is massive, the finely laminated coal containing tiny lenses of bone. The coal is crossed by irregular joints, which in the laminated coal are, however, nearly at right angles to the bedding. The coal is fairly hard and strong, breaks with a hackly fracture, and weathers well. In places it contains some pyrite and in some of the fractures thin films of calcite. In places, the coal is contorted and brilliantly polished along slickensided planes.

As is shown by the analyses given above, the Wellington coal is a rather high volatile bituminous coal and does not differ essentially in composition from the other Nanaimo coals. However, it appears from the tests made by Stansfield and Porter[1] to be a much better coking coal than the Newcastle and Douglas coals. At present, no coke is made from it, but it is used entirely as a steam, gas, and domestic coal.

The Newcastle coal seam occurs between the Cranberry and Newcastle formations. It extends through the west central part of the map-area, with a general N. 20° W. trend from northern Newcastle island to south of Nanaimo river. It is exposed on both sides of Newcastle island and presumably extends across the island. It outcrops to the west of the Brechin mine on Pimbury point, the Brechin shaft sunk to the seam being only 84 feet deep. In this vicinity the seam averages fron 30 to 40 inches thick and contains one or more fairly persistent partings. The seam is doubtless continuous between the Brechin mine and Nanaimo although the outcrop is not exposed. It was exposed in one or two old slopes in the city of Nanaimo, and is now being mined in depth, where the seam averages 30 to 40 inches in thickness, although it is reported to have a maximum thickness of 6 or 8 feet. South of Nanaimo it outcrops for a mile and a half in the Chase River valley and is exposed in a few prospect slopes and in the Douglas slope of the Western Fuel company. The seam averages about 6 or 8 feet thick, but contains only from 2 to 4 feet of fairly clean coal, separated by partings of coaly shale. South of Chase river the seam is of doubtful commercial quality but is well defined as far as South Wellington and is exposed in several prospect slopes. The seam varies in thickness from 18 inches to 6 feet, but consists chiefly of dirty coal and thick partings of coaly shale. The seam is not exposed between South Wellington and the Nanaimo river, and its character and the position of its outcrop are not known. South of the Nanaimo river, what is probably a continuation of the Newcastle seam is exposed in a prospect slope in the southwest limb of the southeastward pitching syncline of the crescent-shaped cuesta between the Esquimalt and Nanaimo railway and the Extension

[1]Coals of Canada, Dept. of Mines, Mines Branch, Pub. No. 83, Vol. I, 1912, Part VI, pp. 205-233, and table XLIV.

Collieries railway. The seam is 6 feet thick, but it consists chiefly of bony coal and carbonaceous shale, with lentils of coal up to 10 inches in thickness. South of the exposure the farther continuation of the seam is very doubtful. The eastward extension of the seam is unknown. It has been mined by the Western Fuel company near Nanaimo for over a mile off shore and presumably extends much farther. South of Chase river, where the seam even at the outcrop is thin and dirty, the eastward extension is problematical and is probably not great.

Few details concerning the Newcastle seam can be given since it was not seen by the writer where it is mined. The average thickness of the seam where mined is from 30 to 40 inches, with extremes of 20 inches and 6 or 8 feet. It is, therefore, although thinner, much more regular than the Wellington or Douglas seam. Where seen on the surface the seam contains more numerous and more regular partings. The floor of the seam is usually the typical dark green thin-bedded, flaggy or shaly sandstones of the Cranberry formation. The roof varies from a sandy shale, where the Newcastle formation is composed largely of shaly rocks, to sandstone, grit, or even fine conglomerate, where these rocks composed the larger part of the Newcastle formation. The former predominates in the vicinity of Newcastle island, and Chase river and South Wellington, and the latter in Nanaimo and near the Nanaimo river.

To judge from the few available analyses, especially that by Stansfield of the commercial coal, the Newcastle coal while not differing in any pronounced degree from the Wellington and Douglas coals, being a high volatile bituminous coal, yet appears to be lower in fixed carbon and actual carbon content, and higher in oxygen and ash. Neither does the coal appear to coke readily. It is used as a steam coal.

The Douglas coal seam occurs in the Newcastle formation, as stated, about 25 to 100 feet above the Newcastle seam, so that its outcrop occurs from 100 to 1,000 feet to the east of the Newcastle seam dependent upon the character of the topography and the angle of dip. It extends from northern Newcastle island to south of Nanaimo river, and may extend as

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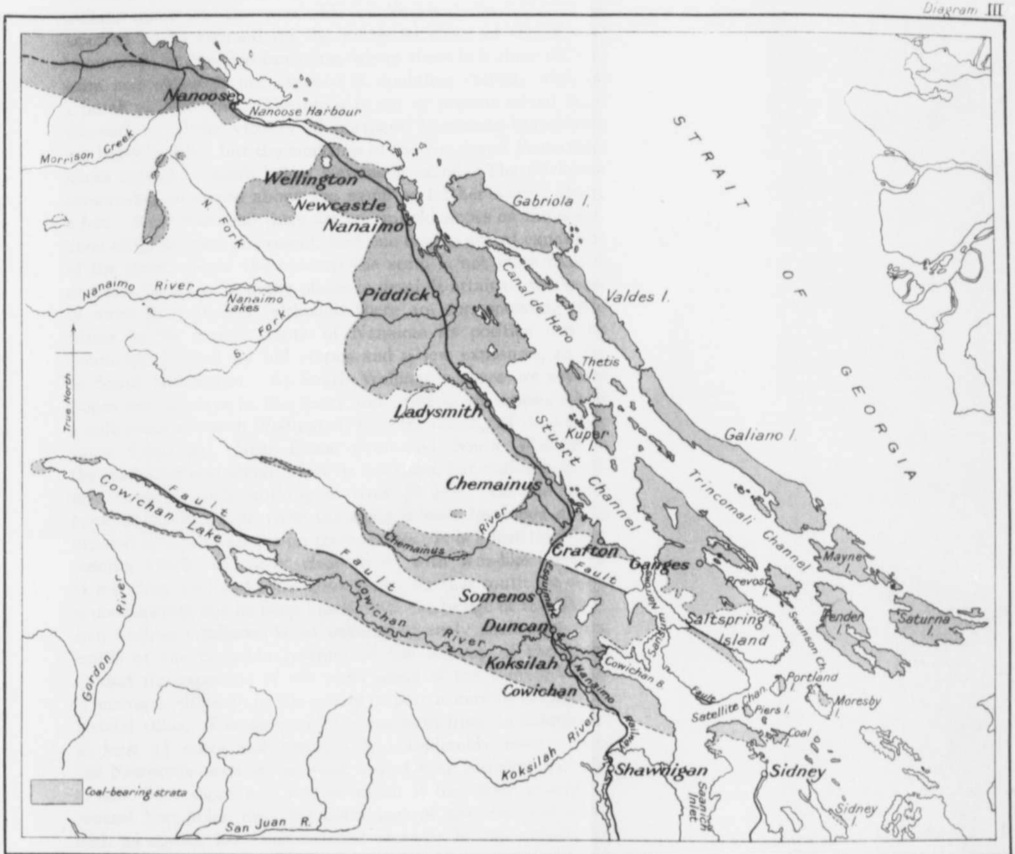
Diagram III



Geological Survey, Canada.

Cowichan Basin and Nanaimo coal-field

Miles

To accompany Memoir by D. B. Dowling

far south as Ladysmith. It is exposed in an old slope (Fitz-william mine) on the west side of Newcastle island, and is reported to be exposed on the northeast shore of the island. It outcrops at the Brechin mine, where there is a slope on the seam and although not exposed it doubtless extends without a break to Nanaimo. The seam is not at present mined near the surface in the vicinity of northern Newcastle island and the Brechin mine, but the workings of the No. 1 and Protection mines extend in depth below Newcastle island. The thickness presumably averages about the same as farther south, about 5 feet. Near Nanaimo there are several old slopes on the seam, none of them open at present, and one or two actual exposures of the seam. Near the outcrop the seam is not more than 4 or 5 feet thick but in many places in depth it attains a thickness of more than 10 feet, although there are corresponding thin places in the seam. South of Nanaimo its position can be accurately located by old stopes and a few exposures, as far as South Wellington. At South Wellington there are several slopes and airways in the seam and there is an exposure half a mile south of South Wellington, near the railway of the Pacific Coast Collieries. Near Chase river and South Wellington the seam averages about 5 feet in thickness, but varies in thickness from virtually nothing to over 30 feet. On the south bank of the Nanaimo river the seam is well developed and is exposed in a prospect pit on the outcrop. It is 8 feet thick and consists chiefly of fairly clean coal, with lens-like partings of soft dirty coal and some bony coal. Farther south the seam is not exposed, but in Bush creek, near the bridge of the Extension Collieries railway, is an outcrop of coaly shale with coal lentils at the probable position of the outcrop of the seam, so that the extension of the seam south of the Nanaimo river is assumed, although in the southern part it may be of no commercial value. The seam extends eastward from its outcrop for at least 1½ miles and presumably considerably more. With the Newcastle seam it has been mined near Nanaimo for over a mile from shore and farther south it has been located by several bore-holes, near the lower part of the Nanaimo river, and, as stated, has been reached recently in this vicinity by two shaft mines.

The floor and roof of the Douglas seam vary in character from grit or fine conglomerate, as at Nanaimo, to sandy shale as in places near northern Newcastle island and South Wellington. Near South Wellington the floor is usually a rather weak sandy shale, and the roof, although stronger, varies from a sandy shale to a fine-grained conglomerate with fragments of coaly material and irregular thin partings of slickensided, coaly shale. The roof consists chiefly of a shaly sandstone with sandstone layers and lenses of fine-grained conglomerate. The seam varies greatly in thickness from nothing to 30 feet, and averages about 5 feet, although over large areas the average thickness of the mineable coal is 3 and 4 feet. Unlike the conditions in the Wellington seam the pinches and swells are caused chiefly by irregularities in the floor, the roof being fairly smooth. Neither are the rolls in the floor so abrupt as those in the roof of the Wellington seam. In some places the roof rolls up nearly to the roof and in other places rolls rather abruptly downward. The strike of the rolls corresponds in general with the strike of the measures, that is about N. 30° W., but varies considerably, and the rolls are not so long or so regular as those of the Wellington seam. The abrupt side of the up-rolls is usually to the southwest, and of the down-rolls to the northeast.

At the pinches the seam is composed almost entirely of rash like that of the Wellington seam, although as a rule the rash is harder. The coal of the swells is clean, with a compact texture and rather dull to sub-brilliant lustre. It is irregularly broken into large irregularly shaped blocks. Near the pinches some of the coal is slickensided and contorted, but where these features are shown the coal contains a rather large amount of ash. The floor is almost invariably sheared and slickensided at the rolls and in places the roof is the same. The seam both in the pinches or swells, or even where it is relatively undisturbed, contains no regular or very persistent partings, but there are thick partings or "wants" of carbonaceous and coaly shale, which in places entirely replace the seam, but which pinch rapidly in all directions.

The seam is also displaced by rather numerous small faults, although an actual break seldom occurs, the coal having been forced along the plane or zone of dislocation. More rarely the entire seam folds or wrinkles without any appreciable variation in thickness.

Where the rolls, pinches, faults, and wrinkles occur at comparatively shallow depths, their presence is usually indicated on the surface by a small cuesta-like ridge, with a steep front slope at right angles to the bedding, and a gentle back slope nearly parallel to the bedding.

The Douglas coal is black with a sub-brilliant to brilliant lustre. It is massive and broken by irregular joints producing an irregular hackly fracture. It is fairly hard and weathers well. As in the Wellington coal, thin films of calcite occur on some of the fractures. In places where the coal has been sheared it develops highly polished, very irregular, slickensided surfaces, between which the coal has a rather dull to sub-brilliant lustre. Except where it is dirty and contains a rather large amount of ash, it is rarely contorted.

The Douglas coal is a high volatile bituminous coal, and as may be seen from the analyses, is very similar to the Wellington coal. From the analyses it appears as if the coal from Southfield and South Wellington was higher in fixed carbon and lower in ash than from that near Nanaimo, and it also appears to coke more readily. At present, the Douglas coal is used as a steam, gas, and domestic coal.

Little is known concerning the actual origin of the coal seams, but since the coal measures were deposited under rapidly varying marine and terrestrial conditions, and since the seams rest indiscriminately on sandstone, shale, and even conglomerate, there seldom being any underclay and very few fossil roots, it is not probable that the coal is the result of accumulation of vegetable matter in large, coastal plain swamps, with standing timber and luxuriant undergrowth. It is more probable that the vegetable matter accumulated in peat bogs, which may have been formed in lagoons protected from the outer, marine basin by bay bars. It is probable, therefore, that the seams do not extend indefinitely to the northeast, below the Strait of Georgia, but are confined to a greater or less extent to the neighbourhood of the old shore of pre-Upper Cretaceous rocks.

Since the seams, especially where undisturbed, are dirty, the dirty coal alternating with clean coal, and in places are composed entirely of dirty coal or carbonaceous shale, silt must have been deposited in the bogs with the peat, in sufficient amount in places to form some of the "wants" of the present seams.

As described under the structural geology of the Nanaimo series, the measures were deformed by forces acting from the northeast. Local deformation occurred while at least some of the measures were unconsolidated, but the larger movements did not take place for a long period after the deposition had ceased. It appears that the local deformation caused some of the minor disturbances of the coal seams; for it looks as if, when the seams were first folded, that the clean coal was softer and more plastic than the dirty coal or rash. It was, therefore, squeezed away from the tight bends, where there was an increase of vertical pressure, to the limbs of the bends or rolls, where there was a corresponding decrease in vertical pressure. Thus swells were formed, which consist, except for the rash at the top and bottom, chiefly of clean coal, while the pinches were left, composed almost entirely of rash. Since it is the sandy shale roof of the Wellington seam and the relatively weak sandy shale floor of the Douglas seam that are deformed, it appears as if the relative strength of the roof and floor determined in general the relative amount of deformation in each. It is possible that original or initial irregularities in the seams determined the location of the minor disturbances. The later and larger movements produced the large open folds and faults in which the seams are involved and presumably caused the minor faulting and wrinkling of the seams. These movements necessitated lateral adjustment by the sliding of one bed upon another; and it is probable that much of the lateral adjustment took place by sliding along the coal seams,[1] and caused some of the slickensiding and contortion of the coal as well as of the roof and floor.

Minor disturbances or local variations or interruptions of

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[1]See, Bailey, Willis, Some Coal Fields of Puget Sound: 18th Ann. Rept. Part III, 1897, U.S. Geol. Survey, pp. 408-409.

coal seams similar to those described as affecting the seams of Nanaimo field, are rather common and have been described by various writers.[1] They appear to have been formed in several different ways—by irregularities in deposition, by contemporaneous or later erosion, but as in the Nanaimo field, chiefly by some kind of deformation. They are not only of scientific interest but of great commercial interest as well, for, as has already been pointed out,[2] "the constantly recurring industrial disputes owe their origin, in no small measure, to the difficulties experienced in framing satisfactory agreements for the "working of deficiency places" where the miner cannot under ordinary circumstances, make what he considers a fair living wage."

DESCRIPTION OF MINES.[3]

There are four operating companies in the Nanaimo coal field—the Western Fuel company, Canadian Collieries (Dunsmuir) company, Pacific Coast Collieries, and Vancouver-Nanaimo Coal Mining company.

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[1]The following references give the fullest treatments of the subject.

Bain, H. F.—"Origin of certain Features of Coal Basins:" Journal of Geology, Vol. 3, 1895, pp. 646-654.

Collin, A. J.—"The Arkansas Coal Fields:" Bull. 326, U.S. Geol. Surv., 1907, pp. 48-49.

Gresley, W. S.—"Clay-veins Vertically Intersecting Coal Measures." Bull. Geol. Soc. Am., Vol. 9, 1898, pp. 35-58.

Keyes, C. R.—"Coal Deposits of Iowa:" Iowa Geol. Survey, Vol. 2, 1894, pp. 49-53; pp. 178-189; p. 229, and p. 249.

Willis, B.—"Some Coal Fields of Puget Sound:" 18th Ann. Rept. Part III, 1896-97. U.S. Geol. Survey, pp. 410-412.

Woolnough, W. G.—"Stone Rolls in Bulli Coal Seam of New South Wales": Jour. Roy. Soc. N.S. Wales, Vol. 44, 1910, pp. 334-340.

[2]Woolnough, W. G.—"Stone Rolls" in the Bulli Coal Seam in New South Wales. Jour. Roy. Soc. N.S. Wales, Vol. 44, 1910, p. 334.

[3]Memoir 51, Geological Survey, Canada, pp. 116-120.

Vancouver-Nanaimo Coal Mining Company.

The Vancouver-Nanaimo Coal Mining company operates the New East Wellington colliery at East Wellington. The mine, opened in 1907, is located on the Wellington seam. The seam is reached through a slope or rather an inclined shaft, paralleling an old slope driven in the little Wellington seam. The Wellington seam in the mine is fairly even, with a low dip 5 to 10 degrees to the northeast, but to the southwest the seam is faulted in a series of steps, and outcrops at the surface to the southwest of the surface plant with a steep dip to the northeast. The mine is worked on the pillar and stall method, the pillars being drawn and the roof supported by cogs. There has been a long wall mining, but the method is not adaptable owing to the great variation in thickness of the seam, which has already been described. The coal is undercut where possible but is chiefly shot from the solid. Horses and winches are used for hauling in the mine. Since the roof is rather weak, the mine is well timbered, and, as stated, when the pillars are drawn the roof is supported by cogging. The mine is ventilated by a fan and the ventilation is good, there being virtually no gas. The output for the mine in 1911 was 72,918 long tons.

Canadian Collieries (Dunsmuir) Company.

In the Nanaimo field the Canadian Collieries (Dunsmuir) company operates the Extension collieries opened up in 1899 and formerly worked by the Wellington Collieries company. The Extension collieries consist of four mines, all on the Wellington seam. Mines Nos. 1, 2, and 3 are situated in the southwest limb of the Extension anticline and mine No. 4 in the northeast limb, the mine being situated about 1½ miles southeast of the entrance to the adit or "tunnel" to the other three mines, in the town of Extension. The seam in mines Nos. 1, 2, and 3 is broken by a reversed strike fault of about 500 feet displacement. Mine No. 1 is situated in the northeast, downthrown side of the fault and mines Nos. 2 and 3 are in the southwest upthrown side. The mines are at present reached by an adit, or as it is called a "tunnel" about a mile long, which crosses the southwestward dipping seam in the downthrown side of the fault, and the fault, to the southwestward dipping seam in the upthrown side. No. 2 mine is situated to the southeast of the end of the tunnel and No. 3 mine to the northwest. Both portions of the faulted seam extend to the surface and the slopes of No. 2 and No. 3 mines are kept open and used for air-ways and roadways. In the downthrown side, the seam dips to the southwest at angles varying from 5 to 20 degrees, although near the fault it wrinkles and in places turns up against the fault zone. In other places it seems to dip under the fault, which as described appears in places to have a low dip to the southwest and to be of the nature of an overthrust. In the upthrown side the seam has been folded into a broad syncline or shallow basin, which in its northern part, in No. 3 mine, is broken by a reversed strike fault of a displacement from nothing to about 150 feet, the displacement increasing to the northwest.

The mine is worked chiefly by the pillar and stall method, the pillars being drawn. In places in No. 2 mine where the roof is conglomerate, the seam is mined by the long-wall method. The coal is mined by hand and by various systems, depending upon the thickness and character of the seam. Mules and winches are used to haul the coal to the collecting roads. It is then taken to the surface through the tunnel by electric locomotives. Since in most places the roof is sandy shale the mine is well timbered and when the pillars are drawn the roof is supported by cogging. Each mine is well ventilated by a separate fan system.

At No. 4 mine the seam, which is reached by a shaft 280 feet deep, dips to the northeast at an angle of about 15 degrees, outcropping about 1,000 feet to the southwest of the shaft. The mine is worked by the pillar and stall method. The mine is timbered and cogged and ventilated through a separate shaft southwest of the main shaft. The output from all of the Extension mines in 1911 was 331,576 long tons.

Western Fuel Company.

The Western Fuel company operate two collieries in the Nanaimo field, the Nanaimo and the Northfield or Brechin collieries. As already mentioned the company have recently opened up a new shaft mine on the Indian Reserve at the north of the Nanaimo river, and a slope, abandoned during 1912, in the Newcastle seam, outcropping in the valley of Chase river. The following description of the mines, which were not examined by the writer, is largely condensed from T. C. Denis, description in the Coals of Canada, Publ. No. 83, Vol. I, Part II, pages 112-13, Dept. of Mines, Mines Branch, 1912, and from Inspector Thomas Morgan's report for 1911, Minister of Mines, B.C., pages K 224 to K 230.

At the Nanaimo colliery the Douglas and Newcastle seams are mined. The seams are reached through the No. 1 shaft (Esplande) near the shore in the southern part of the city of Nanaimo, 640 feet to the Douglas seam and 700 feet to the Newcastle, and by the Protection Island shaft on the southern point of Protection island, about 588 feet to the Douglas seam, and about 652 feet to the Newcastle. The underground workings, which extend below Nanaimo harbour and the Nanaimo River delta, are very extensive, and from face to face on opposite sides of the mine is over 5 miles.[1] The general dip of the seams is about 10 degrees to the east. The Newcastle seam is worked by the long-wall method, the coal being undercut by machines, and the Douglas seam is worked by the pillar and stall method, and as a rule, all the coal is removed where the cover exceeds 500 feet.[2] The underground haulage is partly by electric locomotives and partly by endless rope, to the bottom of No. 1 shaft. The mine is ventilated by fans, most of the air going down

[1]Report Minister of Mines, B.C., 1911, p. K226.

[2]Denis, T. C., Coals of Canada, Pub. No. 13, Vol. I, Part II, Mines Branch, Dept. of Mines, 1912, p. 112.

the Protection shaft and returning through the No. 1 shaft. The total production of this colliery in 1911 was 411,909 long tons.

At the Brechin mine situated on Pimbury point, the coal mined at present is all from the Newcastle seam although the workings connect with the Douglas seam. The seam is reached by a slope and by a shaft 84 feet deep,[1] and the workings extend below Newcastle island. The general dip of the seams is about 5 degrees to the southeast but turns to the eastward in depth and increases slightly. The mining is by the long-wall method and undercutting machines are used. Haulage is by endless rope to the bottom of the shaft. The ventilation is by fan, the downcast shaft being on Newcastle island. The output of the mine for 1911 was 161,852 long tons.

Pacific Coast Collieries.

The Pacific Coast Collieries, who took over the property of the Pacific Coast Coal Mines in 1912, operate in the Nanaimo field the Fiddick or South Wellington colliery at South Wellington and have recently opened up a new shaft mine 610 feet deep, at Morden, about a mile east of South Wellington. The South Wellington colliery is located on the Douglas seam and is operated through two slopes in the seam. The seam has a general dip of about 10 degrees to the northeast, although the seam is involved in several minor rolls, and as described is subject to great variation in thickness by the irregularities of the floor. The coal is mined by the pillar and stall method, and where the coal is thinner and of fairly uniform thickness it is worked by a modified long-wall method. The

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[1]Denis, T. C., Coals of Canada, Pub. No. 83, Vol. I, Part II, Mines Branch, Dept. of Mines, 1912, p. 113.

coal is shot from the solid. In the mine the coal is handled by electric winches and horses. The roof has to be well timbered and where the pillars are drawn and when the long-wall method is employed, has to be supported by cogging. The mine is ventilated by a fan. The production in 1911 was 205,048 long tons.

COMOX COAL AREA.[1]

(Extracts from report by Jas. Richardson.)

(*See Diagram IV.*)

The portion of this area which will be described, is bounded on the southwest by the southeast end of the Beaufort range of mountains, and farther southeast by Mounts Mark, Wesley, and others, rising to heights of from 2,530 to 5,420 feet. On the northeast it is bounded by the Strait of Georgia, extending from Sable river on the northwest to Northwest bay on the southeast, a distance of about thirty-six miles.

Measurements upon the coast line were made partly in 1872 and partly in 1873[2] from Sable river to Deep bay, opposite the southeast end of Denman island, thence an examination of the coast line was made without measurements to the Great and Little Qualicum rivers. From the latter, measurements were made to Englishmans river, and the coast was examined from there to Northwest bay without measurements.

Measurements were also made up a stream falling into Baynes sound, a little to the east of Fanny bay, or two and a-half miles southeast of Sable river; up Donaldson river, which falls into the same sound about two miles farther east; and also up a stream fully halfway between the last and Deep bay. The next measurements to the southeast were along the Alberni trail, and the Little Qualicum river, while still farther on, this river was ascended for an estimated distance of six or seven miles; but on account of the difficulty met with in penetrating the thick wood along its banks, and the only exposures of rocks being in the bed of the stream, it had to be ascended by wading in the clear, cold water of from one to four feet in depth, and no measurements were made. The only other stream examined for a short distance up, falls into the Strait of Georgia about five miles southeast of the Little Qualicum.

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[1]Report of Progress, Geol. Surv., Can., 1876-77, pp. 161-170.

[2]See Report of 1872-73, page 35, and Report 1873-74, page 95.

The two large islands, Texada and Lasqueti, properly belong to this area, also a number of smaller ones to the northeast and southwest of the latter.

The evidence afforded in the exposures observed in these examinations, in the streams and on the coast and islands, is scant enough, and but for the many well defined sections to be found in the streams farther to the northwest, as well as on Denman and Hornby islands (see report of 1872–73), there would be very few data by which to determine the structure. Combining the knowledge previously obtained, however, with the facts now at command, I hope to be able to give a close approximation to the truth.

In the report of 1872–73, page 51, the several groups, with their ascertained thickness, were defined as follows, in ascending order:—

	Feet	*Inches*
A.—Productive coal-measures	739	6
B.—Lower shales	1,000	0
C.—Lower conglomerate	900	0
D.—Middle shales	76	0
E.—Middle conglomerate	1,100	0
F.—Upper shales	776	0
G.—Upper conglomerate	320	0
	4,972	6

In the same report eight sections[1] of the productive coal-measures were given, the most westerly being on Browns river, a tributary of the Puntledge. This section gave a total thickness of 739 feet 6 inches, with nine seams of coal, varying in thickness from six inches to seven feet; the seven-foot seam, however, not being always continuous. The whole thickness of coal is about sixteen feet five inches. The next section was on the Puntledge; but the details are not well seen, and none of the coal seams are exposed. Bearing from the outlet of Puntledge lake, S. 48° E., about two and three-quarter miles, is section No. 3, at the Union Mine claim, in an almost perpendicular cliff. The whole thickness seen in the cliff is 122 feet, with eleven

[1]These sections form an appendix to the present reprint.

seams of coal, of from one to ten feet in thickness, and an aggregate thickness of twenty nine feet three inches.[1] Section No. 4 is twenty-nine chains to the northwest of No. 3, and contains three coal seams, with an aggregate thickness of fifteen feet six inches, being respectively, in ascending order, four feet six inches, two feet, and three feet; this section may be wholly, or in part, a continuation of section No. 3.

A line bearing S. 38° E., from section 3, two and a-third miles in length, strikes the Trent river, where the details of Section 5 were obtained. Here the whole thickness of the measures is 710 feet 7 inches, with thirteen coal seams, the thickness of which varies from two inches to four feet. The next locality where the measures were met with on the strike is Bradleys creek, a tributary of the Trent, the distance being about a mile from the latter to the southeast. This was called Section No. 6. Owing to great irregularity of dip, and considerable intervals of concealment, it was, however, difficult to estimate the thickness. The coal observed occurs in four seams of from eight inches to three feet two inches thick.

The last place examined was at the Baynes Sound coal mine, on the River Sable (Section No. 7). This mine is about five and a-half miles S. 53° E. from the base of Section No. 6 on Bradleys creek. The section comprises 220 feet ten inches, with two seams of coal, respectively of five feet ten inches and six feet; also, a bed six feet thick, which consists mostly of black carbonaceous shale, showing impressions of plants; but includes, also, seams of good coal from two to eight inches thick. In some parts the greater portion of the whole bed consists of thin coal seams. In the report last referred to, it was stated (page 43) that a fault occurs, cutting the above measures off, the underlie of the fault being S. 62° E., $< 38°$. On the east side of the fault, which appears to be an upthrow, there is a thickness of 146 feet of measures (Section 8) which dip under the shales of Division 13. The Baynes Sound coal mine is situated two and three-quarter miles due west from the mouth of the Sable river, which falls into Fanny bay; and, as already stated, this is the farthest

[1]Report of 1872-73, pp. 38, 39.

southeastern exposure of the Productive Coal Measures, described in the Report of 1872-73.

The first place on the continuation of the measures to the southeast, where a few facts were obtained, is on a bearing S. 52° E. from the base of Section 7, three and a quarter miles distant and about two miles at right angles from the coast, in a gorge of an unnamed brook, already mentioned as falling into Bayues sound, a little east of Fanny bay. In this deep gorge, through which the stream finds its way to the coast, the beds enumerated below occur, resting on a greenish-brown dioritic rock. Immediately overlying the diorite is a seam of coal about fifty feet above the bed of the stream, but from its inaccessible position and the surrounding debris, its thickness could not be determined. It did not, however, appear to be less than two feet, although it may be considerably more. The dip of the overlying sandstones is N. 8° E., < 12°. From the abrupt nature of the banks, and the rapid current, the bed of the stream below the coal crop was not accessible for twelve and a half chains. The dip is then, N. 33° E., < 23°; and two chains farther down a second seam of coal occurs, of from one foot six inches to two feet in thickness. Another, or third seam, of three inches in thickness, occurs sixteen chains farther on; and fourteen chains still lower the rocks cease to be exposed. From the prevalence of false bedding and the difficulty in reaching the exposures in the bed of the stream, it was almost impossible to determine the dip accurately, but the average appeared to be about N. 35° E., < 9°. From these data, the following section would be near the truth as regards the whole thickness, but as there were many concealed intervals, it may reasonably be supposed that only some of the coal seams were seen:—

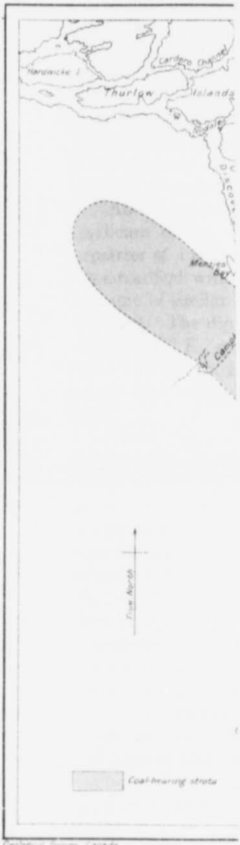
	Feet	*Inches*
Coal	2	0
Brownish-grey sandstones, in beds of from two inches to four feet, with interstratified beds of black soft shale	286	0
Coal	1	6
Brownish-grey sandstones, similar to the above	308	0
Coal	0	3
Sandstones, similar to the above	176	0
	773	9

Allowing seventy-three feet for the fall in the river, we have a very near approximation in this section to the thickness shown by the sections farther to the northwest, on Trent and Browns river, and may, therefore, reasonably presume that nearly the whole of the Productive Coal Measures are included in it, and that it is immediately succeeded by the softer, but here concealed, shales of Division B. If this is the case, the whole breadth of Division A, at right angles to the strike, is something over half a mile wide, across the measures; and including the shales of Division B, would extend to about one mile from the coast.

Two miles from the base of the above section, on a line bearing S. 38° E., there is a considerable stream, already mentioned, which joins Donaldson river at a point less than half a mile from the head of a shallow cove in Baynes sound, and although rocks of the crystalline series, mostly compact crystalline diorite, were observed, rising up from the low land into lofty and rugged cliffs, it is only reasonable to infer that the base of the coal measures is not far off; for, continuing on the same bearing S. 38° E., a little over two miles, in a brook at a point a mile and three-quarters from the coast, at the head of Deep bay, sandstones are seen, resting on a mottled dark-green diorite, with small geodes of white quartz. These sandstones, which are probably at the base of the coal measures, have a breadth, at right angles to the strike, of forty-seven chains. For this distance the waters of the brook intersect them in a deep, narrow ravine, the bottom and sides of which are so much entangled with brush and fallen timber that the details of the measures are by no means well shown, and none of the coal seams are visible. Here the average dip appears to be about N. 30° E., $< 7°$; this would give in forty-seven chains a thickness of 130 feet. Assuming this to be the base of the Productive Coal Measures and the same dip of N. 30° E., $< 7°$ to continue across the measures for a distance from the base of a mile and five-twelfths, we would have a thickness of 924 feet. Deducting 200 feet for the fall of the surface, in this distance, there would remain 724 feet for the total thickness. This agrees very closely with the thickness of the formation, in other localities to the northwest of the Productive Coal Measures here, and would indicate the position of the summit of the productive measures to be about forty-seven chains southwest from the coast at the west end of Deep bay.

Twelve miles and a half from the west end of Deep bay, a line bearing S. 65° E. strikes the mouth of the Little Qualicum river already mentioned. In this distance no exposures were met with on the coast or in the interior. The Qualicum river, which falls into the Strait of Georgia seven and a half miles eastward from the above point in Deep bay, and five miles westward from the Little Qualicum, shows no rock exposures to within one mile of Horne lake, a distance of about four and a half miles at right angles from the coast. Here a bed of dark, almost black, dioritic rock crosses the stream, forming a perpendicular fall of from sixty to seventy feet. This is succeeded higher up mostly by crystalline limestone, while downward towards the Strait of Georgia no indication of coal rocks is met with, the river channel being cut through deposits of gravel and sand. The Alberni trail leaves the coast about one-quarter of a mile to the eastward of the Qualicum river, and for nearly five miles runs almost parallel with it over gravel and sand similar to that seen in the banks of the stream.

In a line at right angles to the coast, about two miles up the Little Qualicum river, the lowest beds in this division are seen. None of the crystalline rocks are here exposed, and the only evidence of their presence is the abundance of loose masses which pave the bed of the stream for a distance of from two to three miles above the lowest exposed beds of the Productive Coal Measures. The latter here consist of soft black shales, interstratified with a few beds of grey, slightly calcareous sandstone, in layers of from two to four inches in thickness. The dip at first is N. 10°, the angle soon changing to from 4° to 5° immediately above the bend in the river about two miles up, but only about one mile from the coast. The dip at the bend is N. 75 E. $<$ 4°, while below it is N. 63° E. $<$ 5° about three-quarters of a mile from the coast. Below this there are no exposures. Those seen higher up are shales interstratified with sandstones similar to the lowest exposed beds above. No coal



Geological Survey, Canada

To accompany Memoir by D.B. Dowling

Diagram IV

Geological Survey, Canada

Comox coal-area

Miles

To accompany Memoir by D.B. Dowling

was observed, but some beds of the shale are marked with imperfect impressions of leaves, and also contain fossil wood.

A calculation of the thickness, from the above dips, on a line across the measures at right angles to the coast, gives a total of 704 feet, but probably as much as 180 feet ought to be deducted for the fall in the river, leaving a total thickness of 524 feet. If in this section the base has been reached (which, from the facts obtained, is open to doubt) and assuming the average thickness to be over 700 feet, then the summit of the division would be some distance out under the water of the Strait of Georgia.

About six miles S. 85° E. from the mouth of the Little Qualicum is the mouth of an unnamed brook, a little over a quarter of a mile up which a small thickness of conglomerates, interstratified with grey sandstone, is met with, while another exposure of similar beds occurs on the coast, about a mile to the eastward. The dip in the brook is N. 62° E. $<$ 5°, and on the coast N. 27° E. $<$ 5°. Although no other exposures were seen up to this brook, I have placed the base two miles inland, to accord with the observed strike farthest up the Little Qualicum river.

Three and a half miles to the eastward of the brook, and somewhat less than three miles to the west of Northwest bay, a stream of considerable size, called Englishmans river, falls into the strait. Although it is said that coal has been found in this stream somewhat less than two miles from the coast, I did not visit the place, owing to the difficulty of penetrating the dense tangled forest, or wading in the bed of the deep rapid stream. On this stream I have placed the base at somewhat under two miles at right angles from the coast. This agrees very well with its supposed position on the southwest side of Northwest bay, viz., about three miles due east from Englishmans river. These beds where they are first met with on the east side of the Shallow bay to the Northwest bay are grey sandstones, in beds of from two inches to five feet. The dip is N. 43° E. $<$ 16°, while farther east, approaching the head of Northwest bay, strata of a similar character dip N. 12° W. $<$ 7°, apparently bringing the edges up against the crystalline rock that forms Tongue point, on the northeast side of the bay. Throughout the whole thickness, which is here a little over one hundred feet, obscure leaves of plants and fossil wood are met with, as well as fossil shells, which were not observed to the northwest, although it will be shown that they characterize the base of the Productive Coal Measures in the Nanaimo area.

Among the more characteristic fossils collected here are, *Ammonites complexus* var. *suciaensis*, *A. breweri*, *Inoceramus undulatoplicatus*, *Cucullaea truncata*, *Axinaea veatchii*, *Trigonia evansi*, and *Astarte conradiana*.

Commencing at the extreme end of Tongue point there are about twenty feet of sandstones similar to those on the shore of the bay opposite. They occupy the coast here for nearly half a mile. Some of the beds are full of fossils similar to those above named, but too much broken to be worth collecting.

These beds rest on and fill up hollows in the older rocks, which here, and for some distance along the coast, are much disturbed, and consist of greenish-grey, finely laminated, compact beds, interstratified with bluish-grey limestone. In some of the hollows of these rocks, boulder-like masses of epidotic and chloritic rocks, embedded in sandstone, are numerous. The largest of these observed, measured twenty-six feet long, twelve feet wide, and five to seven feet high, and would probably weigh not far from 150 tons.

The facts obtained from the various exposures met with from Sable river on the northwest, to Northwest bay on the southeast, as already mentioned, a distance of thirty-six miles, are meagre enough, although there can be no doubt that we have in this distance a continuation of the Productive Coal Measures between Browns and Sable rivers, where workable seams of coal are seen in sections displaying every bed. It, therefore, can hardly be supposed that in their continuation southeast to Northwest bay, seams of good workable coal are entirely wanting. Indeed it appears to me that they may reasonably be looked for. On account, however, of the few and badly exposed sections, as compared with those to the northwest, the only practicable way of proving the value of this comparatively long stretch of productive measures is by boring or by sinking a shaft.

The thickness of these measures has already been several times stated to be somewhat over 700 feet, and by consulting the map, the summit of the formation is easily seen, except where it lies beneath the Strait of Georgia. In sinking anywhere on this line over 700 feet of measures would have to be gone through before reaching the base, and although seams of coal are found toward the summit, those which are workable have so far been found in the lower half of the thickness, so that, in a general way, a shaft or bore-hole sunk somewhere between the summit and base would require only to go through half the thickness, or somewhat over 350 feet. In the event of bore-holes or shafts being sunk, some of the streams in the region might be made available for water-power.

The only exposure of this division (Division B—Lower Shales) seen on the coast, is on a peninsula-like piece of land to the east of Fanny bay, facing Baynes sound. It extends to the east a little over one mile. The beds here consist of a series of brownish-black argillaceous shales, interstratified at intervals with soft grey and arenaceous sandstone, in layers of from one to six inches thick, the general dip being N. 33° to 35° E., $<$ 5° to 20°. This exposure is somewhat above the summit of Division A. The only other exposures in the Comox area have already been described in the Report of 1872-73 (page 44), most of this division being either concealed by superficial deposits, or else under the water of the Strait of Georgia.

Divisions C, D, E, F, and G, are not exposed in the Comox area within the limit of this season's examination, but have all been described as occurring on Denman and Hornby islands,[1] and they doubtless occupy a considerable breadth beneath the waters of the Strait of Georgia.

There are a few patches, not yet mentioned, which appear to belong to Division A, and are seen lying on Lasqueti, Texada, and other small islands. The most southerly one is on Sangster island, about one mile south of Point Young, Lasqueti island. It is wholly composed of sandstone and conglomerate, the latter being largely made up of rounded pebbles of white, yellow, and

[1]See Report 1872-73, pages 46 to 61.

brownish quartzite, ranging from half an inch to fifteen inches in diameter, together with other rounded pebbles of dioritic rocks. The pebbles are held in a matrix of greenish-brown sandstone. On Lasqueti island, to the northwest of Point Young, similar rocks skirt the shore for about three-quarters of a mile. In neither of these exposures could I satisfy myself as to the attitude.

On the coast to the north of False bay (Lasqueti island) a narrow strip skirts the shore, extending northeastward for more than a mile, and opposite, on the largest of the Flat islands, what are apparently the same beds occupy a narrow strip on the east side. These beds are a grey calcareous sandstone, in layers of from two inches to one foot in thickness, holding numerous obscure fossils.

On the northeast side of Lasqueti island, about a mile from the extreme north point, a small island in the bay, as well as a narrow strip on the shore opposite the latter, lying on the dioritic rocks round the bay, consists of beds of calcareous sandstone, similar in every respect to those north of False bay.

The most northerly exposure is seen in Gillies bay, on the southwest side of Texada island. Around this bay beds of grey sandstone come to the surface, in one place interstratified with black and grey argillo-arenaceous shale containing numerous leaves of plants, and resembling, in this respect, the base of the Productive Coal Measures. In the Report of 1872–73, page 51, it was shown that the formation to the east of Tribune bay is the centre of a trough, and wholly occupied by Division G (Upper Conglomerate). In relation to this, it was likewise stated that "it would not be extravagant to suppose that the rise of the measures on the northeast side of this would be something like the rise to the southwest, on the Comox side of the Strait of Georgia, and that as great a breadth of the coal-bearing formation would occur on the one side of the anticlinal axis as on the other." If such is the case, the measures spread out under the Strait of Georgia to near the vicinity of the crystalline rocks on the shore of Texada island.

Judging from what is seen in Gillies bay, there is little doubt that the beds there are really the outcrop of the Productive Coal Measures on the northeast side of the trough.

APPENDIX; SECTIONS IN COMOX COAL AREA.[1]

The most westerly point examined is on Browns river, about nine miles N. 82° W. from the court house or steamboat landing, on the north side of Comox harbour. There is here a continuous exposure of the strata, occupying the bed of the stream for a mile and three-quarters in a straight line, with a bearing N. 84° E. It affords the following section in ascending order:

SECTION 1.

	Feet	*Inches*
Coal (1) impure, and apparently in separated masses, of which two were observed on the strike in the breadth of the stream (between thirty-five and forty feet) one of them on the right, about five feet long and seven feet thick, and the other on the left, seven feet long and two feet thick, both terminating somewhat abruptly. They are from eight to ten feet apart, and carbonaceous shale with a pale brownish streak and argillaceous odour fills the interval between them, and seems to occupy the space in continuation beyond them.	7	0
Brownish-grey slightly calcareous sandstone, the grains of which are composed of quartz mingled with feldspar and a few scales of mica, as well as a greater number of small flakes of blackish argillaceous matter. The mass is divided into beds of from three inches to four feet in thickness; many of the latter show false-bedding, but would in general yield good building stone.	132	0
Coal (2). Clean and bright.		3
Brownish-grey sandstone as before.	94	0
Coal (3). Clean and bright.	2	3
Brownish-grey sandstone as before.	33	0
Blackish argillaceous shale with a white streak, interstratified with thin seams of clean coal interlocking with one another.	5	0
Brownish-grey sandstone as before.	110	0
Coal (4). Clean and bright, varying in thickness from six inches to.	1	0
Brownish-grey sandstone as before.	92	0
Coal (5). Clean and bright.	1	8

[1]From Report by Jas. Richardson, Report of Progress 72-73, p. 35.

	Feet	*Inches*
Black argillaceous shale with a white streak, and thin seams of coal	3	0
Brownish-grey sandstone	86	0
Black argillaceous shale with thin patches of coal interlocking with one another	10	0
Light grey, massive sandstone, in beds varying from two to ten feet, and showing little or no false-bedding	95	0
Coal (6). Good and clean	1	3
Black argillaceous shale	4	0
Light grey sandstone, similar to the last	28	0
Black argillaceous shale with a white streak, interstratified with thin patches of coal interlocking with one another, some of them an inch apart, and altogether making up from ten to twenty per cent of the mass	3	0
Coal (7). Clean and good	1	8
Light grey sandstone, similar to the last	27	0
Coal (8). Good and clean		6
Black argillaceous shale	1	3
Coal (9). Clean and bright	0	8
	739	6

The thickness of the sandstones in the above section is reduced from horizontal measurements, at right angles to the strike; and the inclination is determined by the dips of the coal seams and shales above and below the sandstones, so as to avoid e rrors from false-bedding. The dips vary in direction from E. 30° N. to E. 22° S. and the angles of inclination from 0° to 20°, with the exception of two or three in the middle of the distance, which are a little to the east of north, with an inclination of from 2° to 7°, and indicate an undulation or irregularity, for which a due allowance has been made.

Though to the westward of this section, on Browns river, a mile intervenes before the flank of Mount Beecher rises up to indicate the presence of the crystalline rocks, they are yet supposed to be concealed by drift not very far off, on the west side of a shallow depression which appears to run east of south to an elbow in the Puntledge river. The distance to the elbow is about two miles, and to this point the upper stretch of the river flows in the same depression from the lake for a mile and a half.

This depression marks the strike of the measures, and a rock supposed to belong to the crystalline series is seen in a rapid just below the outlet of the lake. The exposure, which does not exceed forty feet in length, consists of a brown-weathering igneous rock, showing, according to Mr. Harrington, when sliced and examined under the microscope, both a concretionary and a porphyritic structure, with disseminated crystals, which appear to be feldspar, while the concretions are composed of two minerals which exhibit a radiating structure. When treated with an acid the rock assumes a light grey colour, from the removal of the oxide of iron.

There is not much doubt that the base of the productive measures, though not seen, immediately overlies this, while the summit is displayed on the Puntledge, about a mile and a quarter below the elbow, showing that to be the direct breadth of Division A on this stream. The summit on the Puntledge is due south of the same horizon on Browns river, and about a mile and a half from it. The details of the division in the Puntledge, however, are by no means well exposed, and none of the coal-seams are visible. This may be called Section 2, though a very imperfect one.

From the outlet of Puntledge lake a bearing of S. 48° E. strikes the extremity of the line of the proposed tramway to the Union mine, on the south side of the lake, and about a mile from it, the whole distance being about two miles and three-quarters. A section occurring at this mine in an almost perpendicular cliff, from the face of which a landslide had carried away all the trees and loose soil on the north side of a small stream flowing into Puntledge lake, was given in last year's report (Report of Progress 1871-72, page 77). But most parts of the cliff being out of reach, the thickness of many of the beds could only be ascertained approximately, having been merely estimated by the eye. A more favourable condition of the weather on the present occasion permitted me, by the aid of a rope tied to a tree at the top of the cliff, to descend the whole face, and obtain exact measurements. The following is a corrected section in ascending order:—

SECTION 3.

	Feet	Inches	Feet	Inches
Brownish-grey, or light drab sandstone, and black argillaceous shale, interstratified with one another, and both holding flattened stems of plants..................................			6	0
Coal (1). Of a dull earthy aspect, and containing upwards of twenty per cent of ashes by Dr. T. Sterry Hunt's Analysis, Report of Progress, 1871-72, p. 99............................	2	6		
Coal (2). Clean and bright....................	7	6	10	0
Brownish-black argillaceous shale...............			7	0
Coal (3). Clean and bright....................	2	4		
Brownish-black argillaceous shale...............	2	6		
Coal (4). Clean and bright....................	1	6		
Brownish-black shale..........................	1	3		
Coal (5). Clean and bright....................	1	5	9	0
Brownish-black argillaceous shale, interstratified with brownish sandstones and brownish-yellow-weathering, hard, ferruginous beds from two to four inches thick....................			14	3
Coal (6). Clean and bright. This seam occupies the face of the cliff for a distance of only twenty feet, coming from the right, and then terminates somewhat abruptly, the corresponding space on the strike to the left being filled with black argillaceous shale, holding interstratified thin seams of coal............	2	0		
Brownish-black argillaceous shale...............	2	9		
Coal (7). Clean and bright. This seam occupies the cliff for sixty-six feet coming from the right, and then terminates somewhat abruptly like the previous one; but on the right hand there occurs in it a band of brownish-black argillaceous shale, two feet thick, with thin patches of coal, and occupying about twenty-five feet on the strike, with about three inches of coal above and below..................	2	6		
Brownish-black argillaceous shale...............	3	0		
Coal (8). Clean and bright, varying in thickness from five to twelve inches from inequalities sometimes at the top and sometimes at the bottom.................................	1	0		

	Feet	Inches	Feet	Inches
Brownish-black argillaceous shale...............	4	0		
Coal (9). Clean and bright....................	1	6	16	9
Brownish-black argillaceous shale...............			16	0
Coal (10). Clean and bright....................			2	8
Brownish-black argillaceous shale...............			6	0
Coal (11). Clean and bright....................			4	4
Brownish-grey or drab sandstone, slightly calcareous, the somewhat fine grains of which are composed of quartz, feldspar, and a little mica, with small black flakes consisting of argillaceous or carbonaceous shale. The mass is divided into beds of from one to five feet thick, some of which show false-bedding.......			30	0

The deposits of this section rest visibly on the crystalline rocks which pave the brook at the foot. The course of the brook is southeast and northwest. In the former direction these rocks rise gradually higher among the coal-bearing strata, and at the distance of about a quarter of a mile up the brook, reach to within ten feet of the sandstones at the summit. Between the sandstones and the crystalline rocks, there occurs a coal-seam in the brook, of which the thickness could not be ascertained, owing to the depth of the water; beyond this the strata are concealed. Down the brook to the northwest, the crystalline series is exposed for about sixteen chains, and thirteen chains farther on, a coal seam of four and a half feet was last year visible, dipping N. 48° E. < 11°; but at the present time was covered up by a slide. At seventeen chains across the measures to the right, two additional coal-seams were observed, with an interval between them of 192 paces, dipping in the same direction; the lower one two feet thick, with an inclination of five degrees, the upper one three feet thick with an inclination of eleven degrees. In ascending order a vertical section would be:

SECTION 4.	Feet	Inches
Coal..	4	6
Measures concealed................................	54	0
Coal..	2	0
Measures concealed................................	52	0
Coal..	3	0
	115	6

Openings for trial had been made on the two upper seams; but the concealed intervals render it at present difficult to say how the three are related to those in the previous section (3).

In a bearing S. 30° E. from section 3, a line of two miles and a-third would strike the valley of Trent river at right angles, about five and a-third miles from the coast. The crystalline rocks make their appearance at less than a mile and a-half farther up the valley, on a small tributary which has been already mentioned; the spot being about thirty chains above the junction of the tributary and the main stream. They are of mottled dark green and dull red colours, and present a concretionary and porphyritic structure, like the exposure at the outlet of Puntledge lake. Resting upon them the following ascending section occupies the tributary and the main stream for a distance of a mile and a quarter.

SECTION 5.

	Feet		*Inches*	
Coal (1). Clean and bright, resting on red and green crystalline rocks			0	2
Black carbonaceous shale, with thin patches of coal			4	0
Brownish-grey or drab, fine-grained sandstones, in beds of from six inches to five feet, which would yield good building stones, as well as perhaps tolerable grindstones			92	0
Coal (2). Of a dull earthy aspect	1	0		
Brownish-grey sandstones as before	3	0		
Coal (3). Of a dull earthy aspect mingled with black carbonaceous shale	3	0	7	0
Brownish-grey or drab sandstones, imperfectly seen			75	0
Black argillaceous shale			1	6
Brownish-grey sandstones, interstratified with black argillaceous shale, the sandstones predominating, but imperfectly seen			60	0
Coal (4). Clean and bright	0	8		
Black argillaceous shale, with thin seams of coal	6	0		
Coal (5). Clean and bright	1	9	8	5
Brownish-grey sandstones, interstratified with black argillaceous shale, the sandstones predominating			15	0
Coal (6). Clean and bright			0	8

	Ft.	In.	Ft.	In.
Brownish-grey sandstones, interstratified with black argillaceous shale, the sandstones predominating			30	0
Black, rust-stained, argillaceous shale, with short interlocking patches of coal about an inch in thickness	1	0		
Coal (7). Clean and bright	1	4		
Black argillaceous shale, with short one-inch interlocking patches of pure coal	2	6		
Coal (8). Clean and bright	1	0		
Black argillaceous shale, with thin seams of coal	2	6		
Coal (9). Clean and bright	3	8	12	0

These twelve feet of strata occur at the junction of the tributary with the Trent and are exposed in the channel of the latter several times in a distance of about eight chains on the strike, which is N.68°W. The dip is N.22° E. 50° and the thickness of the deposits is sometimes less, and sometimes more, than represented.

	Ft.	In.
Brownish-grey or drab sandstones, in strata of from one to four and five feet thick, many of which show false-bedding	130	0
Black argillaceous shale	4	0
Coal (10). Clean and bright	1	8
Brownish-grey or drab sandstones, in beds of from three to ten feet thick	24	0
Coal (11). Clean and bright	1	0
Black carbonaceous shale	12	0
Brownish-grey sandstone	37	0
Coal (12). Of a dull earthy aspect	0	6
Black argillaceous shale	10	0
Brownish-grey or drab sandstones	28	0
Black argillaceous shale	4	0
Brownish-grey or drab sandstones	41	0
Coal (13). Clean and bright, varying in thickness from one foot to	1	8
Light-grey, fine-grained sandstones, slightly calcareous, in even beds of from three to ten feet thick. They would yield excellent, easily dressed building stones, and probably afford good material for grindstones and whetstones	50	0
Black argillaceous shale	4	0
Light-grey sandstones, similar to the last	47	0
	710	7

The next locality where the coal-bearing strata were met with on the strike to the southeastward, is Bradley creek, already mentioned as tributary of the Trent, the distance between the two streams being upwards of a mile. No crystalline rocks were met with in the portion of the tributary examined, and the lowest exposure of the coal-bearing series occurred about three miles and eleven chains from the junction with the main stream.

The whole of the exposures belonging to this division on Bradley creek, occur in a transverse distance of one mile and three-quarters, being about the same as that holding those of the Trent, but the bearing N. 24° E. is somewhat oblique to that of the average dip. In some parts there are considerable intervals between the exposures. Where seen, the dips are steeper and more irregular, and it thus becomes very difficult to state the true thickness in a vertical column. For this reason I shall describe the deposits in this section (to be numbered 6) as they succeed one another in ascending order on the horizontal line.

SECTION 6.

Resting on a few feet of brownish-grey sandstone the lowest coal-seam, which is clear and bright, is from fifteen to eighteen inches thick, and a few feet of brownish-grey sandstone overlie it. A quarter of a mile down the valley, there is a coal-seam eight inches thick, with a dip N. 32° E. < 32°. Nearly nine chains farther occurs the coal-seam mentioned last year (Report 1871-72, p. 76), as three feet two inches thick, with a dip. N. 27° E. < 18°. This is probably the same as coal-seam 5 of section 3. Twenty-eight chains beyond, resting on black argillaceous shale, is a seam showing eight inches of impure coal. After an interval of fifty chains, again resting on black argillaceous shale, there is another eight-inch seam, displaying good coal, with a dip N. 40° E. < 18°. This supports 128 feet of light-grey sandstones, in beds of from one to six feet thick, similar in character to the two masses at the summit of section 3, which, with the band of black shale between them, show a thickness of 110 feet. They may thus be considered to represent the same horizon; but above the sandstones of Bradley creek, no exposures occur for half a mile. The deposits of the two sections, 3 and 5, are on the Beaufort coal-mining claim.

The last place examined, in the further extension of the rocks of this division, is at the Baynes Sound coal mine, on the River Sable, as it is written by some, being probably a corruption of Riviere aux Sables. The position of this mine is about five and a half miles from the base, section 5, on Bradley creek, in a bearing S. 53° E., and two miles and three-quarters due west from the mouth of the strean and Fanny bay. Here, as stated last year (Report of Progress 1871-72, p. 78), in a deep ravine through which the river finds its way, the following section occurs, resting on a black dioritic rock, the beds being given in ascending order, and their average dip being N. 76° E. 10°-25°.

SECTION 7.

	Ft.	*In.*
Yellowish-weathering, dolomitic-looking conglomerate, with pebbles derived from the crystalline rocks and varying in diameter from half an inch to two inches filling depressions in the black dioritic rock beneath	3	0
Brownish-grey or drab sandstones, moderately fine-grained, and slightly calcareous, with scales of white mica	19	0
Black carbonaceous shale, showing numerous obscure impressions of plants, with nests of good coal, as well as beds of the same from two to eight inches thick; some parts of the whole thickness are half made up of coal	6	0
Black argillaceous shale, with nodules of iron ore, some of them flat and varying in length from six inches to four and five feet, and in thickness from six to eighteen inches, while others are round with a diameter of eighteen inches; they all contain impressions of plants, difficult to be obtained in a perfect state. The thickness of the band is from two feet to	3	0
Brownish-grey sandstones as before	18	0
Coal (1). Clean and bright; varying in thickness, being in some parts five feet two inches, and in others seven feet; the lowest two feet show thin seams of black calcareous argillaceous shale, with obscure impressions of plants, say	6	0
Brownish-grey sandstones as before	60	0
Coal (2). Clean and hard	65	0
Brownish-grey or drab sandstones, forming the whole height of the cliff, and estimated to be about	100	0
	220	10

A partial section of these beds was given last year, from which it will be perceived that the present differs a little in some of the beds; but, as then stated, the two coal-seams are seen descending both sides of the ravine, and the edges of the lower one meet in the bottom of the stream; but while those of the upper one are still about twenty feet above the water, a fault occurs cutting them off, the underlie of the fault being S. 62° W. 38°. The dip of the arenaceous strata which occur immediately on the eastward side of the fault is obscure. The coal seams occupy two chains and then the dip becomes N. 64° E. < 38°-43°. The following is the section of the whole of the measures on the eastward side in ascending order:—

SECTION 8.

	Ft.	*In.*
Brownish-grey sandstones	99	0
Brownish-black, soft, argillaceous shale	22	0
Light-grey sandstones	25	0
	146	0

This is a greater volume of sandstone than was ascertained in this position last year, but as then stated the fault appears to be a downthrow to the northeast, the amount of which has yet to be determined.

From the facts displayed in these various sections, it will readily be seen that workable seams of coal occupy a belt of fairly uniform breadth along the southwestern rim of the Comox field, associated with brownish-grey false-bedded sandstones, interstratified with black carbonaceous and argillaceous shales at the base, and overlaid by light-grey, even-bedded, fine-grained sandstones at the summit. In all the sections a constant character is easily enough recognizable in Division A as a mass; but the notable differences in the thickness of the coal-seams, and their distances from one another when in proximate sections, make it very difficult to establish the identity of individual seams over a very considerable area. This must be the work of practical explorers of the seams, by trial pits along the outcrops. But these irregularities and the occasional sudden interruptions in the continuance of the coal-seams constitute a remarkable distinction between them and the more regular beds of the true Carboniferous era, and may often occasion perplexities in working them. In no part of the exposures of division A were any fossil shells met with.

Notes on the Geology of the Comox Coal Field.[1]

(Extract from report by C. H. Clapp.)

The Comox and Suquash coal-fields were visited by the writer only in order to compare their geological conditions with those existing in the Nanaimo field, and, therefore, only a few notes can be given concerning them, but they may serve to show some of the similarities and differences of the various coal-fields.

In the Comox field the coal is found in several seams that occur in a sandstone formation closely resembling the Protection formation of the Nanaimo series. Three of the seams have been mined. The formation, which may be called the Comox formation, consists chiefly of a white or greyish-white sandstone, composed largely of rounded quartz grains with a coating of kaolin, and with accessory chloritic micas. Interbedded in the sandstone are thin beds of carbonaceous sandy shale, with which the coal is usually associated. The formation has a maximum thickness of about 800 feet and rests directly on the metamorphic volcanics of the Vancouver group. It is overlain by a thick group of shales, called the Trent River shales, which are very much like the Cedar District shales that overlie the Protection sandstone in the Nanaimo district. The sediments of the Comox basin have a much simpler and more regular structure than those of the Nanaimo basin, and form, in general, a simple monocline with a low uniform dip of about 10 degrees to the northeast. The coal seams are more regular than those of the Nanaimo basin, and must be the result of a more uniform condition of sedimentation, although a similar uniformity of conditions

[1]Summ. Rep. Geol. Surv., Can., 1911, pp. 105-106.

appears to have existed in the Nanaimo basin during the deposition of the Protection formation. However, the coal seams of the Comox district show, but to a less degree, the pinching and swelling and sharp rolls so characteristic of the Nanaimo coal seams. Large 'wants' due to a replacement of the coal by silt are probably more frequent in the Comox field. One peculiar feature met with in the Comox field is not met with in the Nanaimo field. The lowest seam of the former field occurs very near the base of the Comox sandstone, and as the Comox basin resembles the Nanaimo basin in that the crystalline rock surface, on which the sediments were deposited, was very irregular, many of the higher irregularities of the base remained above the depositional level when the lowest seam was deposited, and in consequence the lowest seam is frequently cut out by knobs of the underlying volcanics projecting through it. There is also another feature which is not met with in the Nanaimo field. North of the producing mine in the Comox field, between Browns and Puntledge rivers, a dacite porphyry has broken through the Comox sandstone and forms a flow or intrusive sheet, which overlies it. Near the dacite porphyry intrusion, which occurs near the outcrop of the lowest seam on Browns river, the coal is broken, partially coked, and rendered valueless. It is probable that the intrusion of dacite porphyry occurred in early Tertiary times and was a phase of the widespread Eocene volcanic activity.

SUQUASH COAL AREA.[1]

(*See Diagram V.*)

(Extract from report by G. M. Dawson.)

The coast from Port McNeill to Beaver harbour, fourteen miles in length, is occupied by Cretaceous rocks, chiefly sandstones. It was examined by me when on my return from the Queen Charlotte islands in 1878, but the results of this and other unconnected examinations made at the same time, were not included

[1]Ann. Rep. Geol. Surv., Can., Vol. II, 1886, pp. 61-70B.

Geological Survey, Canada

Suquash coal-area

Miles

To accompany Memoir by D.B.Dowling

in my report of that year. In 1885 it was re-examined by Mr. Dowling and in part by myself.

Eel reef, in Port McNeill, a small rocky patch, covered at high-water, is composed chiefly of brownish, blackish, and reddish basalt, compact or vesicular in texture. The whole is much broken, and appears to represent a bed of agglomerate or breccia, made up almost altogether of basaltic material, but including also fragments of the green altered volcanic rocks and of Cretaceous sandstone. It is scarcely possible to determine whether any of the basalt forms part of a solid bed of that material, or whether it occurs merely as large fragments in the agglomerate. The mass is, however, undoubtedly post-Cretaceous, and probably synchronous with the Miocene volcanic rocks of the Queen Charlotte islands, and is of interest as the only instance of undoubted Tertiary rocks met with in the whole area here reported on.

On the south shore of Port McNeill, and round the head of the harbour, no rock is seen, but the north shore and Ledge point afford almost continuous exposures of Cretaceous sandstones, either massive or nodular, and often shaly. At a point on this shore from which Eel reef bears S. 65° W. (mag.), a large collection of fossil plants was made. The rocks here dip N. 25° W. < 10°. The plants occur in beds of shales and shaly sandstones about five feet above a small seam of coal from one to two inches thick. These fossils include, according to Sir Wm. Dawson, a number of dicotyledonous leaves of different genera, together with a *Salisburia* and a *Taxodium*. Some of the species seem to be identical with those of the Productive Measures of Comox and Nanaimo, but many are distinct. They are either referable to the same horizon with these or to a slightly older one.

Ledge point is formed of a coarse, nodular sandstone which weathers brownish. From Ledge point all along the shore to within half a mile of Thomas point (the south entrance point of Beaver harbour), low exposures, chiefly of sandstones, with occasional beds of shale, are frequent on the beach. At one place, three miles west of Ledge point, the sandstone becomes conglomeritic, holding pebbles up to six inches in diameter. The angles of dip of these beds are invariably low, seldom exceeding ten degrees, and the direction somewhat inconstant. Thin seams of coal, which appears to be of good quality, are seen in several places along the shore. At Suquash or Sa-kwash, coal was at one time mined by the Hudson's Bay company, on a limited scale, and I am informed that in all from 9,000 to 11,000 tons were obtained. A short tunnel was driven and other exploratory work carried out, which is subsequently referred to. The seams as now visible on the beach at this place, are two in number the upper being at least one foot, and in places probably two feet in thickness. It is separated by about a foot of soft shale from a lower seam with a maximum thickness of about six inches.

A quarter of a mile southeastward from the old wharf, two seams, each about an inch in thickness, are seen on the shore. Westward, half a mile beyond False head, is a seam of five inches thick; and three-quarters of a mile still farther west, a coal outcrop of four inches in thickness occurs. Again, near the mouth of the Kīuk river, two miles from Point Thomas, two seams of six and three inches respectively were found. Thomas point is composed of the underlying volcanic rocks, but to the west of it, opposite Fort Rupert, on the shore of Beaver harbour, small areas of sandstones and shales are found dipping off the older rocks. Some plants were collected in these shales in 1878, among which Sir William Dawson has found a *Neuropteris* and a *Salisburia*,[1] which appear to be of Middle Cretaceous age.

The Kliksīwi river reaches the coast at a point directly opposite the west end of Malcolm island, and was found by Mr. Dowling, when on an excursion inland from the head of Port McNeill, to occupy a valley to the east of two conspicuous hills marked on the chart. No rock exposures were, however, found until the summit of the southern of the hills above mentioned was reached, and the rocks there seen (trachytes) are probably intrusive. The Kliksīwi river was afterwards ascended for about two and a quarter miles from its mouth, for the purpose of examining a reported coal seam, which, however, proved to be from two to three inches in thickness only, though overlain by about three feet of coaly shale. The beds were found to be

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[1]See Trans. Royal Soc. Can., Vol. I, Sect. IV, p. 15.

practically horizontal. On another small stream which reaches the sea west of the Kliksīwi, at a point about three-quarters of a mile due south of the mouth of the Kliksīwi, a prospecting hole was made many years ago. The seam is here about sixteen inches thick, and dips eastward at an angle of about 5°, though the beds elsewhere in the brook are nearly horizontal. From its appearance and that of the associated beds, the coal here exposed is probably the same as that last alluded to. It further appears quite probable that the coals at Suquash represent a further continuation of the same bed. A short traverse was made by Mr. Dowling up the bed of the stream at Suquash, but without developing any facts of importance or reaching the western edge of the coal-bearing rocks. Like nearly all the streams in the northern part of the island, this is extremely difficult to examine or follow, owing to the thick growth of forest and underbrush and tangled masses of fallen timber.

A traverse was subsequently made by Mr. Dowling, of a part of the trail from Fort Rupert toward the head of Quatsino sound. A small stream was reached at about four and a half miles nearly due south from the fort, which flows into the Kīuk river, and the latter was followed down to the coast. On this small stream and on the river, sandstones occur, and are either horizontal or show very light, irregular eastward dips. Thin streaks of coal were seen at one point on the river, and a new species of *Placenticeras* together with casts of a small *Mactra* or *Cymbophora*, were found.

The low undulating character of the dips along the coast between Port McNeill and Beaver harbour, and the existence of several rather considerable intervals in which the rocks are concealed, precludes the possibility of arriving at any accurate estimate of the thickness of the Cretaceous rocks there exposed, or of presenting a complete section of them. It appeared at first probable that the entire thickness was very inconsiderable, but the existence of fossils, which are probably referable to the lowest beds of the Quatsino region, in the rocks of one end of this shore-line (at Fort Rupert), while those at the other extremity, (at Port McNeil), evidently belong to a much higher stage in the Cretaceous, appeared to call for some explanation. On carefully plotting the observed attitudes of the rocks, it became evident that notwithstanding local irregularities there is a general tendency to northwest by southeast strikes, while dips in a southeasterly direction also greatly preponderate. A section based on these dips, shows that a total thickness of about 6,000 feet of beds may easily occur between Beaver harbour and Port McNeill, the beds at the latter place being the highest. This would be amply sufficient to account for the difference of horizons indicated by the fossils.

Against this explanation it must, however, be urged, that the thickness of the lowest subdivision at Quatsino is probably not greater than 3,000 or 4,000 feet. There is every reason to think that the section in this contiguous area is similar, and in this case the massive conglomerates of Quatsino should appear about midway between the extreme points, or near Suquash, where the Cretaceous beds should be, according to the dips, about 4,000 feet thick. No such massive conglomerates are, however, seen, and it is improbable that beds of this character are concealed beneath low parts of the shore. There is, however, at Suquash, a decided appearance of faulting, and on consideration of the facts, so far as known, I am inclined to believe that an extensive down-throw here occurs to the southward along an easterly and westerly line. On this hypothesis, the beds along the shore south of Suquash are much newer than those to the north, being entirely above the conglomerates (B) and nearly equivalent to the lowest beds of the Nanaimo and Comox basins, as their contained fossils would indicate. The close lithological resemblance of these beds to those seen near Oyster bay lends countenance to this view, according to which the massive conglomerates seen at one place on Malcolm island may represent a portion of subdivision B, of Quatsino, which here appears at the surface owing to a less throw in the fault to the eastward.

The line of the main fault which bounds the Koskeemo coal-basin to the south, if continued eastward, passes nearly through Port McNeill, and it appears probable that this fault does actually so continue, with a similar extensive downthrow to the north, bounding the Cretaceous rocks in this direction, and accounting for the non-appearance of the conglomerates (B) and lower beds (A) at the southern edge of the basin. The occurrence of the small Tertiary volcanic patch of Eel reef may be in connexion with this important fault.

The facts in evidence are not sufficient to prove the hypothesis above stated, which may, nevertheless, be of use as a guide in the future exploration of the field. The rock met with at the bottom of boring No. 2, at Suquash, might be assumed to belong to the Vancouver series at the base of the Cretaceous which must, in this case, be quite thin. It is quite as likely however, that the rock here reached was in reality the top of the massive conglomerate subdivision.

As further confirming the view that the beds at Suquash and southwards represent a horizon lower than those to the north, the analyses of coals from the southern and northern parts of this shore-line, given on a subsequent page, may be referred to. A fuel from the Kīuk is a true coal with strong coke, resembling the Coal Harbour specimen, while fuels from Suquash and Kliksīwi closely approach lignite-coals in character.

From the above notes, it will be apparent that the extension inland of the Cretaceous coal-bearing rocks, which occupy the shore from Port McNeill to Beaver harbour, has not been determined. This must be ascertained by the laborious process of tracing their boundary in the wooded interior. The continuously low character of the country between Kliksīwi and Rupert arm of Quatsino sound, appears, however, to indicate the probability of a wide area of Cretaceous rocks. Here, as elsewhere in the northern part of Vancouver island, it appears that the present surface of the country nearly coincides with the old denuded surface of the Vancouver rocks upon which the Cretaceous was laid down. Whether the Cretaceous was originally deposited only in hollows and valleys among these older rocks, or formed a nearly continuous sheet, of which portions still remain only in these hollows, is as yet uncertain. In either case, however, the result is the same, leading to the appearance of the Cretaceous in isolated patches of irregular form, and sometimes in the most unexpected places—so much so, that until every square mile of the country has been systematically examined, it will be impossible to affirm that all existing outliers are known. Those outliers, however, which have the greatest area, and are on or near the shore, are naturally the most important, and these, fortunately, are not so difficult of discovery and definition. It is probable that about four weeks of work inland will be necessary to fix, with approximate certainty, the outlines of the Cretaceous region here specially described.

Respecting the probability of the discovery of really important coal seams in this area, little can as yet be said with certainty. Those so far found, are all quite thin. The regularity of the beds, the low angles at which they lie, and the long stretch of coast characterized by them, are all in favour of mining operations, should thicker seams be developed. When it shall become important to determine the coal-bearing character of the rocks, boring operations of a systematic character will have to be resorted to.

Through the kindness of Mr. G. Blenkinsop, formerly of the Hudson's Bay company, I have been put in possession of some records of borings already made by that company, in 1852, near Suquash, and at the mouth of the Kĭuk river. These records are signed by Boyd Gilmour, a miner employed by the company to search for coal. They appear to have been kept with some care, but the nomenclature applied to the various rocks is such as in some instances to leave it in doubt what the beds penetrated actually were. In such cases, the names used in the original logs are retained.

No. 1. Boring at Kĭuk river, on the beach, about two and a half miles from Fort Rupert.

	Ft.	*In.*
Gravel and shingle	7	6
Hard confused sandstone	16	7
Dark grey freestone	12	6
Dark scaly tile coal	1	6
Grey freestone	11	0
Freestone, flakes dark coloured	5	6
Grey, hard sandstone	29	4
Dark coloured clayey stuff	1	3
Grey flagstone, "with dougars and kingle plays"	23	4
Dark coloured stuff with coaly streaks	1	3

	Ft.	In.
Dark freestone	10	6
Dark sandstone	60	2
Whin	..	2
Total	180	7

Boring No. 2 was made at Suquash, on the beach, below a "cliff or scar." It is stated that the section in the cliff should be added to that obtained in the hole. The cliff section is as follows, according to Gilmour's notes:—

	Ft.	In.
Brownish freestone	10	0
Grey shaly stuff	13	5
Good coal	0	5
Brownish freestone	18	0
Good coal	0	4
Freestone, in which the boring commences	10	0

Boring No. 2, is then given as follows:—

	Ft.	In.
Freestone	6	0
Grey, soft sandstone	21	5½
Hard freestone	1	4
Soft freestone	0	10
Coal parting	...	...
Coarse fireclay	0	5
Grey shaly or clayey stuff	7	3
Hard freestone	3	4
Hard freestone, confused	1	3
Soft clayey stuff, with white balls	6	3½
Soft, grey flakey stuff	2	11
White, soft stone, with soapy feel	2	11
A coaly stone	1	11
Grey flaky material	5	10½
Flaky freestone	6	0
Dark grey freestone	12	0
Very hard confused rock	0	8½
Very hard stone	1	8
Dark grey freestone	0	10
Hard, bluish-green stuff	2	6½
Very hard stone	0	7½
Very hard confused rock	1	10½
Grey freestone	2	9
Dark clayey sandstone, without partings	6	1½

	Ft.	In.
Grey freestone	3	2½
Very hard confused rock	2	3
Grey freestone	2	9
Dark grey clayey sandstone	2	4
Dark grey stuff	5	8
Hard grey freestone	3	10
Hard grey freestone	12	4
Hard white stuff	6	5½
Dark clayey stuff	0	1½
Whitish hard stone	3	8
Hard freestone	3	1
Hard, dark freestone	3	9
Dark clayey stuff	4	2
Dark grey clayey stuff, without partings	3	9
Dark and a little more clayey	1	7
Hard freestone	0	4
Light grey clayey stuff	1	0
"Dougar plays"	2	6
Greenish-blue clayey stuff	2	5½
Dark clayey stuff	1	5
Very dark stuff	2	1
White, soft freestone	5	9
Very hard freestone	3	0½
Soft freestone	8	6
Grey clayey stuff	6	10
Grey clayey stuff, without partings	3	5
Sandstone full of boulders (nodules?)	4	6½
Similar, but darker coloured	1	9
Dark coloured stuff, some coaly streaks	4	11
Dark rock, "Dougar plays"	10	0
A dead grey coloured sandstone. The only change in this stuff is from a lighter to a darker colour	60	9
Very hard, green whinstone, much mixed with white spar	2	0
Total	329	4½

Boring No. 3. This boring was, according to Mr. Blenkinsop, about two miles inland from Suquash, and, on the hypothesis previously stated, must be to the north of the Suquash fault and in beds equivalent to subdivision A, at Quatsino.

	Ft.	In.
Whitish clay, sand and shingle, alternating	31	6
Grey flakes	25	6
Soapstone	1	0

	Ft.	In.
Dark grey stuff	3	0
Light-coloured soft freestone	3	0
Confused soft sandstone	0	10
Hard, greenish stone	3	6
Dark, sandy stuff, with coaly streaks	2	6
Light-coloured freestone	5	5
Confused sandstone	5	5
Confused sandstone, not so hard, and darker	8	0
Dark freestone	19	8
Dark slaty stuff	21	6
Dark clayey stuff	1	10
Clean coal	0	4
Coarse fireclay	2	8
Greyish freestone	9	10
Light-coloured freestone	15	0
Greenish sandstone	16	9
Dark-coloured stuff, with coaly streaks	1	3
Clayey stuff	5	11
Spotted or mixed freestone	2	8
Dark clayey stuff	2	5
Dark scaly stuff, with coaly streaks	5	6
Dark grey sandstone	18	1½
Dark clayey stuff	2	5
Dark greyish sandstone	27	8½
Dark clayey stuff	3	6
Dark grey sandstone	2	3½
Dark clayey stuff, slight coaly streaks	5	4½
Light-coloured sandstone	1	0
Grey shaly clay	16	3
Dark grey sandstone	10	10
Dark grey dead stuff	1	11
Hard, grey sandstone	0	11
Total	285	4

Of boring No. 1, it is remarked that an open "cutter" was struck in the whin, which yielded a great quantity of salt water, though the hole was begun six or eight feet above high-water mark. This hole was abandoned owing to the loss of the boring rods. As no description of the "whin" in which it terminated is given, it remains uncertain whether the Cretaceous rocks were completely passed through, though from the proximity of the older rocks to the Kĭuk river, it is not improbable that this was here the case.

Boring No. 2, at Suquash, has already been referred to on page 64 B. It may have ended in the massive conglomerates, of subdivision B, of Quatsino.

The result of these borings must certainly be considered as unfavourable to the view that the Cretaceous, in this part of its extent, includes coal-seams of importance. There is, however, it may be added, a persistent rumour that a coal-seam, six feet in thickness, was reached at Suquash, but not reported, owing to the wish of the men engaged to discontinue operations at this place. In the circumstances, little weight can be given to such a report. If further work should be contemplated in this region, I should be inclined to advise an experimental boring on the south shore of Malcolm island, at the locality of the occurrence of the conglomerate. This would test an entirely new portion of the field.[1]

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[1]Dr. W. F. Tolmie, in 1835, was the first to make known the occurrence of coal on this part of the coast, this being also the first discovery of coal on Vancouver island. See Bancroft, History of British Columbia (1887), p. 186, and Tolmie's statement, given as a footnote in the same volume (p. 189). Bancroft closely follows Grant in his account of the early exploration of the coal, but falls into error with respect to Port McNeill and Beaver harbour, which he regards as alternative names for a single place. This is clearly shown by the latitudes quoted by him on p. 189, which are correct, and not erroneous, as he assumes. The original coal mine was at Suquash, to which Port McNeill was the nearest convenient and safe anchorage. Fort Rupert was afterwards (1849) founded at Beaver harbour, which then became the chief point of call. Ellenborough Promontory (p. 191) is evidently Ledge point, and Bailie Hamilton's bay is near the position of Suquash. There is also some confusion as to the dates between which systematic exploration of the coal was carried on by miners imported by the Hudson's Bay Company. The work occurred between 1849 and 1851, according to Bancroft; but that it was continued until 1853 is shown by the fact that the original record of boring No. 2 at Suquash (communicated to me by Mr. G. Blenkinsop) states the progress of each day's work, beginning on Monday, October 30, 1852, and ending July 8 (1853 ?). Though it is impossible now to locate the places described by Grant as those at which work was done, it is evident from the details which he gives, that several trial shafts and borings, besides those of which I have been able to obtain records, were made.—See Description of Vancouver island, by W. C. Grant, Journ. Royal Geog. Soc., Vol. XXVII (1857), p. 275.

The following assays of coal from three points on the coast between Port McNeill and Beaver harbour have been made by Mr. G. C. Hoffmann in the laboratory of the Survey.

From small seam of coal on stream about three-quarters of a mile south of mouth of Kliksīwi river. This coal produces a coherent but tender coke, and is considerably acted on by a solution of caustic potash.

Hygroscopic water	3·65
Volatile combustible matter	42·23
Fixed carbon	39·84
Ash	14·28
	100·00

From Suquash. This coal yields a moderately firm coke, and is considerably affected by a solution of caustic potash, yielding a brownish-yellow colour, like the last.

Hygroscopic water	5·03
Volatile combustible matter	41·51
Fixed carbon	46·52
Ash	6·94
	100·00

From a thin seam at Kīuk river. This coal yields a firm coherent coke, and is scarcely affected by a solution of caustic potash.

Hygroscopic water	3·68
Volatile combustible matter	39·29
Fixed carbon	47·03
Ash	10·00
	100·00

NOTES ON THE SUQUASH COAL AREA.[1]

(Extract from report by C. H. Clapp.)

Conditions in the Suquash field are similar in many respects to those in the Comox field. Several seams of coal occur in a formation consisting chiefly of a grey, siliceous sandstone resembling that of the Comox and Protection formations. Inter-

[1]Summary Report Geol. Surv., Can., 1911, p. 106.

beds of shale in the Suquash sandstone are, however, thicker and more numerous, and the shale is finer-grained and more plastic, some of it being a clay shale apparently of excellent quality. The structure of the measures is very regular and appears to be, in general, a broad syncline, striking about N. 60° E., and pitching slightly to the northeast. The dips are very low, less than 10 degrees, and although there are several local rolls there are no sharp ones. The measures are broken by a few normal faults of very small displacement. The coal seams are also very regular and do not pinch and swell as do those of the Nanaimo and Comox basins. The known seams are, however, thin, and the seam mined at present contains a large number of very persistent partings of various kinds. As in the case of the Comox basin, the coal-measures have been intruded by Tertiary volcanic rocks, in the Suquash field by a trachyte porphyry. The trachyte porphyry occurs in the southern part of the basin, on Haddington island, where it is quarried extensively and furnishes the best grade of building stone on the coast. It probably occurs as an injected body.

The present knowledge of the Suquash field is meagre since the measures are largely drift-covered and only a few bores have been put down. The development work is also small in amount and confined to two seams. The basin is, however, somewhat larger than generally supposed, containing Malcolm and Cormorant islands and possibly extending southwest to Quatsino sound. On account of the uniformity and regularity of the coal seams and strata and their small amount of disturbance, the mining conditions are excellent. The coal is of good quality, burning with a long flame and little smoke. The large number of partings in the seam which is at present being worked, and the thinness of the other known seams are the chief disadvantages of the field. The conditions are such, however, as to greatly encourage further development and prospecting, especially in the lower part of the measures.

QUATSINO SOUND COAL AREA.[1]

(*See Diagram VI.*)

(Extract from report by G. M. Dawson.)

The shores of Forward inlet are chiefly composed of rocks of the Vancouver series, but in part also of Cretaceous sandstones. On the east side of Robson island, and on the shores of the point to the north, which separates the main inlet from Browning creek, there are extensive exposures of the flaggy argillites, which, though much crumpled and confused, and penetrated by a number of grey feldspathic dykes, appear in the main to assume an anticlinal form, overlying a greenish-grey compact volcanic rock, and being overlaid by agglomerates, which are often well bedded, and sometimes have a rather tufaceous appearance. The argillites themselves present their usual black flinty appearance with regular and thin bedding where undisturbed, and are frequently more or less calcareous. The general strike of these and the associated altered volcanic rocks, is about northwest by southeast, but there are, doubtless, several folds and possibly other complications, as the argillites recur at two places on the shore to the east of, and opposite, the point above mentioned, and also at two places on opposite sides of Winter harbour, farther up the inlet. The exposures of these argillites in Forward inlet afforded a considerable number of specimens of the *Belonites*, for which Mr. Whiteaves proposes the name *A. Vancouverensis*.

The altered volcanic rocks here present no unusual characters and do not require special description. One of the Cretaceous outliers above referred to, occurs at the head of Browning creek, at the middle of the west shore of the expansion in which this branch of the inlet terminates. It is a very small patch of greenish-grey sandstones, not more than fifty yards wide. The beds dip N. 75° E. < 25° at the southeast, and about N. 20° W. < 30° at the northeast of the exposure. The sandstones rest on reddish-weathering hard feldspathic rocks of the

[1]Ann. Rep. Geol. Surv., Can., Vol. II, 1886, pp. 83-89B.

Vancouver series, of which they include rounded pebbles. Some layers contain great numbers of shells of *Aucella Piochii*, together with a few other fossils. Specimens collected at this place by me in 1878, have been figured and described by Mr. J. F. Whiteaves (Trans. Royal Soc. Can. Vol. I, sect. iv, p. 81).

A second and much more important Cretaceous outlier is that which surrounds the upper part of Forward inlet, known as Winter harbour, and appears, on both shores, to the exclusion of other rocks, for a mile and a half from its head. The rocks are here again chiefly greenish-grey sandstones, but also include layers of conglomerate, and hard, fine-grained, calcareous beds, more or less nodular in character. The dips are generally northward, at angles of 60° to 5°, and the beds appear to form an ascending series of considerable thickness, of which layers characterized by a great abundance of *Aucella* and other fossils form the lowest visible member. Local irregularities in dip and other circumstances lead to the belief that the beds have not alone been affected by folding, but that faults also exist, and as the land is rather low and densely wooded on both sides of the inlet, the form and dimensions of the Cretaceous area of this place have not been determined. To the northeastward, it extends to the lower end of the lagoon, which opens from the head by Winter harbour, but on the channel connecting the lagoon and the harbour, there is a projecting mass of the older volcanic rocks. The lagoon itself (known as Huhnĭsh by the Indians), was examined by me in 1878, in consequence of the reported existence of coal upon it. So far as the small rock-exposures show, its shores are chiefly composed of altered volcanic rocks. The coal was found to occur upon a small creek or stream at the upper southwest angle of the lagoon, the exposures being at about forty yards from high-water mark. The beds are nearly vertical, and a couple of small holes had been sunk upon them, the first showing—coal, apparently of good quality, 1 foot; shale, 1 foot 6 inches; coal, partly impure, 1 foot; shale and coal, 2 feet 6 inches; carbonaceous shale, 2 feet. The second hole, at a distance of thirty feet across the measures, shows about 3 feet of coal and shale intermixed, followed by carbonaceous shale, and this again by a pale clayey material. The area of the coal-bearing rocks is here, apparently, quite small, and they are so much disturbed, that even if the seams were of a more promising character, this would not be a suitable place for work.

With the exception of the place just described, no coal was seen in the Cretaceous rocks of any part of Forward inlet. There is reason to believe that the coals seen at the head of the lagoon occupy a horizon near the base of the Cretaceous series, and that they might be found by boring through the less disturbed Cretaceous rocks of the vicinity of Winter harbour, possibly in greater thickness.

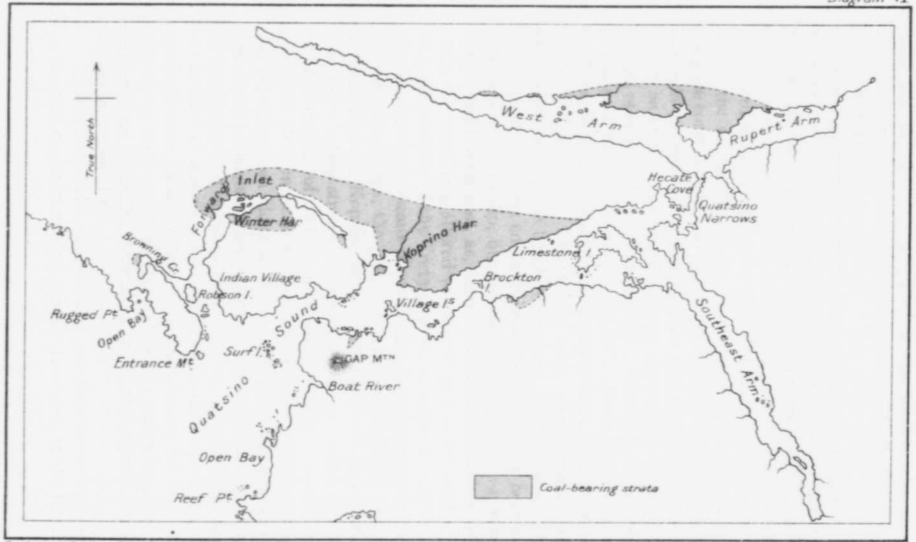
In addition to the Cretaceous outliers seen in Forward inlet, there are probably numerous others of the same kind yet to be found inland from it, and the extension of the Winter Harbour area to the northward may be considerable. Mr. Dowling examined a small stream known as the Zenaad river for about a mile from the shore in a northward direction, without reaching the limit of the Cretaceous. A number of circumstances appear to establish a probability of the existence of an important fault, with downthrow to southwest, which may run nearly parallel in direction to the lagoon, passing near the head of Winter harbour. The probable thickness of the Cretaceous series from the southern outcrop to the head of the harbour, is about 3,600 feet, the highest rocks seen, at the head of the harbour, being rather massive conglomerates. Similar conglomerates are again seen a short distance up the Zenaad river, these rocks probably being in both cases to the southwest of the fault. These conglomerates are supposed to be identical with those forming the upper number of the series in the Koprino area, subsequently described, and as sandstones resume farther up the Zenaad river, with regular low dips to the northward, or northeastward, it is quite probable that the upper part of the range of high hills, rising above this part of the river, which is continued in a southeastward direction to the east of the lagoon, may prove to be composed of the same massive conglomerates, coming in again at a higher level in consequence of the fault. In this case the Cretaceous area may extend some miles to the north. The whole question of the inland extent of the Winter Harbour and Koprino Cretaceous areas deserves examination, but would require two or three weeks of work in the bush.

In addition to *Aucella Piochii*, which has already been referred to as filling entire beds, both on Browning creek and Winter harbour, *Scaphites Quatsinoensis* is found in both the above localities. On the south side of Winter harbour, in addition to the *Scaphites*, the fossiliferous nodules have yielded a *Cinulia*, a *Dentalium*, fragments of an *Alaria*, the cast of small *Protocardium*, an *Astarte*, like the supposed *A. Packardi* of the Queen Charlotte islands, a *Yoldia*, an *Arca*, and a few scattered bones of some teleostean fish.

From the east side of Koprino harbour, for a distance of some miles, or to a point opposite the middle of Limestone island, Cretaceous sandstones and conglomerates occupy the shore, forming a part of what may be called the Koprino Cretaceous area. Thence to Hecate cove, the altered volcanic rocks are again met with, with westward dips, at angles of 30° to 45°. These rocks run across to Limestone island to the south, of which they form the greater part. Bluish and grey limestones, however, which conformably underlie these volcanic materials, outcrop along the east shore of the island, and in a small islet off it, were found to contain silicified corals in considerable abundance. Of these, Mr. Whiteaves states that one form resembles *Thamnastræa*, while a second is probably an *Astrocenia*. They are probably not older than the Trias, and might be newer.

The shores of Koprino harbour, and the islands in it, afford a number of excellent exposures of the Cretaceous sandstones and conglomerates, but the dips and strikes of these are so extremely varied and irregular, that a minute survey of the whole would be required before any definite conclusions could be drawn as to their exact relations. It is highly probable, however, that the section is here complicated by one or two faults, one of which may possibly be continuous with that previously referred to, as probably running parallel with the lagoon of Winter harbour, on Forward inlet. A coal-seam was reported to exist in the vicinity of Koprino, but on obtaining an Indian to guide me to it, I found that it was the same coal occurrence

Diagram VI



Geological Survey, Canada

1418

Quatsino Sound coal-area

Miles

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To accompany Memoir by D. B. Dowling

which has already been described at the head of the Winter Harbour lagoon. This is reached by a trail from Koprino, in less than two miles.

The Cretaceous rocks, of that part of the Koprino area which extends from the east entrance point of the harbour, for at least seven, and probably, for eight miles, along the north shore of the main inlet, are throughout, pretty regular and not much disturbed. They consist chiefly of conglomerate and sandstones, the former frequently producing bold bluffs and hills along the coast, which in the main, very closely follows the strike. The beds dip inland, the direction varying generally only a few degrees on either side of north, though one or two rather sudden changes of strike were observed locally. The angle of inclination varies, as a rule, between 10° and 20°. Beneath the massive conglomerates, which must have a thickness of at least several hundred and possibly of 1,000 feet or more, are softer sandstones, which often occupy the beach. Near the last exposures to the east (opposite the west end of Limestone island), the beds take on a light eastward dip, but probably dip westward, at pretty high angles, farther east, as, after a concealed interval of about a mile, the underlying altered volcanic rocks appear, terminating the possible extent of the Cretaceous basin in this direction.

As affording a means of examining the inland extension of this Cretaceous area, the Tēnosuh river, which flows into the northeast angle of Koprino harbour, was followed up for about three miles. This stream is quite a small one in the autumn, but from the size of its bed, and the inextricable log-jams with which it is filled, must be a formidable torrent at some seasons. The exposures seen along it were rather few, but appeared to indicate an anticlinal, followed by a light synclinal. The rocks are sandstones and conglomerates without distinctive features, and no trace of coal was observed, nor was the northern edge of the Cretaceous basin reached. The Indians, by following this river to its head, and then descending the valley by a second small stream, reach the West arm, at a place nearly opposite the Nookneemish river.

It may, I think, be assumed with considerable certainty that the massive conglomerates so largely developed in the Koprino area, are equivalent to these of which the base is seen forming the highest beds in the Koskeemo Cretaceous area, subsequently described. They are probably also identical with those seen at the head of Winter harbour, forming the highest member of the Forward Inlet Cretaceous. The greater part of the comparatively soft sandstones shown in the lower parts of the sections in both these areas is doubtless now covered by the water of the main inlet east of Koprino harbour, thin selvage edges only appearing in a few places on the south shore, as before noticed. By assuming an average angle of dip for the measures, the thickness of the beds underlying the conglomerates, and for the most part beneath the inlet, would appear to be at least 2,000 feet, and it may be much greater. This is somewhat less than the estimated thickness of the same part of the section of Forward inlet, and greater than that taken as a minimum for the same beds in the Coal Harbour area.

The only locality in which beds pretty certainly overlying the conglomerate portion of the series were seen, was in a small island in Koprino harbour, opposite the East cove. These are grey, finely fissile, rather hard, and very regularly bedded shales, quite different in appearance from any other rock seen about Quatsino sound. These are at angles of 60° to 80° in the centre of a small synclinal, and conformably overlie massive conglomerates to the south, though in contact with an intrusive rock to the north. The exposed thickness is probably over a hundred feet. No fossils were obtained from these beds, but they closely resemble the Upper Shales, which are found overlying the conglomerate member of the Queen Charlotte Island Cretaceous series (See Report of Progress, Geol. Surv., Can., 1878-79).

It appears quite probable that the Cretaceous basin, here spoken of as the Koprino area, may prove to be the most important, from an economic point of view, of those of Quatsino sound. It is much larger than any of the others; the regularity of its beds to the east and north of Koprino harbour is great, and it is more easy of access than the Coal Harbour area, to reach which, the Quatsino narrows must be passed, which can only be done at favourable stages of the tide. The circumstances being such, it would seem to be a quite legitimate (though it must be admitted, in the present state of our knowledge, a purely speculative) enterprise to test this area for coal, by boring at some favourable point or points near the shore to the eastward of Koprino harbour. Such an enterprise should, as a matter of course, be preceded by a thorough examination of all parts of the surface of the area, which would be somewhat laborious, on account of the thick and tangled character of the forest growth.

In all attempts to determine the character of this and other Cretaceous basins of the vicinity by an examination of the natural outcrops, it must be borne in mind that, as before stated, they probably fill pre-existing hollows in the surface of the older rocks, upon which they progressively overlap.

KOSKEEMO COAL AREA.[1]

(*See Diagram VII.*)

(Extract from report by G. M. Dawson.)

The area of Cretaceous rocks on the north side of the West and Rupert arms of Quatsino sound has attracted considerable attention, and several praiseworthy attempts have been made to prove and develop its coal-bearing character. The latest of these has been carried out by the West Vancouver Commercial company, who executed various borings and other operations, at intervals from November, 1883, to May, 1885. Having been supplied with copies of the drill records obtained, through the kindness of Mr. J. Preston Moore, a somewhat detailed investigation of that part of the district in the vicinity of Coal harbour and the Nookneemish river was undertaken, including paced surveys along the shores and between the several points at which borings had been made, and extending inland on the Nookneemish and tributaries of the Natzinughtum to the northern edge of the Cretaceous area. A general examination of the shores had already been made by me in 1878, but the somewhat fragmentary information then gained had not been published.

[1]Ann. Rep. Geol. Sur., Can., Vol. II, 1886, pp. 90-99B.

Though the northern edge of the Cretaceous basin has not been continuously traced, it has been defined at four points, viz., at its two extremities on the shore, and at two intermediate places where it crosses the streams above named or their tributaries. By joining these, with due regard to the observed dips and strikes of the rocks, it may be assumed that a fairly correct outline of the basin on this side is obtained, the Cretaceous rocks there resting unconformably on, and dipping regularly southward from, those of the Vancouver series. To the south, the basin is cut off by a fault, with an extensive downthrow to the north, and a course of about N. 89° W. The throw of this fault must exceed the entire exposed thickness of the Cretaceous of this basin, which is at least 1,500 feet. To the westward, it runs past the mouth of Coal harbour, cutting into the shore near a small cove, a mile and a third beyond the west entrance point of the harbour. It then crosses the bay at the mouth of the Nookneemish river, again cutting the shore a mile beyond the mouth of that stream. Eastward, it must cut the west shore of Rupert arm, about two miles from its head, and as the shore in the intervening stretch is all low, it is possible that the rocks of the Cretaceous series here reappear, and continue for some distance eastward. Still farther in this direction, the fault appears to run completely across the island to Port McNeill and beyond, as explained on page 64 B. The rocks to the south of the fault, which form Hankin point, are massive, greenish amygdaloids, overlain by a thick bed of limestone, which forms low cliffs near the east entrance point of Coal harbour, and reappears in the cove at the east side of Hankin point. On both sides of the bay into which the Nookneemish flows, the older rocks to the south of the fault are hard, shattered, rusty quartzites, and greenish and purplish feldspathic materials, sometimes evidently altered agglomerates.

The total length of the Cretaceous area thus outlined, from east to west, is seven miles; its greatest probable width about two miles, and its approximate probable area—without including under-water extensions—about 5,630 acres. So far as I have been able to ascertain, its rocks comprise a series of sandstones, shales, and conglomerates with general southward dips, generally at angles of from 10° to 30°, complicated only by one slight synclinal flexure, which runs nearly east and west across the northern part of Coal harbour. When immediately in contact with the great fault, near the east entrance point of the harbour, the beds are much disturbed, and for a few yards assume a very steep northward dip. It must be stated, however, that in consequence of the thickly wooded, and drift-covered character of the land and the want of continuous sections on shore, numerous minor dislocations might occur without affording any evidence of their existence.

The nearest approach to a complete section of the basin, is obtained on the west side of Coal harbour, and in the vicinity of the road or trail which has been cut in a northward direction from the harbour, and by which the sites of the more important borings and prospecting openings are reached. An examination of this section leads to the belief, previously alluded to, that the entire thickness of the Cretaceous series here shown is from 1,300 to 1,500 feet. An attempt has been made to formulate a general vertical section of the measures by bringing together all the facts afforded by the natural exposures, and those obtained in the borings, in the vicinity of the line of section above defined. It has been found, however, impossible satisfactorily to accomplish this, in consequence of the almost complete absence of well marked zones or beds with distinctive characters which might serve as planes of reference. Shales, sandstones, and more or less, conglomeratic beds, together with numerous thin seams of coal and coaly streaks, are met with in comparatively thin alternating layers throughout all parts of the series, and the character of individual beds appears to vary from point to point in different parts of their extent, to a perplexing degree. It seems pretty certain, however, that the highest exposed part of the formation is largely composed of massive conglomerate, of which only the lowest beds probably remain, and which are exposed in the light synclinal which crosses Coal harbour, and again on the east side of the harbour, to the north of the fault.

At a probable depth of from 200 to 300 feet below these, is a coal-bearing zone, of which the outcrop appears on the shore of the west side of the harbour, to the south of the axis of the light synclinal, with a northwestward dip at an angle of 25°. There is here about two feet of coal of fair quality. The westward extension of this light synclinal is not known, but its northern edge, not far from the horizon of the coal, should pass near the position of boring B, on the plan, and the coal which is reported to outcrop near the mouth of the Natzinughtum (but of which I saw only detached fragments), is probably the continuation of the northern outcrop of the seam just mentioned. It is, doubtless, also the same seam which was reached in boring E, near the mouth of the Natzinughtum, at a depth of twenty-eight feet, and reported to be 5 feet 4 inches in thickness, but of poor quality. The same seam is again supposed to be represented by the outcrop on the shore two and a quarter miles northeastward from Hankin point. It is here separated into three parts, the two lower of 6 inches each, the upper of 1 inch, separated by several feet of clayey shales, and dipping S.5° E. and 30°.

The second coal-bearing zone is probably from 400 to 500 feet lower in the series. It occurs, farthest west, a mile and a quarter beyond the mouth of the Nookneemish river, near the beach, where a small shaft has been sunk, and a few tons of coal extracted. The outcrop could not be seen, but was reported to show about 3 feet 6 inches of coal, of which, however, about a foot was of inferior quality. There are no exposures on the Nookneemish where this seam should cross, but it is probably the same which was struck in boring F, near the mouth of that river, at a depth of 217 feet. It is evidently the same which has been opened farther east by a small slope about a mile due north of the west entrance point of Coal harbour. The seam is here reported to be from 2 to 3 feet in thickness, and is of good quality. No outcrop of this seam was found on the shore east of Hankin point, but if my view of the structure of the basin is correct, it is probably that which was reached in the deep boring at A, at a depth of 456 feet, with a thickness of 6 inches only. The position of this coal-bearing horizon must be about 300 feet above the base of the Cretaceous rocks.

North of the opening last mentioned, a coal seam of about 3 inches in thickness was observed. It is associated with hard flaggy sandstones and hard dark shales, which form the lower part of the formation, and appear to have been penetrated to some depth in the bottom of boring A. At the eastern extremity of the field, about three miles northeastward from Hankin point, on the shore, a considerable thickness of conglomerates occur in what here must be the lowest part of the series. These were not seen elsewhere in the same position, and this occurrence is somewhat anomalous.

The particulars above given, in conjunction with the record of borings, will show that no coal-seams of satisfactory workable dimensions have yet been found in this area, notwithstanding the exploration of it, which has been carried out by boring and otherwise. While, therefore, not ignoring the fact that more important seams may yet be found here, I cannot concur with Mr. Robert Brown, in his exceptionally high estimate of the value of this field.[1]

Analyses given in Mr. Robert Brown's paper, already quoted, show that the quality of the Koskeemo coals is often very good. An analysis by Mr. G. C. Hoffmann of the coal from the opening marked D, on an accompanying plan, shows the following result:—

Hygroscopic water	1·05
Volatile combustible matter	34·38
Fixed carbon	54·01
Ash	10·56
	100·00

This fuel produces a fine compact coke, and is scarcely acted on by a solution of caustic potash.

Few fossils were obtained from the Cretaceous rocks of this area, but so far as they go, they bear out the view expressed in the preliminary pages of this report, as to the position of the beds in the Cretaceous series. On the Nookneemish river, some casts of molluscs were found not far above the lowest of the Cretaceous beds. These represent a small *Trigonia*, and the shell named *Pleuromya lævigata*, by Mr. Whiteaves, in his report

[1]See his paper on Coal-fields of the North Pacific Coast. Trans. Edinburgh Geol. Soc., 1868-69.

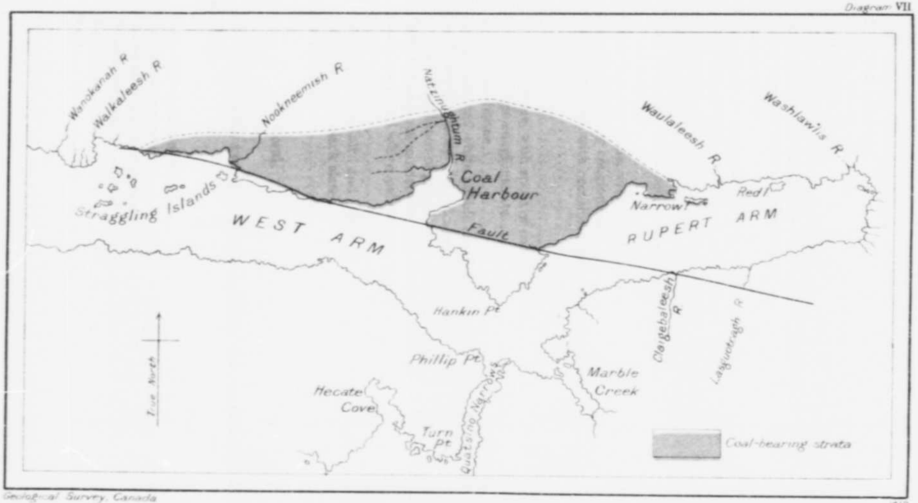
on the fossils from the Queen Charlotte islands. Among some fossil plants collected near the west entrance point of Coal harbour, Sir Wm. Dawson has recognized *Sequoia Reichenbachi* Heer, and a form near to, if not identical with, *Thinnfeldia arctica* Heer. These two forms are found similarly associated in Spitzbergen, in beds which are supposed to be Cretaceous, but must be low down in that formation.

The detailed records of borings in the vicinity of Coal harbour, and on the Nookneemish, are as follows, the letters by which they are denoted, referring to those placed on the accompanying plan and section:—

Deep boring near "The Settlement" (A).

	Feet	*Inches*
Coarse-grained sandstone	29	10
Seams of coal shale and clay	2	10
Hard sandstone, ending in black shale	14	0
Pipe-clay	8	9
Coarse-grained sandstone	15	8
Seams of shale and coal	3	6
Fireclay,	5	10
Seams of shale, slate, and coal (all mixed)	15	9
Fireclay, with small pieces of coal intermixed	6	10
Seams of shale and coal (all mixed)	6	0
Dark, smooth, greenish slate	12	9
Reddish shale and sandstone, mixed with coal	8	0
Sandstone, with occasional spots of coal	20	11
Hard, smooth, grey shale	11	10
Same shale, with seams of shale and coal	38	8
Bluish sandstone, with hard, black grains and occasional pebbles	28	6
Hard, grey slate, showing pyrites	4	0
Sandstone	9	4
Hard, blue clay	2	11
Bony coal and shale	5	5
Mixed clay and shale	3	7
Hard sandstone, with hard, black grains and occasional pebbles	34	9
Seams of slate, shale, and coal	14	6
Same black-grained sandstone as above	5	0
Grey slate with occasional spots of coal	31	0
Seams of slate, coal, and sandstone	13	0
Hard, fine conglomerate	13	4
Hard, grey sandstone, with spots of conglomerate	12	0

Diagram VII



Geological Survey, Canada

Koskeemo coal-area.

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	Feet	Inches
Hard, fine conglomerate, same as above............	18	6
Soft, coarse, yellow, sandstone....................	4	8
Bony coal and shale..............................	3	6
Fireclay, mixed with shale.........................	5	4
Coal, same as above..............................	0	6
Hard sandstone, with black grains................	5	0
Hard, black pebble conglomerate..................	7	8
Mixed seams of shale and bony coal...............	9	3
Hard sandstone.................................	3	11
Fine quartzite conglomerate (very hard)...........	13	5
Hard, fine-grained sandstone......................	5	6
Coal..	0	6
Same sandstone as just above....................	10	0
Very hard, fine, black pebble conglomerate (same as above)......................................	15	7
Black slate and shale, with streaks of coal..........	5	11
Same black pebble conglomerate....................	2	8
Dark sandstone, with occasional spots of conglomerate..	32	5
Dark slate......................................	6	8
Dark sandstone, with spots of conglomerate........	3	8
Very hard, fine conglomerate.....................	12	3
Reddish sandstone.............................	5	0
Hard, black and white pebble conglomerate........	15	7
Black, sandy shale, with occasional streaks of coal and abundance of gas........................	28	10
Hard, fine-grained sandstone.....................	21	8
Hard, black and white pebble conglomerate	21	11
Sandy shale....................................	14	9
Grey sandstone, hard and uniform................	80	0
Hard, compact black slate.......................	8	6
Conglomerate.................................	2	0
Total.............................	739	8

Boring, about two-thirds of a mile to the northward of the last (B.)

	Feet	Inches
Fine, white and blue clay........................	26	4
Pebbly conglomerate............................	12	8
Coarse sand (like beach sand)....................	2	3
Mixed sandy shale and coal......................	1	9
Sandstone......................................	6	9
Slate..	3	0

	Feet	Inches
Sandstone	7	0
Sandy shale and slate, and dark sandstone	21	4
Coal, of good quality, and fireclay	4	6
Fine-grained sandstone	14	9
Sandy shale and slate	1	3
Sandstone, with occasional spots of conglomerate	89	11
Black, sandy shale and black slate	11	9
Sandstone	18	3
Mixed shale, slate, clay, and coal	4	3
Sandstone 6′ 1″ and black, compact slate 5′ 1″	11	2
Dark sandstone 10′ 1″ and same black compact slate 6′ 8″	16	9
Hard, fine-grained, black sandstone	5	2
Same hard, black, compact slate	6	7
Hard, dark, brittle sandstone	9	7
Hard, black slate	0	4
Total	280	10

Boring about three-quarters of a mile northward from first hole (C.)

	Feet	Inches
Coarse sandstone	3	8
Shale and coal	0	4
Coarse sandstone, same as above	5	4
Slate	3	4
Very fine-grained sandstone	10	0
Black, mucky clay, with pieces of coal	1	1
Mixed slate	9	8
Black sand	0	3
Same fine-grained sandstone as above	3	3
Black, sandy shale	3	0
Sandstone	4	0
Black slate	0	10
Soft coal	0	9
Dark shale mixed with coal	1	7
Very fine-grained sandstone	1	1
Black, flinty sandstone, like chert	0	3
Siliceous limestone	3	8
Same black, flinty substance	0	2
Black, sandy shale	3	2
Same siliceous limestone	1	0
Hard, black slate	9	8
Hard, grey slate, in places sandy	26	5

	Feet	Inches
Coarse-grained sandstone	18	2
Hard, black slate	8	0
Sandstone	15	9
Grey slate	3	0
Hard, grey sandstone	7	9
Coal, good quality	0	8
Shale	0	4
Sandstone	31	10
Slate	3	9
Same sandstone	6	10
Hard slate, with shell impressions	5	1
Sandstone, with two small streaks of coal	9	0
Same slate as above, with shell impressions	1	6
Hard, dark, brittle slate	42	9
Shale and coal	0	3
Some hard, brittle slate, as before	11	2
Layers of slate, sandstone, and conglomerate	9	2
Mixed seams of coal, slate, and clay	1	4
Bands of shale, coal, sandstone, and conglomerate	5	1
Sandstone and sandy shale	10	3
Brittle, dark sandstone	10	2
Fine, brittle conglomerate	8	3
Hard, coarse-grained sandstone	3	0
Hard slate with white seams of flint and lime	4	1
Hard, black sulphurous sandstone	5	0
Soft, grey slate	5	0
Fine conglomerate, slaty matrix	17	5
Reddish sandstone	4	0
Different coloured, sulphurous slates	22	6
Hard, flinty slate (white seams)	4	5
Total	368	0

Boring on the Wagstee, at bottom of Coal harbour, east of mouth of Natzinughtum (E.)

	Feet	Inches
Coarse conglomerate	24	10
Coarse sandstone	3	0
Coal seam (poor quality)	5	4
Fireclay	4	0
Sandstone, same as above	30	0
Dark conglomerate	24	4

	Feet	Inches
Sandstone, with spots of conglomerate	49	8
Fine conglomerate	7	0
Hard sandstone	40	0
Total	188	2

Near this place, on the Natzinughtum, a hole was put down 709 feet, but no record has been obtained of it. It ended in conglomerate, and it is to be presumed that it did not cut any coal seams of importance.

The probable position of this hole is marked (F).

Boring near the mouth of the Nookneemish river. (G.)

	Feet	Inches
Soft shale	5	7
Sandstone	149	2
Tough, white clay	9	6
Sandstone with occasional streaks of coal	43	7
Conglomerate	4	6
Dark, sandy shale	5	2
Good coal	1	0
Soft, sandy shale	4	0
Hard, dark, smooth shale	1	6
Soft coal	0	6
Pipe-clay	0	3
Hard, blue slate	0	6
Soft, dark sandstone	20	10
Sandstone, with streaks of slate and shale	43	8
Smooth, black slate	3	3
Very hard conglomerate	43	7
Light, bluish clay, with quartz chips	12	3
Hard, dark sandstone	14	5
Soft, sticky, dark-blue clay	2	0
Hard, light-coloured sandstone	5	1
Total	370	4

GRAHAM ISLAND COAL AREAS.[1]

(*See Diagram VIII.*)

(Extracts from report by J. D. MacKenzie.)

The oldest formations exposed on Graham island are a series of metamorphic volcanic and sedimentary rocks, which have been considered deformed in general, and are often extremely contorted in detail. These rocks, which are of Jurassic and perhaps Triassic age, have been intruded by stocks of diorite and granodiorite, in areas not investigated by the present writer. Fossils are abundant in the metamorphosed sediments, and the rocks are correlated with the Vancouver group. The intrusive rocks probably are satellites of the great Coast Range batholith, supposed to be of upper Jurassic age.

On the rough, denuded surface of these older metamorphic and igneous rocks, a series of conglomerates, sandstones, and shales were laid down unconformably. These sediments are called the Queen Charlotte series, and in their lower portion contain a coal-bearing horizon. The date of their deposition is placed in the Upper Cretaceous. The surface on which they were deposited was hilly, and often very uneven in detail. The general topographic conditions surrounding the basin probably resembled to some extent those found in the vicinity of Skidegate inlet to-day.

After, and perhaps to some extent during the deposition of the Queen Charlotte series, they were intruded by dykes and sills of volcanic rocks. These dykes and sills are up to 50 feet in thickness and occur abundantly in many localities. After the deformation and partial erosion of the Cretaceous rocks, extensive flows of volcanic rocks, probably coincident with the later phases of dyke and soil intrusion, covered part of the area now reported on. With these volcanics, which are presumably of Tertiary age, are intercalated sediments, seen only at one locality, the southeast slope of Mount Kahgan. Tertiary sediments occur in the northeastern part of Graham island, in

[1]Summary Report for 1913, Geol. Surv., Can.

places carrying lignite. The Tertiary volcanics have been removed from the larger portion of the area examined this year, and in fact it is uncertain as yet just how far they ever extended over it. Erosion and denudation have greatly affected the slightly resistant rocks of the Queen Charlotte series, which now lie in several basins separated by ridges of the pre-Cretaceous metamorphic and volcanic rocks.

The Queen Charlotte series consists of unmetamorphosed sediments lying unconformably on the rocks of the Vancouver group. The lowest member of the series contains coal, at what is thought to be a single horizon. Since the time of Dawson's[1] examination of Skidegate inlet, there has been some confusion of the relative ages of the pre-Cretaceous and Cretaceous rocks; due probably, as Dowling[2] suggested to the fact that the fossils on which the determinations are based are from both of these formations. Clapp[3] gives a more detailed account of the difficulty, so it need not be gone into here.

The Queen Charlotte series has been subdivided on lithologic grounds into three members. Clapp[4] considered that there was a fourth, the Image basal conglomerate, but more detailed work has shown that what he supposed was basal Cretaceous are more probably conglomerate members of the Yakoun volcanics.

The Haida formation is the lowest member of the Queen Charlotte series, and contains the coal horizon. It is also the thickest, and most extensive areally of the Cretaceous sediments. The Haida formation outcrops on most of the islands of Skidegate inlet at Alliford bay on Moresby island, and extends along the shore of Bearskin bay from Haida point to The Narrows. It also occurs on the western limb of the syncline into which the Queen Charlotte series is folded, at Shoal bay, Long Arm, and other points in the western part of Waterfowl bay. Inland, the Haida formation underlies the Honna valley, and most of the country between the headwaters of the Honna on the east,

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[1]Dawson, G. M., Rept. of Progress: Geol. Survey, Canada, 1878-79.
[2]Dowling, D. B., Bull. Geol. Soc. America, No. 17, 1906, pp. 298-299.
[3]Clapp, C. H. Summ. Rept. Geol. Survey, Canada, 1912, pp. 20-25.
[4]Clapp, C. H. Summ. Rept. Geol. Survey, Canada, 1912, p. 21.

Yakoun lake on the west, and from the hills south of Camp Robertson to the highlands north of Cascade creek. This formation also occurs in an extensive basin west of the Yakoun river, and in several smaller synclines between the Honna and the Yakoun basins. It is possible that the basin west of Yakoun river is connected with the Honna basin, the junction being concealed by Tertiary volcanics south of Yakoun lake. The Yakoun basin, containing the coal seam at Camp Wilson, is a narrow area in the valley of Wilson creek lying between highlands of pre-Cretaceous rocks, and widening to the north and northeast. Its extent in this direction is unknown, but it may underlie the country as far as Masset inlet.

Lithologically the Haida formation is largely composed of sandstones and shales, the proportion varying in different districts. In general, the rocks are coarser near the base, angular grits and arkoses predominating. In the vicinity of Skidegate inlet, the formation as a whole is fine grained, well laminated, and highly fossiliferous. Sandy shales are the characteristic rock here, of a distinctly green colour, though yellowish and greyish rocks are found. Concretions, and calcareous and siliceous bands are common. On Maude and Line islands, there are very thick massive beds of fine green sandstone in the upper two-thirds of the formation. About Camp Robertson the rocks are on the whole coarser, and here are divisible into two well-marked members, a division which is not so distinct around Skidegate inlet. The lower member is variable in its character, consisting of rapidly alternating bands of sandstones, shales, and coarse angular greenish grits. The upper portion of this lower member is finer, characterized by grey shales, and it is here, about 2,500 feet above the base, that the coal seam at Camp Robertson is found. The upper Haida is almost wholly composed of fine, even-grained, strikingly homogeneous, thinly laminated, grey and greenish grey sandstones, with occasional thin interbeds of shales or grits. The Haida formation west of the Yakoun river is almost wholly fine-grained massive sandstone, similar to the above. In the vicinity of Camp Wilson, the beds are coarser, and characterized near the base by arkosic tufaceous rocks, greatly resembling, and difficult to separate from, the underlying Yakoun volcanics.

In thickness, the Haida formation varies. At Skidegate inlet, it is from 2,000 to 3,500 or 4,000 feet, while near Camp Robertson it is not far short of 3,500 feet. Here, the lower member is from 2,500 to 3,000 feet thick, and the upper massive sandstones are about 2,300 feet. The coal seam here occurs about 200 feet below the base of the upper massive sandstones.

The Honna formation, largely composed of conglomerate, is conformable on the Haida formation, and outcrops on Maude island, Nose point, and many of the islets in Waterfowl bay. It also is exposed in a horseshoe shaped ridge the eastern leg of which runs north from the Narrows, parallel to the Honna river and west of it, and, swinging westward north of Sadie creek, caps the high hills east of Mt. Etheline and south of Camp Robertson. The western outcrop of the horseshoe shaped syncline is largely covered by Tertiary volcanics, but is exposed on the shore from the mouth of the Slate Chuck to Steep point.

The Honna formation consists of two bands of conglomerate, one at the base, the other at the top, separated by coarse, cross bedded sandstones and some grey shales. The conglomerates are well bedded, the pebbles are excellently rounded, and form 30 to 60 per cent of the rock. They range in size up to three feet in diameter at the base but average much less, and many beds do not contain a pebble over one inch in diameter. The materials of the pebbles are various, consisting of diorites, granodiorite and other plutonic rocks, quartzites, argillites and slates, cherts, quartz, and rarely pebbles of the Yakoun volcanics. The Honna conglomerate has a sharply gradational contact with the underlying Haida sandstones where exposed at the Narrows, and the contact with the overlying Skidegate sandstones is also rather abrupt. The thickness of the Honna conglomerate is about 2,000 feet.

Conformable on the Honna conglomerate, is the Skidegate formation, almost altogether made up of shales and sandstones. The Skidegate formation is exposed along the north shore of Waterfowl bay, also on Nose point. Northward these rocks underlie the district between Waterfowl bay and the conglomerate hills south of Camp Robertson, and are partly concealed by the overlying Tertiary volcanics.

The rocks are very largely fine grey to black slightly carbonaceous shales, with thin interbeds of sandstones, and siliceous, ferruginous, and calcareous concretions. These concretionary beds weather to a light buff colour, and stand out in relief above the softer shales. Fossils are occasionally found in the Skidegate beds. The top of the formation is not exposed, but the visible thickness is about 2,000 feet.

The sediments of the Queen Charlotte series occur as separated synclinal basins over a large area in south-central Graham island. It seems reasonable to suppose that these now separate basins were formerly part of a small geosyncline of Cretaceous sediments, occupying the area in central Graham island, between Skidegate and Masset inlets, and perhaps having an even wider extension.

The surface on which the Queen Charlotte series was deposited, as evidenced by the variable thickness of the Haida member, was one of considerable relief, and it is possible that some of the present highlands of pre-Cretaceous rocks remained out of water during the depositional period, as suggested by Clapp.[1] However, owing to the frequency with which small basins of Cretaceous rocks dot the pre-Cretaceous hills, and on account of the large amount of erosion which has taken place, it seems more probable to the writer that the area was wholly submerged during the later period of deposition at least. Post-Cretaceous folding has elevated this area and denudation has stripped much of the sedimentary veneer from the pre-Cretaceous basement, leaving the Queen Charlotte series in the now localized basins.

It has been already mentioned that there has been some doubt regarding the age and relationship of the Queen Charlotte series, owing to the uncertainty in respect to some of the fossils previously collected from this vicinity. Full collections were made during the work now reported on, and have been examined by Dr. T. W. Stanton. He states that there are a few very imperfectly preserved specimens or single species that may be Jurassic, but most of the fossils are certainly Cretaceous and,

[1]Summ. Rept., Geol. Surv., Canada, 1912, p. 24.

judging from European standards, not older than Gault. The single species said to be probably of Jurassic age was not found in place, though in an area underlain by sediments of the lower Haida formation. The occurrence of the *Inoceramus*, closely resembling if not identical with *I. labiatus* Schlotheim, is said by Doctor Stanton to suggest a higher horizon, represented by the Benton shale of the Rocky mountains and the Turonian of Europe.

It is perhaps worth while to indicate the relation between the various formations of Skidegate inlet as now determined on structural and fossil evidence, and as Dawson determined them.

Present subdivision.		Dawson's subdivisions.[1]	
Skidegate formation. Honna " Haida "	Upper Cretaceous.	Cretaceous.	A. Upper shales and sandstones. B. Coarse conglomerates. C. Lower shales. D. Agglomerates. E. Lower sandstones.
Unconformity.			
Yakoun volcanics.	Middle Jurassic.		
Maude argillites.	Lower Jurassic.		

Coal is found at a single horizon in the Haida formation of the Queen Charlotte series, of Lower Cretaceous age. The coal-bearing horizon is at a variable distance up to 2,500 feet, above the base of the formation. In the vicinity of Camp Robertson, a good horizon marker is the base of a massive band of sandstone composing the upper Haida, about 200 feet below which the coal seam occurs. At Cowgitz the coal apparently rests on the Yakoun volcanics, but here it is almost certainly faulted, and at Slate Chuck creek, a short distance northeast, a considerable thickness of shales intervenes between the coal and the underlying volcanic rocks. The coal has been exposed at several localities, and the seams show considerable variation, due probably to original differences of deposition as well as to later changes.

[1]Dawson, G. M. Rept. of Progress, Geol. Surv., Canada, 1878-79, pp. 63B-64B.

The openings examined this year are at Cowgitz, Slate Chuck creek, Camp Robertson, Camp Anthracite, southeast of Yakoun lake, and at Camp Wilson. Of these, all, excepting possibly the last, are different outcroppings of the same seam or of different seams at the same horizon. So far as the surface exposures give evidence, there is on Graham island just one horizon in the Cretaceous at which favourable conditions for coal formation occurred, although it is not impossible that others may be found.

Cowgitz and Vicinity. Coal was discovered at Cowgitz, near the headwaters of Hooper creek, in 1859, and in 1865 a company was formed in Victoria to exploit the deposit. A description of the workings has been given by Richardson[1] and Dawson[2]. The workings are at present wholly caved and covered up by undergrowth, so that little is to be learned at this locality. It is evident, however, that the coal is near the underlying volcanics, and this is probably due to faulting, as nowhere else has the coal been found near the base of the measures. The seams at this place are said to be vertical, and the rocks disturbed. The coal is lenticular in its occurrence, and Dawson concludes that only one seam exists, repeated by folding or faulting. The more extensive field work of the present season supports this conclusion. The greatest thickness observed was six feet, and this seam contained "two veins of pure coal, averaging three feet, and one foot three inches in thickness respectively, but separated by a shaly midrib of about six inches."

Specimens seen on the old dumps give the appearance of a bright semi-anthracite, and are apparently quite unaffected by their forty years exposure to the atmosphere.

On King creek, about a quarter of a mile northeast of the openings on Hooper creek, a coal seam was found this summer. The seam is at least five feet thick, though not wholly exposed, and is fairly clean. The coal is anthracitic in appearance, quite

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[1]Richardson, James. Rept. of Progress, Geol. Surv., Canada, 1878-79, pp. 57-60.

[2]Dawson, G. M. Rept. of Progress, Geol. Surv., Canada, 1878-79, pp. 71B-77B.

Analyses of Coals from Cowgitz and Slate Chuck Valley.

	1	2	3	4	5	6	7	8	9	10	11
Water............	1·60	1·89	3·61[1]	6·68	6·85	6·69	6·60	6·45	6·75	6·77	2·3
Volatile matter....	5·02	4·77	8·14	6·28	5·43	6·59	3·95	4·15	4·25	4·23	3·8
Fixed carbon	83·09	85·76	74·09	68·49	66·32	57·23	68·17	63·60	65·50	85·48	90·8
Ash..............	8·76	6·69	14·16	18·55	21·40	29·49	21·28	25·80	23·50	3·52	3·1
Sulphur...........	1·53	0·89	....	....	0·20	0·30	0·43	0·45	0·34	0·42	....
	100·00	100·00	100·00	100·00	100·20	100·30	100·43	100·45	100·34	100·42	100·0
Coke.............	Nonco	herent	88·25	87·04	87·72	86·72					

[1] Loss at 105°C.

Noncoherent.

1. Six foot seam at Cowgitz.
2. 2 ft. 5 in. seam at Cowgitz. Collector J. Richardson, Analyst B. J. Harrington, Geol. Survey, Canada, Rept. of Progress, 1872-73, p. 81.
3. Five foot seam on King Creek. Collector J. D. MacKenzie, Analyst F. G. Wait, Mines Branch.
4, 5, and 6. Tunnel, British Pacific Coal Co., Coal Creek. Collector C. H. Clapp, Analyst F. G. Wait, Geol. Survey, Canada, Summ. Rept., 1912, p. 31.

4. Coal from A seam.
5. " " B "
6. " " C "
7, 8, 9, and 10. Different benches from B seam, tunnel of British Pacific Coal Co. Collector Alexander Faulds, Analyst Noble E. Perrie. Geol. Survey, Canada, Summ. Rept., 1912, p. 31.
11. Picked sample, best clean bright coal, British Pacific Coal Co., tunnel. Collector J. D. MacKenzie, Analyst Edgar Stansfield, Mines Branch.

like that at the other workings, and there is little doubt that it is the continuation of the same seam. The dip is high, and the apparent roof is a black shale. This outcrop is directly on the line of strike between Cowgitz and the openings on Slate Chuck creek. Outcrops of black shale farther up the creek show that the seam here is at least 500 feet above the base of the measures, and on Coal creek, farther north, the distance is still greater.

Slate Chuck Creek. In the Slate Chuck valley, two exposures of the coal horizon have been prospected. On Coal creek, a small tributary of Slate Chuck creek from the west, the coal is exposed in the stream bed about half a mile above the junction of the creeks. Here an adit across the measures has been driven for a distance of 757 feet by the British Pacific Coal Company. This adit cuts three coal seams which, according to Clapp[1] are involved in several small folds. This adit was not entered by the present writer on account of its gassy condition. Descriptions and analyses of the coal are given in Clapp's report[2]. About three-quarters of a mile northwest of this locality the coal is again exposed in a small prospect adit on the right bank of Slate Chuck creek. Here a seam, said to be six feet thick, was found. The coal on the dump is similar in appearance to that at the adit on Coal creek.

Specimens on the dump at Coal creek show the coal to be a brilliant, hard, rather heavy substance, greatly resembling high grade anthracite in appearance. It occurs in streaks and lenticles in a soft black carbonaceous shale. Analyses of the material resemble those of a semi-anthracite, high in ash and water. The cause for its anthracitic nature is thought to be due in part at least to some metamorphosing action of the Etheline volcanics, dykes and sills of which are found cutting the coal seams, and thick flows are at no great distance even at the present time.

Yakoun Lake. Two openings on coal seams have been made near Yakoun lake, one less than a quarter of a mile from the southeast corner of the lake, the other, Camp Trilby, nearly

[1]Clapp, C. H. Summ. Rept. Geol. Survey, Canada, 1912, p. 30.
[2]Loc. cit.

two miles southeast of this. The first is on the southwest limb of a narrow syncline striking about N. 25° W., and the second is on the northeast limb. Both seams dip at high angles. At the locality nearer the lake, an adit has been driven S. 60° E. for 50 feet across the measures. Exposed in this opening are several thin seams of coaly material, none seen over three inches thick. Appearances here resemble the exposures at Slate Chuck, but the coal is coked, rather than changed to anthracitic material. It is very light, and often shows columnar structures, the individual columns being arranged perpendicular to the bedding, and often no larger than the lead in a pencil. Mr. Slipper, who visited Camp Trilby, states that the occurrence there is similar to that just described.

There appears little doubt that these Yakoun Lake exposures are a continuation of the horizon found near Skidegate inlet, and that in both cases later volcanic rocks have changed the character of the seams.

Camp Robertson. A large amount of prospecting work has been done at Camp Robertson since 1892, when these outcrops first attracted attention, and a number of shafts and other openings have been made. Through the co-operation of Dean Milnor Roberts, who was examining the property here and at Camp Wilson, at the time of the writer's visit, opportunity was given to make a thorough study of the various exposures of the coal.

Robertson creek, on which the coal was discovered and opened, flows along the axis of a small anticlinal fold. Minor wrinkles and small faults further complicate the locality, so it has generally been supposed that there are two coal seams at this camp. This is not the case. There is one seam, but it is folded and faulted, so that previous investigators have been misled.

The outcrop of this seam has been traced along the eastern limb of the anticline for a distance of about 1,500 feet south from the most northerly opening. At this most southerly exposure, the so-called Nutter mine, it is not certain that the same seam as farther north has been encountered, as only thin coaly streaks are found in place, though a large amount of blossom

Analyses of Coals from Camp Robertson.

	1	2	3	4	5	6	7	8	9	10	11	12
Water	1·28[1]	0·30[2]	2·12[1]	0·64[2]	1·76[1]	0·42[2]	1·61[1]	0·47[2]	1·09[2]	0·80	1·33	1·20
Volatile matter	25·99	27·73	24·60	26·27	29·66	27·29	24·19	25·81	13·92	23·27	35·25	29·13
Fixed carbon	52·58	52·18	38·56	44·44	41·12	46·09	43·85	45·53	41·83	51·39	42·57	47·52
Ash	20·15	19·82	34·72	28·65	27·46	26·20	30·35	28·29	43·16	24·54	20·85	22·15
Sulphur	....	0·88	....	0·92	....	0·50	....	0·54	0·54	......	......	......
	100·00	100·91	100·00	100·92	100·00	100·50	100·00	100·64	100·54	100·00	100·00	100·00
Coke	72·73 coherent	.... but tender	73·28 firm	....	68·58 coherent	....	74·20 coherent					

[1] Loss at 105°C. [2] Air dried.

1. Lowermost 7½ in. from drift from No. 1 shaft. Collector J. D. MacKenzie, Analyst F. G. Wait, Mines Branch
2. Same as No. 1. Duplicate sample. Collector Milnor Roberts, Analyst C. R. Corey, University of Washington.
3. 33 in. of upper bench, slope at end of tunnel, N.W. wall, 14 ft. from face of slope. Collector J. D. MacKenzie, Analyst F. G. Wait, Mines Branch.
4. Same as No. 3. Duplicate sample. Collector Milnor Roberts, Analyst C, R. Corey, University of Washington.
5. Same location as 3 and 4, sample of 25 in. beginning 12 in. below roof. Collector J. D. MacKenzie, Analyst F. G. Wait, Mines Branch.
6. Same as No. 5. Duplicate sample. Collector Milnor Roberts, Analyst C. R. Corey, University of Washington.
7. Lowermost 8 in. best coal on S.E. wall, five feet in from turn of tunnel. Collector J. D. MacKenzie, Analyst F. G. Wait, Mines Branch.
8. Same as No. 7. Duplicate sample. Collector Milnor Roberts, Analyst C. R. Corey, University of Washington.
9. 8 in. seam. Nutter opening, lower tunnel. Collector Milnor Roberts, Analyst C. R. Corey, University of Washington.
10. Collector W. A. Robertson, Analyst G. C. Hoffmann, Geol. Survey, Canada, Ann. Rept., Vol. VI, 1895, p. 12R.
11. Collector R. W. Ells, Analyst J. T. Donald, Geol. Survey, Canada, Ann. Rept., Vol. XVI, 1906, p. 43B.
12. Collector R. W. Ells, Analyst M. F. Connor, Geol. Survey Canada, Ann. Rept., Vol. XVI, 1906, p. 44B.

The writer is indebted to Dean Milnor Roberts for permission to publish Analyses 2, 4, 6, 8, and 9.

occurs. East of Camp Robertson, the rocks are folded in a narrow canoe-shaped syncline, with a north-south axis probably about a mile in length, the width probably not exceeding 300 yards east and west. Westward, however, the coal seam though not certainly exposed in this immediate vicinity, underlies a large extent of country, between Camps Robertson, Anthracite, Mount Etheline, and the Baddeck river, and judging from surface exposures, is lying rather flat or is gently rolling. In much of this area, the depth of the seam probably does not exceed 1,500 feet, and a good deal of it is not deeper than 1,000 feet.

The coal seam itself at Camp Robertson has a maximum thickness of 8 feet 9¾ inches, and the greatest amount of coal found is 3 feet 10½ inches. This occurs in several different bands up to 25 inches thick, varying somewhat in their character, and separated by thin bands of shale and bone. The coal resembles the bituminous variety, and is hard, dense, and rather heavy. This seam was carefully sampled and the results of the analyses follow as well as other available analyses:—

Camp Anthracite. The coal from this opening, which is clearly on the so-called Robertson seam, has been called anthracite probably on the strength of the analyses 2 and 3, quoted below. It does not, however, resemble anthracite in any way, and has a great likeness to the Robertson seam. This similarity is all the more striking when the variable character of the measures is recalled, and it strengthens the probability that the Robertson seam is of considerable extent.

The coal, exposed in an adit across the seam from which a drift runs along it for 30 feet, is 9 feet thick where measured, containing 4 feet 5 inches of rather slaty, crushed coal in several bands separated by shale and bone. The seam is doubtless thickened by minor faults and slips. The thickness and general appearance of the seam resemble the occurrences at Camp Robertson.

Where opened, the seam strikes N. 32° W. and dips 85° S.W., but this high altitude is only local, as up Anthracite creek, on which the opening is located, the massive overlying sandstone is rather flat and regular.

Analyses of the coal are quoted below:—

Analyses of Coal from Camp Anthracite.

	1	2	3
Water.............	5·69	1·52	2·85
Volatile matter.....	7·83	8·69	7·59
Fixed carbon........	42·10	80·07	68·25
Ash...............	44·38	9·72	21·31
	100·00	100·00	100·00
Coke.	86·48	Noncoherent.	

1. Tunnel, 20 ft. in from mouth, Collector J. D. MacKenzie, Analyst F. G. Wait, Mines Branch.

2 and 3. Collector W. A. Robertson, Analyst G. C. Hoffmann, Geol. Survey, Canada, Vol. VI, 1895, p. 13R.

Camp Wilson. Camp Wilson is located in the NW. ¼ sec. 25, tp. 7. At this place three openings have been made on a single coal seam, varying from 4 to 18 feet thick, and containing up to 16 feet of coal.

The coal seam occupies the central portion of a narrow synclinal basin, which is complicated by other folds, but which has a general pitch to the north and northeast. It is probable that the extent of this syncline northward and northeastward may be considerable, and if the pitch is sufficient, a considerable body of coal may underlie this area.

The measures of this syncline, the so-called Yakoun basin, differ from the rocks in the Honna basin in being much coarser and less sorted, and there is a noticeable lack of the dykes and sills so prevalent farther south. The Wilson seam is nearer the base of the Haida than is the coal at Camp Robertson. It is probable that the seam is about 1000 feet from the base.

The opening showing the largest body of coal is on the right bank of Wilson creek, about half a mile from the Yakoun river, and consists of an adit on the seam, from which a winze gives access to a drift at a lower level. The seam at this place strikes from north-south to N. 23° W. and dips from 60° NE. to vertical. In the face of the adit, fifty feet from the portal, the seam is cut off by a vertical strike fault, which brings the floor and roof of the seam together. From the drift, 11 feet 10 inches below the adit, a narrow cross-cut has been driven through the seam, showing it to have a thickness of 18 feet, 1½ inches. The seam is divided by 5 inches of whitish grey sandstone into two benches, the upper about 12 feet, and the lower about 5 feet thick. There are a few other thin partings in the seam, but on the whole it is clean, and much more so than the coal at Camp Robertson. Not all the coal, however, is of the same quality, and the upper three feet or so of the upper bench is distinctly inferior. In appearance the coal is bright and clean, and much broken by fractures in several directions, although it may well become more solid at depth. Contrasting with the coal at Camp Robertson, the Wilson coal is light in weight. The seam is broken by several smaller faults, in addition to the one appearing in the upper level.

The coking qualities are excellent. Tests of a pound or so of the coal as it came from the seam, without selecting the best parts, crushed and coked in a tin by means of a slow coal fire, gave bright, shiny, hard coke.

A shaft and drift at 310 feet in a direct line southeast up Wilson creek, on the left bank, shows the seam to have a thickness of 9 feet 5 inches, containing 6 feet 2 inches of coal, in appearance like that already described. It is here evidently faulted to some extent.

About 75 feet northeast of the first opening, the seam is cut by an adit. When first encountered it is lying rather flat, suggesting, as do other facts, that the measures are involved in a minor anticline. Farther in, the seam steepens rapidly, and in the end of the workings, which follow the seam, it is dipping 45° NE. The greatest thickness of coal exposed in this opening is 3 feet 6 inches, but it is not certain that the whole seam is exposed here. In appearance the coal is like that at the other openings.

From the foregoing descriptions it will be seen that the seam where at present exposed is of a distinctly lenticular nature, and this fact, together with the known variable character of the

Analyses of Coals from Camp Wilson.

	1	2[3]	3	4	5	6	7	8	9	10	11	12	13
Water..........	1·8	1·22[2]	2·2[1]	1·82[2]	2·02[2]	1·6[1]	1·33[2]	2·3[1]	2·44	2·65	1·06	2·47	1·91
Volatile matter..	35·2	36·20	30·1	30·81	39·21	29·9	30·40	6·1	35·96	38·19	43·48	35·25	35·24
Fixed carbon....	46·4	46·48	38·3	40·84	50·51	31·8	31·17	74·1	48·64	53·73	46·01	59·36	59·39
Ash	16·6	16·10	29·4	26·53	8·26	36·7	37·10	17·5	12·96	5·43	9·45	2·92	3·46
Sulphur.........	......	1·00	....	0·50	....	....	1·20	....	0·80	......	......	....	......
	100·0	101·00	100·00	100·50	100·00	100·00	101·20	100·0	100·80	100·00	100·00	100·00	100·00
Coke..........		Barely cokes	Firm coher-ent	Barely cokes			Barely cokes		61·60 Firm Coherent	Firm		Coher-ent	Non-friable

[1] Total moisture. [2] Air dried. [3] B. T. U. 11, 235.

1. Upper bench, No. 1 opening. Collector J. D. MacKenzie, Analyst Edgar Stansfield.
2. Same as No. 1. Collector Milnor Roberts, Analyst C. R. Corey, University of Washington.
3. Lower bench, No. 1 opening. Collector J. D. MacKenzie, Analyst Edgar Stansfield.
4. Same as No. 3. Collector Milnor Roberts, Analyst C. R. Corey, University of Washington.
5. Same as No. 2. Specimen sample. Collector Milnor Roberts, Analyst C. R. Corey, University of Washington.
6. Sample of 18 in. coal, beginning 27 in. below roof, No. 1 opening. Collector J. D. MacKenzie, Analyst F. G. Wait.
7. Same as No. 6. Collector Milnor Roberts, Analyst C. R. Corey, University of Washington.
8. Coke, Upper bench No. 1 opening. Collector J. D. MacKenzie, Analyst Edgar Stansfield.
9. Collector C. H. Clapp, Analyst F. G. Wait. Geol. Survey, Canada, Summ. Rept., 1912, p. 36.
10. G. C. Hoffmann, Analyst, Geol. Survey, Canada, Ann. Rept., Vol. III, 1887-88, p. 17T.
11. Collector W. A. Robertson, Analyst G. C. Hoffmann, Geol. Survey, Canada, Ann. Rept., Vol. VI, 1892-93, p. 12R.
12. Collector R. W. Ells, Analyst J. T. Donald, Geol. Survey, Canada, Ann. Rept., Vol. XVI, 1904, p. 40B.
13. Collector R. W. Ells, Analyst M. F. Connor, Geol. Survey Canada, Vol. XVI, 1904, p. 44B.

sediments forces one to the conclusion that the seam is apt to be uneven in its thickness. The great mass of coal in the first opening described, although somewhat faulted, and doubtless slightly thickened by this agency, is on the whole well bedded, and the unusual thickness is probably due to original deposition. Until the seam is exposed at several other localities, little can be said regarding its probable character from the miner's point of view. The fact that there is known to be a rather widespread coal-bearing horizon at about this place in the measures, together with the occurrence of a distinct seam of good coal of workable size, points to the conclusion that there is every probability of finding workable coal north of Camp Wilson. The extent and value of this coal can only be determined by careful prospecting directed by a competent geologist. Haphazard boring operations are of little value, and even if a coal seam is encountered by them, a drill core tells very little about the structure, and virtually nothing about the extent of a seam.

PROBABLE AREA AND COAL RESERVE OF GRAHAM ISLAND.[1]

(By C. H. Clapp.)

Those areas which, so far as our knowledge goes, are, with a high degree of probability, underlain by coal seams, are small. They consist merely of 1·1 square miles in the vicinity of Cowgitz, 0·8 square miles in the vicinity of Camp Robertson, and 0·3 square miles at Camp Wilson. The first consists of two connected basins occupying Slate Chuck Creek valley and the valley to the south. The measures are greatly deformed, and there are doubtless several complete folds. The measures are also cut by dacite and andesite porphyrite dykes. There are, in places, at least three seams of coal which is semi-anthracite in character. If the total workable thickness of these seams is taken as 6 feet over the area, the reserve, allowing 1,000,000 tons per square mile-foot, is about 3,300,000 long tons. The second area, at Camp Robertson, consists, as already described, of a closely-

[1]Summary Rep. Geo. Surv., Can., 1912, p. 37.

folded synclinal basin, cut by dacite and andesite porphyrite, 600 to 2,000 feet wide and almost 2 miles long. There appears to be virtually only one seam of a high ash, bituminous to anthracitic coal, and if its average thickness is taken as 3 feet, the coal reserve would be 2,400,000 long tons. The third area, at Camp Wilson, consists of a long, folded synclinal basin hardly more than half a mile long and 600 to 700 feet wide. There is at least one seam of a good quality bituminous coal, and if its average thickness is taken as 4 feet, the coal reserve would be 1,200,000 long tons.

It is perhaps probable, or possible, that the coal seams exposed on the west limb of the Skidegate Inlet-Honna River basin, exposed near Cowgitz and at Camps Robertson and Anthracite, extend beneath the basin and underlie the greater part of the area underlain by the upper part of the Haida member and the Honna and Skidegate members of the Queen Charlotte series. This possibility has never been proved or disproved, as no systematic prospecting has ever been carried on in the east limb of the syncline except below the coal horizon. The prospecting of this limb by bore-holes located just below the base of the Honna conglomerate is very strongly recommended. If coal were found here it would indicate strongly that coal would be found beneath the entire syncline. At no place in the syncline is the coal horizon more than 4,000 feet deep and over much the larger part of the syncline it is less than 2,500 feet. Another feature strongly in favour of the prospecting of the east limb is the fact that the measures of the east limb are much less deformed than those of the west limb, and are cut by fewer dykes of dacite and andesite porphyrite. The area underlain by the syncline under which there is a fair possibility of finding coal, is about 57 square miles. If the average thickness of the coal, which would be largely of a bituminous character, be taken as 5 feet, the possible reserve, or reserve of a low degree of probability, would be 285,000,000 long tons.

It is also probable that the Camp Wilson syncline extends to the northwest, thence turning to the northeast, fringing or collaring the west flank of the monadnock east of Camp Wilson. It may also, although with a less degree of probability, extend farther to the southeast. The total area of the syncline that may be considered as probably underlain by coal is, however, only 0·8 square miles. With the average thickness of the seam taken as 4 feet, this would give a probable reserve of 3,000,000 tons. On account of the high-grade character of the known coal, the prospecting of the northwest extension of the Camp Wilson syncline is strongly recommended.

It does not seem probable that the minor occurrences of coal described above indicate basins of coal of any great commercial value. Neither does there seem to be much possibility of finding commercial coal in the other parts of the basin underlain by the Queen Charlotte series, with the exception of a small syncline area, somewhat over one square mile, in the central part of township VI, in the valley of Threemile creek.

It has been seen that while the "actual reserve" of Cretaceous coals, that is the reserve of a high degree of probability, is small, only about 6,900,000 tons, the reserve of a fair degree of probability is rather large, about 293,000,000 tons.

KITSEGUECLA COAL AREA.

In the late Mr. Leach's field note books for 1909, the notes of a traverse along the Skeena river from the old Indian village at the mouth of Kitseguecla river to the new village about 6 miles above, contain references to the presence in the opposite banks of the river of the coal-bearing rocks and what appeared as thin coal seams. These rocks, mostly sandstones, were dipping northward. At the mouth of the Kitseguecla river and on the south side is, apparently, an anticline as indicated in the following note: "At this point the coal measures strike S. 50° W. dip 40° W. About 1 foot of coal here, impure and crushed, extra fine example of slickensiding. Across the river W. 40° N. from here is an outcrop of rock that resembles the volcanics and 200 to 300 yards down stream the coal measures apparently outcrop again with southerly dips of about 15° to 20°. The volcanic rock exposed may be the axis of an anticline."

Dr. G. M. Dawson also describes possible coal-bearing rocks, in the Report for 1879-80, exposed on this part of the

Skeena. The following extract is from pages 102-103B of the above report:—

"From Kitselas canon to the Forks (Hazelton) about forty miles following the course of the river, hard sandstones and argillites, often well bedded, are the prevailing rocks. At Kwatsalix canon, these rocks occur in their regular beds, resembling those of the Nechacco group of the Report of 1876-77. For some miles above Kwatsalix a range of hills follows the right bank of the river, forming in some places a rampart-like escarpment, which is composed of beds of the kind just mentioned, dipping away from the water. Near Kitseguecla the rocks change somewhat in character. The sandstones are not highly indurated as before, but rather soft, and associated with Carbonaceous shales, which occur at different stages in the formation, and are sometimes ten or more feet in thickness. At a little distance these quite resemble coal seams, and on closer examination are in fact found to include films and small lumps of a material, which, though very impure and ashy, may be called true coal. Ironstone in nodules and sheets occurs in abundance in some parts of the formation and obscure plant impressions were observed in the sandstones. The rocks have been irregularly deposited in many instances, the carbonaceous shales in particular showing a tendency to lenticular forms. The whole series of rocks has since been violently flexed, crushed, and disturbed, so much so that even if coal seams of good quality occurred they would scarcely under any circumstances be workable in this particular spot. About two miles above Kitseguecla a well marked anticlinal axis crosses the river, a bed of conglomerate participating in the flexure."

BABINE PORTAGE AREA.

On the old trail from Hazelton to the outlet of Babine lake, following the valley of Suskwa river, sandstones probably without coal seams but bearing plant impressions were noted by Dr. G. M. Dawson in the Report for 1879-80, page 104B. These plants are evidently Lower Cretaceous types such as are also found in the Kootenay rocks of southern British Columbia. A few fragments of coal were found near the Babine river where it leaves the lake.

BABINE LAKE AREA.[1]

(Extract from report by W. W. Leach.)

A hurried trip was taken to a reported new coal area on Babine lake. Four claims had been staked on the Tuchi river about 17 miles above its mouth. This stream flows into Babine lake from the west about 50 miles above the outlet, and drains most of the eastern slope of the Babine range.

On arrival at the claims, it was found that very little work had been done, and most of that had been obliterated by a small landslide. Without time and tools it was impossible to determine the extent of the area or the size and value of the coal seams. All that can be said in reference to these claims is, that the coal measures are present, and that one small seam (about 2 feet thick) of impure coal was seen. It is possible that other and better seams may ultimately be found underlying a considerable area, but much prospecting is necessary before the value of this property is determined.

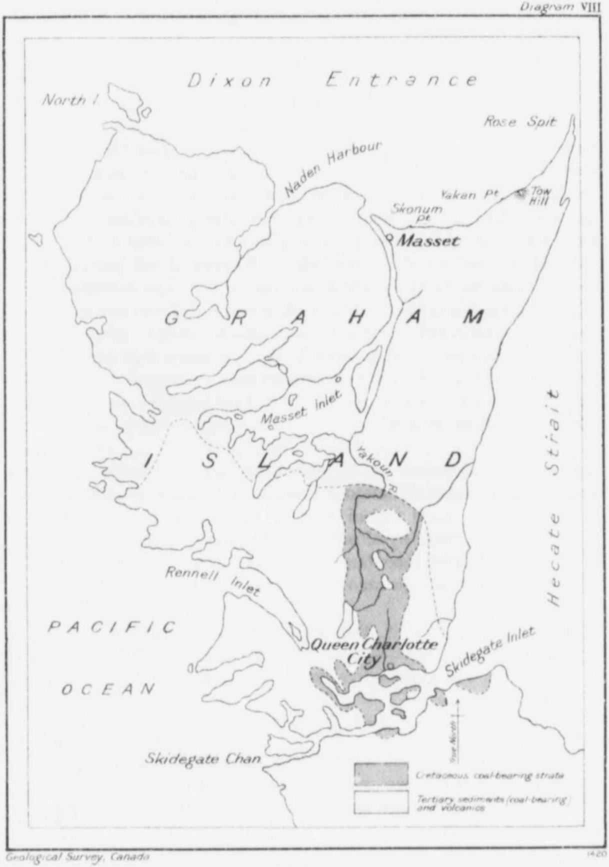
The following analysis is from a sample of the above-mentioned 2 foot seam:—

	%
Moisture	2·55
Volatile combustible matter	17·28
Fixed carbon	52·20
Ash	27·97

Does not coke.

Since this visit, the finding of seams of coal of fair width is reported.

[1]Summary Report 1909, p. 67, Geol. Surv., Can.



Geological Survey, Canada 1420

Graham Island coal-areas

Miles
5 0 10 20

To accompany Memoir by D.B. Dowling

ZYMOETZ RIVER AREA.[1]

(Extract from report by W. W. Leach.)

Glacier Creek Area.

This area is situated near the head of the river (that branch of Zymoetz river which rises with Pine creek near the Hudson Bay mountains) which here occupies a wide, marshy valley. The coal-bearing beds were seen cropping in the bed of Glacier creek, a small stream rising in the Husdon Bay mountains and entering the Zymoetz from the east. The contact of the conglomerate and the underlying volcanics is at an elevation of from 500 to 600 feet above the valley, and at this point the strata are very highly flexed and otherwise disturbed, but have general high westerly dips. Following down the creek from the contact, it was seen that everywhere the rocks have been severely folded and faulted until near the flat, where they become more regular, dipping under the valley to the west at about twenty degrees.

Some time was spent here in an endeavour to uncover a workable seam, but without success, although a number of small seams, from four to nine inches thick, were stripped. It would appear probable that the large seams of Goat creek are here split up into a number of small ones, though it is possible that larger ones do exist, whose outcrops are covered deeply with drift.

The coal here is very hard, with all the appearance of an anthracite, but the one sample taken showed by analysis such a high percentage of ash as to render it useless.

Coal Creek Area.

About eighteen miles from Glacier creek, down the Zymoetz river on its northwest bank, another area of the coal-bearing beds is met with. The best exposures are seen in a small stream from the northeast, locally known as Coal creek, which cuts

[1]Summary Report 1908, Geol. Surv., Can.

the strike of the rocks at a wide angle. The beds here appear in the general form of a shallow syncline, with a general strike nearly northwest and southeast; but there are many minor undulations and the strata were seen to be faulted in a number of places. The width of the basin is probably about two miles, but its extent along the longer axis was not seen, though it is fairly certain that it does not go any great distance southeast of Coal creek. To the northwest the country has a gentle slope, is heavily drift-covered, and for a considerable distance there are no transverse valleys, so that it was found impossible to trace the coal-bearing beds farther in that direction, in the time available.

A number of coal claims have been staked here by Mr. J. Ashman, but so far little or no work has been done. Two small seams only were seen outcropping in the bed of Coal creek, about one and a half miles above its mouth. The lower of these showed 3 feet of clean coal, while the upper one was 1 foot 4 inches in thickness. Mr. Ashman has since informed me that he overlooked another seam that had been uncovered a short way from the bank of the creek and farther up-stream, which was about 5 feet thick, with a small parting. The following analysis is from a sample from the lower or 3 foot seam:—

Moisture	5·45
Volatile combustible matter	34·03
Fixed carbon	48·17
Ash	12·35

Coke: partly fritted.

On the other coal properties, which have been described in previous reports, no new work has been undertaken during the past year, as all the owners of the lands in question are waiting for railway construction, before going to the expense of further development.

SHEGUNIA COAL AREA.[1]

(See Diagram IX.)

(Extract from report by W. W. Leach.)

The Shegunia River (Salmon river) coal area is situated on the east bank of the Skeena river, 2 or 3 miles above the mouth of the Shegunia. The limits of this basin were not traced out, but sufficient work was done to prove it to be of considerable extent. The strata, however, where exposed along the Skeena banks, are so highly flexed and faulted that it seems improbable that mining can ever be successfully undertaken unless further prospecting proves the seams to be in a less disturbed condition in other parts of the basin.

This property has been more or less prospected for some years, but never systematically. At present all that can be seen is an old shaft about 25 feet deep (now partly caved), a few open-cuts, and a cross-cut tunnel 35 feet in length which has not yet reached the coal.

At least three seams were noted, their relative position being somewhat doubtful on account of the disturbed nature of the strata. An approximate section of the coal beds, where the seams are stripped, is here given:—

	Grey shales	——
1.	Coal	2·0 feet
	Shales and sandstones	75·0 "
	Black carbonaceous shale	3·0 "
2.	Coal	2·1 "
	Sandstone and shale ... about	50·0 "
3.	Coal	5·1 "
	Grey and carbonaceous shale	

In all three seams the coal is very severely crushed, and in the case of seams 2 and 3 at least, is high in ash. Analyses of the two lower seams are as follows:—

	Moisture.	Vol. comb.	Fixed carbon.	Ash.
	%	%	%	%
No. 2 seam	1·42	18·76	58·20	21·62
No. 3 seam	1·18	20·63	57·27	20·92

No. 2 seam, non-coking.
No. 3 seam, cokes.

[1]W. W. Leach, Summary Report 1909, Geol. Surv., Can.

KISPIOX COAL AREA.[1]

(*See Diagram IX.*)

(Extract from report by G. S. Malloch.)

As has been stated, rocks of the Skeena series outcrop on the Kispiox and Skeena rivers for some 14 miles above the junction of the two rivers. Exposures of coal seams occur on both rivers, but the strata are so badly disturbed that it would be unwise to spend any money in attempting to work them near the present outcrops.

The section measured at the Big slide on the Skeena shows that there are at least five seams in the lower 1,000 feet of the series, and while the thickness of coal in them is not great, there is at least the possibility that the seams may be thicker in other parts of the field.

In the Summary Report for 1909, Mr. Leach gives an approximate section measured on the east bank of the Skeena, between 2 and 3 miles above the mouth of the Shegunia river. It contains three seams, respectively, 2, 2·1, and 5·1 feet in thickness. The writer made an examination of the west bank in 1911 for 4 miles above the Kispiox, but the strata are cut by igneous dykes and sills and only two crushed and dirty seams were seen. On the Kispiox river the strata are also badly disturbed for 5½ miles, though the strikes and dips were not so irregular as on the Skeena and there are fewer dykes and sills. At the upper edge of this disturbed area, and on the western side of the river, a tunnel has been driven for a few feet into a 3 foot seam on the north limb of a faulted anticline, and a few tons of coal hauled on the ice to Hazelton and used in a blacksmith forge. On the eastern side, a little higher up, a 2 foot seam was found and beyond that exposures are not numerous. These would indicate, however, that the beds form a rather shallow and presumably a regular basin. A bed of black bituminous shale is exposed at low-water on the bend south of Kispiox post-office, and a large

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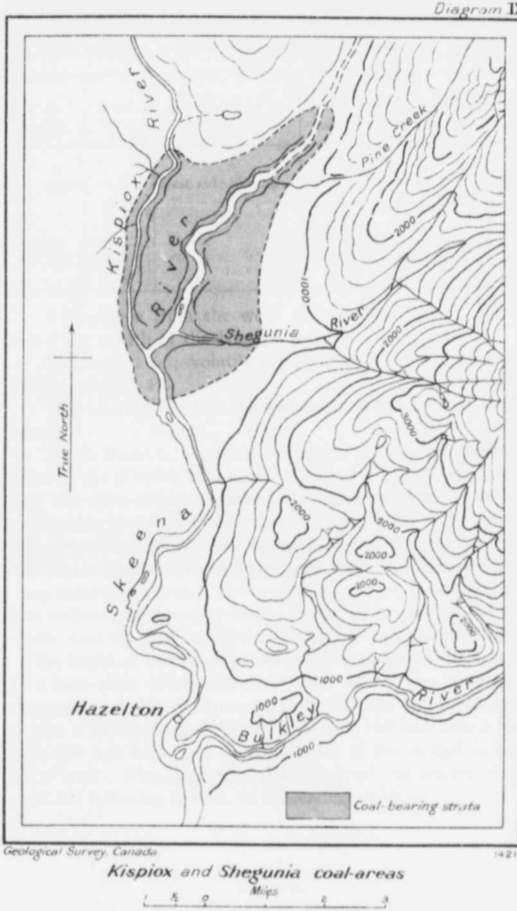
[1]Summary Report 1911, Geol. Surv., Can.

Diagram IX.



Geological Survey, Canada (421)

***Kispiox** and **Shegunia** coal-areas*

Miles

1 ½ 0 1 2 3

To accompany Memoir by D.B. Dowling

river flat a mile north of this would probably be as favourable as any for boring in the hopes of finding workable seams.

The following analyses are of the three main seams in the Big Slide section on the west side of the Skeena:—

No. in Section.	Seam.	Locality.	Moisture.	Vol. comb.	Fixed carbon	Ash.
			%	%	%	%
6 upper	1·9	West side Skeena...	1·07	20·43	51·26	27·24
9	0·65	" " ...	1·19	10·33	64·77	23·71
11	1·3					
2 lower	1·4					
4	0·9	" " ...	2·10	11·32	68·34	18·24
6	0·6					

A specimen from the west side of the Skeena, 1½ miles above the mouth of the Kispiox, gave:—

Moisture, 1·65; volatile combustible, 22·86; fixed carbon, 50·02; ash, 25·47.

This and the 5·1 foot seam above were the only coals which coked.

While there is a general resemblance between the Skeena series in the Kispiox area north of Hazelton and in the Groundhog, the differences are sufficiently pronounced to make it advantageous to describe the two areas separately. The points in common are the general yellow and brown tints of the sandstones and shales which serve to distinguish the series from the underlying Hazelton group. The sandstones of the Kispiox area are also yellow and brown in colour in the lower part of the series, which was all that could be found. Exposures are confined to the banks of the Kispiox and Skeena, and with the exception of a bare slide on the Skeena 7 miles above the junction, the exposures are widely separated and the beds too much faulted to give a satisfactory section. This slide has laid bare a face of rock 300 feet high, but the continuity of the section is broken by a fault. Measurements were made of the section exposed with the following results, in descending order:—

Big Slide Sections.

		Feet
1.	Brown sandstone grey on fracture and moderately coarse, about	70
2.	Brown shale	30
3.	Coarse yellow sandstone	8
4.	Yellow and brown shales	60
5.	Yellow sandstone	30
6.	Coal	1·9
7.	Brown shale	10
8.	Yellow sandstone	58
9.	Coal	0·6
10.	Bone and coal	0·9
11.	Coal	1·3
12.	Yellow sandstone	49
13.	Yellow and brown shales	100
14.	Coarse yellow sandstone with stringers of calcite	20
		419·7
	Fault	?

		Feet
1.	Yellow and brown shales	220
2.	Coal	1·4
3.	Bone	0·9
4.	Coal	0·9
5.	Bone	1·5
6.	Coal	0·6
7.	Yellow and black shales	25
8.	Coal with 0·4 feet bone	2
9.	Yellow shales with black bituminous bands and some brown sandstone	20
10.	Coal	1·3
11.	Similar series of shale	260
12.	Yellowish and grey shales alternating	56
13.	Black shale, bottom not seen	6
		595·6

Below the base of the lower section, exposures are missing for an interval of several hundred feet, after which the coarse, tufaceous sandstones of the Hazelton group were seen dipping under the Skeena series. The uppermost bed of these sandstones contained a number of pebbles of blue and green cherts, but these were not sufficiently abundant to constitute a conglomerate bed. As has been stated, Mr. Leach found a bed of conglomerate underlying the Skeena series, in some, but not in all the sections examined.

BULKLEY RIVER COAL AREAS.

(Extracts from reports by W. W. Leach.)

INTRODUCTION.[1]

The Bulkley river is the most important tributary of the Skeena, entering that river from the southeast about 150 miles from its mouth. The town of Hazelton, the present commercial headquarters of the district, is situated at the junction of the two rivers, at the head of river navigation of the Skeena.

Dr. Dawson in his report on "An Exploration from Port Simpson to Edmonton" (Report of Progress 1879-80) briefly reviewed the geology of part of this district; while Mr. Wm. Fleet Robertson, Provincial Mineralogist for British Columbia, visited the mineral properties of the Telkwa in 1905 (Report of Minister of Mines for British Columbia, for 1905). Apart from these reports, nothing has been written concerning the geology of this country with the exception of the summary reports, 1906-1909, and the preliminary report on Telkwa river and vicinity, by the writer.

The country is on the whole mountainous, although it is intersected by many comparatively wide and fertile valleys: such as those of the Bulkley, Kispiox river, and parts of the Skeena river and of Babine lake. The greater part of the district examined is drained by the Bulkley river, the largest tributary to the Skeena, which occupies a wide valley with many open or slightly timbered areas, which are rapidly being settled. To the south and west, the watershed between the Bulkley and the Kitseguecla and Zymoetz rivers consists of the Rochers Déboulés mountains and the Hudson Bay mountains respectively; both of these are large isolated blocks of mountains, reaching

[1]Summary Report 1910, p. 91, Geol. Surv., Can.

elevations of from 7,500 to 8,000 feet, and are cut off on all sides by low valleys.

To the east and north, the Babine range divides the waters of the Bulkley from those of Babine lake. This range reaches its greatest height to the northeast of Hazelton, the highest peaks attaining elevations of 8,000 feet. About 10 miles above Hazelton the Suskwa river enters from the east, taking its rise in a comparatively low pass (3,500 feet). Southeast of the Suskwa the Babine range reaches heights of from 6,000 to 7,000 feet; until in the neighbourhood of Moricetown (30 miles from Hazelton), a region of much lower timbered ridges is met with, gradually rising again to culminate in a group of high, rugged peaks, in which head Twobridge, Driftwood, and Cañon creeks—the chief tributaries of the Bulkley from the east—north of the Suskwa. From this point southeast the range gradually diminishes both in height and width.

The valleys of the Skeena and the Bulkley, and of the lower portions of the Suskwa and Telkwa rivers, are, for the most part, terraced, and the rivers have in many cases cut through the ancient valley floors forming secondary, deep, canyon-like channels. This is particularly noticeable on the Bulkley, which flows in a canyon for nearly 30 miles from its mouth, with a total fall of about 1,000 feet in this distance.

The country is, on the whole, well wooded, the principal trees being spruce, poplar, jack-pine, balsam, and birch, with a little hemlock and cedar.

Hazelton Group.—These rocks were originally named by Dr. Dawson the 'Porphyrite Group'; but this name has been abandoned as being somewhat misleading. Where originally met with by Dr. Dawson, in the François Lake district and on the Skeena near Kitselas, they consisted almost exclusively of porphyrites; whereas in the vicinity of Hazelton, tuffs, sandstones, and shales, are extensively developed.

Generally speaking, it may be said that to the south, this formation is built up almost entirely of flow rocks, chiefly andesites, massive, and with characteristic dark red and green colours. At the top of the series, a few thin beds of fossiliferous sandstones and shales appear, a number of fossils from which have been determined to be of Jurassic or early Cretaceous age. These are overlain directly by the coal-bearing Skeena series, so that in the Telkwa River district little difficulty was encountered in separating these two formations in the field. On travelling northwards, however, it was found that these flows gradually thinned out, and were replaced by a considerable thickness of tuffs and tufaceous sandstones, although a few of the andesite beds extended as far north as Hazelton. Locally, these tufaceous beds are known as sandstones, and where altered near the contact with intrusive masses, as quartzites. A number of thin sections of these rocks were examined microscopically by Dr. G. A. Young, and in all cases were found to be of volcanic origin.

The best section available of these tufaceous rocks is to be found in the canyon of the Bulkley, from Hazelton to Moricetown, where, although the strata are highly folded and faulted, it is hoped that a fair estimate of their minimum thickness may be obtained.

Well down in the series, and intercalated with beds of purely volcanic material, a series of sediments occur which do not exceed 150 feet in thickness, but which are of importance, inasmuch as several beds of black carbonaceous shale, with thin streaks of coal contained therein, have been mistaken for coal, and many coal claims located on them. From the evidence on hand it seems improbable that workable coal seams occur in these shales. Typical exposures of these rocks can be seen in the Bulkley canyon near the mouth of Mud creek, and about 2 miles above the mouth of Boulder creek. A few fossils were collected from these beds, but they were so imperfectly preserved that it was found impossible to identify them. The similarity of these sediments to those of the coal-bearing Skeena series, and the great amount of disturbance that the strata have been subjected to, entails very careful study before an opinion can be expressed as to the horizon of any given outcrop.

In the Babine range, at the headwaters of Driftwood canyon, and Twobridge creeks, the rocks of the Hazelton group consist chiefly of dark reddish, and greenish andesites, very similar to those seen on the Telkwa river, with this difference, however, that in the Babine they show, nearly everywhere, a certain amount of schistosity, whereas on the Telkwa they are always massive. This schistosity is also very apparent on the Bulkley river, in the neighbourhood of the mouth of Twobridge creek.

Roughly speaking, rocks of the Hazelton group underlie about four-fifths of the area under consideration, and, with the exception of the above-mentioned shales and sandstones, are, as a rule, readily distinguishable from the other formations present.

From the Morice river northward to the vicinity of Moricetown they consist almost entirely of thick beds of massive, fine-grained andesites (usually either dark red or green in colour), but with some beds of tuff. From Moricetown to Hazelton the tufaceous beds predominate; which are generally rather fine-grained, and hard, and show well-defined bedding. They are usually light in colour with prevailing greenish tints.

Skeena Series.—This series is of great economic importance, inasmuch as all the known coal of commercial value is contained therein. The strata consist essentially of rather soft, thin-bedded shales and sandstones, the former, in places, carrying many clay-ironstone nodules and holding a number of coal seams. At the base of the series there is usually found a bed of coarse, crumbly conglomerate, but this, though fairly persistent, is not always present.

Owing to the disconnected nature of the exposures and the seeming lack of continuity of the beds, a complete section of these rocks has never been obtained. It seems probable, however, that their total maximum thickness is in the neighbourhood of from 600 feet to 800 feet. A number of fossils (chiefly plant) collected at various times, have been determined by Mr. Lawrence Lambe and Mr. W. J. Wilson, and show the age of these beds to be Lower Cretaceous, and about equivalent to the Kootenay series of the Crowsnest pass.

The Skeena series is apparently conformable with the Hazelton group, and the line between them must be rather arbitrarily drawn, the coarse conglomerate already mentioned being regarded as the base of the Skeena series.

These beds occur in a number of comparatively small patches in various widely-separated localities, being folded in with the harder, underlying volcanics. These small isolated areas seem to be remnants of one or more large fields, which, owing to favourable circumstances, have escaped denudation. It is only in the valleys and low country that these rocks are now to be found, erosion having completely removed them from the higher ridges and mountains. The most important coal-bearing areas are situated on the Telkwa river and the head-waters of the Morice. Other important localities where they have been noted are on the Shegunia and Kispiox rivers, and on the Bulkley river near the mouth of Boulder creek.

Bulkley Eruptives.—These rocks, consisting chiefly of granodiorites and diorite porphyrites, have evidently played an important part in the deposition of the various mineral deposits in the district, since it is in the immediate neighbourhood of these intrusive masses that all the principal ore bodies have been discovered.

Numerous areas of these eruptive rocks are found at various points in the district, almost invariably accompanied by more or less mineralization near their contacts with the intruded volcanics. Among others examined during the past season is a comparatively small but important area situated on the head-waters of Tuchi river: a stream rising in the Babine mountains, and flowing easterly to Babine lake. It is near and along the contact of this granitic mass with tufaceous rocks and argillites of the Hazelton group that the claims of the Babine Bonanza Mining and Milling company, as well as many others, are situated. Other important areas occur on the Bulkley river near Gramaphone creek, in the Babine mountains at the head of Sharp creek, and in the Rochers Déboulés mountains at the head of Boulder and Porphyry creeks; as well as the areas mentioned in previous summary reports on the Telkwa river, and on Ninemile, Sixmile, and Twentymile mountains. The rocks of this group vary greatly in texture and appearance, but are, as a rule, rather coarse-grained, porphyritic, and grey in colour, although in a few localities pink colours prevail.

Nothing definite is known of the age of these rocks except that they are younger than the Skeena series; dykes from them cutting the coal measures at a number of places. They are here provisionally classified as Tertiary.

Tertiary Sediments.—On Driftwood creek (which enters the Bulkley about 45 miles above Hazelton), 2 or 3 miles above the Hazelton-Aldermere road crossing, a small area of soft conglomerates, sandstones, and shales occurs. Some of these beds contain many plant impressions, often well preserved, a number of which have been identified by Mr. W. J. Wilson as "clearly belonging to the Tertiary formation, and being very common in the Oligocene."

A number of seams of lignitic coal have been found in these beds, but where stripped, they are so banded with shales that it seems unlikely that they can be profitably mined.

The country in this neighbourhood being very heavily drift-covered, it was found impossible to trace the boundaries of this basin with any degree of accuracy, but its total extent is probably not more than 4 by 2 miles. The strata are usually very soft and readily-weathering, and the sandstones and conglomerates are very light in colour. In places, along Driftwood creek, the coal has evidently been burned, with the result that the clay shale, interbedded with the coal, has been baked to a hard, white, brick-like material, although at times very finely laminated.

Though unconformable with the underlying volcanics, these beds have been very highly flexed and faulted in places, although where the coal seams have been prospected the strata are nearly horizontal.

The Bulkley eruptives appear to have been the main factor in the deposition of mineral deposits in this district. All the important mineral-bearing localities are situated near the contact of these eruptives with rocks of the Hazelton group, either in or alongside of dykes radiating from the main masses, in fissures in the volcanics near the contact, or in sheared zones in the intrusive rocks themselves.

The coal seams have also been affected to a considerable degree by these rocks, as the quality of the coal appears to depend to a great extent on contiguity to these eruptive areas, becoming more anthracitic in character as they are approached. The seams have also, in places, been cut by dykes, often accompanied by faulting which will undoubtedly complicate future mining operations.

The problem of delimiting the coal areas in this district is one of extreme difficulty. The exceedingly soft nature of the coal-bearing rocks, and their consequent failure to resist erosion, has resulted in their removal everywhere from the higher ridges, only a few detached remnants remaining in the valleys. The total thickness of the coal formation being small, probably not in excess of 300 feet, and having been folded and faulted to a considerable extent, it is seen that even in the lower valleys the volcanic rocks occupy a large extent of the area, the coal-bearing beds having been removed by denudation except in the case of a few small basins where the seams at no time attain any great depth.[1]

The only natural exposures are to be found in the creek bottoms, in the few places where the streams have cut through the heavy covering of drift of the wide, terraced valleys to the bed-rock. Away from the creeks no rock exposures need be looked for until the higher ridges are reached, and these are in all cases composed of the volcanic rocks, the actual contact being almost invariably masked by drift covering. It will, therefore, require very close prospecting before the extent of the coal areas is proved.[1]

TELKWA RIVER COAL AREAS.[2]

(*See Diagram X.*)

The areas, as on the map, must be considered as showing in a general way only the extent of the basins. The exposures are all in the streams so that the lateral boundaries are not definitely known. It will be seen that the coal is found in a series of shallow troughs with a general northwest and southwest trend, there also existing a number of minor undulations within these main synclines, and numerous small faults. The extent of the largest basin northward of the Telkwa river is uncertain, as no exposures are to be seen for four or five miles north of the river. The position of the small, isolated area on Mud creek, as shown on the map, is very doubtful; no exposures could be found on that

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[1]W. W. Leach. Report on the Telkwa valley, Geol. Surv., Can., p. 14.
[2]Op. cit., pp. 14 to 18.

part of the creek, but a certain amount of drift from the coal measures was seen in the stream bed about there. It is possible that this area is an extension of and continuous with the one on Cabin creek.

It is quite probable that other small coal basins exist which are not shown, perhaps at times being completely masked by drift-covering; for example, in the stretch of country from a short distance below the mouth of Goat creek to the Bulkley river no rock exposures are to be found, but it is within the range of probability that part of it is underlain by coal.

There are, at present, four companies holding coal locations in this district, all of which have done some prospecting of a desultory nature.

Cassiar Coal Company. The Cassiar Coal company, whose property lies in part on Goat creek, a large tributary of the Telkwa river from the southwest, have stripped several seams about six miles up that stream. The following section, in descending order, was measured by the writer in 1903 when the work had just been done. Since then the cuts have fallen in, to some extent.

	Ft.	Ins.
Clay shale		
Top seam—		
Coal with a few small clay partings	12	0
Clean coal	7	7
Clay	2	0
Grey sandy shale and covered, about	30	0
Middle seam—		
Coal	1	5
Clay shale	2	7
Coal with a few irregular clay partings	14	5
Shale with ironstone nodules	3	3
Coal	2	0
Grey clay shale with nodular ironstone bands, about	50	0
Bottom seam—		
Carbonaceous shale and coal	2	0
Coal	1	5
Shale	0	5
Coal with small irregular clay partings	9	0
Clay shale		

Analyses of the above coals gave the following results:—

	Moist	Vol. comb. mat.	Fixed carbon	Ash.
	%	%	%	%
1. Lower 7 feet of top seam................	1·92	30·45	61·30	6·33
2. Lower 7 feet, middle bench, middle seam..	4·70	30·40	60·80	4·10
3. Middle bench (14 ft. 5 ins.) middle seam...	6·60	29·00	56·90	7·50

No. 3 analysis is by the British Columbia Provincial assayer (Report of Minister of Mines, B.C., 1905). No. 1 gave a dense and non-expansive coke, while Nos. 2 and 3 were non-coking. No. 3, the only one of these tested for sulphur, showed 0·52 per cent.

This coal should make an excellent fuel as it is fairly hard and well able to stand considerable handling without much loss in slack; it is, however, apparently not suited for the manufacture of coke. The strata here dip irregularly at low angles and show several small faults.

A short distance up Goat creek from these openings, in a high cut bank, what are probably the same beds are seen, but, in this case, it appears that the two upper seams have been burnt, leaving in their place thin beds of ash and slaggy material and colouring the neighbouring shales a brick red, thus forming a very noticeable feature in the landscape. A fourth seam, overlying the others, outcrops at the top of the cut bank; it shows about two feet of coal, but no regular roof was seen, the present overlying material being the gravel wash of the terrace. It does not seem probable that the burning extends over any large area here as there is no further sign of it higher up the creek, although a couple of miles down Goat creek a similar occurrence was noted.

These exposures give what is probably the best section of the coal measures in the district, about 200 feet of strata being uncovered between the creek bed and the top of the terrace, but it is by no means complete.

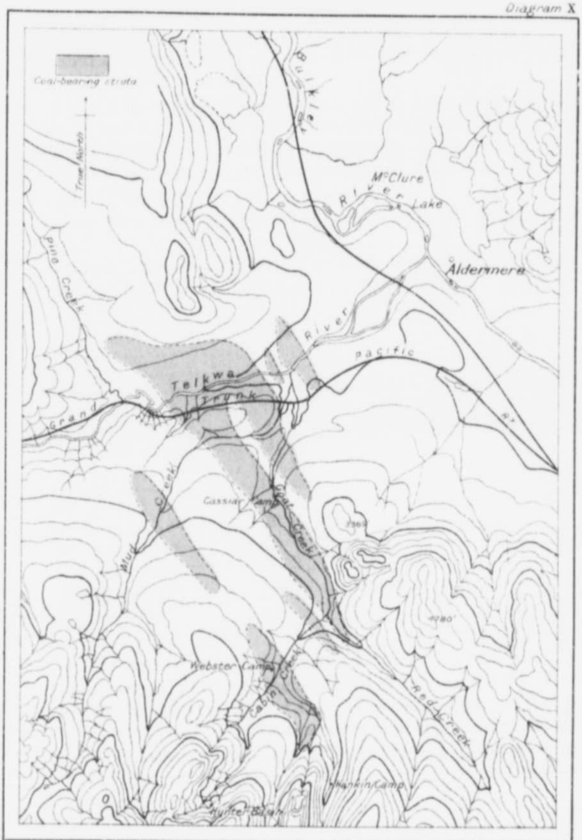
Several other coal exposures were seen on the property of this company farther down Goat creek, but no other work of any extent has been done. About a mile down Goat creek from the above-mentioned cuts a seam of impure coal is to be seen cut by a small dyke, and both dyke and coal are slightly faulted.

This company has sunk two diamond-drill bore-holes in search of coal, one at the end of the mouth of the Telkwa and the other near the mouth of a small creek entering the Telkwa about two miles above Goat creek. The first of these, said to be about 300 feet deep, was sunk in the fine-grained, sandstone-like volcanic rock described on a previous page and supposed to be of a lower horizon than the coal beds. The second was started in the conglomerate, representing the lowest member of the coal-bearing beds, and driven through to the underlying volcanics.

To the north and west of this property a number of locations are held by the Kitimat Development Syndicate. No work has been done beyond mere surface stripping at various places. On Mud creek, a branch of Goat creek from the southwest, near its mouth, and on the Telkwa river a few miles above the mouth of Goat creek, the coal has been exposed by the action of the stream; several good seams are uncovered of a nature very similar to those of the Cassiar company on the north side of the Telkwa, one seam showing twelve feet of coal with the floor below water level, but in all cases the strata are subject to faulting as elsewhere in the field.

Transcontinental Exploration Syndicate. The coal lands of the Transcontinental Syndicate are situated on Goat creek, above those of the Cassiar Coal company, and separated from the latter by rocks of the Porphyrite group, here exposed along the axis of an anticline. During the past season two prospecting tunnels have been driven, and a shaft sunk, with the intention of proving the number, size, and condition of the seams at this point. At the close of last season No. 1 tunnel had been driven a distance of one hundred and forty-six feet across the strike of the measures, the strata here dipping at about thirty degrees. Five seams had been cut in ascending order, three feet six inches, two feet eight inches, four feet nine inches, three feet and one foot, respectively, in thickness.

No. 2 tunnel, fifty-five feet in length, also cross-cutting, had passed through two seams, the lower six feet six inches, Diagram X



Geological Survey, Canada.

Telkwa River coal-areas

Miles

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To accompany Memoir by D.B.Dowling

and the upper two feet eight inches, thick. The roof of the larger seam is missing, a fault having cut through the seam here, but it is probable that this is the same bed that is shown in a natural exposure a short distance down the creek, where about ten feet of coal is in sight.

No. 2 tunnel cuts the strata at a slightly higher horizon than No. 1, and it is probable that the two upper seams in No. 1 tunnel are the same as the large lower seam in No. 2.

Near the entry to No. 1 tunnel a shaft had been sunk to a depth of thirty-seven feet to prospect the strata at a lower horizon than could be reached by the tunnels, but no coal was found.

An attempt to combine the sections afforded by these three openings shows the following results, in descending order:—

	Ft.	*Ins.*	
Shale	..	..	
Coal	2	8	
Shale	12	0	This thickness uncertain as a fault intervenes.
Coal	6	6	This seam split in No. 1 tunnel.
Shale	13	0	
Coal	4	9	
Shale	19	6	
Coal	2	8	
Shale	3	0	
Coal	3	6	
Shale	52	0	
Total	119	7	
Coal	20	1	

The coal measures at this point, being nearer to the later eruptive areas, are more highly flexed than those farther down Goat creek and evidences of faulting are abundant. Although, in all probability, the same seams are represented here as those mentioned before on the Cassiar Coal Company's land, the character of the coal is entirely different, as the following analyses show:—

	Moist.	Vol. com. mat.	Fixed carbon	Ash.
	%	%	%	%
No. 1. Seam 2 ft. 4 ins., 200 ft. down creek from No. 1 tunnel (non-coking).........	0·80	8·20	81·60	9·40
No. 2. Six foot seam of No. 2 tunnel (non-coking)............................	0·90	9·90	75·80	13·40

No. 1. Analysis by British Columbia Provincial Assayer. (Report of Minister of Mines, B.C., 1905).

This coal is firm and bright, and may be classed as a semi-anthracite, and should make a most excellent fuel of its kind.

As has already been mentioned, on the nearer approach to the newer eruptive areas the older rocks, including the coal beds, have been highly disturbed and the resultant heat and pressure have had a marked effect on the coal, altering it from a bituminous to a semi-anthracite; it must be expected, however, that more difficulties will be met with in mining, due to the probable greater frequency of faulting and increased intensity of the folding.

Grand Trunk Pacific Railway Company's Coal Lands.[1]—Considerable prospecting has been carried on by this company during 1910 on their coal locations situated on the Telkwa river and its tributaries, Mud and Goat creeks.

A number of short tunnels were run on the seams outcropping on Mud creek. The first of these (No. 1) was driven near the northeastern edge of the synclinal trough in which the coal measures lie. At the point of entry, on the southeast bank of Mud creek, the seam was nearly horizontal, but on driving, it was found to have a light southwesterly dip which, at 118 feet from the entry, brought the coal to the surface again. The seam is 3·9 feet in thickness, and is overlaid by 3 feet of shale followed by 3 feet of coal. The lower bench appeared to be good, clean, firm coal, and an average sample taken from near the face of the tunnel gave the following analysis:—

[1]W. W. Leach. Summary Report 1910, Geol. Surv., Can.

Moisture..	2·35 %
Volatile combustible matter............................	27·72 "
Fixed carbon..	60·65 "
Ash..	9·28 "

Coke firm and coherent.

No. 2 tunnel, also driven from the southeast bank of Mud creek, but about 400 yards above No. 1 tunnel, opened up a 4 foot seam of coal for a distance of 140 feet. The coal here, however, is rather severely disturbed and much crushed.

On Goat creek an attempt was made to sink a slope on a 9 foot seam of what appears at the surface to be good, clean coal. The slope was started near the level of the creek, but had to be abandoned on account of flooding.

BULKLEY RIVER COAL AREAS.[1]

On the Bulkley river near the mouth of Boulder creek, about 21 miles above Hazelton, the beds occur in the form of a shallow, synclinal basin, with a number of minor undulations, the river cutting across it diagonally. The greatest width of this trough is probably not more than 1½ miles, with a length of about 4½ miles. The only outcrops occur in the banks of the river so that it is a matter of some difficulty to define the boundaries definitely. To the north the coal-bearing beds are cut off by a granitic intrusion, while at the southern extremity there is a faulted contact with rocks of the Hazelton group. A number of small coal seams have been uncovered here and a little prospecting has been undertaken.

The Ashman Coal Mines Limited.—This company holds twelve sections of land as local locations on the Bulkley river between Boulder creek and Moricetown-Twomile creek. This area is underlaid by rocks of the Hazelton group, consisting chiefly of tufaceous sandstones, tuffs, and some andesitic flows. There are, however, several beds of shaly sandstones and carbonaceous shales with thin irregular streaks of coal, and it is due to the presence of an 11 foot bed of carbonaceous shale and

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[1]W. W. Leach, Summary Report 1910, Geol. Surv., Can.

its resemblance to coal that these lands were located. The bed in question outcrops in the deep, canyon-like channel of the Bulkley, near the mouth of Swamp creek (a small tributary of the Bulkley entering that stream about 23 miles above Hazelton), where it strikes S 18° W. with a dip of 60° NW. It is about 11 feet in thickness, has been stripped at several places, and a short tunnel driven on it from near the level of the river. The following analyses, by the Mines Branch, Department of Mines, from average samples taken at different times, will show that this can hardly be classed as a true coal; but rather as a carbonaceous shale:—

—	No. 1	No. 2	No. 3
	%	%	%
Moisture	1·91	1·73	2·04
Volatile combustible matter	10·79	12·38	10·40
Fixed carbon	20·50	37·98	23·86
Ash	66·80	47·91	63·70

All the rocks of the Hazelton group, from this point to Moricetown, are much folded, and many faults may be seen.

The Grand Trunk British Columbia Coal Company, Limited.—The property of this company, consisting of twelve claims, is situated on the Bulkley river about 20 miles above Hazelton. The coal beds of the Skeena series are here found in a rather shallow but fairly regular basin, with a total length of about 4½ miles, and a maximum width of probably not more than 1½ miles.

A number of small coal seams were stripped some years ago at the northwestern extremity of the basin, when a total of eleven seams were uncovered, ranging from 12 to 40 inches in thickness, and included in about 500 feet of sandstones and shales. The following analyses from two of the best looking of these seams proved disappointing, the percentage of ash being very high:—

	Moisture	Vol. comb.	Fixed carbon	Ash
	%	%	%	%
No. 1—15 inch seam	1·02	25·70	52·96	20·32
No. 2—18 inch seam	1·39	25·56	50·06	22·99

Coke in both cases firm and coherent.

Near the centre of the basin the company has stripped six seams, varying from 12 to 38 inches in thickness, and probably representing in part the above-mentioned seams. The strata at this point are very regular, the strike being S. 40° E, and the dip 30° to the northeast.

The following analyses, by the Mines Branch, of samples from three different seams, show an unduly high percentage of ash:—

—	Moisture	Vol. comb.	Fixed carbon	Ash
	%	%	%	%
No. 1—20 inch seam	1·12	23·70	51·72	23·46
No. 2—38 inch seam	2·15	22·03	43·66	32·16
No. 3—20 inch seam	1·36	25·18	55·41	18·05

Coke in Nos. 1 and 2 firm and coherent.

Coke in No. 3 coherent, but tender.

This coal differs considerably in appearance from that of the Telkwa river. It is very hard, is finely laminated, and shows a very distinct cleavage at right angles to the bedding planes.

Driftwood Creek Coal.—This area of coal-bearing rocks has been known for a number of years, but it was during the past season only that any claims have been located thereon. The coal seams occur in a comparatively small patch of Tertiary sediments—probably not more than 4 by 2 miles in extent—although its boundaries have not been closely defined. On part of the area the coal has been burned, baking the interbedded clay shales to a whitish brick-like material.

The Tertiary rocks are found outcropping in the valley of Driftwood creek, about 2 to 3 miles above the crossing of the

Hazelton-Aldermere wagon road. An open-cut in the bank of Driftwood creek shows this section.

	Feet
1. Grey and carbonaceous shale and a little coal	5·00
2. Fairly clean coal	1·80
3. Coal and dark shale	4·40
4. Dark clay shale and a little coal	3·60

In Nos. 3 and 4 of this section, the coal and shales alternate in very narrow beds, never more than an inch or two in thickness, the shales themselves being usually highly carbonaceous.

The analyses here given are from the 1·8 feet of clean coal (No. 2), and from an average sample from 6·2 feet of combined coal and shale (Nos. 2 and 3):—

—	Moisture	Vol. comb.	Fixed carbon	Ash
	%	%	%	%
No. 1—1·8 feet fairly clean coal	7·90	36·64	42·06	13·40
No. 2—6·2 feet banded coal and shale	7·39	31·88	28·07	32·66

In No. 1 the coke was non-coherent, while in No. 2 it was coherent but tender.

The above analyses show the coal to be of lignitic character. In picked specimens it is hard and bright, with a conchoidal fracture, but it is extremely doubtful whether a workable thickness of coal clean enough for market purposes will be found here. Several small seams varying from a few inches to one foot were noted below this one.

With regard to this field as a whole, it may be said that wherever the coal formation has been exposed faults were seen, not, as a rule, of any great size, but in such numbers as to be a matter of serious importance to future mining operations. The coal has also been cut by numerous dykes, and nearly everywhere is somewhat severely flexed. These facts, taken in connexion with the uncertain extent of several areas, seem to render it imperative that systematic and careful prospecting should be undertaken well in advance of regular mining. Some method of boring could possibly be utilized to determine the position and the nature of the strata underlying the great gravel deposits of the terraces; until something of this sort is done it will be impossible to define the limits of the several coal areas with any degree of accuracy. It is possible that in certain cases mining could be successfully carried on by stripping the overlying gravel and shales from the coal, when not of too great depth, a method that was formerly somewhat extensively utilized in the anthracite fields of Pennsylvania.[1]

Coal has been reported as occurring in the bed of a small creek entering Burnie lake from the east, and also in a small tributary of Pine creek, and it is quite possible that other small basins will be found when the country has been more thoroughly prospected.[1]

Nearly all the faults noted, especially in the coal areas on Goat and Mud creeks, were normal ones with downthrows to the south and west.[1]

COAL CREEK COAL AREA.[2]

Faulting and folding prevail at the property of the Telkwa Mining, Milling, and Development company, situated on Coal creek, a small stream running into Goldstream, one of the head-waters of the Morice river, and not far from the head of the south fork of the Telkwa river; here a number of seams of good coal have been opened up. The disconnected nature of the work done, with the disturbed condition of the strata, renders it almost impossible to be sure of the relative positions of the seams, and whether several of the openings are on the same or different seams. It is fairly certain, however, that at least four different workable seams have been uncovered. In descending order these have the following respective thicknesses: four feet two inches, four and one half feet, four feet, and seven feet three inches. Analyses of the second, third, and fourth of these seams resulted as follows:—

[1]W. W. Leach, Report on the Telkwa valley, Geol. Surv., Can., pp. 19 and 20.

[2]W. W. Leach, Report on the Telkwa valley, Geol. Surv., Can., pp. 18 and 19.

	Moist.	Vol. com. mat.	Fixed carbon	Ash
	%	%	%	%
No. 1—4½ foot seam	1·36	10·87	80·82	6·95
No. 2—4 foot seam	0·58	10·82	82·70	5·90
No. 3—7 ft. 3 ins. seam	0·80	11·10	78·90	9·20

All of the above coals are non-coking and, like those from the Transcontinental Syndicate's property, can be classed as semi-anthracite. They are all strong, bright, and lustrous.

Where these seams have been uncovered the area of coal-bearing rocks is very narrow, probably not more than a few hundred feet in width. It appears to lie on the line of, and on the downthrow side of, a fault which is parallel to, and near the axis of, a sharp syncline, and represents a small remnant of a once much larger coal-field now mostly removed by erosion. The southern boundary of this coal area was not determined and it is probable that to the south and west, in the main valley of Goldstream, a much wider belt of coal land will be found to exist.

GOLDSTREAM COAL AREA.[1]

On Goldstream, a little below its junction with Coal creek, and separated from the above area by a short distance only, a new coal area was discovered in 1907. This area, about two by two miles and one-half, at its greatest diameters, is in the form of a basin, the coal outcropping on both sides of, and from 400 to 500 feet above the floor of the valley. The coal dips towards the creek from both sides with a slope rather greater than that of the hills, so that it underlies the bed of the stream, although at no great depth.

Up Goldstream this area is separated from that on Coal creek—probably by an anticline, the coal-measures having been removed from its axis by denudation. At the lower end the limits of the coal-bearing strata are not so clearly defined, but, in all probability, the creek has there cut through the coal-meas-

[1]W. W. Leach, Summary Report 1910, Geol. Surv., Can.

ures to the underlying volcanics, this cutting being accentuated by another anticlinal fold.

The coal has been opened up at only one place, where two seams have been uncovered, the upper one showing five and one-half feet of clean coal overlain by about one and one-half feet of soft impure coaly material, the cut not having been extended far enough to locate the roof clearly. The lower seam shows three and one-half feet of clean bright coal. No analyses have as yet been made of these coals, but in appearance they closely resemble the coal from Coal creek, analyses of which have been given above. At several other points across the basin the coal outcrop was noted, but no time was available to open up the seams.

No evidences of local disturbances or faulting of any great extent were noted.

Another and smaller area was seen about two miles farther down Goldstream, but has not been opened up.

The following results are from analyses made of samples taken in 1908:—

	Moisture	Vol. comb. matter	Fixed carbon	Ash
	%	%	%	%
(1) 8 ft. seam	4·67	30·55	55·23	9·55
(2) 6½ ft. seam	6·36	28·36	58·75	6·53
(3) 3½ ft. seam	6·86	27·24	59·47	6·43

Coke: non-coherent in all cases.

All these samples were from surface coal, so that the percentage of moisture is in all probability higher than will be found at greater depth.

CLARK FORK COAL AREA.[1]

(See Diagram XI.)

Clark Fork rises with the south fork of the Telkwa, near Howson camp, in a wide, flat pass with an elevation of about 3,600 feet, thence its course is nearly due south for a distance of about 20 miles, when it unites with the main Morice river. Its chief tributaries are Starr creek, Goldstream, Gabriel creek, and a large unnamed creek coming in from the east a few miles below Gabriel creek. From the mouth of Gabriel creek down, the valley is wide, the hills on either side being comparatively low, with gentle slopes, while the grade of the stream itself is not great.

From the pass southward to about one-half mile below the mouth of Gabriel creek, the rocks met with consist of the volcanics of the Porphyrite group (underlying the coal-bearing beds), except for a short distance midway between Starr creek and Goldstream, where the basal conglomerate of the coal series crops. It appears, however, that here the coal seams have been almost entirely eroded.

A short distance below Gabriel creek, the conglomerates again outcrop on the west side of the river, for a distance of at least eight miles, that being as far south as the valley was explored. Along this stretch the river follows pretty closely the strike of the rocks, near, but usually a little west of a synclinal axis. On the west side the dip of the strata is very low, conforming more or less to the slope of the hills. Practically the whole of the coal-measures above the conglomerates has been lost by erosion. On the east side of the valley, however, the hills have a steeper slope; the dips are quite low and the synclinal axis is roughly parallel to, and some distance to the east of, the river bottom. Taking these facts into consideration, it was thought probable that an important coal basin might be found on the east side of the valley. Some days were spent, therefore, in carefully examining a number of small creeks on the east side, with the result that the conglomerates were found outcropping

[1]W. W. Leach, Summary Report 1908, Geol. Surv., Can.

Diagram XI

Geological Survey, Canada

Clark Fork coal-areas

Miles

To accompany Memoir by D.B. Dowling

at from one to one and a half miles back from the river, at elevations varying from 400 to 600 feet above it, and with westerly dips. The conglomerate here appears to reach a much greater thickness than where observed elsewhere in this country. Two distinct beds were noted, the lower about 100 feet thick, and the upper probably 30 or 40; they are separated by about 50 feet of soft sandstone. On a small creek, about one mile below Gabriel creek, and about one mile from the river, the coal-bearing shales were seen overlying the conglomerates. Two coal seams were here found, the lower one showing 3 feet of coal, with no roof, while the upper one gave the following section:—

Clean coal, 12 inches.

Shale, 4 inches.

Coal, 3 feet 6 inches.

Later on in the season this point was again visited, when it was found that during the interim Messrs. C. B. Clark and T. Howson had done considerable prospecting in the vicinity, and staked a number of coal claims. They had opened up what is undoubtedly the upper of the above-mentioned seams, at several points, showing it to be about ten feet thick and dipping to the west at thirty degrees. At none of these openings had they reached below the level of the surface waters, the coal in all cases being wet and decomposed, so that any sample taken at that time would hardly give a fair idea of the character of the coal. The seam, however, appeared to be quite regular, except at one point, where a slight local disturbance was noted.

The following analysis is from a sample taken under the conditions already mentioned. It can be confidently expected that the percentage of moisture, and probably of ash, will be materially reduced in a sample taken under more favourable circumstances:—

Moisture	10·81 %
Volatile combustible matter	31·22
Fixed carbon	48·62
Ash	9·35

Coke: non-coherent.

This area appears to be one of the largest in a district where the coal beds occur, as a rule, in small basins. Although the seams were opened up at one point only, still there is little doubt that this basin extends down to the forks of the Morice, and probably widens out below the place where the seams were stripped, at which point it is approximately three-quarters of a mile in width.

The general attitude of the strata is quite regular; the valley is wide, with an easy grade, and no serious engineering difficulties need be looked for in the construction of a branch line of railway down the Morice river, to connect with the main line of the Grand Trunk Pacific. There is a plentiful supply of timber in the valley for all future mining purposes.

CHISHOLM CREEK COAL AREA.[1]

(*See Diagram XII.*)

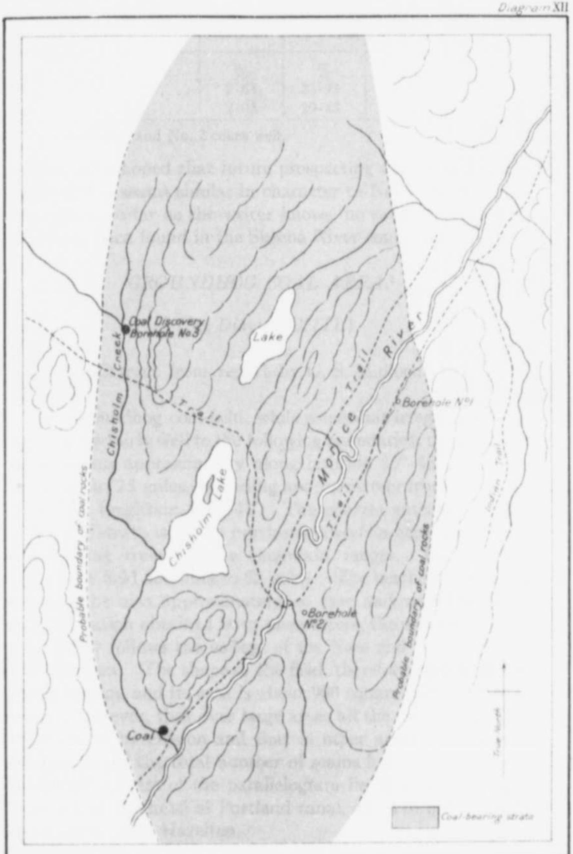
A new coal area was discovered in the latter part of the summer of 1909 on the Morice river, below those described in the Summary Reports for 1907 and 1908, and about 30 miles above the junction of the Morice and Bulkley rivers. As the season was rapidly drawing to a close, little time was available for examination of this basin. From a cursory visit, it would appear that there is quite an extensive area here underlain by the coal-bearing beds, but only one seam has so far been stripped, showing the following section:—

Grey shale	Feet
Clean coal	0·45 "
Shale	0·05 "
Clean coal	0·40 "
Shaly coal	1·20 "
Hard, blocky coal	1·40 "
Grey clay shale	2·00 "
Coal	0·80 "

Of the following analyses, No. 1 is from the lower bench (0·8 feet) and No. 2 from the cleaner portions of the upper part of the seam:—

[1]W. W. Leach, Summary Report 1909, Geol. Surv., Can., p. 68.

Diagram XII



Geological Survey, Canada 1424

Chisholm Creek coal-area

Miles

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	Moisture	Vol. comb.	Fixed carbon.	Ash
	%	%	%	%
No. 1....................	2·65	23·93	48·95	24·47
No. 2....................	2·05	29·43	57·38	11·14

No. 1 is non-coking, and No. 2 cokes well.

It is to be hoped that future prospecting will bring to light some workable seams similar in character to No. 2, as up to the present time, so far as the writer knows, no satisfactory coking coal has yet been found in the Skeena River country.

GROUNDHOG COAL AREA.[1]

(*See Diagram XIII.*)

(Extract from report by G. S. Malloch.)

The Groundhog coal-field, while somewhat irregular in outline, conforms fairly well to the following boundaries: the southern boundary runs approximately along latitude 56° 48′ for a distance of about 25 miles, extending approximately from longitude 128° 02′ to longitude 128° 41′. The general extension of the coal-bearing strata is to the north-northwest in accordance with the prevailing trend of the mountain ranges. The extreme length of the field amounts to 52 miles. The northern boundary appears to be also approximately an east and west line, and, from information obtained from prospectors, the western boundary probably follows the valleys of the Nass and the main fork of the Klappan. The shape of the field, therefore, approximates a parallelogram, and its area is about 900 square miles. It is to be noted, however, that over large areas all the coal seams have been removed by erosion and that in other areas, only a very small fraction of the total number of seams has been preserved. The nearest corners of the parallelogram lie 80 miles northeast of Stewart, at the head of Portland canal, and 110 miles a little west of north from Hazelton.

[1]Summary Report 1912, Geol. Surv., Can., pp. 69-100.

The entire region, including the coal-field and the route thereto from Hazelton, is mountainous, though the difference in elevation between the valley bottoms and the summits of the mountains varies greatly in different localities. In some cases, as in the vicinity of Hazelton, these differences exceed 7,000 feet, whereas, in other restricted areas, as for example, near the fourth cabin on the Yukon Telegraph trail, the general difference between the valley of the Skeena and the mountains is, in some cases, as low as 2,500 feet. A striking feature is that where the differences in elevation are greatest the valley bottoms are widest. With the exception of the immediate vicinity of Hazelton, the trend of the main valleys is in a general north-northwest direction, but there are many transverse valleys developed along an east-northeast direction, which are often wide and contain seams of large size. The Skeena itself partly follows transverse valleys, one near the mouth of the Babine and another for 30 miles below the mouth of Bear river. The main valleys are long extended, and in many cases contain very low divides, so that on these divides streams head which flow in diametrically opposite directions. The main valleys in the neighbourhood of these low divides do not change their general character and in passing away from their divides, their widths do not increase nor is the slope of the walls decreased. As a result of the general structure, most of the drainage carried by the main valleys is derived by tributary streams entering from transverse valleys, while the divides in the main valleys are very often occupied by lakes.

The rocks of the Hazelton group outcrop over almost the entire area along the route between Hazelton and the Groundhog field, except where small patches of the succeeding Skeena series remain or there have been intrusions of the Bulkley eruptives. In the Groundhog field, the Hazelton strata outcrop along anticlines on both sides of the Skeena-Stikine valley, and surround the field on all sides. The base of the formation was not seen, but not improbably it rests upon the Cache Creek series of Carboniferous age. The thickness of the formation must be many thousands of feet. Only the upper 2,300 feet were measured, and this portion overlies horizons which, at other points, overlie several thousand feet of the formation.

South of Hazelton, the group contains lava flows, but to the north these are generally, if not altogether, replaced by tuffs and tufaceous sandstones interbedded with black and more or less bituminous shales. In some cases the tuffs weather to reddish tints, especially in the upper part of the formation north of Hazelton; the prevailing colours are dark grey and black. The sandstones contain many rounded grains of shale similar to those with which they are interbedded. A marine horizon also occurs probably about near the base of the upper third of the formation. This horizon was recognized at many points between Hazelton and the Groundhog field and yielded poorly-preserved fossils from which the genera *Astarte* and *Inoceramus* were made out, but not the species. The amount of tufaceous material seems generally to be greater in the lower part of the formation, though near Hazelton true tuffs occur in the upper portion.

Plant remains are abundant throughout the formation, but in the majority of cases they consist of casts of tree trunks and branches. Sometimes, however, delicate leaf tissues have been preserved in the interbedded shales, and fossils found in 1911 go to show that the formation is of Jurassic age. In places, the black shales of this formation have been metamorphosed into schist and even the sandstones have in some cases developed enough micaceous material to give them a slightly schistose look. These areas of metamorphism are closely connected with lines of thrust faults which traverse the region.

The distribution of the coal-bearing, Skeena series in and adjacent to the Skeena watershed is very widespread, and the close resemblance of its characteristic conglomerates and of its fossil flora to those of the Kootenay formation of the eastern range of the Rockies, and to those of the Tantalus conglomerate and Laberge series at the head of the Yukon river, suggests that these formations were contemporaneously formed and that many more remnants may be found in the intervening territory. Mr. Cairnes has found small areas of the Tantalus conglomerate in the Atlin Lake region, and coal is reported from near Telegraph creek, and this year it was found by Mr. Taylor on the Stikine, some 25 miles below the point where it leaves the Groundhog field. In addition to the occurrence in the Groundhog field, the

Skeena series also occurs on the Sustut river from the junction with Bear river northward, and also farther south in the neighbourhood of Hazelton, where there are a number of areas underlaid by it. The most important of these areas is situated on the Telkwa river, and has been examined by Mr. Leach. He also reports areas on the Copper river, and on the Bulkley, 21 miles above Hazelton. A large area extends from the mouth of the Kispiox (7 miles above Hazelton), upstream for about 10 miles on the Kispiox and about 8 miles on the Skeena. The southern part of this area is much disturbed and is cut by many igneous dykes and small batholiths, but the northern end is more regular, and the writer suggested last year the possibility that borings might reveal the presence of seams of coal of economic value. Except on the Skeena the precise boundaries of this field could not be determined, owing to the lack of exposures.

The Skeena series consists of siliceous and shaly sandstones, black, yellow, brown, and purple shales, and beds of conglomerate, composed of partially rounded pebbles of dark blue and light green cherts, the former predominating. The conglomerates also contain fragments of undecomposed volcanic ash, and it seems probable that more or less volcanic material is scattered through the entire formation. As has been stated, the base of the formation is usually determined either by a bed of conglomerate or by a siliceous sandstone containing pebbles characteristic of the conglomerates. In the vicinity of Hazelton, over a thousand feet of the formation was measured in the big slide section which was published in last year's summary. This is much the greatest thickness reported from the vicinity. Mr. Leach places the maximum thickness at between 600 and 800 feet. In this section, the strata comprise soft yellow and light brown shales, with soft, crumbly, yellow sandstones and bands of black bituminous shale, and five thin seams of coal. At the base, there are hard grey sandstones with the characteristic pebbles, and at the top some rather coarse, thick-bedded, grey sandstones occur, which weather to a dark brown colour.

The occurrence of the coal-measures on the top of the mountains south of Blackwater lake was noted last year.[1] This

[1]Geol. Surv., Can., Summary Report, 1911, p. 78.

exposure was examined in more detail this year, and besides very thin coal seams, fossil plants, characteristic of the Skeena series, were found. The supposition that the strata in the valley to the south belong to a still higher formation was not confirmed, but, on the contrary, it was found that the coal-measures extend only for a short distance down the southern slopes and that the strata of the lower slopes of the mountain and of the valley bottom belong to the underlying Hazelton group. The formation on the mountain top shows no pebbles, though there are beds of siliceous sandstones differing in no way from those in the Skeena series. Marine fossils also occur. As the coal seams are very thin, no section was measured, but the total thickness of the formation which has escaped erosion is probably less than 500 feet.

In the Groundhog field the measured sections indicate that west of the Skeena and north of Currier creek, the Skeena series has a total thickness of over 3,900 feet. Very probably, when deposited, it was even thicker to the north and east. The strata composing the series are heterogeneous in character, but may be divided into three general classes. The first of these is composed of highly siliceous material, either conglomerates or sandstones, consisting essentially of blue and green chert grains and pebbles cemented together by a siliceous cement into extremely hard masses. Conglomerates of this character occur at the base of the formation in many places, especially at the eastern edge of the field. A comparison of the measured sections has brought out the fact that the very siliceous beds, as well as the coal seams, occur in every section at nearly the same respective horizons, whereas a considerable amount of irregularity is manifested by the other beds. Many of these siliceous beds weather to reddish tints, but are dark grey on fracture, owing to the dark blue chert. A particularly thick and massive bed of conglomerate occurring almost at the top of the section west of the Skeena, could be traced north for over 15 miles, and caps many of the highest peaks.

The remaining sandstones of the series form the second lithological group. Though often containing pebbles similar to those in the conglomerates, these sandstones are characterized by a shaly matrix, and weather to various shades of brown and yellow. Some of these beds apparently can be correlated between the different sections, but show marked changes in thickness. In some places they seem to change abruptly to shales similar to those above and below. The shales show great variation in colour. Probably black shales are the most common, but brown and yellow shales were nearly as important, and at two distinct horizons purplish colorations were noted. It seems natural to group the shales and shaly sandstones together since it appears that they may often replace each other from section to section.

The coal seams constitute the third lithological division. A comparison of the sections shows that the various horizons of many of the seams agree as closely as might be expected, considering the probable degree of accuracy of the measurements. It seems evident, however, that certain of the seams are absent from one or more of the sections, but it is to be remembered that the seams are often so deeply buried by debris that they are easily overlooked. In one case where the writer had reason to suspect the presence of a seam, it was not until a hole 3 feet deep had been dug that the first black particles were recognized in the disintegrated fragments of shales and sandstones which had slidden down over the outcrop. Furthermore, it is believed that the tendency of heavier sandstones and shales to crush down upon the seams is responsible for some of the variations in the measured thicknesses of what, in all probability, is the same seam. Where the horizon of a coal seam in one section appears to be represented in another by beds of strong sandstone there is less chance that the seam is present, though concealed, since, in all probability, in such cases the seam has been removed by erosion shortly after its formation. In several cases, members of the Skeena series contained fragments of shale exactly similar to that composing underlying beds. Many of these fragments were rounded, but others were more or less angular, as though the clay had crumbled off a cut bank and had been carried only a short distance by the eroding current before being redeposited. While in the field, Mr. Evans told the writer that he had found angular fragments of coal in such a conglomerate and apparently such occurrences are common in coal fields.[1]

An example illustrating the regularity of one of the seams is furnished by the tunnels which were driven in 1911 by Mr. McEvoy's party on Discovery creek. In the upper tunnel the measurement of the seam in descending order was[2]: coal, 1·5 feet; bone, 0·6 foot; coal, 3·9 feet; and in the lower tunnel, 3,800 feet lower down, the measurements were almost identical, viz., coal, 1·6 feet; bone, 0·4 foot; coal, 3·8 feet. Further study this year has led the author to believe that the same seam is exposed by the tunnel on Abraham creek, only 1,500 feet from the Skeena and 2 miles from the lower tunnel on Discovery creek. Here the measurements were: coal, 2·35 feet; bone, 0·5 foot; coal, 2·7 feet.

The following are the measured sections of the Skeena series arranged in descending order; the figures before each division in measured section refer to the probable depth in feet of its base referred to a common datum line which is the top of the highest bed of the first section, while the numbers succeeding refer to the thickness of each division. By this means, comparisons of the different sections can readily be made.

The first section is that on the southern edge of the Anthracite Creek cirque, and is the only one containing the highest bed. It extends downwards for 2,086 feet.

Anthracite Creek Section.

Depth. *Feet*		*Thickness.* *Feet*
90	Thin-bedded brown sandstone	90
227	Conglomerate in heavy beds	137
230	*Coal* (dirty)	3·5
363	Black shale with dirty *coal* seams	133
377	Coarse crumbly grey sandstone	14
395	Black shales	18
443	Brown shaly sandstones with fossil plants and pebbles	48
490	Conglomerate	47

[1]John J. Stevenson, "The formation of Coal beds," Proceedings of the American Philosophical Soc., vol. II, No. 207, Oct.-Dec., 1912, pp. 444-469.

[2]Geol. Surv., Can., Summary Report, 1911, p. 85.

Depth. Feet		Thickness Feet
517	Brown shaly sandstones	27
538	Conglomerate (crumbly), this thins out and is replaced by shale 300 feet to the south	21
671	Black shales with several dirty coal seams	133
726	Yellow sandstone with pebbles at base; shows crossbedding and fossil plants	55
727	*Coal* seam about	1
741	Black shale	14
764	Hard siliceous grey sandstone, weathering red	23
806	Black shales and grey shaly sandstone with some brown concretions	42
812	Conglomerate (crumbly)	6
855	Black shale and grey shaly sandstone	43
861	Greenish grey sandstone	6
924	Black shales	53
970	Greenish grey sandstone with 10 feet containing pebbles near bottom	46
1,075	Black shale and purplish shale and sandstone	105
1,076	*Coal*	1
1,214	Black shale	138
1,257	Hard siliceous sandstone	43
1,505	Black shales and beds of coarse, grey, purplish sandstones	248
1,555	Grey sandstone	50
1,628	Black shale	73
1,634	Siliceous sandstone, weathering red	6
1,676	Black shale	42
1,714	Grey sandstone	38
1,743	Black shale	29
1,748	Shaly sandstone	5
1,832	Black shale, bituminous in two places	84
1,837	Sandstone, with pebbles	5
1,911	Black shale	74
1,928	Coarse grey sandstone	17
1,981	Black shale	53
2,051	Concealed (probably black shale)	70
2,068	Coarse grey sandstone, rather soft	17
2,083	Black shale	15
2,086	Dirty coal	2·5

The second section is the same as that given in the Summary Report for 1911,[1] but is here given in a little more detail to bring out as far as possible the correspondence with the other

[1]Pp. 79 and 80.

sections. The tops of the two sections are nearly 2 miles apart, and, as they are measured on opposite limbs of a syncline, the corresponding divisions throughout the greater part of the sections are still farther apart.

Main Section.

Skeena Series.

Depth. *Feet*		*Thickness.* *Feet*
210	Massive bed of conglomerate	107
218	Brown shale	8
230	*Coal*, with 0·7 feet shale in centre	12
235	Brown shaly sandstone	5
245	Brown shale	10
248	*Coal*	3·2
272	Black shale	24
277	*Coal*, with 1 foot bone in centre	4·5
292	Black and brown shale	15
301	Shaly sandstone	9
309	Black shale	8
312	*Coal*	2·8
426	Brown shales and shaly sandstones, with a few streaks of *coal*	114
463	Massive bed of sandstone, with chert pebbles in lower two-thirds, shaly above	37
464	*Coal*	1
714	Black shales with a number of streaks of *coal* and ironstone concretions	250
732	Coarse sandstone soft and crumbly	8
724	*Coal* seam, dirty	2
736	Black shale	12
770	Hard siliceous sandstone, weathering red, fairly coarse in places	34
803	Black and brown shale with three thin seams of *coal*	33
804	*Coal*	1
820	Black and brown shale with ironstone concretions	16
836	Shaly sandstone	16
887	Brown sandstone with bands of calcareous shale below and chert pebbles above	51
910	Brownish shale with bands of fossiliferous ironstone concretions and streaks of *coal*	23
925	Brown sandstone, fine-grained above, with some pyrite crystals, coarser with chert pebbles below	15
941	Partly concealed, probably all brown shale	16

Depth. Feet		Thickness. Feet
947	Siliceous sandstone weathering red	6
955	Black shale	8
959	Shaly sandstone (streaks of *coal*)	4
960	*Coal*	1·3
981	Black shale	21
983	Shaly sandstone	2
985	Dirty *coal*	2·5
1,026	Black shale and shaly sandstone, with three streaks of *coal*	41
1,030	*Coal*	4·5
1,071	Black shale and a little shaly sandstone	41
1,110	Beds of soft yellow sandstone with some chert pebbles and shale bands	39
1,145	Coarse sandstone with many chert pebbles below, finer above	35
1,185	Black and brown shales, with streaks of *coal*	40
1,186	*Coal*	1·3
1,208	Black shales with streaks of *coal*	22
1,210	Coarse grey sandstone, with lines parallel to bedding planes	2
1,221	Black shales and streaks of *coal*	11
1,222	*Coal*	1·1
1,239	Black shales	17
1,240	*Coal*	1
1,279	Black shale and shaly sandstones	39
1,299	Hard siliceous sandstones	20
1,441	Black shales and brown shaly sandstones, some streaks of *coal*	142
1,660	Black shales, separated by thin beds of brown shaly sandstones	219
1,672	Coarse grey sandstone, weathering brown	12
1,693	Black shale	21
1,695	Dirty seam of *coal*	2
1,835	Black shales, with a few streaks of *coal* and some shaly sandstones	140
1,910	Sandstones, separated by a few bands of black shales	75
2,065	Black shales, with a few streaks of *coal*	155
2,067	Siliceous sandstone, weathering red	2
2,417	Black and brown shales, with three seams of *coal*, apparently under 1 foot thick	350
2,417	*Coal*	0·5
2,505	Black shale and soft shaly sandstones	88
2,551	Coarse grey sandstone, weathering yellow	46

Depth. *Feet*		*Thickness.* *Feet*
2,601	Shaly sandstones and black shales, with at least one *coal* seam not dug out	50
2,639	Coarse grey sandstones, separated by shales, weathering yellow	38
2,647	Shaly sandstones	8
2,688	Fine shaly sandstones and shales with streak of *coal* and fossil plants	41
2,689	*Coal* (roof fallen in, at least 1 foot)	1
2,800	Soft shaly sandstones and yellow shales with calcareous concretions	111
2,806	Coarser sandstone, showing banding parallel to bedding planes, weathers yellow	6
2,964	Black shales and shaly sandstones, partly concealed	158
3,025	Brown shales and shaly sandstones, with numerous concretions	61
3,221	Brown shales and shaly sandstones, sometimes with purplish tints. One bed with fossils and a streak of *coal*	196
3,435	Coarse sandstones and shales similar to the above, the shales predominating	214
3,460	Hard siliceous sandstone, weathering red	25
3,603	Black shale, with beds of concretions	143
3,609	Conglomerate	6
3,624	Black shale	15
3,624	*Coal*	0·4
3,697	Black shales and shaly sandstones, the shales predominating	73
3,735	Massive bed of hard sandstone	38
3,821	Brown shales, with a few beds of shaly sandstone, and streaks of *coal*	86
3,822	*Coal*	0·3
3,937	Black shales and grey shaly sandstones	115
3,944	Hard grey sandstone	7

Hazelton Group.

3,974	Black shales, with a few bands of shaly sandstone	30
4,010	Alternating beds of brown sandstone (grey on fracture, and black shale)	36
4,090	Grey sandstones and black shales, the shales greatly predominating	80
4,416	Grey sandstones predominating over black shales	326
4,452	Black shales, with calcareous concretions	36
4,458	Hard grey sandstone, cross bedded with grains of black shale	6

These two sections are correlated by means of the coal seam occurring at the depth of 230 feet beneath the very heavy bed of conglomerate. The correspondence of the beds of hard siliceous sandstones at depths of 764 and 770 feet, and 1,634 and 1,612 feet will be noticed, and that of the coal seam at 724 and 727 feet. Although the correspondence of the other seams is not established, yet it will be noted that in many cases the occurrence but not the precise position of seams were noted at corresponding depths. Thus, in the Anthracite Creek section, between depths of 538 and 671 feet, several seams were seen in black shales, and in the Main section, 464 feet to 714 feet, a number of streaks were noted also in black shale. Clearly, however, the beds of shaly sandstone, with scattered pebbles, do not correspond in the two sections, and indicate great irregularity in the distribution of these beds. The continuation of the Main section downwards is not given as the horizon is evidently below that of the important coal seams.

The following section on the southern slope of the ridge east of the forks of Trail creek is important, since there was little talus over the rocks and a large number of more or less dirty seams were found. The continuation of this section, measured in 1911, is also given, and together they cover 1,500 feet of strata, and probably the seams correspond with the great majority of those discovered throughout the field. The sections are correlated with the Main section by means of the seam occurring at the depth of 2,417 feet. The name Jackson Mountain section is introduced instead of the name, Trail Creek section, used last year.

Jackson Mountain Section.

Depth. *Feet.*		*Thickness.* *Feet*
1,137	Brown shale and rather coarse crumbly sandstone......	56
1,197	Blue shale, with plant remains........................	10
1,207	Soft yellow shale..................................	10
1,210	*Coal*...	3·3
1,243	Yellow sandstone..................................	33
1,244	Bituminous shale..................................	1
1,261	Black shale..	17
1,266	Crumbly sandstone, with some chert pebbles..........	5

Depth. Feet		Thickness. Feet
1,335	Yellow shale, with bed of black shale near top.........	69
1,341	*Coal* seam (dirty)................................	6
1,429	Brown flaky shale..................................	88
1,432	Bituminous shale...................................	3
1,457	Black shale..	25
1,456	Dirty *coal*.......................................	1
1,592	Black and brown shale..............................	134
1,612	Hard siliceous sandstone...........................	20
1,682	Black shale..	70
1,683	*Coal*...	1
1,698	Black shale..	16
1,709	Thin-bedded, shaly sandstone.......................	10
1,835	Yellow and black shale.............................	127
1,883	Rather coarse grey sandstone.......................	47
1,924	Black shale..	41
1,926	*Coal* seam (dirty)................................	1·8
1,988	Yellow and black shale.............................	62
1,991	*Coal* seam (dirty)................................	3·1
1,994	Black shale..	3
2,044	Yellow shale.......................................	50
2,048	*Coal* seam (dirty)................................	4·2
2,064	Yellow and black shales............................	16
2,088	Thin-bedded grey sandstone.........................	24
2,089	*Coal*...	1
2,102	Black and brown shale..............................	13
2,144	Crumbly yellow and brown sandstone.................	42
2,145	*Coal*...	1
2,150	Black shale..	5
2,171	Rather coarse sandstone, massive in centre, but rather shaly above and below..........................	21
2,195	Black shale..	24
2,199	*Coal* (dirty).....................................	4
2,273	Black shale..	74
2,292	Yellow sandstone, very shaly below, more massive above	19
2,314	Black shale..	22
2,335	Yellow shaly sandstone.............................	21
2,350	Black shale..	15
2,351	*Coal*...	1
2,366	Concealed, probably black shale....................	15
2,403	Heavy beds of shaly sandstone, weathers yellow.......	37
2,413	Black shale..	10
	Coal, not dug out................................	
2,398	Massive grey sandstone, weathering yellow............	21

Depth. Feet		Thickness. Feet
2,413	Black shale	15
2,417	*Coal*	4·3
2,420	Black shale	3
2,438	Massive grey sandstone, weathering yellow	18
2,454	Black shale, partly concealed	16
2,455	Dirty *coal*	1·4
2,497	Black shale	42
2,501	*Coal*	3·5
2,511	Black shale	10
2,538	Grey sandstone, weathering yellow	27
2,555	Black shale, slightly arenaceous above	17
2,601	Partly concealed, probably all black shale	46
2,605	*Coal*	3·6
2,607	Black shale	2·5
2,608	*Coal*	0·9
2,623	Light yellow shaly sandstone	15
2,666	Black shale, with a few thin beds of sandstone near top	43
2,671	Coarse yellow sandstone	5
2,710	Partly concealed, probably all black shale	39
2,713	Shaly sandstone	3
2,755	Black shale rather arenaceous in places	42

The following correlations seem to hold between the Jackson Mountain, Main, and Anthracite Creek sections.

Jackson Mountain section.	*Main section.*	*Anthracite section.*
1210—Coal 3·3 ft.	1222—Coal 1·1 ft.	....
1266—Sandstone with pebbles, 5 ft.	1299—Hard siliceous sandstone 20 ft.	1257—Siliceous sandstone, 43 ft.
1612—Hard siliceous sandstone, 20 ft.	....	1634—Hard siliceous sandstone, 6 ft.
1683—Coal, 1 ft.	1695—Coal, 2 ft.	....
2089—Coal, 1 ft.	....	2085—Coal, 2·5 ft.

A general correspondence in the broader details will further be noticed between the sections, though individual beds often do not correspond. The Jackson Mountain section is situated 8 miles southeast of the Main section.

From a comparison of the sections and of the strata throughout the basin, a subdivision of the Skeena series may be made into four groups. The depths assigned to each are taken from the sections; possibly the thicknesses vary in different parts of the field.

GROUP 1.

Depth.	
0–1300	Heavy conglomerate beds, hard siliceous sandstones, shaly sandstones, often with chert pebbles, usually yellow or weathering yellow, brown and black shales and coal seams.

GROUP 2.

1300–2300	Essentially a succession of black, brown, and purplish shales, with subordinate beds of coarse, crumbly, grey sandstones, weathering brown, a few siliceous sandstones and shaly sandstones, with chert pebbles and numerous seams of very dirty coal.

GROUP 3.

2300–3000	A series of yellow and brown shales and grey shaly sandstones, weathering to yellow colour. These are interbedded with black shales and coal seams.

GROUP 4.

3000–3950	Coarse, crumbly sandstones and brown, black, grey, and purplish shales, also beds of hard siliceous sandstones, conglomerates, and a few coal seams.

It will be noticed that all these groups are coal bearing and that black and brown shales and shaly sandstones are common to all. The coarse, crumbly, brown-weathering grey sandstones and associated purplish shales, are characteristic of the groups 2 and 4, while shaly sandstones, weathering to yellow tints, yellowish brown shales, and well preserved plant fossils are characteristic of groups 1 and 3. These two latter groups also contain the cleanest coal seams. Group No. 4, where it occurs in the range bounding the field on the northeast, contains a much greater proportion of conglomerate beds than in other localities, and associated with the conglomerates are a large number of marine fossils, while a tendency towards a calcareous cement was noticed both in the sandstones and conglomerates. These factors suggest that the strata here were laid down along the seaward margin of a delta which was subjected to many ingressions of the sea. In group No. 2, a few marine shells occur, both in the valley of Moss creek and in that of the Skeena, but west of this valley no marine shells were found. Probably the heavy bed of conglomerate near the top of group No. 1 which extends northwest for 15 miles, represents a further advance of the sea westward.

Because of the similarity of individual beds throughout the different subdivisions of the Skeena series, and the absence of good horizon markers, it is impossible to at all sharply define the areas in which the different groups outcrop, and the task is rendered all the more difficult by the complicated geological structure which holds throughout the field. The following is, however, a general outline of the distribution of different groups.

Group No. 4.—This group outcrops along the southwestern slope of the range bounding the field on the northeast; on the top of the range between the longitudinal valleys of Moss creek and the Skeena; and on the limbs of an anticline which crosses Currier creek about 5 miles from its mouth and runs northwest across Beirnes creek a little below the main north fork. The occurrence of the Hazelton group along the axis of this anticline has already been noted, and a narrow strip of the same formation also occurs on the northwest face of the range between Moss creek and the Skeena.

Group No. 3.—This group is the most widely distributed group in the Groundhog field and occupies the greater part of the longitudinal valleys of Moss creek and the Skeena, as well as the uplands between the range east of the Nass and the anticline mentioned in the preceding paragraph. In the northern part of the field, Klappan mountain and the transverse valley of the east fork of the Klappan are underlain by wide belts of strata of this group.

Group No. 2.—This group is an easily eroded formation, and although the lower beds overlie those of group No. 3 at many points in the valleys, it is probable that a considerable thickness is represented only about the areas where the succeeding group No. 1 occurs. The best exposures were seen on the eastern slope of Table mountain, south of the valley of Langlois creek.

Group No. 1.—The lower beds of group No. 1 cap both Jackson and Table mountains and the range west of the Skeena longitudinal valley, where the greatest thickness of the formation was seen, and may occur at a few other points. Between Currier and Anthracite creeks the lower beds extend down the eastern slopes of this range, and near the mouth of Currier creek they cross the Skeena for a short distance. North of Anthracite creek the group seems to occur only near the summits of the range, but its extent westward was not determined in the area lying north of Beirnes creek where possibly it may be present in a broad strip.

The metamorphism noted in connexion with the Hazelton group is also apparent in the rocks of the Skeena series, but more particularly in the vicinity of numerous fault lines and in regions of close folding. Not only is schistosity set up in the shales but the sandstones are often so thoroughly cleaved that the secondary planes so produced have been mistaken for bedding planes. In many cases the coal seams are so much crushed as to be reduced to powder. Quartz veins and veinlets traverse the sandstones and particularly the uncrushed coal seams, in various directions, and in some cases one or more series of fractures intersecting and offsetting each other have been filled with veinlets of quartz. Some veinlets of calcite also occur, but they are less common.

Bulkley Eruptives.

The Bulkley eruptives form huge batholiths in the vicinity of Hazelton and for some distance north of it but do not occur in the Groundhog coal-field. The Rocher Déboulés, Hudson Bay mountains, Babine range, and others of the higher mountains are largely composed of these rocks, and their jagged crest lines are due to the resistance which the igneous rocks offer to erosion. These rocks are obviously younger than the Skeena series, for numerous dykes and small batholiths cut through that series on both the Skeena and Kispiox rivers.

In 1911, only a few specimens of invertebrate fossils were found. Dr. Percy E. Raymond determined *Mactra utahensis.*

In 1912, when the eastern portion of the field was visited, a larger collection was made, and Dr. T. W. Stanton has determined:—

Lima sp.
Ostrea, sp. 1.
Ostrea, sp. 2.
Cardium ? sp.
Pleuromya ? sp.

The invertebrate fauna appears to contain no species described from well-determined horizons.

North of the intrusions of the Bulkley eruptives, in the vicinity of Hazelton, the strata of the Hazelton group strike, with but few exceptions, to the northwest and the prevailing dips are to the southwest. The dips to the northeast which occur are usually at high angles, thus representing in places the steeper limbs of symmetrical anticlines. In the great majority of cases, however, the northeastern sides of the ridges are probably composed of a succession of overthrust blocks, each accompanied by folding which is of such a nature as to point to the development of the faults from folds overturned towards the east. In one case no fewer than three such fault lines were observed between the crest of a ridge and timber-line on its eastern slope, and evidences of similar faults were seen in the valleys of many streams tributary to the Skeena. In wooded country the occurrence of a strike fault is very difficult to detect unless the geological section has previously been worked out in detail, and since this was manifestly impossible in travelling from Hazelton to the Groundhog field, the author's belief in a succession of faults on the eastern slopes of the range rests partly on inference.

In the vicinity of Hazelton the strata show an upbowing about the edges of the batholiths, and as these igneous masses are usually elongated in a general east and west direction, many of the strikes at Hazelton are quite discordant with those which prevail over the greater part of the area traversed en route to the Groundhog field.

The geological structure of the Groundhog field is complex and is difficult to describe. In general the strata appear to lie in folds overturned to the northeast and whose axes strike about northwest. As a result of the structure the strata, in general, dip to the southwest, though locally the measures dip to the northeast. The main folding in many places is complicated by minor folds and crumples. The intricate structure due to the folding has been further complicated by pronounced faulting. The faults, in general, strike about north 60° west and appear to be in most cases of the nature of thrust faults by which blocks of the recumbent folds have been thrust northeastward.

There is a somewhat close correspondence between the main topographic forms exhibited in the field, and the geological structure. Four mountain ranges are present in the district and strike northwest parallel with one another and with the three longitudinal valleys that traverse the district. The most easterly of these ranges forms the northeast slope of the Moss Creek-Kluayetz longitudinal valley. The next range to the west lies between the Moss Creek-Kluayetz and the Skeena-Stikine longitudinal valley; the third range borders the Skeena-Stikine valley on the southwest; the fourth range borders the Nass longitudinal valley on the northeast and is separated from the third range by a depression.

Each of these four ranges has, in places at least, broad summits cut by deep transverse cirques. The bounding slopes are steep, and each range presents the same broadly developed geological structure. In each case the southwestern slopes consist of strata of the two lower groups of the Skeena series, dipping to the southwest at angles of 30° to 40°. These measures appear to form the western limbs of overturned anticlines. On the summits of the ranges, strata of the lower portion of the Skeena series are exposed also, but dip and strike in various directions and, as a rule, with much lower angles of dip. These measures presumably lie close to the plane of the main anticlines expressed by the ridges, but are, in general, separated by thrust faults from the more regularly dipping strata on the southwestern slopes of the ranges.

The irregularly dipping strata of the summits are in their turn thrust northeastward over another fault block which in the case of the range lying east of the Moss Creek-Kluayetz valley, belongs to the Hazelton group which outcrops along the northeastern border of the field and marks, in a general way, the position of the main anticlinal axis of this range. In the case of the next mountain range to the west, lying between the Moss Creek-Kluayetz and the Skeena-Stikine valleys, the position of the main anticlinal axis is indicated in part by outcrops of the Hazelton group occurring along a sinuous band, striking to the northwest along the northeastern slopes of the range. The third major anticlinal expressed by the range bordering the Skeena-Stikine valley on the west, is also indicated by an irregular band-like area of the Hazelton group striking to the northwest along the southwestern summit of this range. The fourth major anticlinal axis, developed in the lower strata of the Skeena series, follows the southwestern side of the summits of the range bordering the Nass valley on its northeastern side.

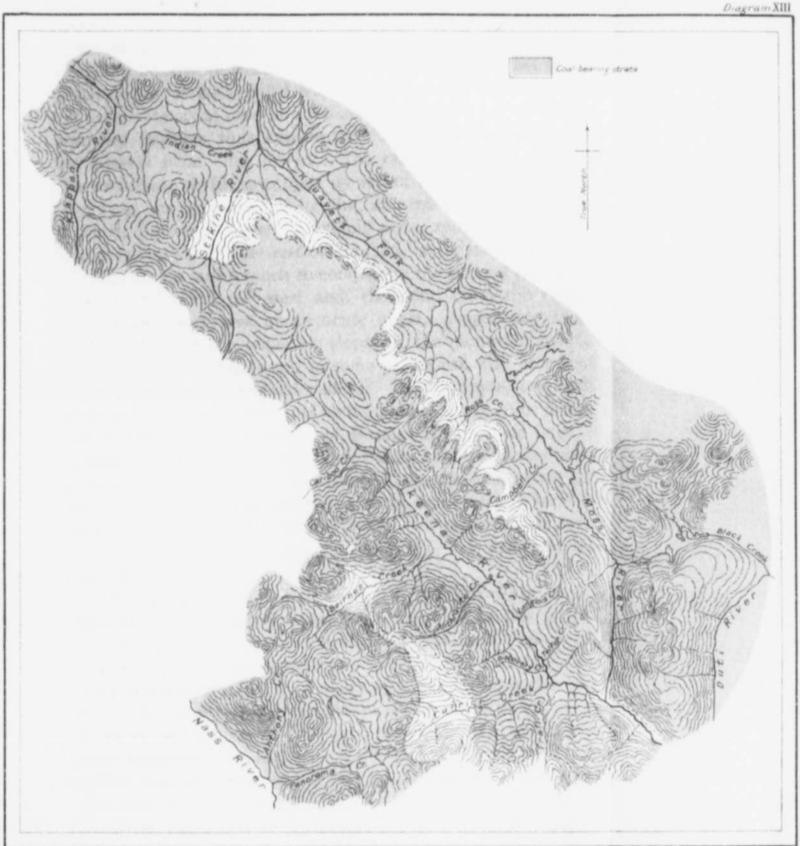
The northeastern slope of the anticlinal range bordering the field on the east was not visited, but presumably exhibits the same general structures believed to be present in the three parallel ranges lying to the west within the limits of the coalfield. In the case of these three main ridges on their northeastern slopes below the major anticlinal axes, the strata belonging to various divisions of the Skeena series dip in general to the southwest, and apparently form the eastern overturned limb of the major anticlines, but these measures are also traversed by thrust faults and furthermore in places at least are bent in major or minor synclines.

The four mountain ranges are thus believed to represent, in a general way, overturned major anticlinal folds deformed by thrust faults and minor crumples and folds. The three main, longtitudinal valleys and the parallel depressed area lying between the Skeena-Stikine and the Nass valleys, are believed to mark, in an analogous fashion, the positions of the major synclines along which, in general, the strata are less steeply inclined than on the limbs of the folds. These synclinal portions are doubtless bounded by thrust faults and are deformed by minor crumples and folds, but the geological structures are not clearly exposed in these overlying areas where drift and forest growth hide the bed-rock.

Geological Survey, Canada

To accompany Memoir by D. B. Dowling

Diagram XIII



Geological Survey, Canada

1425

Groundhog coal-area

Miles

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To accompany Memoir by D. B. Dowling

The above description gives, in a generalized fashion, an outline of the major structural features of the field. But, owing to the presence of minor crumples and folds and perhaps more especially because of the presence of the numerous thrust faults which do not strike parallel with the main axes of folding but cut across the axial lines at an acute angle, there are many exceptional features that apparently do not correspond with the general plan. For instance, the range lying west of the Skeena-Stikine divide is capped by strata of the highest group (No. 1) of the Skeena series forming an area 4 to 6 miles wide, in which the strata generally exhibit a flat synclinal structure, but, in common with the rest of the field, are crossed by faults.

The thrust faults which so complicate the general structure, strike about north 60° west and, therefore, cross the ranges which strike northwest at an acute angle. Apparently these faults as seen on the bounding slopes of the mountain ranges, extend across the ranges and in some places can also be traced across the main longitudinal valleys. For example, two fault lines can be distinctly seen just above timber-line on Alec mountain, northwest of the mouth of Beirnes creek. One fault is exposed in the strata on the creek banks about 2½ miles from its mouth and two faults cross the Skeena, one just above the mouth of Langlois creek and the other at the apex of a bend to the west, about 2,000 feet farther down. A sharp fold or fault occurs on Telfer creek in such a position that it is nearly in line with these other points.

The emergence of fault lines on the western slopes of the ridges was not definitely recognized except at a few points, but at some points where the continuation of fault lines might be expected, the topography shows irregularities as though the steeply dipping beds had been displaced. For example, the contours of the range east of the Skeena swing more to the north just below the mouth of Cariboo creek and then back again farther upstream. A fault to which this offsetting might be ascribed, was seen near timber-line on the mountain northwest of Cariboo creek and could be traced for a long distance on the crest of the range east of the Skeena. The irregularities resulting from the fault blocks on the northeastern sides of the ranges are much more pronounced, for here the strata affected are much flatter and hence there is much more lateral displacement of the hard beds. The range west of Moss creek from the pass at the head of Langlois creek, north to the Kluayetz fork, exhibits two well defined re-entrants and the faults thus expressed by the topography were seen in the field. In the range west of the Skeena, at least one well-marked re-entrant occurs, at the apex of which is the transverse valley of Beirnes creek, and in this case, again, a fault was seen.

In nearly all cases the faults are marked by steeply dipping beds striking approximately parallel to, but in reality a little to the north, of the direction in which the faults extend. As has been stated, this direction is about north 60° west. The steep inclination of the beds seems to be due to the drag effect of the faulting and the beds near the fault lines exhibit the pronounced metamorphism which has been described. In many cases where coal seams occur in this steeply inclined strata, the coal is crushed to powder and intimately mixed with fragments of shale as though there had been differential movement between the beds on either side.

The structural features which have so far been described pertain to the whole Groundhog field except near its southern and northern ends.

The structure of the portion of the field south from a line joining the mouths of Anthracite and Anthony creeks, exhibits important modifications. Except in the vicinity of the fault lines, the strata in the mountains south of the Currier Creek transverse valley dip to the north at angles of from 20 to 30 degrees. This northerly dip is reduced to about 10 to 20 degrees in the transverse valley and a short distance north of it the general dip is changed to the south but at low angles. These southerly dips extend as far as Anthracite creek with only a few exceptions and, even in the rest of the basin, it appears that the flattest strata on the axes of the synclines exhibit, as a rule, southerly dips.

The fact that the strata in the greater part of the field remain at about the same horizons is explained by the overthrust of the oblique faults. South of Anthracite creek, however, where the southerly dips are pronounced, the lower beds of the highest group of the Skeena series make their appearance both in the Skeena valley and on Table mountain east of it. The fact that still higher beds are not seen there is due to the faults, three of which at least were observed on the Skeena, each with upthrow to the south-southwest.

Another modification of the geological structure at the southern end of the field is the fact that the fault lines which were nearly straight, striking north 60° west in the central portion of the field, are bent to a more nearly east and west direction in the southern portion. One of these faults could be traced on the northern faces of the mountains south of Currier creek for nearly 7 miles and it swings around until its strike is north 78° west. As the overthrust block is composed of strata far down in the Hazelton group, this fault line forms the boundary of the field for this distance.

Another feature of the southern end of the field is the occurrence of a large area of easterly dipping strata on the crest and eastern slopes of the mountain northwest of the mouth of Currier creek. It also seems likely that in this area, the faults which occur have small throws.

The writer's time in the northern border of the field was limited, but apparently the structure there is analogous to that of the southern end. The rocks in the range running west from the east fork of the Klappan, dip at about 30 degrees to the south and on Klappan mountain an inclination to the north was observed, features which correspond with the dips south and north of the Currier Creek transverse valley. Two well defined fault lines were also seen, and apparently these also bent rather more to a westerly direction on the bordering range.

The main economic interest in the geology of the district examined, is centred in the coal seams occurring in the Groundhog field.

The following seams were reported by Messrs. Beaton and Kobes on their sketch map to which reference has already been made. On the Nass river they saw float coal in two places; on Panorama creek a 3 foot and a 6 foot seam, and similar seams in the mountain southeast of the mouth of Panorama creek. On the mountain between the south branch of Panorama creek and the head-waters of Beaton creek (a tributary of Sowmalda creek) they report a 20 foot and a 12 foot seam, and a 6 foot seam on the head-waters of Beaton creek. Near the mouth of Anthony creek they found a 3 foot seam, near the head of Beirnes creek, a 12 foot and 16 foot seam, and farther down, near the mouth of the second tributary from the north, a 6 foot seam. On the head-waters of Meadow creek, a large tributary of Currier creek from the north, they discovered two 4 foot seams and a 6 foot seam. Besides these seams, whose thicknesses they determined, they found coal wash in a great many other places. The writer also saw much evidence of coal but actually measured only three seams in this area. The first of these was on the first large tributary of Panorama creek from the south. It outcrops on the northern bank about 200 yards south of the mouth of the stream, and 70 feet above it. The thickness of this seam is 4½ feet and it strikes 118° and dips 42° to the northeast. One 8 inch seam occurs at the stream level below this. The rocks in this locality are much crumpled. On the main south fork of Anthony creek, measurements were made of the following seam in descending order:—

Coal	2·95 feet
Bone	1·00 feet
Coal	2·25 feet
Bone	0·75 foot
Coal	0·9 foot
Total	7·85 feet
Total coal	6·1 feet

A sample was taken omitting the bone and quartz stringers, and an analysis by Mr. F. G. Wait gave the following results:—

Moisture	4·09%
Volatile combustible matter	8·48 "
Fixed carbon	46·29 "
Ash	41·14 "

The high percentage of ash is due to fine lamellæ of bone occurring in the coal. The seam strikes 76° and dips to the south at 17°. It is probable that this seam belongs to the group

No. 2 and that nearly all the other seams in this portion of the field belong to group No. 3, but the want of continuous exposures made it impossible to determine the exact horizons. A picked sample from the 12 foot seam on the mountain between the south branch of Panorama creek and the head of Beaton creek, given to the writer, was analysed last year,[1] with the following results:

Moisture	3·83%
Volatile combustible matter	8·80 "
Fixed carbon	82·98 "
Ash	4·39 "

From a comparison with the other seams the writer doubts whether a sample across the entire seam would yield nearly so low a percentage of ash.

On the ridge east of the junction of the three forks of Trail creek, the seam occurring at the depth of 1,210 feet in the Jackson Mountain section was sampled and the results of Mr. Wait's analysis is as follows:—

Moisture	10·16%
Volatile combustible matter	23·73 "
Fixed carbon	45·79 "
Ash	20·32 "

This seam is 3·3 feet in thickness and has been weathered. Near the summit of the ridges south of Jackson mountain and west of the summit of the Groundhog pass, a seam measuring 6·2 feet was sampled and the following are the results of the analysis, also by Mr. Wait:—

Moisture	10·52%
Vol. comb	22·15 "
Fixed carbon	40·81 "
Ash	26·52 "

This seam strikes 127 degrees and dips 40 degrees to the south and is very near the fault line by which the rocks of the Hazelton group have been overthrust so as to form the southern boundary of the field. This seam probably belongs to No. 2 group. As has been stated, no close examination was made of the

[1]Summary Report, 1911, p. 89.

seams belonging to the British Columbia Anthracite Company holdings, but some facts were gathered in their property both on Currier creek and on the Skeena. Currier creek was examined from the mouth of Canyon creek, a small creek entering it from the south about 4 miles up. Near this creek the strike is 124 degrees and dip 20 degrees to northeast. A coal seam 2 feet in thickness occurs a short distance above the mouth of Canyon creek, and on Canyon creek a dirty seam designated as 'C1' is exposed on the south bank. Between this point and a point a mile above the Skeena, the abrupt changes in dip and strike of the strata indicate four faults besides numerous crumples. The 'C1' seam was seen again farther down, also two other seams, one with 3 feet of fairly clean coal and another with 2 feet of coal overlying 2 feet of bone. All these seams probably belong to group No. 2. The two seams mentioned last are on the property of the Western Development company. Other seams on the property of the British Columbia Anthracite company were found on the Skeena below the mouth of Anthracite creek. In lot 2190, a seam 4 feet 7 inches thick was measured, and it is repeated twice farther down owing to faults as the dips are to the south at low angles. Abrupt changes in strikes also occur. The occurrence of a 3·4 foot seam on the north slope of Jackson mountain and 2·65 miles south of the mouth of Currier creek was mentioned in last year's Summary (page 87). It is just within lot 985.

The most important seams on the property of the Western Development company, if not the most important seams in the entire field, outcrop on Discovery creek; the lowest 2¼ miles from its mouth and the other 3,800 feet higher up. The measurements of these seams have already been given. In the upper tunnel they are: coal, 1·5 feet; bone, 0·6 foot; coal, 3·9 feet; and in the lower: coal, 1·6 feet; bone, 0·4 foot; coal, 3·8 feet. At the higher tunnel the strike is 151° and the dip 19° to the northeast, and at the lower the strike is approximately parallel but the dip is only about 5° in the same direction. The following analyses of the coal from the two tunnels are taken from the Summary Report for 1911, and the result of an analysis by Mr. Wait of a sample taken by the writer this year is added.

Locality	Sampler	Moist.	Vol. comb.	Fixed carbon	Ash
		%	%	%	%
Upper tunnel.....	McEvoy...	2·62	6·96	84·49	5·93
Lower tunnel.....	McEvoy...	1·17	6·54	83·37	8·92
Lower tunnel.....	Malloch...	2·88	7·64	78·84	10·64

In both cases not only the band of bone but all quartz stringers and nigger-heads were rejected in taking the sample. The amount of quartz and nigger-heads exposed at the face of the lower tunnel was measured. The tunnel face measures 5·7 feet horizontally and 5·5 feet vertically. It is crossed diagonally by a quartz stringer with an average width of 1 inch and three parallel stringers, 2 with widths of ¼ inch and one with width of ⅛ inch. Two stringers occur in bedding planes near bottom, each with a width of ¼ inch, and two stringers each two feet long are present in the lower left hand corner cutting bedding planes at low angles; these also average ¼ inch in width. The three-tenths of a foot streak of bone has already been mentioned. Nigger-heads of the following dimensions occur, one, 3 inches by 2 inches, one 4 inches by ¾ inch, and one 2·6 feet by 2 inches extending beyond the face. Considering the quartz and nigger-heads 1½ times as heavy as the coal, they would amount to twenty per cent of the total tonnage from the seam, and omitting the band of bone three-tenths of an inch in thickness which could easily be separated in mining the coal, there would remain about ten per cent of quartz and nigger-heads. If, as experience in some other regions seems to indicate, the nigger-heads are chiefly surface occurrences, then, under mining conditions there would remain about 7 per cent of quartz occurring in veins provided the exposure of the seam in the tunnel face furnishes a fair average of the amount of quartz present.

What is almost certainly the same seam, outcrops on Abraham creek, a small tributary which enters Currier creek very near the Skeena. The measurements of this seam are as follows: coal, 2·35 feet; bone, 0·5 foot; coal, 2·7 feet. The strike is 54 degrees and the dip 16½ degrees to the north. Two analyses of samples from this seam were given in last year's Summary and a third is now available. It was made from a sample taken by Mr. W. Fleet Robertson. These analyses are as follows:—

Sampler.	Moisture.	Vol. comb.	Fixed carbon	Ash.
	%	%	%	%
McEvoy..........	1·17	6·05	76·20	16·58
Malloch..........	1·04	8·39	67·89	22·68
Robertson........	2·50	8·10	62·30	27·10

This seam is probably the same as the 4·5 foot seam at a depth of 1,030 feet in the Main section.

The big seam on Trail creek into which the 50 foot tunnel was driven, was also sampled by Mr Robertson. This seam has a total thickness of 7·6 feet but is composed very largely of bone. The analyses are as follows and in all probability different widths were sampled in each case:—

Sampler	Moisture	Vol. comb.	Fixed carbon	Ash
	%	%	%	%
McEvoy..........	1·39	5·75	63·02	29·84
Malloch..........	1·36	7·17	49·04	42·41
Robertson........	2·5	6·1	42·6	48·8

The seam strikes 133 degrees and dips 17 degrees to the northeast. What is probably the same seam was discovered and dug out on the high west bank of the Skeena about 1¼ miles above the mouth of Currier creek. The following measurements were made, and a sample taken across the seam, omitting the bone and shale nigger-heads and quartz, was analysed by Mr Wait. The following are the results:—

Bone, with some clean coal......................	1 foot 3 inches
Coal (rather dirty)............................	2 feet 1 inch
Shale..	7 inches
Coal, with many quartz stringers...............	2 feet 0 inches
Bone...	6 inches
Coal...	1 foot 1 inch
Bone with some coal...........................	6 inches
Coal...	2 feet 1 inch
Bone and some coal...........................	5 inches
Total....................................	10 feet 6 inches
Total coal sampled.........................	7 feet 3 inches

Moisture	3·84%
Volatile combustible matter	7·85 "
Fixed carbon	51·17 "
Ash	37·14 "

In taking this sample, as in all the others during 1912, no quartz nor nigger-heads were included.

The horizon of this seam is in black shale above a succession of yellow shaly sandstones and the horizon is probably the same as the 4 foot seam at depth of 2,199 feet in the Jackson Mountain section.

The outcrop of a seam 4·4 feet in width on Davis creek, near the mouth, was reported last year. The strike is about 8 degrees and dip about 21 degrees to the south. The analyses were:—

Sampler.	Moisture.	Vol. comb.	Fixed carbon.	Ash.
	%	%	%	%
McEvoy	1·40	6·06	70·68	21·86
Malloch	1·57	7·55	65·52	25·36

What is probably the same seam outcrops on the Skeena at some distance above Langlois creek and probably it corresponds with the 1 foot seam at depth of 2,351 in the Jackson Mountain section. Only a short distance above the mouth of Langlois creek, two lower seams were seen. The lower of these is on the east side and was apparently quite thick, but no accurate measurements of it could be made owing to a slide of sandstone blocks from above. A picked specimen containing a little quartz yielded the following analyses:—

Moisture	3·24%
Volatile combustible matter	7·67 "
Fixed carbon	68·92 "
Ash	20·17 "

The upper seam on the west side was measured with the following results; it was not sampled as it was evidently very dirty.

Coal	0·6 foot
Shale	0·9 foot
Coal	0·6 foot
Bone	0·1 foot
Coal	0·8 foot
Bone	0·1 foot
Coal	0·3 foot
Total	3·4 feet
Total coal	2·3 feet

The strike is 152 degrees and dip about 40 degrees to the northeast.

As in the case of the Western Development company, no work was done on the property of the British Columbia Anthracite Syndicate in 1912. The writer hoped to be able to sample the Ross seam which had not been fully dug out when he left the field in 1911. It was found, however, that the tunnel, like the others on Beirnes creek, had caved in. No satisfactory coal was seen on the dump. The analysis of the samples taken from the Pelletier and Scott seams is repeated.

	Moist.	Vol. comb.	Fixed carbon	Ash
	%	%	%	%
Pelletier seam	1·35	7·69	61·90	29·06
Scott seam	1·08	7·06	64·97	26·89

Samples of these seams taken by Mr. McEvoy showed even higher percentages of ash. The Pelletier seam sample represents 5·2 feet of coal, but the beds are disturbed and the dip is nearly vertical. The sample of the Scott seam represents 5·3 feet, omitting 0·2 foot of bone, and there were 2 feet of bone and dirty coal above. It is not impossible that the Scott seam represents the big seam on Trail creek into which the 50 foot tunnel was driven.

No satisfactory roof was found for the Benoit seam, so that no reliable measurements or samples are available, but three analyses of picked specimens from it yielded between 6 and 8 per cent ash. These seams, with the Choquette and Garneau, all occur in a shallow syncline which steepens suddenly near the outcrop of the Pelletier seam. The strike throughout the greater part is about 139 degrees and the dip as high as 26 degrees to the northeast. About a mile and a half up Beirnes creek from the Pelletier seam two seams occur. The upper showed 6 feet dirty coal, 8½ feet shale, 3 feet coal; the lower, coal, 2·4 feet, bone, 2·6 feet, coal, 5·8 feet. The strata are disturbed here and the seams may be locally thickened. It was found impossible to determine the horizons of these seams.

The lower two seams on Anthracite creek were described last year. The first showed bone and dirty coal, 4 feet, cleaner coal, 2·4 feet. The seam is much crumpled and possibly it corresponds with the seam in the lower tunnel on Davis creek. The second showed 4·2 feet of coal and would have been sampled this year, but the tunnel had caved. No. 3 was measured and sampled with the following results:—

Coal..	28 inches
Bone and dirty coal..........................	6 inches
Coal..	19½ inches

This seam strikes 92 degrees and dips 21 degrees to the south. Mr. Wait's analysis of a sample, omitting the bone and dirty coal, is:—

Moisture..	6·09%
Volatile combustible matter	13·70 "
Fixed carbon....................................	65·52 "
Ash..	14·69 "

A picked sample from it analysed last year for Mr. Campbell Johnson gave:—

Moisture and volatile combustible matter.	6·98%
Fixed carbon..........................	86·74 "
Ash..................................	6·15 "

A number of seams occur on the last branch of the Klappan, and were prospected by Mr. Grossmann's party. A much crushed seam in the disturbed belt occurs and outcrops both on Conglomerate creek and on the creek immediately east of the Indian graves. Other seams are reported on Slate creek and near the head of Indian creek. A large seam on this fork of the Klappan, about 4 miles above the graves, had been trenched by Mr. Grossmann's party and was measured and sampled with the following results:—

Coal	14 inches
Bone and dirty coal	9½ inches
Coal	32 inches
Bone	3 inches
Coal	22 inches
Bone	15 inches
Coal	29½ inches
Total	10 feet 5 inches

Total coal sampled, 6 feet 1½ inches.

More bone and coal occurred both above and below, but none of it was clean. Mr. Wait's analysis is as follows:—

Moisture	4·48%
Volatile combustible matter	9·98 "
Fixed carbon	63·48 "
Ash	22·06 "

This seam strikes 117 degrees and dips 78 degrees to north. It is in another disturbed belt and though not much crushed a 3 foot seam only about 75 feet higher up is crushed to powder, and was not sampled. What was thought to be the continuation of these seams was found in the saddle on Klappan mountain by Mr. Grossmann's party, and some pits were sunk on them.

On the mountain on the northern edge of the field, and just west of the east fork of the Klappan, two seams were measured. The lower has a thickness of nearly 3 feet, but is dirty. The other separated from the first by a fault and probably representing the top of No. 3 group, has a thickness of 3 feet 3 inches and is apparently much cleaner. A picked sample taken from it was analysed by Mr. Wait with the following results:—

Moisture	4·14%
Volatile combustible matter	8·43"
Fixed carbon	80·27 "
Ash	7·16 "

Mr. Robertson also reports the analysis of a picked sample from W. Pike seam which is as follows:—

Moisture	5·00%
Vol. comb	9·00 "
Fixed carbon	79·04 "
Ash	6·06 "

It seems probable that all the seams on Klappan mountain and in the vicinity belong to the No. 3 and No. 2 groups of the Skeena series, but the writer is not certain.

As the boundaries of the different holdings in the Moss Creek valley have not been run, the writer cannot discriminate between the different holdings there. On Campbell creek, which flows into Moss creek a short distance above Kluayetz lake, the writer found what is in all probability the same seam as the one into which the tunnel was driven near the mouth of Davis creek. It is in a disturbed condition, however, and so badly crushed that it was neither measured nor sampled. A short distance farther up (about half a mile from the mouth of the creek) the following seam was measured and sampled:—

Coal	3 feet
Bone	0·1 foot
Coal	1·1 foot
Bone	0·1 foot
Coal	1·9 feet
Total	6·2 feet

Total coal sampled, 6 feet.

Mr. Wait's analysis is as follows:—

Moisture	5·02%
Volatile combustible matter	6·38"
Fixed carbon	66·95 "
Ash	21·65 "

This seam strikes 77° and dips 34° 30′ to the north. It belongs to No. 3 group thrust over No. 2 group by the fault. Another similar fault occurs only a short distance above.

Higher up on Moss creek, just below the mouth of the next large creek from the west, another seam was measured and sampled and also, a second near the head of this creek. The results for the first seam are as follows:—

Bone and dirty coal	3·85 feet
Coal (sampled)	5·05 feet
Bone	0·5 feet
Coal	0·2 feet
Total	9·6 feet

The 5·05 feet sampled contained the following:—

Quartz stringers and bone	0·1 foot
Quartz	0·05 foot
Quartz	0·04 foot
Bone with quartz stringers	0·3 foot
Bone	0·35 foot
Total	0·84 foot

So that of whole seam, 9·6 feet in thickness, only 4·21 feet were included in sample. Mr. Wait's analysis of this sample is as follows:—

Moisture	3·40%
Volatile combustible matter	5·33 "
Fixed carbon	60·27 "
Ash	31·00 "

This seam strikes 112 degrees and dips 63 degrees to southwest. Possibly it is the same as the 50 foot tunnel seam on Trial creek.

The second seam near the head of the creek gave the following measurements:—

Coal	2·02 feet
Bone and dirty coal	2·01 feet
Coal	0·73 foot
Bone	0·43 foot
Coal	1·01 feet
Bone	0·45 foot
Coal	2·4 feet
Total	9·05 feet

Total coal sampled, 6·16 feet.

SUSTUT COAL AREA.[1]

(Extract from report by G. S. Malloch.)

The Skeena series, where examined on the Sustut, is much thicker than in the Groundhog coal-field. Fully a thousand feet of conglomerates, interbedded with brown and purplish and yellow shales, occur, and below these there is a considerable thickness of black shales and yellow sandstones, in which two seams of lignitic coal were found. The base of the formation was not seen, but undoubtedly it rests on the Hazelton group which was seen only a short distance west of the first exposures of the yellow sandstones. The pebbles of the conglomerates are only partially rounded and are scattered through the sandstones, and also occur in the shales. Much cross-bedding was seen and also many fragments of volcanic rocks, as well as the characteristic chert pebbles. These pebbles occur also as irregular lenses in many of the sandstones and in the shales interbedded with them.

The result of the writer's trip to the Sustut was the discovery of two seams of dirty coal, each 3 feet in thickness. A picked sample from the lower surface of the lower seam was analysed by Mr. Wait with the following results,

Moisture	5·40%
Volatile combustible matter	23·32 "
Fixed carbon	57·48 "
Ash	13·80 "

Mr. Geodfrey has told the writer that he found a 2 foot and a 4 foot seam in another part of the field, but was unable to furnish analyses. Since the above sample is from the surface and some of the surface samples from Groundhog resulted in somewhat similar analyses, viz., the 3 foot seam near summit of Jackson mountain the analysis of which is as follows,

Moisture	10·16%
Volatile combustible matter	23·73 "
Fixed carbon	45·79 "
Ash	20·32 "

[1]Summary Report 1912, Geol. Surv., Can., pp. 78, 100-101.

it is not certain that the coal is a true lignite, as the analyses might prove had the sample been taken from a tunnel. The writer, however, is of the opinion that the coal is lignitic in character since the firmer portions of the seams gave a brown powder when struck with a shovel. As the conglomerates overlying the coal form a mountain ridge extending both to the northwest and southeast, it is evident that the field must be a large one, and as it lies on the probable route of a transcontinental railway north of the Grand Trunk Pacific, the author believes that it would be a suitable one for further prospecting. The approximate latitude of this field is 56° 15′ and the approximate longitude 126° 35′.

ATLIN AREA.[1]

(*See Diagram XIV.*)

(Extract from report by D. D. Cairnes.)

No coal in place had been discovered in Atlin Mining district to October 1, 1910, but a considerable amount of float and wash coal had been found near the summit of Sloko mountains at a point to the northeast of and overlooking the lower end of Sloko lake, and a number of claims, generally known as the Sloko Lake claims, were located to cover the supposed coal seams presumed to occur in that locality. The nature of the detrital coal shows that it has come only a short distance, and Tantalus conglomerate (which wherever found in southern Yukon is associated with coal seams), is exposed immediately above the coal float; it, therefore, appears as if a small amount of work should uncover the seams from which the float is derived. As the float and Tantalus conglomerate have been found near the summit of the mountain, the seams when found, unless they can be traced down to lower, more accessible points, will not be profitably workable.

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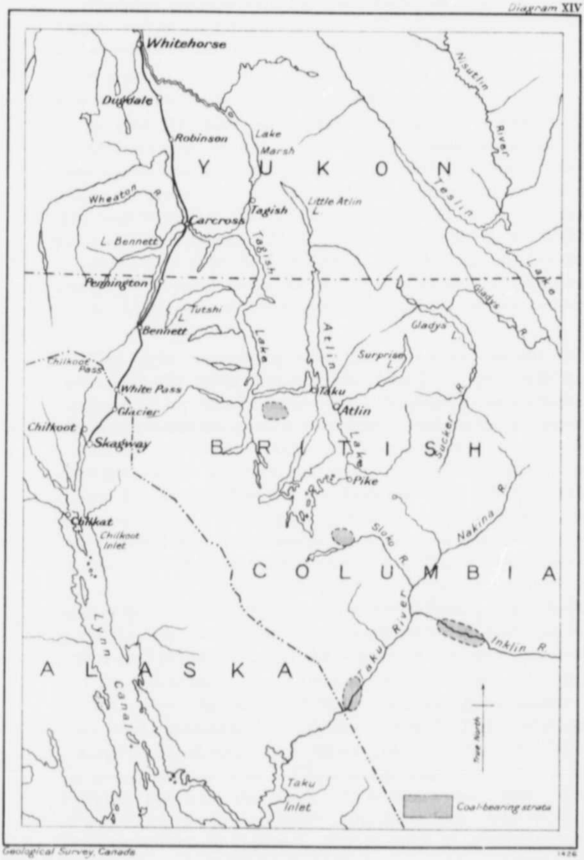
[1] Memoir No. 37, Geol. Surv., Can.



Geological Survey, Canada

1426

Atlin coal-areas

Miles

To accompany Memoir by D. B. Dowling

Tantalus conglomerate has been found elsewhere in Atlin district, and in all probability coal will yet be found in other places besides in the vicinity of the present Sloko Lake claims.

A seam of coal, 4 feet thick, is reported to occur on Taku river to the south of Atlin Mining district.

In 1908 Mr. Alex. McDonald was informed by Indians of the occurrence of float coal near the southeastern summit of Sloko mountains, and at a point to the northeast of and overlooking the lower (east) end of Sloko lake. Since then ten claims have been located in the vicinity, by Alex. McDonald, Norman McLeod, James Johnson, M. A. Dickson, J. Dunham, M. Wynn Johnson, David Gibb, E. Lambert, N. C. Wheeling, and Samuel Johnson. Seven of these claims are now owned or controlled by the Amalgamated Development company, of Vancouver, B.C.

The rocks outcropping along the shores and on the hills overlooking the lower end of Sloko lake from the north are mainly lavas and tuffs belonging to the Wheaton River volcanics, and are prevailingly greyish to yellow in colour, except where stained by iron oxide. Occasional basaltic dykes pierce these materials, but do not comprise any considerable portion of the general formation. The volcanic flows and beds still lie nearly flat, and outcrop horizontally along the walls of Sloko Lake valley, giving rise to numerous successive benches or terraces forming broad steps up the mountain slopes. These rocks weather and decrepitate rapidly, giving rise to an abundance of talus, which in turn decomposes readily to form a fine ash-like material. The mountains are consequently, in most places, rugged and precipitous, and the scenery is wild and imposing.

These volcanic rocks extend to the east down the valley of Sloko river, the outlet of Sloko lake, for approximately 2 miles, where sedimentary rocks belonging to the Jura-Cretaceous Laberge series outcrop, and thence continue down the valley for several miles at least. The Laberge beds occur also on the mountain slopes on the north side of Sloko river, where they extend to an elevation of 2,550 feet above Sloko lake at their most northwesterly exposure, and 2½ miles in a northeasterly direction from the northeastern corner of the lake.[1] Here only a narrow tongue of these rocks has been stripped by erosion and weathering processes of their original cover of volcanics, and is still surrounded, and overlain on three sides, by flat-lying beds, which hide the remaining portions of the Laberge to the north, east, and west.

The sedimentary beds, where exposed, strike about N. 70° W., dip to the southwest at from 20° to 50°, and consist mainly of dark, finely textured shales and sandstones, but also include near the summit of the ridge some dark conglomerates that belong to the Tantalus conglomerates, and consist entirely of quartz, chert, and slate pebbles, generally firmly cemented together. All the important coal seams that have been found in northern British Columbia and southern Yukon occur associated with these Tantalus conglomerate beds.

The uppermost portion of this sedimentary area just described is, in most places, covered by several feet of weathered and decomposed material, which is derived from the surrounding and underlying volcanics and sediments, predominantly from the volcanics, and is in the form of sand, mud, and clay; this in places contains a certain amount of wash coal, which occasionally occurs in layers more or less mixed with other products of erosion and weathering, and near the summit of the ridge, pieces of lignitic coal and carbonized wood, as much as 6 inches thick, have been found. Some of the layers of detrital coal were at first thought to be coal seams in place, but the fallacy of this idea soon became apparent.

When this locality was visited in the latter part of September, 1910, the seams from which the float coal is derived had not been discovered, but a small amount of work should expose them. The pieces of coal found are lignitic in character, and would make a good fuel. The utilization of this coal, when found in place, will be difficult, owing to the fact that it is situated on a mountain top high above timber-line and in an almost inaccessible portion of the district. An attempt should be made

[1]The level of Sloko lake on September 25 was approximately 230 feet above that of the upper end of Atlin lake.

to trace the seams, when uncovered, to the more accessible country to the east or southeast, in the valleys of Sloko river or its tributaries, where it might pay to mine the coal, if found in clean seams of sufficient thickness.

Coal is to be expected wherever the Tantalus conglomerates occur, especially where any considerable thickness of these beds remains. The south side of the lower end of Sloko lake, and along Sloko river, are very probable localities that should be carefully prospected.

Tantalus conglomerates were found on an inconspicuous summit on the south side of Graham inlet, about 5 miles southwest of Taku Landing, but only about 30 feet of the bed remain, as the overlying portions have been removed by erosion; however, it is probable that more of the conglomerates occur farther to the south and southwest where the accompanying coal seams should also be found. This probability almost reaches a certainty, from the fact that small pieces of coal are reported to have been found during the past season in one of the creeks running into the north side of Graham inlet.

A piece of solid, firm coal, apparently bituminous in character, and weighing possibly 20 or 30 pounds, was brought to Atlin by prospectors, and placed on exhibition in the Gold Commissioner's office. This sample is reported to have been obtained from a 4 foot seam on Taku river, 12 miles above canoe navigation, and about 30 miles from Juneau.

REPORT BY J. A. FRASER, GOLD COMMISSIONER.[1]

The existence of coal at different points within the Atlin Mining division is now an assured fact, though the extent of the deposits has not been ascertained at any of these points. The prospecting work expended upon the deposits near Sloko lake, at the south end of Atlin lake, was disappointing in its meagreness; still, sufficient has been done to disclose the existence of coal "in place", but from its location it can be properly and economically prospected only with a diamond drill. A fine sample of coal was brought to this office last summer from a

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[1]Ann. Rep. Minister of Mines, B.C., 1910, p. 56.

deposit located near the Inklin river, and development, so far as prosecuted, indicated the existence of a large deposit. Near the northern boundary of the district and province and a few miles to the east of Rainy Hollow, a new discovery was reported, and a number of locations (about forty, I believe) staked on it, but for some reason, unknown to me, they have not been advertised. The various samples shown and the reports of the locators, however, indicate the presence of coal there in some quantity, and should development prove its existence in commercial quantities, it will enhance the value of the ore deposits lying a little farther westward.

PEACE RIVER COAL AREA.[1]

(*See Diagram XV.*)

(From report by C. F. J. Galloway, to Provincial Mineralogist.)

The Cretaceous rocks of the Peace river have been divided by Dr. Dawson[2] into four subdivisions, each well marked lithologically, as follows:—

(1). Upper sandstones and shales, with lignite coals (Wapiti River sandstones).

(2). Upper dark shales (Smoky River shales).

(3). Lower sandstones and shales, with lignite and true coals (Dunvegan sandstones).

(4). Lower dark shales (Fort St. John shales).

In the comparative table accompanying his report, he places the Fort St. John shales opposite the Benton group of Nebraska and the Rocky mountains, and the Upper Shales (Div. A.), of Queen Charlotte islands. The Smoky River shales he considered as undoubtedly corresponding to the Pierre group, and the Productive Coal Measures of Nanaimo and Comox.

The Dunvegan sandstones, which are the productive measures in this region, are thus seen to be older than those of

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[1]Report of Minister of Mines, B.C., 1912, p. 125 et seq.

[2]Can. Geol. Surv., Rep., Prog., 1879-80, p. 115 B.

Nanaimo and Comox, and more recent than those of Queen Charlotte islands and the Crowsnest fields.

Descending the Peace river through the Rocky mountains, measures of Palæozoic age are passed through, greatly disturbed in the process of mountain-making, several great overthrust faults occurring.

A few miles below Parle Pas rapids, where the mountains proper end and the foot-hills commence, the sandstones and shales of the Dunvegan series come in, and although the valley itself is almost everywhere covered with glacial and alluvial deposits, the sandstones are seen at frequent intervals in the steep faces of the hills on either side, all the way down to the canyon of the Mountain of Rocks, a distance in a straight line of about thirty miles, but over forty by river.

For about half this distance they dip to the southwest at angles of from 15 to 25 degrees. In the neighbourhood of Twentymile creek an anticline crosses the valley, the measures appearing horizontally for a short distance, and then dipping at small angles to the northeast almost to the head of the canyon.

At this point a chain of high hills comes in from the northwest, barring the progress of the river. These hills consist of the Palæozoic limestones, etc., tilted at a high angle to the southwest, the most prominent being Bulls Head mountain, a dome rising to a height of about 2,000 feet above the level of the surrounding country, a little to the south of the general line of the Peace river, which here makes a large detour to the south, flowing round the flank of this mountain, having cut a deep canyon in doing so.

To the south and southwest of Bulls Head mountain the coal-measures have been tilted up, showing a southwesterly dip of from 10 to 25 degrees through the upper part of the canyon.

Where the river crosses the axis of uplift, the coal-measures have undergone greater disturbance; in Grant mountain, a southerly spur from Bulls Head mountain, they are tilted at an angle of 45 to 50 degrees southwesterly. Beyond this the river is more open for some miles, the hillsides being generally densely wooded, and exposures are few.

A few miles farther west the sandstones are again seen, now dipping to the northeast at moderate angles. Continuing down the river, they gradually flatten out, showing a very slight southerly dip throughout the lower part of the canyon, to within about four miles of Hudson Hope, beyond which the sandstones disappear, and the underlying Fort St. John shales occupy the walls of the canyon and the banks of the river beyond the end of the canyon at Hudson Hope for a distance of about sixty miles.

Beyond the mouth of the North Pine river the coal-measures again come in, and continue with a slight easterly dip all the way down to Dunvegan, but no coal has yet been observed in this portion.

The extension of the measures back from the river is undoubtedly very considerable in either direction. Coal has, for many years, been known on the South Pine river, and locations have been staked for coal-prospecting licenses along the whole course of that river from the boundary of the Dominion Block to the neighbourhood of the Pine River pass. Coal has been discovered on this river at least as far east as the forks.[1]

On the North Pine river coal is also reported outside of the Dominion Block, so that, if the measures are continuous between these points, this gives the field an extension of at least seventy-five miles north and south, without the limit being established in either direction.

On the upper part of the Peace the coal formation extends, as has already been described, for about forty miles in an east-west direction, from just below Parle Pas rapids nearly as far as Hudson Hope, and, whether this portion is continuous with either of those mentioned to the north and south or not, it is reasonable to expect that it has considerable extension to the northwest and southeast.

It would obviously be impossible to form any estimate of the area actually underlain by coal-measures without exploring a very considerable amount of territory.

The lowest beds seen at the head of the canyon consist of

[1]Can. Geol. Survey, Rep. Prog., 1875-6, p. 53.

grey and brown sandstones, with beds of grey and dark, almost black, shale. One coal-seam, 1 foot 6 inches thick, was seen in this part of the series on the right bank of the river, half a mile above the head of the canyon.

In the lowest beds visible are included some irregular beds and patches of fine conglomerate, containing pebbles up to half an inch in diameter of quartz, feldspar, slate, jasper, etc. This was the only conglomerate seen in these measures, and indicates at this point the measures of the Dunvegan series were deposited unconformably on the older measures, without the Fort St. John shales being present.

Following the canyon down towards the mouth of Gething creek, about 600 feet of measures are passed through, consisting of similar brown and grey sandstones in beds of from 10 to 50 feet thick, alternating with beds of dark grey sandy shale from 2 to 20 feet in thickness. This portion of the canyon is for the greater part inaccessible, being in places 200 feet deep.

About a mile above the mouth of Gething creek a number of dark seams are seen in the distance, which are no doubt coal, and probably represent some of the seams seen on Johnson creek.

On Gething creek, just below the forks, a fault, with a westerly down throw, appears; the extent of its throw has not yet been determined, individual beds not having been correlated on either side. It is probable, however, that the beds on the west side of the fault are the highest seen.

The coal-seam, G 4, on the west of the fault has a certain resemblance to G 12 on the east, and if these are the same, the fault must have a throw of about 300 feet. It is possible, however, that G 12 is higher in the series, occupying perhaps a position intermediate between G 10 and G 11, in which case the throw of the fault will be 50 or 60 feet.

Continuing down the canyon towards Hudson Hope, the underlying Fort St. John shales present a totally different appearance from the coal-measures, being dark brown in colour and containing no beds of sandstone.

On Grant mountain the Cretaceous rocks are seen tilted at an angle of 45 to 50 degrees for a distance of half a mile, proving a thickness of at least 1,500 feet below the coal-bearing horizon described. This, no doubt, includes a considerable portion of the Fort St. John shales as well as the lower portion of the Dunvegan series.

We have seen that at the upper end of the canyon there is a thickness of at least 600 feet of measures in the Dunvegan series below the known coal-bearing zone, which may be said to commence on the river a mile above the mouth of Gething creek.

From this point up to the seam, G 12, is a thickness of about 700 feet of coal-bearing measures. As the actual position of the higher measures exposed on Gething creek is not known, the thickness above G 12 cannot yet be determined. In the lower canyon of Gething creek, where the seam is seen, there is about 200 feet of similar measures seen above it.

On the Johnson Creek section the seam, J 15, being probably identical with M 2 on Moose Bar creek, may be expected to occupy a position between P 9 and P 10 in the Peace River canyon, being thus about 620 feet below G 12.

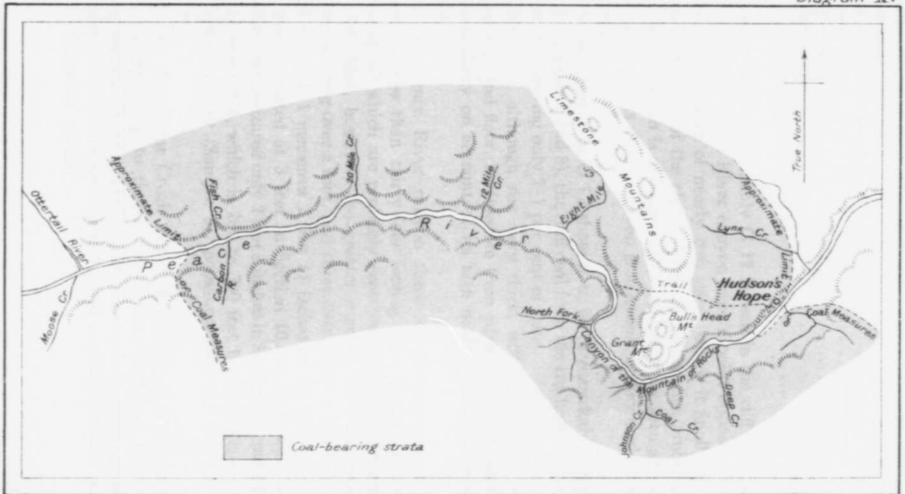
From J 13 down to J 20 is about 280 feet, making the latter 700 feet below G 12, and, therefore, about the horizon of the dark bands seen in the canyon a mile above the mouth of Gething creek.

The measures for several hundred feet below this, as already described, are inaccessible in the upper part of the canyon, and not exposed in the lower, so that it is quite possible that coal-seams may occur in this portion also, the 700 feet described being only that portion in which coal-seams have been observed.

We have, then, in addition to the 700 feet of coal-bearing measures, a minimum thickness of 200 feet of similar measures above and 600 below, making a total of 1,500 feet for that portion of the Dunvegan series which can be observed. It is probable that the actual thickness of this series is at least 2,000 feet in this part of the field.

On the Gething Creek section twelve seams were observed, but of these only five, G 4, G 5, G 7, G 8, and G 12, are over 2 feet in thickness, the last being the only one over 3 feet, having the following section:—

Diagram XV



Geological Survey, Canada

1427

Peace River coal-area

Miles
5 4 3 2 1 0 5 10 15
(approximate scale)

To accompany Memoir by D. B. Dowling

Sandstone roof.	Feet	Inches
Shale		7
Coal (dull)	1	4
Coal (bright)	1	4
Parting (shale)		1
Coal (bright)	1	0
Sandstone floor		
Total coal	3	8

A seam which is probably G 12 is seen in the cliff on the south side of the Peace River canyon from a point opposite the islands for a distance of nearly two miles, where it finally disappears at the top of the cliff. Several dark seams, probably of coal, one of which is of considerable thickness, are seen above it; but as that part of the canyon is inaccessible they could not be examined.

The analyses from G 12 show it to be of remarkably high quality (Samples 7 and 8), the dull coal from the top bench being the best, and having only 2·1 per cent of ash.

This seam, although not very thick, will, on account of its good roof and floor, its freedom from admixture with shale, and particularly on account of its high quality, prove a most valuable one.

In the Peace River canyon there are numerous seams exposed, no less than thirty-four having been counted, after eliminating all which are probably repetitions of those already seen. Of these, however, the greater number are very thin, only twelve being over a foot, and three over 2 feet in thickness.

Of these, P 1 measures 2 feet 11 inches in one place, and P 16 was estimated at 3 feet in Section 10, where it was inaccessible, but measured only 2 feet 3 inches in Sections 11 and 12.

The seam P 1, which is 280 to 300 feet below G 12, is of even higher quality (Sample 6), possessing also a strong roof and floor.

In the Moose Bar Creek section a number of thin seams occur, corresponding to those seen in the lower part of the canyon section (Section 15). Above these, four more seams were seen, only one of which, M 2, is of any importance. It has the following section:—

Sandstone roof.	Feet	Inches	
Shale..................................	1	0	
Coal (dull)............................		9	Rider (M 1). Total coal, 1 ft. 0 in.
Shale..................................		7	
Coal (dull)............................		3	
Sandstone..............................	1	7	
Coal...................................		1	
Sandstone..............................		3	
Coal...................................		2	
Shale..................................	2	7	M 2. Total coal, 2 ft. 8½ in.
Coal (bright)..........................	1	1½	
Sandstone		½	
Coal (bright)..........................	1	6	
Shale..................................		3	
Coal (bright)..........................		1	
Hard shale floor.			

The analyses from this seam (Samples 17 and 18) are not so satisfactory, but the excessive ash, particularly in Sample 18, is no doubt due to an admixture of shale in the sample. If the seam was stripped for a distance of a few feet and fresh samples taken from the clean surface, much better results would undoubtedly be obtained. In places there is a band of shale, from ½ to 1 inch in thickness, in the middle of the lower bench of coal, and it would be hard to separate this altogether from the coal in working, so that this cannot be regarded as a very clean seam.

Passing across to the section on Johnson creek, we find twenty seams exposed, of which nine are over 1 foot, four over 2 feet, and three, J 13, J 14, and J 16, over 3 feet in thickness.

Of these latter, however, it is just possible that J 13 and J 14 may be identical, both corresponding to M 2. The sections of J 13 and M 2 are very similar, each having a small rider of dull coal above it, and the correspondence of these two is highly probable. In the case of J 14, however, the similarity is much less, and its analysis would almost exclude the possibility of its being correlated with M 2. Unfortunately no samples were taken of J 13.

The sections of the principal seams seen on Johnson creek are as follow:—

J 12 and J 13.

Shaly sandstone.	Feet	Inches	
Shale	1	0	
Coal (dull)		10	Rider (J 12). Total coal, 1 ft. 4 in.
Shale	1	0	
Sandstone		2	
Coal (dull)		6	
Shale	2	6	
Coal (bright)	2	0	J 13. Total coal, 3 ft. 3 in.
Shale		2	
Coal (bright)	1	3	
Sandstone		1	
Shale floor.			

J 14.

Sandstone.	Feet	Inches	
Grey shale	1	6	
Hard shale		2	
White sandstone		4	
Hard grey shale	1	6	
Coal	1	8	Total coal, 3 ft. 11 in.
Sandstone	0 to	2	
Coal	2	3	
Sandstone floor.			

J 15 and J 16.

Sandstone.	Feet	Inches	
Coal	1	3	Rider (J 15).
Sandstone	1	6	
Shale	3	0	
Coal (hard)	2	6	J 16. Total coal, 3 ft. 4 in.
Shale		1	
Coal		2	
Shale	1	0	
Coal		8	
Shaly sandstone floor.			

J 20.

Sandstone roof.	Feet	Inches	
Coal	2	3	Total coal, 2 ft. 9 in.
Coal		6	
Shale ....4 in. to	1	0	
Sandstone floor.			

In cases where a seam is visible over a considerable distance, the thicknesses of the individual benches of coal and shale are very variable, the shale sandstone partings in the seams being frequently of a lenticular nature, increasing within a distance of a few feet from 1 inch to over 1 foot in thickness, and diminishing again as rapidly. The sections given represent, as nearly as could be observed, average conditions.

The analyses of these seams (Samples 10 to 14) show considerable variation in quality; J 14 shows a higher proportion of volatile matter than any of the other seams except G 1 (Sample 9). Only the lower bench of J 14, however, shows any coking qualities. The lower bench of J 16 is also described as coking fairly well.

Several of the samples from the Johnson Creek seams show fairly high ash, although not by any means excessive in comparison with other coals worked in this country. It is, moreover, to be expected that clean samples, taken from a fresh face, free from surface impurities, will show better results in this respect.

From the foregoing it appears that among the multitude of seams exposed there are only five outcrops yet known in which the thickness is greater than 3 feet, viz., G 12, M 2, J 13, J 14, and J 15, and of these it is probable that M 2 and J 13 are the same.

The canyons of the Peace and its tributary creeks afford unequalled opportunities for examining the measures; but, in spite of this, it is obvious that the amount of strata within the known coal-bearing zone, which have not yet been examined, owing to their being nowhere exposed, or only in inaccessible places, is very great, and there is every reason to believe that many more seams exist besides those described, among which there may well be a number of larger ones.

Coal outcrops are also reported on Eightmile creek, seven or eight miles from its mouth. These are probably the same measures as those seen in the canyon.

With the exception of the fault mentioned on Gething creek and a few minor rolls, the strata are remarkably free from disturbance, in spite of the uplift caused by the elevation of Bulls Head mountain and the range of which it forms part.

To the south and west of the canyon a large area of practically horizontal, undisturbed measures may confidently be expected and, as the highest measures seen were coal-bearing, it is likely that coal will underlie a great deal of this area at no very great depth. Owing to the inaccessible nature of much of the country, the only really satisfactory way to prove the measures will be by diamond-drilling.

The accompanying analyses have been made by H. Carmichael, Government Analyst for the Province of British Columbia, the split volatile ratios according to Dowling's classification having been added by the writer.

The samples, with the exception of Nos. 9, 10, and 11, all come under the head of "high-carbon bituminous," those three being "bituminous."

These analyses show the coal to be of very high grade. While not comparable with the best Welsh Admiralty steam coal, it is equal to a high grade of steam coal from that field, and compares favourably with the best West Virginia coals, being altogether of an exceptional quality for western America.

There are, it is true, other fields in the west in which coals of all grades from bituminous to anthracite occur; but as a rule the high quality of these coals is due to local disturbances, and they are generally in very disturbed regions, and frequently exceedingly dirty.

In this field, on the other hand, the regularity of the measures and their freedom from disturbance are remarkable, and the low ash-content in most of the samples, taken as they all were from outcrops, shows the exceptionally clean nature of these seams.

Only three of the samples showed any coking quality, and these only fair, so that great expectations are not to be based upon the prospects of this field for coke-making purposes, although it is by no means impossible that fair-sized seams will be found which will yield a good coke, especially in retort ovens.

The top benches of the seams P 13 and G 12, and the riders (probably identical) M 1 and J 12, consist of coal of a peculiar dull, stony appearance, resembling carbonaceous shale. The analyses show this to be coal of a very good quality, that in the upper bench of G 12 (Sample 7) only having 2·1 per cent of ash.

Analyses of Peace River Coals.

Sample No.	Seam	Thickness		Hygro. water	Vol. comb. mat.	Fixed carbon	Ash	Sul-phur	Coking quality	Split vol. ratio
		Ft.	In.	%	%	%	%			
1	P 8, top bench	1	10	2·0	20·2	72·2	5·6	....	None	6·80
2	P 8, bottom bench	0	7	1·7	17·7	78·9	1·7	....	"	8·31
3	P 5, (Section 6)	1	9	2·0	19·7	75·7	2·6	....	"	7·22
4	P 13, top bench (dull coal)	1	0	2·9	16·9	71·4	8·8	....	"	7·03
5	P 16 (Section 11)	2	3	3·0	16·6	78·0	2·4	....	"	7·63
6	P 1 (Section 1)	2	11	2·2	15·6	80·6	1·6	....	"	8·84
7	G 12, top bench (dull coal)	1	4	2·9	15·6	79·4	2·1	....	"	8·15
8	G 12, lower benches	2	2	2·8	16·9	77·2	3·1	....	"	7·61
9	G 1 (Section 25)	2	0	5·3	19·1	69·0	6·6	....	"	5·29
10	J 14, top bench	1	8	2·7	20·9	67·6	8·8	....	"	5·93
11	J 16, bottom bench	2	3	1·8	23·9	67·8	6·5	....	Fair	5·80
12	J 16, top bench	2	8	1·6	15·9	77·4	5·1	....	None	8·93
13	J 16, bottom bench	0	8	1·0	21·4	73·7	3·9	....	Fair	7·21
14	J 20	2	9	1·1	16·0	73·1	9·8	....	None	8·91
15	P 34	1	8	1·3	18·6	77·4	2·7	....	Fair	8·18
16	M 1 (dull coal)	0	10	1·0	14·5	70·6	13·0	....	None	9·43
17	M 2, top bench	1	1½	3·0	18·0	73·6	5·4	....	"	6·88
18	M 2, lower benches	1	7	1·7	16·3	53·7	28·3	....	"	6·28

CHAPTER III.

THE TERTIARY COALS.

GEOLOGICAL NOTES.

The Tertiary deposits of British Columbia are in more or less isolated areas and correlation must be made mainly on palæontological evidence. This consists of impressions of plants and insects. A study of the plant collections was made by Prof. D. P. Penhallow whose published report bears the publication number 1013, of the Geological Survey publications. In this he points out that the various collections may be divided into two groups; the older which he includes in the Eocene, is closely related to the Fort Union and Laramie of the Great Plains region; and the younger is found in isolated lake basins of the interior of the province and has been grouped under the general term Oligocene. The strata of the various isolated areas of the younger group are not definitely to be correlated as belonging to a single horizon but are to be considered rather as a series of beds or deposits in which certain are probably higher or lower than others. This second general group was referred to in the earlier reports as Miocene. These Oligocene deposits are frequently covered by volcanics dating from various periods in Miocene time. A series of sediments near Kamloops lake is classed as lower Miocene, representing a period of quiescence after the first Miocene volcanic outflows.

In these basins an abundant flora seems to have flourished and in many of them the accumulation of the vegetable remains has formed important coal seams. Many of these have been compressed and altered by the weight and heat of the superincumbent volcanic rocks, and are now bituminous coals, though many of the Tertiary deposits are still only in the lignite or sub-bituminous stage.

The coal-bearing deposits may be grouped thus according to the evidence of the plant remains.

Lower Miocene	*Tranquille beds* on Kamloops lake. *Stump Lake deposits* south of Kamloops.
	LOCAL UNCONFORMITIES.
Oligocene (*Coldwater series*)	Deposits at Kamloops; Quilchena; Horsefly river; Coal gully (Nicola valley); Tulameen; Guichon creek; Similkameen; Hat creek; Kettle river; Quesnel.
Eocene (*Puget Group*)	Blackwater river; Coal brook (North Thompson river); Finlay river; Omineca river; Fraser River delta.

Puget Group.

The Puget formation or group consists of interbedded sandstones and shales with coal beds and attains in the state of Washington a thickness of 10,000 feet. They are of variable composition, texture, and colours and are frequently cross-bedded.

In general the beds are similar and similarly interbedded from top to bottom. The shales range in colour from light grey and blue to black. In the southern part of the area in Washington the formation is divisible into three parts: (1) An upper member which is barren of coal deposits about 7,000 feet thick called the Pittsburg; (2) the Wilkeson sandstones 1,000 feet; and (3) the Carbonado beds, 3,000 feet in thickness in places, containing many coal beds, from 5 to 10 being workable seams.

In the northern part of the state the Eocene rests on metamorphic schists and many of the coal seams are at the extreme base of the formation. In other localities where coal is also found it is not definitely known that the coal beds belong to the base of the Eocene and it is possible that some of these are to be correlated with the Oligocene deposits of British Columbia.

In Canada the rocks of the Puget group are recognized on Burrard inlet. The following description is quoted from a report by O. E. LeRoy.[1]—

[1]Preliminary Report on a portion of the Main Coast of British Columbia and adjacent islands, 1908, No. 996, pp. 24-25.

"The Puget group is developed in two separate regions, one occupying the area between Burrard inlet and the International Boundary, while the other occurs at and inland from Wolffsohn bay on Malaspina strait.

"In the former area the rocks are exposed in a series of interrupted bluffs along the south shore of Burrard inlet, from English bay to a point a little east of Barnet. From Hastings to Barnet they form a long ridge known as "North mountain" which, south of Barnet, rises to a height of 1,335 feet. This ridge slopes towards the Fraser river, and it is only on its northern face that continuous outcrops are found.

"Southwards to the Boundary no more exposures are seen, as the whole country is covered by glacial drift and alluvium; but the group has an extensive development in the State of Washington.

"The group consists of conglomerates, with well stratified sandstones and shales. The beds are but slightly disturbed, with strikes varying from northeast to east and west, and dipping southeast and south at low angles. The conglomerates consist of well rounded pebbles of schist, granite, quartzite, etc., in a sandy ferruginous matrix. The sandstones are argillaceous, and disintegrate rapidly on exposure. In places they hold small lenticular areas of dark brown lignite. A coarse thick-bedded feldspathic sandstone is interbedded with the finer sandstones. It weathers differentially, leaving large projecting knobs in the face of the bluffs. The shales are dark grey or black and usually carbonaceous. Some of these beds hold numerous plant remains. The whole group indicates estuarine conditions of deposition, and the area underlain by these rocks in this southwest portion of British Columbia represents but the northern rim of an extensive basin. It has been estimated by Mr. A. Bowman that the group has a thickness of 3,000 feet in the vicinity of Vancouver, while in the State of Washington it attains a thickness of 10,000 feet. Several collections of the plant remains were made, and were submitted to the late Sir William Dawson for examination with the result that the group has been placed in the Eocene.[1]

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[1]Trans. of the Royal Society of Canada, second series, 1895-96, vol. I, sect. IV, p. 137.

"In Washington the group contain sseveral seams of lignite which are of commercial importance. No coal has been found on the Canadian side, and if any beds exist they are much below the horizon of the exposed beds. The superiority of the coal on Vancouver island will prevent any active prospecting in this group for a coal that would in any case be a very inferior one.

"On Wolffsohn bay and Sandstone river there is a series of sandstones which are probably of this age, and have been placed provisionally as Eocene. It is supposed there is an extensive basin inland; but the dense forests and heavy growth of underbrush prevent a close examination being made at present. On lot 1803, along the bank of a small creek, the soft sandstones contain thin streaks of impure lignite; but no bed of any value has been exposed."

Coldwater Series.[1]

"The detailed study of the coal-bearing beds of Nicola valley in southern British Columbia by Dr. G. M. Dawson, previous to 1894 had led him to conclude that these beds were earlier than Miocene and in his report for that year he proposed the name *Coldwater Group.* A large part of the original description is here quoted.[1]

"Before the beginning of the period of Tertiary vulcanism in this region, certain beds had been deposited which consist entirely of ordinary clastic materials. These beds were laid down in lakes or river estuaries, in hollows then existing in the old denuded surface of the Palæozoic and Triassic rocks. They consist chiefly of conglomerates, sandstones, and shales, with which coals and lignites are in some places associated. These particular beds have not been found in actual unconformity with the upturned Cretaceous rocks of the Thompson or Fraser, but as they do not appear to have participated in the great crumpling of the Cretaceous which probably took place at or about the close of the Laramie period, they are regarded as post-Cretaceous and probably as post-Laramie. They may,

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[1]Ann. Rep. Geol. Surv., Can., Vol. VII, pp. 68-70B.

therefore, be described as intervening between the close of the Cretaceous and the inception of the great volcanic period in this region.

"The nature of the deposits, and particularly the abundance of well-worn conglomeritic material in them, seems to show that they may very well represent the work of some river systems of the great early Tertiary time of denudation, during which the Interior Plateau was being worn down to an approximately level surface. Particularly on the interruption or close of this period, might such deposits be formed; but as the time involved was undoubtedly very long, the isolated deposits now found in various parts of the field might very well be referable to horizons differing widely although all included in the early part of the Tertiary.

"It is found, however, that there exists, in several localities, so complete a lithological resemblance and similarity in the order of superposition of these deposits, that there can be little, if any doubt that the beds of these localities are contemporaneous and due to the same sequence of events in the Tertiary history. The deposits thus evidently related are those of the following places: Hat Creek valley, Copper Creek, vicinity of the confluence of the Coldwater and Nicola, and (to the south of the Kamloops sheet) near Lac a la Fourche. In each of these places the lowest beds are found to consist of conglomerates almost entirely composed of materials of proximately cherty pebbles, with which some sandstones are associated. Above these, in the Coldwater-Nicola vicinity and on Hat creek are sandstones and shales with coals and lignites.

"It is proposed to designate these evidently synchronous deposits by the name of the *Coldwater group*, and there can be little doubt that the conglomerates found on the plateau to the west and south of Savona, as well as those forming small outliers on the Garde Lafferty, represent further remnants of the basal conglomerates of the same series. In the case of the sedimentary deposits of the North Thompson, situated near the north edge of the map, no distinct lithological identity can be appealed to; but there is at least nothing to show that they differ in age from those of the Coldwater group.

"The Coldwater group as a whole, evidently represents the remnants of a once more extensive formation, most of which has been removed by denudation, and of which what still exists is often covered by the volcanic materials. It may in part be regarded as filling hollows in the pre-existing surface, but this surface has since been considerably modified in its relief by later flexures and by some faulting, and it is thus generally in synclinal folds, or where let down by faults, that the Coldwater beds are actually found. It is, therefore, impossible now to determine whether the remaining beds of the series represent portions of a deposit once largely spread over the area of the Kamloops sheet, or, if more restricted, what areas such deposits may originally have covered.

"That these deposits antedate the period at which volcanic activity on a great scale began, is rendered evident by two circumstances. They include in their material no characteristic volcanic Tertiary rocks, while they appear without doubt to be affected by more pronounced folding than that affecting the volcanic rocks.

"In some places these beds are now nearly or quite vertical. This is particularly the case near Clapperton and Copper creeks; but in other localities, as for instance on the plateau to the west and south of Savona, the basal conglomerates are found to be still nearly horizontal, or inclined at comparatively low angles like those normal in the case of the later volcanic rocks of the Tertiary. In the place last mentioned, not only are the basal conglomerates nearly flat, but they differ for a few hundred feet in elevation from their similarly undisturbed representatives in outliers on the Garde Lafferty—twenty miles distant. Thus it would appear that, after the Coldwater beds had been laid down, a period of orogenic movement occurred, by which these beds were affected particularly along certain lines, running in north-northwest by south-southeast bearings, while large intervening blocks of country preserved their rigidity; that a period of denudation followed, during which a great part of the Coldwater beds was removed, and that the denudation had been long in progress before the first beds of the succeeding volcanic series were formed."

Tranquille beds.

These beds occurring in the Kamloops area were described and named by G. M. Dawson in the Report for 1894, p. 72B, a part of which description is appended.

"From the beginning of the Tertiary eruptions until their close, though the eruptions were doubtless more or less irregular and spasmodic, the accumulation of materials of volcanic origin in the plateau region probably never entirely ceased. The occurrence of water-bedded rocks, composed almost altogether of rearranged volcanic debris, indicates the formation of lakes which endured for considerable lengths of time, and the blocking up of the old drainage channels of the country by the lava-flows or other volcanic products, may to a great degree if not entirely, explain the impounding of these waters.

"There was, however, apparently, one such very notable interlude, of which the water-arranged deposits are believed to be recognizable over a wide area. To the deposits then formed, the name of Tranquille beds has been applied. They are largely developed in the vicinity of Kamloops lake, particularly near the mouth of the Tranquille river, and the persistent zone of stratified tuffs met with on the Nicola river, is believed to pertain to the same horizon. Volcanic action was not entirely quiescent during the formation of these beds, for they include much material which appears to represent volcanic ash, while they are often found to graduate almost insensibly into tufaceous agglomerates. That the time represented by these deposits was of some duration, is shown by the fact that they include thin beds of coal near Kamloops."

BULL RIVER AREA.

Loose pieces of lignite have been found at the mouth of this stream in Kootenay river and indicate a possible Tertiary outlier in this valley such as has been found in many others in the southern part of British Columbia; but very little evidence of valuable deposits has been discovered.

NORTH FORK OF KETTLE RIVER AREA.

A small Tertiary outlier has been found at the head of this stream west of Arrow lake; but the seams so far found are not of ecomonic importance.

MIDWAY AREA.

In the clastic and pyroclastic rocks of Tertiary age, underlying the volcanics some small lenses of coal are found. West of Midway, a bed is of sufficient thickness to have attracted attention; but nothing worthy of note was found in the Tertiary rocks mapped in the Boundary Creek sheet (see Vol. XV, p. 132A).

WHITE LAKE COAL AREA.[1]

(*See Diagram XVI.*)

(Extract from report by Charles Camsell.)

White lake is a small post-office situated on the western side of Okanagan valley about 6 miles west of Okanagan Falls. It lies in an area of coal-bearing rocks which has for convenience been named the White Lake coal area. The area of the field is about 6 square miles in extent and occupies the northern part of township 53 of the Similkameen land division.

The value of the field as a possible producer of coal is doubtful and has not yet been determined. Some mining of coal has, however, been done from a narrow seam near the centre of the basin, and the coal extracted used for blacksmithing purposes at Fairview when quartz mining was being carried on at that point.

No geological work had previously been done on this area; but a small collection of fossil plants was made by the author in 1910 from an outcrop of shale and sandstone, and this collection has been sufficient to determine the age of the coal-bearing formation.

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[1]Summary Report 1912, Geol. Surv., Can., pp. 213-216.

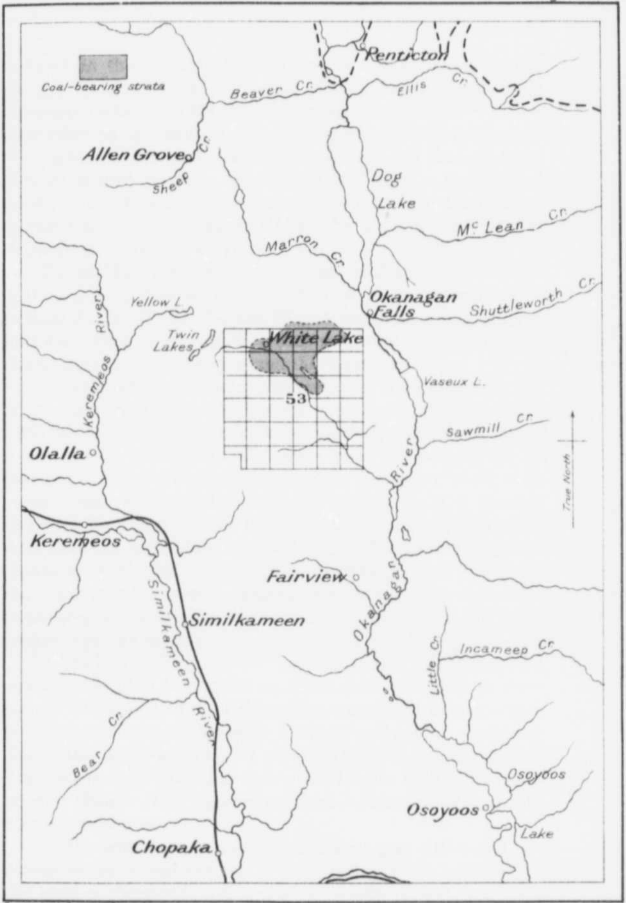
White Lake coal area is a basin-shaped depression almost completely surrounded by hills which rise more or less steeply from its central part. A small lake, known as White lake, which has no visible outlet, lies almost in the centre of the area, and from this the slopes rise on all sides. To the west the slopes rise high and steep but not irregularly to the summits of the range which forms the divide between Okanagan valley and Keremeos creek. On the east the slopes are not as high but are more broken, and in this direction an exceedingly rough and broken country, consisting of a jumble of steep hills and depressions, separates the coal area from Okanagan valley. This broken country is probably the locus of an ancient volcano which was active about the time that the coal-bearing formation was being deposited.

Two streams, each of them dry during the latter part of the summer, traverse the coal-field. Park rill enters the field from the west and flows out by a narrow valley at the south. Prather creek enters from the north and leaves by a narrow inconspicuous gorge which cuts through the broken country southeast of the coal-field. White lake has no outlet, and this with other small ponds in its neighbourhood appears to be fed from springs. There are several springs in this neighbourhood, some of which are sulphurous and, possibly, represent the last stages of expiring vulcanism.

All the central and lower parts of the area are open and free from any growth of timber. Higher up the slopes, however, and covering the summits of the bordering hills is an open forest of pine, fir, and poplar. The whole area of the coal-field was at one time an excellent grazing ground for horses and cattle; but so many cattle have been allowed to range over it that the grass which formerly covered it, is being replaced by sage brush. The climate of White lake is dry and mild and if water for irrigating purposes could be obtained it might be made to produce a variety of fruits.

No rocks older than Tertiary are exposed in or around the White Lake area; but some cherty quartzites associated with argillites, probably Palæozoic, outcrop in the valley of Park rill south of the area. Angular fragments of these rocks are also

Diagram XVI



Geological Survey, Canada. 1428

White Lake coal-area

Miles

5 4 3 2 1 0 5 10

To accompany Memoir by D.B. Dowling

included in the volcanic agglomerates and tuffs which overlie the coal-bearing rocks, indicating that a basement of these Palæozoic rocks underlies the Tertiary rocks, fragments of which were rifted off the walls of vents during outbursts of vulcanism.

Underlying the coal-bearing rocks is a series of volcanic flows of basic or medium basic composition, consisting of basalts and porphyrites. This series appears to lie in conformable relation to the coal-bearing rocks and from the attitude and general character of its beds is of Tertiary age.

The coal-bearing rocks cover an area of about 6 square miles in the northern part of township 53 and occupy almost all of sections 27, 28, 29, 33, 34, and 35 and small parts of adjoining sections. They consist of tufaceous sandstones and true tuffs, shales, conglomerate, breccia, and thin seams of coal.

A section along the valley of Prather creek on the north side of the basin was measured, which gave a thickness of about 2,000 feet of beds. It is very likely, however, that this thickness is not uniform throughout the whole area; but because of the conditions under which the beds were deposited must vary greatly from one side of the area to the other. It is possible also that the 2,000 feet of thickness in the section represents more than the actual thickness of the beds for, while there is no apparent duplication of the beds by faulting, it is very probable that there has been some slipping or faulting along the planes of bedding so as to give to the section an apparent thickness greater than the actual.

A study of the measured section shows that the whole series can roughly be divided on lithological grounds into three parts. The lowest third of the section contains a preponderance of black and grey shales with a minor amount of sandstone. The shales are associated in places with thin seams of coal. The middle third contains chiefly sandstones with some bands of grey shales. The uppermost third consists wholly of tufaceous sandstones.

In the central portion of the area some grey shales and two narrow seams of coal outcrop. These beds are not contained in the section measured and probably overlie it and constitute the topmost members of the series.

The sandstones are all grey in colour and vary in the coarseness and angularity of grains from the east to the west side of the area. On the east the grains are more rounded and waterworn while on the west they are very angular, showing a proximity to their original source.

The coal seams are all small and none of those so far exposed are of much commercial importance. On the north side of the area in the valley of Prather creek a seam 3 feet in thickness has been exposed in an incline shaft about 45 feet deep. The seam, however, contains so many partings and bands of clay that it is of little commercial value. About 100 feet east of this point a vertical shaft 50 feet in depth is said to have cut a bed, 9 feet in thickness, of coal and shale. The section on Prather creek, shows that both above and below the two seams exposed in the shafts are other thin bands of coal, all, however, of small size and of no commercial importance.

So far as at present known the most important seams of coal are those exposed in a small ravine on the northwest side of White lake. These seams are respectively 14 and 20 inches in thickness. A shaft 35 feet in depth was sunk some years ago on the coal seams and about 1,000 tons of coal mined. This coal is of a bituminous character and was used at Fairview for blacksmithing purposes.

In general the structure of the White Lake coal area is that of a synclinal basin, the strike of which is east and west. In detail, however, there are often wide variations from this direction, especially on the eastern side of the area where apparently there has been considerable disturbance since the deposition of the coal-bearing beds. The dips range 0° to 50° and average about 30°. Some faulting has taken place, especially in the disturbed region on the east.

The rocks of the coal-bearing formation appear to have been laid down in a gradually subsiding basin on the western edge of a region in which vulcanism was active at intervals throughout the whole period of their deposition. The eruptions at this focus were of the explosive type and great volumes of tuff were blown out and deposited in the basin. In parts of the basin these tuffs were water worn to form true sandstones; but in other parts they have not been so worn and they retain the same angularity of grain that they had when first ejected.

Both the sandstones and shales contain a great many plant remains, and from a very small collection of these the age of the rocks was determined as Oligocene. They are, therefore, correlated with other areas of coal-bearing rocks at Princeton, Nicola, Tulameen, and other points in the southern interior of British Columbia.

Overlying the coal-bearing rocks on the east is a series of volcanic breccias and tuffs and some flows of an andesite or more acid nature. In places the overlying volcanic rocks succeed the coal-bearing rocks conformably; but in other places there is a marked angular unconformity between them. It is probable, however, that this unconformity does not indicate any great time interval between the two series. The upper volcanic rocks occupy an exceedingly irregular and broken country to the east of the coal basin, which no doubt is the source from which tuffs were derived. This broken country is apparently the locus of an ancient Tertiary volcano which was active at intervals during and after the deposition of the coal-bearing rocks. It has all the characteristics of an ancient, denuded volcanic crater about a mile in diameter, the bottom and sides of which have slumped in leaving a series of steep-sided hill and deep sinkholes now often filled with water.

From the evidence that has been obtained, which consists merely of an examination of the surface, it is not possible to make any definite statement relative to the actual or probable value of the field. Small coal seams occur both at the top and bottom of the series. The two seams at the top are small but contain a good grade of clean coal and some mining has been done on them. Those at the bottom are larger, but where they outcrop at the surface are too dirty to make a useful fuel. Their dirty character may be due to proximity to the border of the basin and it is possible that they may become cleaner toward the centre of the field. This, however, can only be determined by putting down a bore-hole which, in the centre of the field, would have to be driven about 1,500 feet in depth to intersect the seams.

(Summary of information communicated by Jas McEvoy.)

In addition to the information obtained by Mr. Camsell in 1912 as embodied in the above report, a further examination was made by Mr. Jas. McEvoy in 1914 and he has placed the following information at our disposal:

In the lower part of the series the volcanic beds are fairly thick and the interbedded sediments contain carbonaceous shales, but only thin seams of coal; so far no greater thickness than 12 inches of clean coal has been uncovered. Some portions of this lower part of the section have not been uncovered and may contain seams of importance; but this is not probable.

In the upper part of the series, for a thickness of 1,000 feet, the shales and sandstones predominate. In the shales in this part 7 seams of coal were uncovered, 4 of which did not contain more than one foot of clean coal.

The other 3 seams, designated in the descending order in which they occur in the section Nos. 3, 4, and 5, are the ones which determine the value of the property for coal mining purposes.

No. 3 seam shows the following section:

Coal and shale	11 inches.
Coal	35 to 38 inches.

It strikes east and west and dips to the south 52 degrees from the horizontal.

No. 4 seam has the following section which varies slightly, as measured at two points in the prospect shaft, as below:

	1.	2.
Coal	15 inches	17 inches
Shale	3 "	5 "
Coal	18 "	16 "
Shale	6–8 "	7½ "
Coal	15 "	22 "
Total coal	48 inches	55 inches

Half a mile westward from where the above section was measured the seam was again opened up and showed the following section:

Coal	8 inches
Shale	4–6 "
Coal	14½ "
Shale	4 "
Coal	20 "

No. 5 seam has the same dip and strike as Nos. 3 and 4, and near the surface showed the following section:

Coal and shale	11 inches
Coal	40 "

At a depth of 20 feet the section was:

Coal and shale	11 inches
Coal	42 "

Half a mile to the west another opening on the seam gave the following:

Coal and shale	12 inches
Coal	38½ "

The following proximate analysis of the coal of seam No. 5 is by the Kelso Laboratories of Calgary.

Moisture	3·20
Volatile combustible matter	21·52
Fixed carbon	66·40
Ash	8·88
	100·00

From its behaviour in the open fire and crucible, the coal is apparently of coking quality, but this cannot be absolutely decided until a test is made under working conditions in a coke oven. The indications are that fast coking in retort ovens will be the best suited to this coal.

PRINCETON COAL AREA.[1]

(*See Diagram XVII.*)

(Extracts from reports by Charles Camsell.)

Princeton is situated at the junction of the Similkameen and Tulameen rivers, in a shallow depression in the Interior Plateau region, which was formerly an Oligocene lake basin. The region is characterized by comparatively moderate relief, gently rounded hills, and broad open valleys. It is sparsely forested and in portions quite open and grassy, so that it affords good grazing for horses and cattle.

The principal rocks of the region are flat lying sediments of Oligocene age, resting on a basement of tilted Palæozoic rocks. They include sandstones, clays, shales, conglomerate, and coal seams, and contain a variety of fossil plants, insects, and fish remains. These rocks are overlaid by volcanic flows of andesite, basalt, and fragmental materials.

The Palæozoic rocks to the south of the town of Princeton, at Copper mountain, contain low grade copper deposits of considerable magnitude, which are now being vigorously prospected. They carry chalcopyrite as the principal copper mineral, and are either in the form of contact metamorphic deposits situated in altered sedimentary rocks at the contact of irruptive igneous bodies, or are in fissures in both the igneous and sedimentary rocks.

The Oligocene rocks cover an area of about 40 square miles (103 sq. km.) and contain a number of seams of coal, ranging in thickness from a few feet up to 60 feet (18·29 m.). Some of the seams are being mined. The Oligocene also includes important beds of clay which are utilized in the manufacture of cement.

Boring operations for lignite began in this vicinity in 1901, and have been prosecuted by several parties interested in the

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[1]C. Camsell, Preliminary report on a part of the Similkameen district, British Columbia, Geol. Surv., Can., pp. 16 et seq.

C. Camsell, Guide Book No. 9. Transcontinental Excursion C2, Geol. Surv., Can., pp. 116-117.

development of the Princeton coal basin. The Princeton Coal and Land company, formerly known as The Vermilion Forks Mining and Development company, is the largest holder of coal claims and it has sunk six bore-holes to test its properties. Two others have been sunk by Blakemore and one by Sharp; and with the exception of Sharp's bore-hole all have been sunk in the valley of the Similkameen river between Princeton and Ashnola.

The Princeton district lies in a part of what has been called by Dr. G. M. Dawson the great Interior plateau of British Columbia. In the southern part of the district, however, it partially loses the chief characteristics of a plateau, which are so well exemplified in the region to the north of this district, and which gave the author of the name the reasons for calling it such, and it here becomes gradually more mountainous, until it finally merges into the high rugged and snow-covered peaks of the Cascade range to the south of the International Boundary line. To the north of the district, and in the country north of the Similkameen and Tulameen rivers, the plateau features become more pronounced and the ruggedness of a mountain region is lost. In looking southward over it towards Nicola lake from some of the higher points the eye appears to travel over a gently undulating surface showing a succession of rounded and generally wooded hills, and nowhere any sharp and rugged peaks or any banks of snow.

Above Princeton the southern portion of the Similkameen river flows in an almost north and south course until it forks some twenty-five miles south. The main branch or Pasayton river continues in the same course up to and across the Boundary line, while the west branch or Roche river comes from the south-west.

About a mile below the junction of the two streams the southern portion of the Similkameen river enters a deep and narrow canyon, through which it flows for a distance of about eighteen miles, or as far as the mouth of Whipsaw creek.

Below the mouth of Whipsaw creek the stream enters the low, shallow Tertiary coal basin, and the change in character is very abrupt. Here the grade becomes slightly easier though still very steep, and the banks of the valley are usually composed of unconsolidated material, and only occasionally are there exposed sections of the coal-bearing rocks.

Plutonic, volcanic, and sedimentary rocks are all present, covering a range in age from Palæozoic to later Tertiary times. Fossils occur in the Tertiary coal basin, about Princeton, and also in the Cretaceous sandstones of the Roche river; but the remaining sedimentary rocks—limestone, argillite, and quartzite—are either unfossiliferous or have been so badly crushed as to destroy any remnant of animal life that they ever contained. Contacts between the igneous and sedimentary rocks are rarely exposed.

The formations in this district and their approximate or relative ages, are as follow:—

(1) *Glacial and recent deposits.*

(2) *Post Oligocene*—

Volcanic, consisting of andesites, basalts, trachytes, tuffs, and breccias.

(3) *Oligocene*—

Sedimentary, consisting of sandstones, shales, clays with seams of coal.

(4) *Cretaceous*—

Argillaceous sandstones, grits, conglomerates, and slates.

(5) *Post Palæozoic*—

Remmel granodiorite; monzonite of Copper mountain.

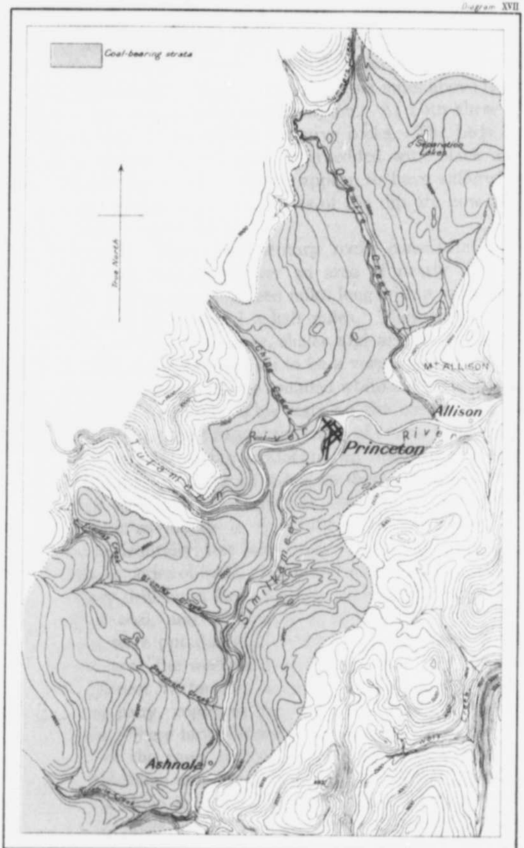
(6) *Palæozoic*—

Limestone, quartzite, and argillite of Copper mountain. Green and spotted schists, talc and graphite schists, mica and hornblende schists, with some limestone and siliceous bands.

Palæozoic.—The oldest rocks in the district are the Roche River schists, which cover an area about the junction of the Roche river with the Pasayton.

Post-Palæozoic.—These are batholithic intrusions, and under this head are classed the Remmel granodiorite of the Pasayton river, the gneiss of the Roche river, which is probably

Diagram XVII



Geological Survey, Canada

Princeton coal-area

Miles

To accompany Memoir by D. B. Dowling

only a phase of the Remmel granodiorite, and the monzonite of Copper mountain.

Cretaceous.—Lower Cretaceous rocks cover a wide area in the southwest corner of the district. They appear on the Pasayton river, just north of the Boundary line, and striking about 330° cross the Roche river, about six miles above the junction of that stream with the Pasayton. At both these places they are seen to overlie the eruptive rocks. The beds consist of hard sandstones and grits, interbedded with black and red argillaceous slates, all of which appear to have suffered much stress and pressure, for the angles of the dip are now all high, being usually about 50°.

Oligocene.—These sedimentary rocks constitute the coal-bearing formations and cover an area of nearly fifty square miles, the basin being fourteen miles long with a variable width of from three to five and a half miles. They consist of thick beds of sandstone, with clay, shales, and several seams of coal. The base of the series appears to be a very coarse-grained sandstone containing many large rounded white feldspars in a matrix of calcareous material. This rests on the eastern side of the basin, on the Copper Mountain series of rocks, while on nearly all other boundaries the sediments dip under the more recent volcanic rocks, which lie as sheets on them. In parts also these volcanics have thrust themselves through the sediments and now appear as islands in the older rocks. The strata do not now lie horizontally, but have been tilted at low angles, making an irregular series of folds. Some faults also occur.

Many drill holes have been bored in this Tertiary basin in search of coal, and with some good results. Most of them, however, were put down at or near the edge of the river, and only one near the western edge of the basin. By the kindness of Mr. Ernest Waterman, manager of the Princeton Coal and Land company, copies of the records of these drills have been obtained. These have disclosed the thickest seams to be in the vicinity of the town of Princeton, where a bed over eighteen feet in thickness was struck at a depth of 49 feet below the surface. The hole in which this seam was found was sunk near the bridge over the Similkameen river to a depth of 280 feet.

In this hole seams, aggregating thirty-five feet seven inches, were crossed in the first ninety feet, while the rest was in shales and sandstones.

The following is a record of this drill hole:—

Material.	Thickness.		Depth.	
	Feet	Inches	Feet	Inches
Gravel	14			
Shale	21	6		
Coal	4	6		
Sandstone	0	5½	40	5½
Coal	6	7½		
Clay	1	10	48	11
Coal	18	5½		
Shale	3	1		
Carbonaceous shale	4	6		
Clay	0	5		
Carbonaceous shale	0	8		
Sandstone	1	7		
Fire clay	2	1		
Coal	0	2		
Shaly coal	1	1		
Shale	1	0	81	11½
Coal	1	8		
Clay	1	4		
Coal	1	6		
Shaly coal	1	2		
Coal	1	6		
Clay, shale, etc	26	4½		
Sandstone	31			
Clay, shale, etc	79	6	227	
Sandstone	44	6		
Clay, shale, etc	8	6	280	

Aggregate of clean coal, 34 feet 5 inches.

One and a half miles farther up the Similkameen river the following section was obtained of the measures by the Vermilion Forks Mining and Development company, in bore-hole No. 2:—

Material	Thickness.		Depth.	
	Feet	Inches	Feet	Inches
Clay	17	0		
Shale	18	0		
Sandstone	1	0		
Shale	36	0		
Sandstone	1	9		
Clay	2	9		
Carbonaceous shale	3	0	79	6
Coal	1	0		
Clay	7	4		
Coal	0	2		
Sandstone	27	11		
Shale	1	7		
Clay	12	6		
Shale	6	6		
Sandstone	17	7		
Shale	1	5		
Sandstone	41	7		
Carbonaceous shale	4	0	201	1
Coal	5	0		
Carbonaceous shale	3	6		
Shale	3	6	213	1
Coal	1	7		
Clay	2	11		
Shale and sandstone	23	1	240	9
Coal	3	0		
Sandstone and shale	16	0		
Coal	0	9		
Shale and sandstone	41	7	302	1

Aggregate of clean coal, 11 feet 6 inches.

The deepest hole bored in the whole coal basin was Blakemore's No. 2, which was sunk to a depth of 1,000 feet at a point on the Similkameen river, about two miles above Princeton. The following record shows the thickness and the depth at which each coal seam was cut. The only workable seam was struck at 676 feet. This was found to be ten feet seven inches thick, with a clay parting of six inches near the middle of it:—

Depth.	Thickness of coal seam.
At 95 feet	1 inch.
95 " 4 inches	1 "
395 " 8 "	2 inches.
404 " 0 "	2 "
427 " 2 "	8 "
475 " 6 "	6 "
479 " 0 "	4 inches
508 " 9 "	3 "
579 " 4 "	2 "
579 " 8 "	2 "
676 " 8 "	10 feet 7 inches.
694 " 6 "	1 inch.
699 " 3 "	1 foot 3 inches.
793 " 2 "	1 " 0 "

Total thickness of coal 1,000 feet, fifteen feet.

Four miles up the Similkameen river a bore-hole, sunk to a depth of 257 feet, only went through two feet five inches of coal; while a drill hole near the south end of the basin at Ashnola, which penetrated to a depth of 398 feet, gave no workable seams at all, and only a few bands of what has been called in the record "coaly shale."

A bore-hole was also drilled near the western edgeof the basin where the sediments dip under the volcanics, and not far from where there is an outcrop of coal four feet thick. The depth of the hole is 863 feet, and in that distance seventeen seams of coal were cut through with an aggregate thickness of fifty and a half feet, of which the thickest seam was nine feet.

From a study of these records it would appear that most, though not all, of the workable seams are within 300 feet of the surface. It must be noted, however, that no prospecting by drilling has been done north of the Similkameen river.

The coal basin undoubtedly extends some distance north of the Similkameen river and beyond the limits of the area mapped, for outcrops of lignite and sandstone were found at the mouth of Summers creek. Two miles up this creek the sandstones are well exposed on the banks of the stream, and are here found to be overlaid by recent volcanic rocks. Farther north they appear to dip below the surface; but it is very likely that other areas of these coal measures may be discovered outcropping in places between here and Nicola lake.

Coal outcrops in many places, both on the Similkameen and Tulameen rivers, also on Summers creek, Bromley creek, and on Ninemile creek. At the latter place a cut in the bank made by the stream discloses a bed fifteen feet in thickness of fairly clean coal, with five very thin partings of clay, and all resting on white clay.

A selected sample from the big eighteen-foot seam at Princeton, worked by the Princeton Coal and Land company, was sent to Mr. Hoffmann, of the Geological Survey Department. After analysing it he found it to be a lignite, but one of the better class (sub-bituminous). Analysis by fast coking gave the following results:—

Hygroscopic water	16·17	per cent.
Volatile combustible matter	37·58	"
Fixed carbon	41·67	"
Ash	4·58	"
	100·00	
Coke, per cent	46·25	

Character of coke, pulverulent; colour of ash, brownish yellow.

Mr. L. M. Lambe of this department has correlated these lignite beds with the Coldwater group of Nicola lake, and similar beds on the Horsefly river. As a result of his investigations they have all been referred to Oligocene age, and are similar to the Amyzon beds of Colorado.

Though these beds are of the same age as the Coldwater group of the Nicola country, in which coal also occurs, there is a difference in the quality of the fuel contained in each. The Nicola coal is a true bituminous, whereas this is a sub-bituminous. The former, also, is considerably higher in fixed carbon and lower in water, while the fuel ratio is 1·447, as against 1·108 of the Princeton coal.

Some of the beds of the Princeton coal area are only in a primary stage of formation, and they still show the brown, woody fibre of the slightly altered vegetable remains. Much retinite also occurs in them. Some also have been completely destroyed by combustion, and it is to the combustion of an underlying bed of lignite that Dr. Dawson attributed the metamorphism and colour of the rocks at the Vermilion bluffs.

Post-Oligocene.—The solid rocks of this age are all of volcanic origin. They have a very wide distribution and prove that this part of the country was the scene of tremendous volcanic activity during that period. Their area must have been considerably diminished during the glacial period, so that their present distribution cannot be taken as indicative of their original extent. Detached areas of these rocks, too small to be mapped, are often found capping the older rocks, and these must at one time have been continuous with the larger areas, but have been separated from them by erosion. An instance is on record where these volcanic rocks have acted as a shield to the underlying rocks, preventing the erosive action of glacial ice from removing the decomposed material of these underlying rocks, and only going so far as to remove the overlying volcanic sheet; so that now there is a much greater thickness of decomposed rock than is usually found in much glaciated regions, and a local condition has been produced which resembles the unglaciated regions of the Southern States.

These volcanics are the youngest rocks in the district, for they are seen on Tulameen river and also on Onemile creek and Summers creek to rest directly on the coal-bearing rocks. On Tulameen river the stream cuts through beds of clay, shale, and sandstone overlaid by these volcanics for a distance of at least two and a half miles. The schists of Roche river are overlaid by these volcanics to the north, east, and west, and they also overlie the Copper Mountain series on the north and west. They consist of rhyolites and trachytes, andesites, basalt, tuffs, and breccias. The surface lavas are often amygdaloidal, the vesicles being filled with chert, chalcedony, or zeolites. Some agates and semi-opal were found in the volcanic area east of the Coldwater river.

Some of the dykes cutting the Copper Mountain rocks appear to be contemporaneous with these volcanic rocks, and in some way connected with them.

TULAMEEN COAL AREA.[1]

(*See Diagram XVIII.*)

(Extracts from report by Chas. Camsell.)

The Tulameen district lies in the southwestern portion of British Columbia in a part of the Similkameen Mining Division. Its central point, the village of Tulameen, situated at the junction of Otter creek with the Tulameen river, is about 37 miles north of the International Boundary line and about 27 miles east of the Fraser river at North Bend.

Coal occurs in the Tulameen district in a small basin which has been referred to by engineers and others as the Tulameen coal basin, the Granite Creek coal basin, or Collins Gulch coal basin. The last two names were originally applied to outcrops of coal seams in two separate localities, and since the two localities have been found to be parts of the same basin, it seems advisable to discard both names, retaining the first name—the Tulameen coal basin—for the whole field.

Although this part of the Tulameen district has been well known to prospectors since the time of the gold discovery in Granite creek in 1885, and though the outcrop of coal in Collins gulch must have been quite evident to anyone travelling the bed of that stream, no attempt seems to have been made until quite recently to prospect the basin or to determine its area. Some coal has annually been extracted from the Collins Gulch outcrop for a number of years; but up to the present there has been no demand for it, and what was taken was merely sufficient to supply the needs of the owner, Thomas Rabbitt. About 1902 coal was discovered on the Granite Creek side of the basin, and shortly after the whole field was taken up in coal claims. These claims were then bonded to the Erl Syndicate, and some development work was done; but the option expired without the syndicate buying up the claims. Almost the whole basin is now owned by the Columbia Coal and Coke company, which is prospecting it vigorously.

[1]C. Camsell. Geology and Mineral Deposits of the Tulameen District, B.C. Memoir 26, Geol. Surv., Can.

The first mention of the field is made by W. F. Robertson in 1901.[1] Brief mention is made of it in the Summary Report of the Geological Survey in 1908, and a more extended account is given in the Summary Report for 1909.

The coal-field lies in the southeast corner of the area covered by the Tulameen map, partly in the drainage basins of Collins and Fraser gulches and partly on the other side of the divide, in the basin of Granite creek.

The basin is roughly oval in shape, having its longer axis running northwest and southeast. In this direction it has a length of nearly 3⅓ miles, while its greatest width is about 2¼ miles. The area covered by the coal-bearing rocks is 3,700 acres, and that covered by the coal itself has been calculated at 3,254 acres. Of the coal area, however, 1,070 acres are covered by a flow of volcanic lava.

Almost all of the coal is included in eight coal claims, each one of which is a mile square. Six other coal claims have been staked; but they lie mostly outside the limits of the productive field.

Small stringers of coal, associated with sandstone, are known to outcrop in Cedar creek and in Blair creek on the north side of the Tulameen river, and really form part of the main basin. Their thickness is so small, however, and the probable quantity of coal so limited that they have not been included on the geological map within the area coloured as coal-bearing.

The situation of the coal-field on the divide between Granite creek and streams flowing into the Tulameen river makes it difficult of access for mining, and the topography of the field adds somewhat to that difficulty. The field has a topography characteristic of the upper levels of the Interior Plateau region. The summits of the hills are rounded and the slopes from them gentle. The highest point in the basin has an elevation of 2,100 feet above Tulameen river at Granite creek, or about 3,500 above the sea, and the lowest point at which coal outcrops is in Collins gulch, where there is a difference of 850 feet in height between that point and Tulameen river.

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[1]Annual Report, Minister of Mines, B.C., 1901.

It is impossible to obtain access to the coal basin by any valley with an easy grade, because it lies at the headwaters of the streams and all of them have steep gradients down to the master stream which is Tulameen river. Collins gulch rises near the centre of the basin and flows northward through it, across the strike of the rocks. Fraser gulch also cuts the basin for about a mile and flows out of it towards the north. The North Fork of Granite creek cuts through the southwest border of the basin and flows in it for about a mile. These creeks, and some of their tributaries, are the only streams which flow through the coal basin and all of them have relatively small valleys, so that they do not expose very good sections of the rocks.

Owing partly to the softness of the members of the coal-bearing series, outcrops of solid rock are very rare, and except in a few places in the stream beds, the whole basin is covered with drift. It is also almost all covered with a forest growth, which assists in disguising the character and structure of the rocks.

The oldest rocks in the Tulameen district are those of the Tulameen group. They are tentatively correlated with Dawson's Nicola series which is of Triassic age. These rocks are mostly of volcanic origin, and because they are interstratified with some argillites and thin beds of limestone are thought to have been laid down under water. Some plant remains have been found in the argillites; but they are too fragmentary to be identified. These rocks have been greatly altered both by regional and contact metamorphism, and now stand at fairly high angles. They cover the largest area of any rock formation in the district.

In the period between the deposition of the rocks of the Tulameen group and the Cretaceous, a number of igneous intrusions took place, which are probably contemporaneous with large batholithic intrusions throughout the whole western Cordillera. These igneous rocks are referred to the Jurassic period, and have been thrust through the rocks of the Tulameen group in the following sequence: (1) boulder granite; (2) peridotite and pyroxenite; (3) augite syenite; (4) Eagle granodiorite.

These igneous rocks are now found in various parts of the district in large and small bodies all having a general north and south trend. Their combined area, within the limits of the sheet, is somewhat less than that of the Tulameen group.

Resting unconformably on top of the above-mentioned rocks are two groups of conformable rocks, which are referred to Oligocene age from the plant remains found in them. The lower of these two groups, consisting almost entirely of volcanic flows of a prevailingly andesitic composition, is called the Cedar volcanic series; while the upper containing nothing but sediments and made up of sandstones, shales, conglomerates, and coal seams, is called the Coldwater series and is correlated with similar rocks in the Kamloops district. The rocks of these two groups cover the greater part of the east half of the area, with the volcanic portion preponderating. They now lie at angles which rarely exceed 45 degrees and have, therefore, not been greatly disturbed since deposition.

Intrusive into the Oligocene rocks, and presumably of Miocene age, is a body of pink alkaline granite, called the Otter granite, which is found on the eastern side of Otter valley from China creek to the northern limit of the sheet. It has a length of about 9 miles and a width varying from a mile to 2 miles.

The youngest consolidated formation in the district is a volcanic flow of olivine basalt. This occurs as a body circular in outline in the region between Granite creek and Collins gulch, where it is seen to rest unconformably on the Oligocene sediments. It still preserves its horizontal position, and from this fact is considered to be late Miocene or perhaps Pliocene in age.

Dykes of a composition ranging from granite porphyry to olivine diabase are very common in the district, and cut principally the pre-Oligocene rocks.

Stream deposits cover the floor of Otter valley and the lower part of the Tulameen valley. Above the mouth of Slate creek, however, in the Tulameen valley, and in the tributary valleys, stream gravels are not very abundant, and are found merely in patches here and there.

Glacial material is irregularly distributed over the whole of the district, having been accumulated to considerable extent in some parts, while in others it appears onlv as a thin veneer.

The name "Coldwater series" is applied to a series of rocks of Oligocene age lying in the drainage basin of Collins gulch and extending over the divide to the Granite Creek slope. This series contains the coal seams. The area covered by them is slightly oval-shaped, with its longer axis running northwest and southeast. In this direction it has a length of almost $3\frac{1}{2}$ miles, while the greatest width is $2\frac{1}{3}$ miles. The total area as measured on the geological map is 5·78 square miles, or 3,700 acres. Of this amount 1,070 acres are covered by a flow of olivine basalt, so that only 2,630 acres of the Coldwater series are mapped as being exposed.

The rocks which make up the Coldwater series are all soft, and weather down so easily that good exposures of them are not numerous. The best natural section of them is exposed in Collins gulch, a ravine which cuts directly across the strike of the beds. This section was carefully measured with compass and chain, and a thickness of 2,270 feet of strata was obtained from the top of the Cedar volcanic series up to a point where the rocks are entirely covered by drift. This point was probably within 100 or 200 feet of the top of the series, so that the total thickness of these rocks would be less than 2,500 feet along this line.

The basal bed of the series is a conglomerate, which on the western half of the basin is separated from the main body of the series by a considerable thickness of Cedar volcanic rocks, but in the eastern half is probably united with the rest of the series. This conglomerate is exposed on the north face of Jackson mountain, on Blair creek, and at points on Cedar creek and the North Fork of Granite creek. A thickness of about 25 feet of this conglomerate is exposed on Blair creek below some sandstone, and is seen to consist of some water-worn pebbles of siliceous and argillaceous rocks cemented together with a matrix of sand grains which contain some plant remains. Some sandstone carrying fossil plants and associated with very thin seams of coal rests directly on top of the conglomerate.

The section of the rocks exposed on Collins gulch may be divided roughly into three groups of rocks. The lowest group measuring 600 feet in thickness and resting conformably on the Cedar volcanic rocks is composed of sandstones with which are interbedded a few thin seams of shale. Above this is 460 feet of very fissile shale containing at least two coal horizons. The upper part of the section has a great preponderance of sandstone, but contains also some thin shale bands and beds of conglomerate.

The sandstone at the base of the Collins Gulch section rests directly and conformably on a flow of andesite, and is a soft, friable arkose, reddish-brown in colour, massive in structure, and containing many plant remains. From the lack of a continuous exposure it is not possible to state the relative proportion of shale to sandstone in this division of the series; but the figure shows four bands of shale each one of which is 10 feet or more in thickness.

The sandstones of the lower division of the series pass gradually into the shales of the middle division by becoming more thin bedded in structure and argillaceous in composition. The middle division contains at least two coal horizons, but is otherwise made up entirely of shales to a thickness of 460 feet. The shales are very fissile and split easily into thin plates. They are dark coloured but often weather whitish on the outcrop. On most of their exposures no fossils could be found in them; but at certain localities such as at the northwest edge of the basin and on the little North Fork of Granite creek they contain many plant remains. These plant remains have served to identify their age and to correlate the whole series with other series of rocks in the adjacent country. These fossils are referred to under a subsequent heading.

The upper division of the series, like the lower, consists mainly of sandstones, but holds also thin beds of shales and some conglomerate. The sandstones are generally rather coarse in texture and massive in structure. They are light coloured and are composed of quartz grains embedded in a white, fine-grained, sandy matrix. The shale and conglomerate bands intercalated with the sandstones are comparatively thin and few in number. The shales are more or less sandy and often contain coal markings. There is a probability that a coal seam may be found in this division of the series, for on the southern side of the basin a small seam outcrops, which belongs apparently to this horizon.

In the sandstones and shales of the Coldwater series no metamorphism is apparent either of regional or contact origin.

There is, however, some evidence of metamorphism in the coal seams which are found associated with the shales. This metamorphism is not apparent on a cursory examination of the coals; but is revealed in the chemical analysis of coal samples taken from different parts of the basin. For example, samples taken from the workings on the Granite Creek slope a short distance from the olivine basalt give a firmer and higher percentage of coke than those taken from Collins gulch at a greater distance from the basalt. The fuel ratio of the former is also higher. This difference can only be accounted for by metamorphic action due to the heat of the basalt, and it is reasonable to expect that when the coals come into close contact with the basalt a stronger metamorphosing action will have produced a still higher grade of coal. This, however, can only be proved by further examination.

The Coldwater series is essentially sedimentary in origin, and consists of a succession of strata deposited in a horizontal, or approximately horizontal attitude. Subsequent events, however, have so affected the whole series that at the present time it does not preserve the original position in which its members were laid down. Its structure is now that of a synclinal basin having its longer axis running approximately northwest and southeast. On the southwest side of this basin the dips of the beds are in general towards the northeast; and in the northeast side of the basin they are towards the southwest. These dips vary—where they have been measured—from 20 degrees up to 70, and are greatest on the outer borders of the syncline. The average dip along the outer edges of the basin is about 40 degrees, and this decreases gradually towards the centre, where the strata presumably become horizontal before rising in the opposite direction.

Although it can be accepted as a general rule that the dips of this series are regular on both sides of the basin, it is sometimes apparent, where sections have been exposed either by natural agencies or in the course of mining development, that there are other dips which do not conform to the general direction obtaining throughout the basin. In these cases pressure has been exerted in a different direction to the main one, which resulted in the formation of the syncline, and minor folds have been produced. Examples of such folds are seen on Collins gulch at the old mine workings, and again at the main workings on the Granite Creek slope. In the latter case at Nos. 1 and 2 tunnels the dip of the strata is towards the east; but it is impossible that it can continue far in that direction before the strata rise and the dip changes to the opposite direction.

Although there are these small folds, no instance has yet been observed where the folding has gone so far as to produce faulting except to a very minor degree. It is not to be expected, however, that faults will not be encountered in the whole basin. It is certain from the age of these rocks and their present attitude that they have passed through periods of orogenic disturbance which in themselves might have resulted in faulting; and it is the experience obtained in mining the coal in most of the basins of this age in this part of British Columbia and the adjacent regions of Washington, that faults have been encountered. It is probable, therefore, that faults do occur.

For another reason faulting might be expected to have taken place. In the structure sections which are drawn through the coal basin, olivine basalt is shown as a sheet covering part of the basin. It is probable that, because dykes of olivine basalt are found in the immediate vicinity of the coal basin, the fissure or fissures through which the olivine basalt reached the surface traverse the rocks of the coal basin, and that, therefore, the source of the olivine basalt was directly beneath the coal basin itself. The withdrawal of the olivine basalt magma from the region beneath, and its deposition on top of the coal basin would cause a readjustment by sinking of the strata between, and in this readjustment faulting might have occurred.

The Coldwater series of the Tulameen district is made up of rocks that are so easily weathered down that natural exposures of them are comparatively rare. To this fact it is due that, although coal was long known to outcrop in Collins gulch, it was years before it was discovered anywhere else. The shale beds of the series are the softest, and can often be identified and followed by a depression on the surface of the ground. The sandstones are the most resistant members, and where they are interbedded with shales they form hard outstanding ribs with depressions between them.

The whole formation is characterized in the topography by rounded outlines and gentle slopes.

The oldest formation with which the Coldwater series is in contact is the Tulameen group, and the nature of this contact leaves no doubt of the relation existing between these two groups of rocks. On Fraser gulch the lower sandstones of the Coldwater series outcrop within a few feet of the black and bluish slates of the Tulameen group. The sandstones dip towards the southwest, and strike about S. 60° E., while the slates strike about N. 65° E. and dip 65 degrees to the north. A discordance of dips with a much higher angle in the Tulameen rocks than in the Coldwater can also be noted on the trail to the Granite Creek mines where that trail crosses the contact between these two groups of rocks. These facts, coupled with the strong difference in structural and physical features between the two groups of rocks, proves that a long period of time must have elapsed between the deposition of each group. The evidence suggests that the rocks of the Tulameen group were upturned and compressed, and their edges truncated before the deposition of the Coldwater series. In other words there is a strong unconformity between the two groups of rocks.

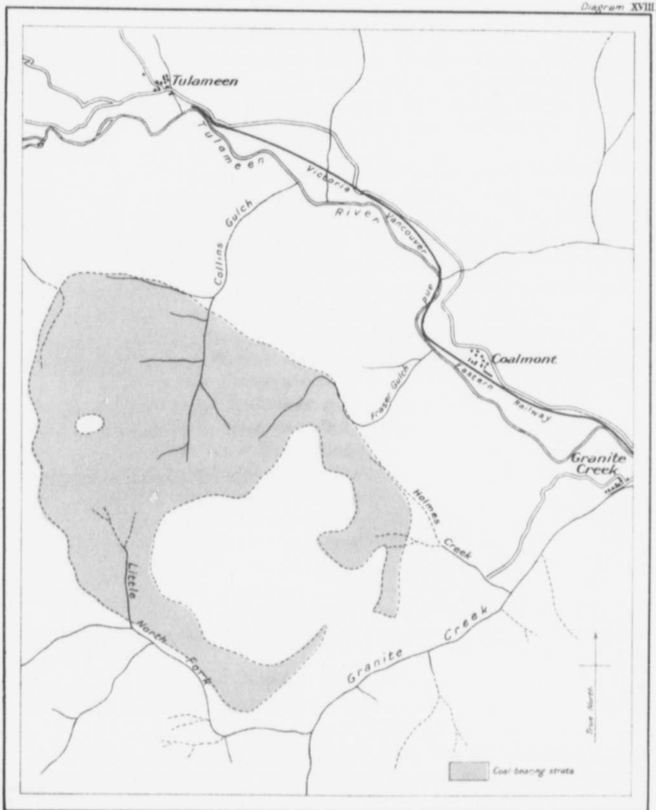
Around two-thirds of its outer border the Coldwater series is in direct contact with the Cedar volcanic series. The two series are conformable with each other, because the lower strata of the Coldwater series are interbedded with the upper members of the Cedar volcanic series. The lower beds of the Coldwater series, consisting of conglomerate passing upward into sandstone, become separated from the main body of the series by a wedge of the Cedar volcanic series at Fraser gulch. Passing around the western side of the basin from north to south, the conglomerate and sandstone do not again unite with the main body of the Coldwater series until the wedge of Cedar volcanic rocks pinches out on the North Fork of Granite creek at the southern end of the basin. In this distance the sandstone and conglomerate can be found outcropping in a number of places, and in others their position can be identified by the topographic expression. The evidence shows that deposition of the lower beds of the Coldwater series began in this region before the extrusion and deposition of the uppermost beds of the Cedar volcanic series, and hence the two periods overlap to a certain extent and there is no time break between them. The dips of the two series also coincide in degree and direction, and their strata are, therefore, conformable.

The only younger formation with which the Coldwater series is in contact is the olivine basalt. This lies as an almost horizontal sheet over the top of the Coldwater series covering about one-third of its total area. The actual contact between the two was nowhere found exposed. The relation between the two formations is best seen near the head of Fraser gulch. At this point the sandstones and interbedded shales of the Coldwater series dip at an angle of 25 degrees towards the south and strike directly underneath the covering of flat-lying olivine basalt. That the strike and dip of the sandstones persist underneath the basalt are indicated by the topography of the surface, which shows parallel ridges, presumably of sandstone, separated by hollows, probably marking shale beds, continuing up to the contact of the basalt. These features indicate that there is an unconformity between the two formations, for the Coldwater series must have first of all been tilted and then the upturned edges truncated by erosion before the olivine basalt flowed over its surface.

The structure of these rocks and their association with beds of coal indicate that they were laid down in a horizontal or nearly horizontal attitude by the action of water. They have been correlated by their fossils with Dawson's Coldwater group described in his report on the Kamloops map sheet.[1] In the course of the examination of them no further information was obtained of their mode of origin than that outlined in the report above cited. Dawson states that "these beds were laid down in lakes or river estuaries, in hollows then existing in the old denuded surface of the Palæozoic and Triassic rocks," and that "they may well represent the work of some river systems of the

[1]G.S.C. Annual Report. Vol. VII, Part B.

Diagram XVIII



Geological Survey, Canada

Tulameen coal-area

Miles

To accompany Memoir by D. B. Dowling.

early Tertiary time of denudation." It might be argued from the present shape of the Coldwater series of this district, a shape which is now oval but before compression might very well have been almost circular, that the evidence in favour of it having been a lake basin is stronger than that for an estuary. Indeed, Penhallow,[1] in speaking of rocks of similar age outcropping on the Tulameen river near its junction with the Similkameen, distinctly states that "the beds were evidently laid down in the bottom of a lake."

The determination of the age of the Coldwater series of the Tulameen district depends entirely on its fossil plants. Plant remains were collected from three different localities within the area covered by this series. The most productive locality was one near the head of the little North Fork about the middle of lot 295. Another was at the head of a small creek flowing into Collins gulch and directly south of Jackson mountain. The third was in Collins gulch immediately below the point at which coal mining was formerly done. The two first-mentioned localities were in the shales which form the middle of the three groups into which the whole series was lithologically divided. The last was in the sandstones which form the lowest of the three groups. Besides these three localities a few plants of the same varieties were observed in sandstones near the head of Collins gulch and in the sandstones intercalated with beds of the Cedar volcanic series which form the base of this series and which outcrop in Blair creek on the north side of the Tulameen river.

A collection was made of over forty specimens, many of which were well preserved. These were studied by Dr. F. H. Knowlton, of the United States Geological Survey, who has been able to identify two different species of plants. These plants are:—

Comptonia cuspidata Lesquereux.
Sequoia langsdorfi (Brongniart) Heer.

Dr. Knowlton says that "this material—thirty-nine specimens of the conifer and a single dicotyledonous leaf—is not sufficient to definitely fix the age, through it is presumably Oligocene or lower Miocene."

[1]Tertiary Plants of British Columbia, G.S.C., 1908, page 20.

Accepting Dr. Knowlton's determination of the age of these rocks, they can, therefore, be correlated with certain coal-bearing rocks called by Dawson the Coldwater group, which are found at the following places in the adjacent region of British Columbia: Hat creek, Copper creek, Nicola valley at the junction with the Coldwater, and the Similkameen valley at Princeton. These various localities had already been correlated with each other by Penhallow in the report cited above and their age determined from plant remains as Oligocene. The same conclusion is arrived at by Handlirsch from a study of the insects found in the beds.[1]

In the adjacent region south of the International Boundary line, coal-bearing beds having a strong lithological resemblance to those of the Tulameen have been described under the name of the Roslyn formation.[2] This formation is classified by the United States Geological Survey as upper Eocene; but it may probably be of similar age to the Tulameen beds.

The occurrence of Amyzon in the beds of the Similkameen area at Princeton led Cope and Lambe to correlate that area with the Amyzon beds of Oregon, Nevada, and Colorado. The correlation of the beds in the Tulameen district with those at Princeton would, therefore, include correlation with the areas in the United States mentioned above.

The total thickness of the coal-bearing rocks, as measured in a section along Collins gulch, is less than 2,500 feet. In this section the whole series can be divided roughly into three groups. The lowest group, measuring 600 feet in thickness, is composed of sandstones, with which are interbedded a few thin bands of shale. The middle group is made up of 460 feet of very fissile shale, and in this group lie the principal coal seams. The upper part of the section contains a preponderance of sandstones, with which are associated some thin shale bands and beds of conglomerate.

From an economic point of view the most important of the three groups is the middle one, for in it lie the principal coal seams. The shales which compose this group are very fissile

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[1]G.S.C. Memoir No. 12-P. Contr. to Can. Palæontology.
[2]U.S.G.S. Folio No. 139. 1906.

and split easily into thin plates. They are dark coloured on fresh surfaces, but often weather whitish where they outcrop. They contain many plant remains which have served to identify their age as Oligocene.

Two coal seams in this group, exposed in the bed of Collins gulch, show a floor and roof composed of shale. In what is believed to be the same horizons on the south side of the basin, the roof and floor are also shale, but the shale is somewhat more sandy.

In the lower of the two coal horizons on the south side of the basin the section exposed in the workings shows 5½ feet of clean coal resting on shale. Above that is 4 feet of impure coal, and above that again for 50 feet are thin seams of coal interbedded with clay or sand.

The upper of the two coal horizons at the same place shows the following section from top to bottom of a raise in No. 2 tunnel:—

SECTION IN NO. 2 TUNNEL, GRANITE CREEK.	Feet	Inches
Mostly sandstone with thin seams of coal..........	23	
Clay..........	4	0
Impure coal..........	2	1
Coal with clay partings..........	3	9
Clay..........	....	4
Coal..........	....	4
Clay..........	....	3
Impure coal..........	1	1
Coal..........	1	7
Clay..........	....	2
Clean coal..........	6	6
Coal with clay partings..........	4	6
Clay..........	1	0
Coal..........	3	0
Clay..........	1	8
Coal with 2 sandy partings..........	1	9
Clean coal..........	5	0
Total..........	60	0

On the same side of the basin a third coal horizon, containing a good seam of workable coal, is said to underlie the lower of the above-mentioned horizons; but its outcrop could not be found.

In the upper group of the three into which the whole series has been divided the prevailing rock is sandstone. On Collins gulch a certain shale band in this group contains many coal markings, and on the south side of the basin a small coal seam is exposed, which is probably in the same horizon.

The most complete section showing the coal has been exposed by prospecting operations on the south side of the basin. This, as already indicated, shows four seams of workable coal, 6½, 3, 5, and 5½ feet, respectively, in width, making an aggregate thickness of 20 feet. The reported coal horizon below and the uppermost seam of all, which may possibly develop into a workable seam, might be added to the estimate of the total thickness of coal in the basin; but for the present the estimate of quantity of coal in this field should be based merely on the known 20 feet of thickness.

The total area covered by the coal-bearing rocks is about 3,700 acres. By following out the outcrop of the coal seams it has been estimated that 3,254 acres in the coal basin are covered by coal. Presuming that the 20 feet of workable coal exposed on the south side extends over the whole basin, and estimating 1,000 tons of mineable coal to the acre, there are in this field over 65,000,000 tons that can be extracted. The total quantity of coal in the basin, however, may greatly exceed this figure.

The coal-bearing rocks are essentially sedimentary in origin, and must, therefore, have been deposited in a horizontal or approximately horizontal attitude. Their structure now, however, is that of a synclinal basin having its longer axis running almost northwest and southeast. On the southwest side of the basin the dips of the beds are in general towards the northeast; and on the northeast side they are towards the southwest. These dips vary from 20 degrees up to 70, and are apparently greatest on the outer edges of the basin. The average dip, however, is about 40 degrees.

The structure of the beds does not always conform to the general structure of the syncline, and many discordant dips are noticed. In such cases pressure has been exerted in a different direction to produce dips and minor folds which strike in directions other than northwest and southeast. Such folds appear at the workings on Granite creek and in Collins gulch, but they are of very little importance.

Faulting is not apparent, except to a very minor degree, in the development work so far undertaken. Small faults, however, with a throw of 6 or 8 inches, appear in No. 2 tunnel on the south side of the basin. Larger faults will probably be encountered as development of the field proceeds. It is quite certain from other geological evidence that rocks of this age have passed through periods of considerable orogenic disturbance which might result in faulting, and it is the experience in most of the coal-fields of this age in British Columbia and Washington that faults of some magnitude do occur, so that it is reasonable to expect that they are present here also.

A sheet of olivine basalt in places overlies the coal-bearing rocks. The basalt is an igneous rock which rose from the interior of the earth through fissures and flowed over the surface. Dykes of the same rock appear in the bed of Granite creek, cutting the rocks which underlie the coal-bearing rocks, and it is quite probable that they traverse the coal-bearing rocks also. The source of the olivine basalt is probably, therefore, to be found beneath the coal basin itself. The withdrawal of the olivine basalt from the region beneath, and its deposition on the top of the coal basin, would cause a readjustment of the strata between and, in this readjustment, it is only to be expected that faulting should have taken place.

The coal varies both in physical and chemical properties from one part of the field to another. On fresh faces it has a banded appearance, due to alternating layers of bright and dull lustre, with the latter predominating. The dull bands, however, show many small lenses of bright coal in them. Sulphur, in the form of films of pyrite, is present, but is apparently not abundant. The powdered coal has a very dark brown colour.

Some of the coal is fractured into small cubical blocks, and in other seams it is more massive. On exposure to the atmosphere it breaks down in time to a fine dust, but as a rule resists weathering for a considerable period.

Chemical analyses of the coal show that it is to be classed as bituminous, though certain analyses from particular parts of the field indicate a somewhat lower grade. The coals resemble those of the Nicola coal-field, and are somewhat better than those of the Princeton field. Most of the coals of this age in British Columbia are lignites; but the higher grade of this coal is accounted for either by the greater compression to which it has been subjected, or else by the presence of volcanic rocks in the immediate neighbourhood, which by their heat have driven off a certain percentage of the water.

The ash of the coals in some analyses is high; but this is characteristic of other coals of the same age in adjacent districts, and is due to the fact that the samples which included thin partings of clay were taken by cutting a channel across the seam from roof to floor.

The coke of the samples from the south side of the basin is strong and coherent and has a bright silvery lustre. A test of a larger sample than that used, however, would be necessary to ultimately determine the coking qualities of the coal.

The coke from the Collins Gulch seams is tender and less coherent and would not stand much pressure. The general quality of the coal from this part of the basin is inferior to that from the south side. The difference may be accounted for by the fact that the Collins Gulch seams lie at a greater distance from the overlying volcanic rocks.

The following analyses of coals from this field have been made in the laboratory of the Department of Mines, the first four from samples taken by the author, and the last two from samples taken by Geo. de Wolf in 1899 and published in the Annual Report of the Geological Survey for 1899, page 29 R:—

ANALYSES OF COAL SAMPLES.

No. of sample.	1	2	3	4	5	6
Locality.	Granite Creek mines.	Granite Creek mines.	Granite Creek mines.	Collins gulch.	Collins gulch.	Collins gulch.
Width of seam.....	6½ feet.	5 feet.	5 feet.	?	?	?
Moisture per cent..	3·04	4·34	2·97	3·26	4·62	4·87
Vol. combustible matter per cent..	31·88	31·08	31·28	43·33	41·16	36·86
Fixed carbon per cent	51·11	48·89	52·49	49·70	49·04	50·99
Ash per cent......	13·97	15·69	13·26	3·71	5·18	7·28
Coke per cent.....	65·08	64·58	65·75	53·41	54·22	58·27
Character of coke.	strong, coherent	strong, compact	strong, compact	tender, coherent	firm, coherent	tender, coherent
Fuel ratio.........	1:1·60	1:1·57	1:1·68	1:1·15	1:1·19	1:1·38
Colour of ash......	light grey	ash grey	light grey	....	light grey	light grey

The earliest work done in this field was that on Collins gulch where three tunnels of unknown length were run in on the strike of the coal. Two of these tunnels enter on the west side of the creek, and both have now caved in. The third is on the east side of the creek and is the longest of the three.

Up to the spring of 1910 the principal work in this field was carried out on the south side of the basin, and consisted of six tunnels of various lengths aggregating over 1,300 feet, and a great number of open-cuts all in coal. The main tunnel is that known as No. 2, which runs in on the strike for a distance of more than 800 feet. In this tunnel a raise goes up on the dip for 40 feet and another across the dip for 60 feet. The problem of transporting the coal mined on this side of the basin to the railway which will run in the valley of Tulameen river was one of considerable difficulty and caused the abandonment of the work.

On Fraser gulch the coal outcrop approached nearer the Tulameen river, and work was consequently concentrated at this point. Here the coal seams outcrop at an elevation of about 1,000 feet above the river and dip away from it towards the southwest. A large number of open-cuts have been made on this side of the basin to trace the outcrop of the seams from Collins gulch eastward, and a prospecting tunnel was run in across the strike at the first bend in Fraser gulch.[1] Some diamond drilling was begun at the head of Fraser gulch to ascertain the depth at which the coal seams lie at this point.

NICOLA AND QUILCHENA COAL AREAS.

(*See Diagram XIX.*)

These two basins of Oligocene rocks occupy depressions in Triassic traps and in this respect resemble the occurrences at Tulameen and Princeton. The discussion by Mr. Camsell on the age of the deposits at Tulameen, applies equally to this area and will be only briefly referred to at this place. The following general summary description is by Mr. Camsell and is extracted from Guide Book No. 9.[2]

"The town of Merritt is situated in Nicola valley at the junction of Coldwater river with the Nicola. The district lies in the Interior Plateau region into which Nicola river has cut one of those deep, wide valleys, characteristic of the region. The bottom of the valley is about 1,900 feet above sea-level, while the surrounding country stands 1,500 feet higher. The country is open or only sparsely timbered, and the slopes, though often steep, are generally covered by a thick mantle of drift.

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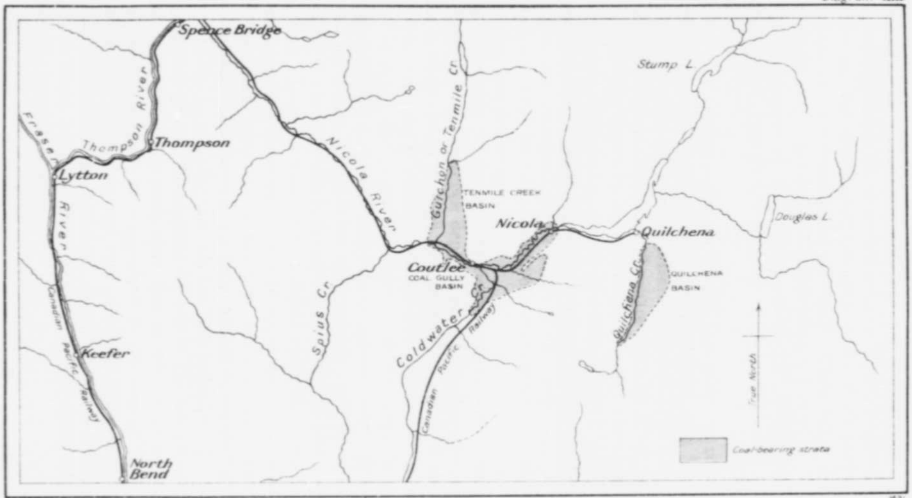
[1]The tunnel which was run from the Fraser gulch although it reached the coal at the point expected, has been abandoned on account of the broken nature of the coal encountered. Development has since been recommenced on the south side of the basin. (C. C.)

[2]Twelfth International Congress Guide Book No. 9, p. 128.

Diagram XIX



Geological Survey Canada

Nicola and Quilchena coal-areas

Miles

To accompany Memoir by D. B. Dowling

"The oldest rocks of the district are of Triassic age, and belong to the Nicola series. They consist of folded and metamorphosed volcanic flows, and some limestone and argillite. Unconformably above them are the coal-bearing Oligocene rocks which consist of sandstone, conglomerate, shale, and coal. These again are overlaid in places by more recent basaltic flows.

"The importance of the district about Merritt depends primarily on the presence of Oligocene rocks containing bituminous coals.

"Like other Oligocene areas in British Columbia the rocks about Merritt are believed to have been deposited in a lake basin and since elevated to their present position. The basin covers a superficial area of about 40 square miles all of which, however, does not appear to be underlaid by coal. The rocks consist of sandstones, shales, and conglomerates, which dip at angles varying from 10 to 40 degrees. In places the strata have been folded into anticlines, and in others faulted and considerably displaced. They contain a variety of fossil plants from which their age has been determined."

The depression in the pre-Tertiary surface, which was partly filled by the Oligocene deposits of the Nicola basin, is irregular in outline, and through it is eroded the valley of the Nicola river and its tributaries. The basin consists of two parts. The larger and probably deeper portion extends from near Nicola lake to a short distance up Coldwater river. It is connected by a narrow depression with another basin lying to the northwest, through which Tenmile creek flows to join the Nicola river. In these basins the stratified rocks dip towards the centre and show some disturbance as noted above. A large part of the coal-bearing strata has been removed by stream erosion from the whole basin and a deep channel scored through the centre of the larger lobe; but this has been subsequently refilled by glacial debris. Prospecting for coal in the low ground has met with great difficulties from this mantle of drift. A block of the Oligocene rocks is preserved to the west of Coldwater river near the Nicola and very successful operations in mining coal seams are being carried on. A series of seams dipping towards the basin are there found and two mining companies are operating several collieries.

The earlier reports on this area made by Dr. G. M. Dawson, drew attention to this section in Coal gully, a cut in the face of this block, and in this four seams are exposed. In the mining operations it is possible that upper seams have been found; but their correlation is problematical.

The various coal seams numbered from the lowest, are described by Dr. R. W. Ells,[1] as below:—

"Thirteen chains south of the mouth of the gully the first outcrop of coal is seen on the west side about forty paces distant from the brook. An opening made here shows the presence of a fault, which cuts off the coal sharply at this place, with a direction of about N. 30° W., the western wall being sharply defined and consisting of grayish grit. The coal at the east of the fault dips N. 60° E.>13°. The beds in the upper part of the hole are somewhat crushed. The elevation of this place is 200 feet above the gully.

"On the east side the same bed has been opened up by a drift driven along the coal to a distance of eighty feet, starting at about fifteen feet above the bed of the brook. A section of the coal as measured in the tunnel, gives:

	Feet	Inches
Sandstone forming the slope of the hill above:—		
Coal	5	0
Shale parting	1	6
Coal seam No. 1.		
Coal	13	6

"The dip varies considerably. A short distance in the tunnel, where a small side drift has been made to the south, the dip of the coal, which here has a shale parting of two and a half feet, appears to be N. 70°E. < 15° and S. 80° E. < 15°, showing a low fold. These outer beds may, however, be somewhat crushed, as they form the eastern slope of the gully. The coal at the entrance to the drift is also crushed. Below this there appears to be about 175 feet of the grayish sandstone. At the inner end of the tunnel the dip of the coal as could be ascertained is N. 70°E.<10°, and the drift cuts obliquely across the coal bed, starting from the bottom, and at the inner end reaching the roof.

[1]Summary Report 1904, p. 51.

The coal itself appears to be of good quality, yielding large blocks, and has been mined for several years for local consumption. Its extension eastward cannot be traced at the surface, but it probably underlies the hill to the east, which we may call Coal Gully hill. It appears to be the lowest seam in this area, and should underlie to the northeast the flat west of the Coldwater unless it has been removed by denudation, a point which can only be proved by boring in that direction.

"On the west side of the gully the coal outcrops at the fault, apparently represent the west side of an anticline, which extends a few degrees east of south along the lower part of the ravine, the opposing southwest dip being seen at several points. A third outcrop, three and a half chains south of the tunnel on the east bank, may represent a still further extension of the seam. The dips along this part of the section show considerable divergence and may represent additional faults or a disturbed anticline.

Seam No. 2.

"About eight chains south of the tunnel another seam outcrops on the east side of the gully. The roof appears to be of shale and shaly sandstone and the outcrop as measured, gave at the top:—

	Feet	Inches
Coal	5	5
Shale	4	0
Coal	3	4
Shale floor.		

"Owing to the bed of this stream and the sides of the gully being much encumbered from the sliding down of the banks, the exact measurements of these seams are difficult to determine in some places.

"The dip of coal No. 2 appears to be southeast $<15°—20°$ and a short distance above, on the brook, the overlying shales dip south $<50°$, showing a sharp change in direction, which may indicate the further extension of the anticline noted on the lower part. Some exploratory work has been done on this seam; but the sides have fallen in and but little can be ascertained as to the exact nature.

"*Coal seam No. 3.* Above this point the course of the gully inclines to the southeast, and four chains further there is another outcrop of coal on the east bank, which appears to measure 17 to 18 feet, capped by gray marly shales with a dip S. 55° E. < 20°. This may represent the upper part of Dawson's section, which he gives as 15 feet 5 in. underlaid by sandstone. Of the details of this seam and its extension, nothing can be said, very little work having been done at this place.

"*Coal Seam No. 4.* Further south near the head of the main gully, a fourth seam is exposed on the east side with thin bedded sandstone, showing a thickness at the outcrop of about three feet, the lower part being concealed in the bed of the stream. No work has been done at this place and it is apparently not included in Dawson's section."

To the east of Coal gully is Coldwater hill around which the stream of the same name flows. A seam in the upper part of the series is here exposed. This is being mined near the Coldwater and is from 5 to 6 feet in thickness.

In order to test the lower ground a series of bore-holes were put down at various times and although many of these did not penetrate the drift, coal seams were found. Thus, the bore of 1892-3 reached a 5 foot seam at 195 feet from the surface near Coldwater river and another near the Nicola river reached a similar seam at a depth of 137 feet. The Quilchena basin lies to the east of the Nicola basin in a valley tributary to Nicola lake. The Oligocene deposits are known to contain several coal seams, of which Dr. Ells[1] writes:—

"The coal outcrops in this basin, of which seven can be recognized in the several gullies, are at a higher level than in the Coldwater district. They all occur on the eastern slope of Quilchena creek, so that the productive portion of the basin will doubtless be found on the east side of that stream. The denudation which has taken place along the valley has doubtless removed large portions of valuable coal lands; but this denudation does not appear to have been so excessive as in the area along the Nicola river where the two streams converge. In view of the widespread nature of the drift throughout the entire area the actual economic value of these areas can only be ascertained

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[1]Summary Report 1904, p. 68.

by a number of bore-holes. Faults may exist of which there is practically no evidence at the surface, and the prospective value of the property as a producer of coals may be largely reduced from this cause."

The coals mined in the Nicola valley are low carbon bituminous coals that do not make a commercial coke. They give very good results in the gas producer and are fair steam coals. The analyses already published by the Mines Branch in "An Investigation of the Coals of Canada" No. 83, are as follows:—

Middlesboro	*Colliery No. 1.*	*Colliery No. 2.*
Mine moisture..........................	4·4%	2·9%
Air dried moisture.....................	3·9	2·3
Proximate analysis of dry coal..........		
Volatile combustible....................	39·1	39·0
Fixed carbon...........................	46·4	48·1
Ash....................................	14·5	12·9

KAMLOOPS LAKE COAL AREAS.[1]

(*See Diagram XX.*)

(Extracts from report by G. M. Dawson.)

The stratified tufaceous sandstones designated as the Tranquille beds probably run continuously round behind the Battle Bluff rocks on the north, following a hollow along the base of the higher cliffs and hills farther back. They reappear on the lake shore near Red point, with a breadth of about a mile; being thrown into a couple of light synclines and traversed at Red point itself by a small fault. At this place, or very near it, a small bed of lignite was found during the progress of the Government railway surveys in 1878. The sandstones are here yellowish and grey, like those near the Tranquille. Their further outcrop is concealed by the lake, until they reappear in the Painted bluffs near Copper creek, where, as already explained, they are much altered and generally reddened.

[1]G. M. Dawson, Ann. Rep. G.S.C., Vol. VII, 1894, pp. 167-170B and 234B.

To the east of Cherry bluff, the same tufaceous sandstones are found in several places, associated with the dolerites already alluded to, but the section is here so much broken that it has been found impossible to satisfactorily unravel it with the information available. The widest and least disturbed exposures of these sandstones and shales here met with, are near mile-post 244 on the railway, where they dip northward at an angle of about 20° and where a few fossil plants were found. It is believed that these beds run from this place inland, in an easterly direction, following the hollow along the south base of Dufferin hill, and that they connect with those of the coal locality near Guerin's, where they terminate in a feather edge upon the underlying old rocks, at a point about three miles due south of the town of Kamloops.

The exposures are not continuous along the line of outcrop thus traced, but there can be little doubt that the beds associated with the coal at Guerin's represent the Tranquille beds of the general section. These particular beds, where found near Guerin's, require special mention, because of the interest consequent on the discovery of coal in them, and the fact that some exploratory work has been carried out in the search for workable seams. The beds containing the coal here rest directly upon the pre-Tertiary surface, by overlap, the underlying members of the Tertiary being absent. The floor consists of a rough surface of diabase-agglomerates, upon which the Tertiary materials lie in the form of a shallow syncline which runs along the northward slope of Coal hill. The exposures are almost entirely confined to the banks and bed of the small stream which flows past Guerin's house, and even with the aid of information obtained in the course of driving an adit into the measures, give but an imperfect idea of the section. The width of this projecting tongue of the Tertiary is somewhat less than a mile—probably not more than three-quarters of a mile, while the thickness of the measures comprised in the syncline may be as great as 500 feet, but is possibly much less. The beds actually associated with the coal outcrops which have been uncovered, dip N. 25° W. $<$ 38°, but probably flatten out to the northward and take the position shown in the annexed section. The measures, so far as exposed, consist of greenish and yellowish tufaceous and agglomerate-like materials more or less distinctly bedded, which weather to soft clayey stuff, often reddish in colour. There are several thin layers of good coal, varying from mere films up to a foot in thickness, and characterizing in all about fifty feet of the measures.

The beds with which the coal is associated, undoubtedly pass under the basaltic agglomerates composing Mount Dufferin, to the northward, and if the coal should be found to occur there in workable thickness, this would prove a more eligible field for exploration than that to the southward of Guerin's, even if the coal beds of the last mentioned locality were much thicker than any yet developed.

In 1892, the locality of the coal occurrence near Guerin's was again visited by Mr. J. McEvoy. At this time an incline was being sunk on the dip of the beds, which eventually reached a depth of from seventy to eighty feet, but without showing any marked improvement in the character of the seams.

The section including the coals, as then seen, was as follows, in descending order[1]:—

	Inches
Coal	3
Shale	5
Coal	12
Clay	4
Coal	2
Shale	6
Coal	3
Shale and clay	5
Coal	5
Shale and sandstone	12
Coal	2½
Sandstone	8
Coal	3

The quantity of clay is variable and some of the shale partings are not continuous. The aggregate thickness of coal at this place is 30½ inches.

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[1]Summary Report of the Geological Survey for 1892, p. 10.

The fuel found here is a true coal rather than a lignite, burning well and producing a coherent coke. If in seams of really workable thickness, it would possess considerable economic importance. To ascertain definitely whether any thicker seams occur at the locality near Guerin's, it would be necessary to sink or bore vertically through the measures, near the position of the present openings, until the subjacent diabase rocks are reached. The depth required cannot be great. Little further information can be hoped for in following the thin seams already found.

The whole area of possibly coal-bearing rocks in this vicinity is, however, so small, that it would appear to be better worth while to test the general question of the occurrence of coal in this neighbourhood by putting down one or more borings in places where the same subdivision of the Tertiary series has a greater development.

On Dropping-water creek, fragments of a fine-grained, silicified, shaly rock are abundant, in which some plant remains occur together with a few poorly preserved specimens of insects. These peculiar rocks were scarcely seen in place, but must underlie some part of the valley in this vicinity, and in all probability are to be found beneath the pale feldspathic materials.

The following species of plants have been recognized in the collection from this place, by Sir J. Wm. Dawson and Professor D. P. Penhallow[1]:—

> *Azollophyllum primævum*, Pen.; *Pinus trunculus* Dn.; *Acerites negundifolia* Dn.; *Carpinus grandis* Ung.; *Carpolites dendatus* Pen.; *Sequoia* Sp.; *Glyptostrobus* Sp.; *Acer* (Fruit).

At McDonald's, between Trapp and Napier lakes, twenty feet or more of sedimentary material is actually seen beneath the basalt-breccia. This consists below of grey arkose sandstone, above of brown earthy material with seams of coaly matter two or three inches in thickness.

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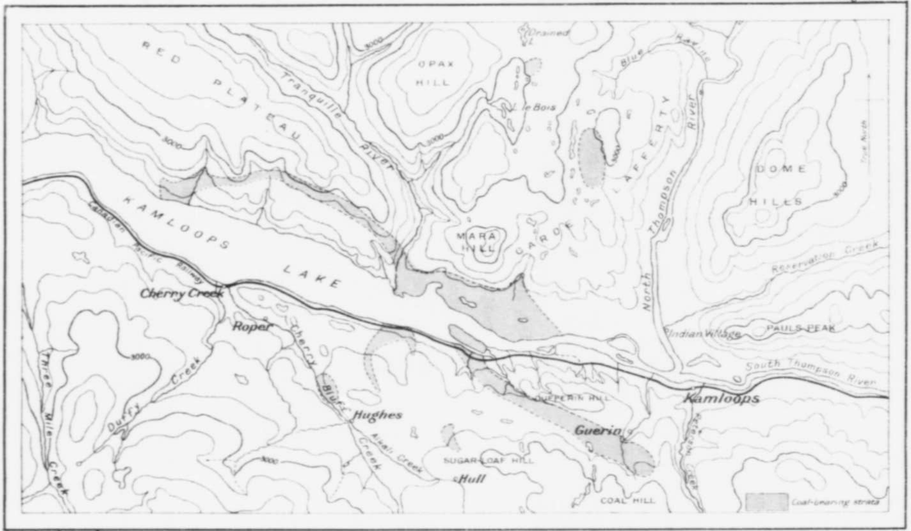
[1]Trans. Royal Soc. Can., vol. VII, sec. IV, p. 75. The specimens are those there described as coming from the vicinity of Stump lake.

Diagram XX



Geological Survey, Canada

Kamloops Lake coal-areas

Miles

To accompany Memoir by D. B. Dowling

Eastward of Stump lake, the basalt-breccias of Dropping-water creek continue for two or three miles, beyond which they are covered by black and brown basalt. The basalt here reaches an altitude of 4,200 feet.

It may be added that the circumstances connected with the southern part of this area of the Tertiary, appear to render it probable that some thickness of ordinary sedimentary beds may exist beneath its volcanic rocks, filling an original lake-depression in the old surface. In addition to the silicified plant-bearing beds just referred to, fragments of grey, sandy shale of Tertiary age have been found in the valley of Dropping-water creek, and it is not impossible that deposits of coal may exist there. This can, however, be tested only by means of boring operations, and if at any time such a test should be applied, the most promising locality seems to be that about two miles above the road-crossing of the creek.

HAT CREEK COAL AREAS.[1]

(See Diagram XXI.)

(Extracts from report by G. M. Dawson.)

The upper valley of Hat creek, which runs from south to north along the east base of the Clear mountains, is largely floored by sedimentary Tertiary beds—generally soft shales and sandstones. The whole surface of this wide valley is, however, so thickly covered with drift deposits, that it is impossible to define the area of these Tertiary beds with any precision. The outline given upon the map is probably as nearly exact as is possible from observation of the natural exposures, but it is really only in that part of the valley near Limestone and Medicine creeks, and thence northward, that the Tertiary sedimentary deposits are actually exposed. Thus, the southern extent of these beds, and their width in the southern part of the valley are particularly open to doubt.

The occurrence of an important deposit of lignite-coal on Hat creek, near the east entrance of Marble canyon, has long

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[1]Ann. Report, G.S.C., vol. VII, 1894, pp. 207-211B.

been known. This locality was visited by me in 1877, and some description of it is given in the report for that year, from which the following is quoted:—

"A locality of some interest in connection with the Tertiary is found on Hat creek, about a mile above its abrupt bend at the eastern entrance to Marble cañon. The exposures here extend for about 500 yards along the stream, but are not continuous, and the arrangement of the beds is somewhat complicated by the fact that considerable landslips have occurred in some parts of the banks. These have formed hollows beyond the margin of the bank, in two of which pools now lie. A great thickness of lignite coal, however, occurs here, associated with sandy or clayey, yellowish, grayish or purplish beds, which are generally rather incoherent. The stream nearly follows the strike of the beds, so that the same deposit of lignite is seen in a number of places. The lowest good exposures show over thirteen feet of lignite, neither the top nor the base of the bed being seen. The lignite is pure throughout, with the exception of a few lenticular or more or less irregular masses formed by silicified or calcified stumps. In following up the stream, lignite of the same kind is frequently seen, and continues to show occasional masses of fossil woods of the kinds above described, but is without shale. Some portions of the wood have been changed to ironstone of good quality, which might be of value if the lignite bed were being worked. At the highest good exposure the beds are dipping into the western bank of the brook at an angle of 30°, and are probably undisturbed. The bank was here scarped down, and the section carefully examined. The result may be stated as follows, in descending order:—

	Feet	*Inches*
(1). Grayish and brownish shales and sandy clays, with lignite in seams a few inches thick, about..	20	0
(2). *Lignite*, with shaly and lenticular layers of siliceous matter, ironstone and shale. Lignite of fair quality forms about two-thirds of the whole and contains much crumbling amber..........	26	0
(3). Lignite, with little or no shale or other impurity. Below very compact, rather softer in the upper layers..................................	42	0
	88	0

"The bottom of this enormous lignite bed was not seen, the measurement going only to the water of the brook, beneath which it is concealed."

In 1889 some attempt was made, by drifting and uncovering the outcrops, to determine the extent and value of this lignite deposit, but the amount of work done was inconsiderable and the additional information gained by it not great. The openings were visited by me in the same year, when attention was also directed to ascertaining the limits and character of the field as a whole. The paucity of information to be derived from the exploratory work, results chiefly from the fact that the beds are much disturbed where they outcrop along the banks of this part of the stream, and that an even greater amount of disturbance and irregularity has been brought to light by the work done than could have been previously anticipated. This disturbance may possibly be entirely due to the effect of old (perhaps pre-Glacial) slides, affecting a former escarpment of the soft rocks, along the base of which the stream was working. Part of the irregularity is certainly attributable to this cause; but I am inclined to believe that there is as well some faulting parallel to the line of the stream, or that the softer beds have been here crushed by pressure, at their line of contact with the more resistant old rocks, as so often occurs.

At the point where the principal openings were made, the lignite and associated shales were found to dip S. 55° W. $<$ 60° or even higher. A drift run in here for eighteen feet, passed through practically solid lignite for nearly that distance, when shales and sandstones dipping in an opposite direction, at an angle of about 45°, were encountered. As it is scarcely probable that the lignite here occupies so narrow a synclinal fold, it is likely that it is either slipped or faulted down to the eastward on the shales and sandstones found at the end of the drift.

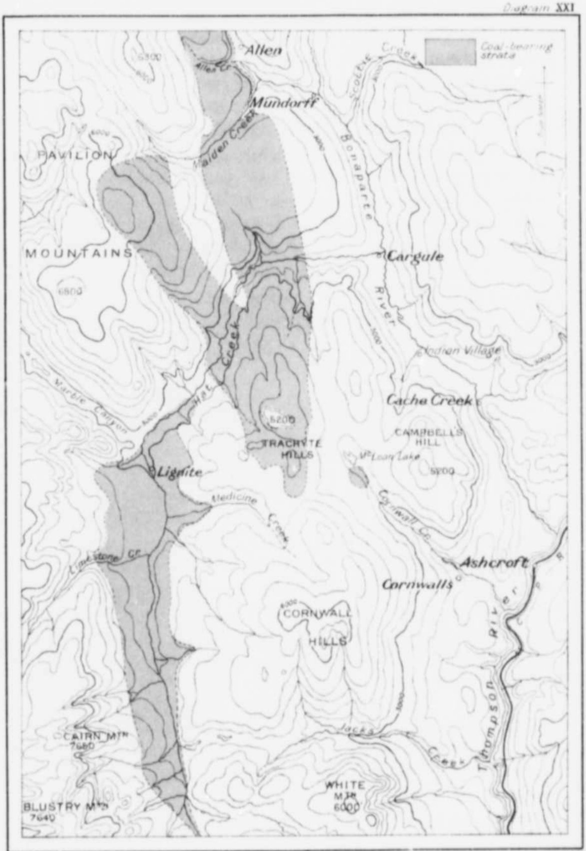
The stream and the exposures along it, are here close to the east side of the wide valley, the floor of which slopes gradually up westward to the base of the Clear mountains. The slope thus formed is lumpy and irregular in detail. This is probably due in part to old landslides, in part to morainic accumulations and irregularly disposed drift materials, with which the surface is in general covered. The stratified Tertiary rocks are scarcely seen in place, but they are frequently represented, for nearly two miles, by yellowish soft shales, poached up and disturbed, but evidently not far moved. The highest appearance of such materials noted, was at about 650 feet above the level of Hat creek, and on the assumption that the beds are in the main horizontal, the thickness of the sedimentary beds must be at least thus great. A little higher up, thick beds of vesicular basalt are found capping the softer materials and running back to the steep base of the Clear Mountain range. The rocks composing this part of the range are granites, and to the north of Limestone creek the volcanic materials were observed to rest directly on these by overlap. The surface of the granite is here somewhat decomposed and soft, and slopes toward the valley at an angle of nearly 20°. The rock actually in contact with the granite, at one place, was found to be a melaphyre, with well-marked flow-structure and including in its mass numerous small fragments picked up from the granite.

The basaltic flows have probably at one time entirely covered the sedimentary Tertiary rocks of this part of Hat Creek valley, for extensive remnants of them occur at nearly corresponding elevations on the opposite or east side, where they form a step-like border to the Palæozoic rocks of the higher hills.

The sedimentary rocks here observed, in their general appearance and in the conditions of their occurrence, closely resemble those already described on Guichon creek. They were not observed to contain any contemporaneous volcanic materials, and it is highly probable that they are referable to the Coldwater series of the classification adopted in this report. No determinable organic remains have been found in them.

The natural exposures do not serve to satisfactorily connect the sedimentary beds of this part of Hat Creek valley with the conglomerates and sandstones of the lower part of the valley, which undoubtedly represent the Coldwater beds; a gap of more than a mile occurring between them, for which there is no information. While it is possible that the two areas are continuous along the bottom of the valley, it has been thought

Diagram XXI



Geological Survey, Canada

Hat Creek coal-areas

Miles

To accompany Memoir by D. B. Dowling

better to represent them on the map as being disconnected. It is believed, however, that the beds seen on the upper part of Hat creek represent the higher parts, while those on the lower part of the creek represent the lower parts, of a single series of Tertiary deposits. The conglomerates were nowhere seen in place in the upper part of the valley, but large, loose pieces of conglomerate, identical with that of the lower valley, were found some miles above the lignite outcrops on the creek.

The Tertiary volcanic rocks, last seen at about a mile and a half below the bend made by Hat creek at the entrance to Marble canyon, are basalts, apparently brecciated, underlain by purplish melaphyre identical with that described as overlying the granites near the mouth of Limestone creek, and probably an extension of the same flow.

In regard to the composition of the lignite here met with, the following assay by Dr. Harrington may be quoted from the report of 1877-78 (page 121B):—

Water	8·60
Volatile combustible matter	35·51
Fixed carbon	46·84
Ash	9·05

For a lignite, the fuel is, therefore, of good quality, and the great thickness of the bed should render it of some importance, at least locally.

As a result of the observations made on the mode of occurrence of the lignite and its associated rocks, it would appear to be desirable to abandon further exploratory work in the disturbed measures near the eastern edge of the valley, and to make a test by means of a boring, put down at a distance of a quarter or a third of a mile to the westward of the locality on the stream at which work has already been done. From analogy with the Nicola Valley occurrences, it is quite possible that in beds beneath the lignite already known, fuels of the character of true coals may yet be found. Whether this is or is not the case in this locality, can be determined by boring only. It is further to be remembered, that the lignite-bearing rocks, if correctly referred to the Coldwater series, should here extend beneath the great volcanic accumulations of the Clear mountains. This implies, that anywhere to the south of Limestone creek, the mountains bordering the valley do not necessarily mark the limit of the lignite-bearing series in a westerly or southerly direction.

COAL CREEK (NORTH THOMPSON) COAL AREA.[1]

(*See Diagram XXII.*)

(Extract from report by G. M. Dawson.)

The detached area of Tertiary rocks, near the Indian village and reservation in the vicinity of Coal creek, was particularly examined in 1877, because of the occurrence of coal in it. The Tertiary rocks here occupy a portion of the trough of the North Thompson, and are bounded on both sides by the old rocks of the higher hills. The amount of drift in this part of the valley is very great. On the east side of the river, a few exposures occur of sandstones and shales, particularly along the small stream named Coal brook, but it is impossible precisely to define the area occupied by these rocks, which can be approximated to only on the assumption that they characterize the lower parts of the valley where the old rocks are not seen. On this assumption, the whole length of the Tertiary area to the east of the river cannot exceed five miles, while it may be much less. On the west side of the river, the only Tertiary rocks seen are grey and brown basalts, which occur quite down to the river-level nearly opposite the Indian village, and were also found on the lower slopes of the hills on that side to a maximum height of 620 feet above the river.

The sedimentary beds in which the coal occurs, may, of course, underlie some part of the area in which only basalts are seen at the surface. A trifling amount of exploratory work has been done in recent years in the immediate vicinity of the coal outcrops at Coal creek, but no addition has resulted from it to our general knowledge of the section, and it is improbable that any material addition to this knowledge will occur until boring

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[1]Ann. Rep. G.S.C., vol. VII, 1894, pp. 228-231B.

operations shall have been undertaken. The sandstones and shales show no traces of volcanic material in their constituents, and it is probable that they represent an area of the Coldwater series of the Tertiary, as previously defined. The basalts are probably referable to a much later date.

The following description and section of the beds are quoted from my report of 1877 (pp. 113B-114B).

"The area of this outlier, in so far as it can be defined by the section on the east bank of the river, is not great. It rests on the older crystalline rocks, forming a ridge about 600 feet high along the base of the tier of mountains which, rising to a height of 200 to 3,000 feet above the river, here forms the border of the valley. The length of the ridge is about two and a half miles, and it is where the little stream called Coal brook cuts through it, that the Tertiary rocks are exposed, by the removal of the thick covering of boulder clay and drift, which elsewhere shrouds it. The beds appear to form a syncline, nearly parallel in its main direction with the trough of the valley.

"The following section, in descending order, includes nearly all the beds seen in the brook channel. Some layers were measured, others estimated by the eye only:—

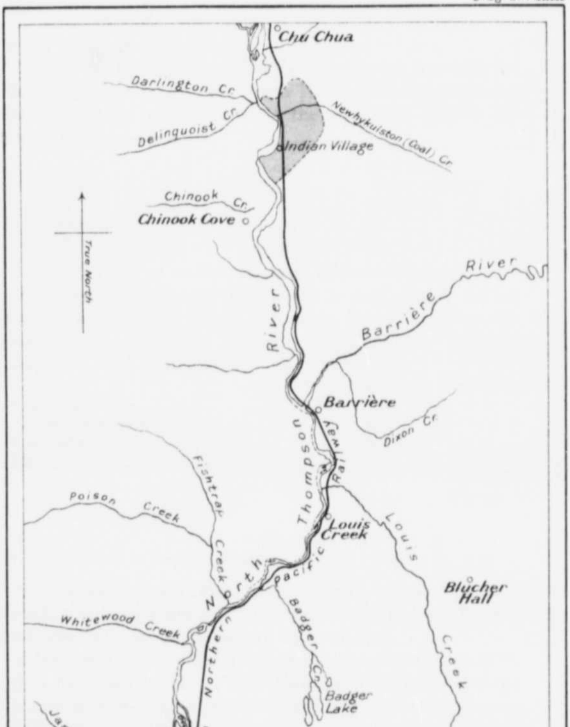
		Feet	*Inches*
1.	Sandstone, soft.......................at least	2	0
2.	Carbonaceous shale..........................	0	6
3.	Shale and sandstone..........................	3	0
4.	*Coal*, shaly..............................about	1	3
5.	Hard clay..................................	0	6
6.	Soft shale..................................	1	3
7.	Grey, fine shale, with fossil leaves..............	2	0
8.	Coarse and fine-grained sandstone..............	15	0
9.	Hard, fine, grey clays.........................	1	0
10.	(Concealed).................................	10	0
11.	Sandstone..................................	2	0
12.	Grey shales..................................	3	0
13.	Sandstone..................................	2	0
14.	Soft, grey shale..............................	1	5
15.	Coal.......................................	1	2
16.	Shale.......................................	0	2
17.	Sandstone and shaly sandstones................	9	0
18.	Coal } irregular..............................	1	5
19.	Black shale } irregular......................	0	8

		Feet	Inches
20.	Grey, crumbling sandstone....................	4	0
21.	Carbonaceous shale.....................1 in. to	0	4
22.	Rusty, nodular sandstone......................	1	8
23.	Soft sandstone in thin layers....................	8	0
24.	Concealed............................15 ft. to	20	0
25.	Sandstone....................................	4	0
26.	Black shales..................................	0	6
27.	Sandstone....................................	0	10
28.	Shales, more or less carbonaceous, with a little coal	4	0
29.	Ironstone, nodular............................	0	3
30.	Thin-bedded clays, greyish and brownish........	2	8
31.	Grey sandstone, generally coarse and rather soft.	10	4
32.	*Coal*, shaly..................................	0	2
33.	Brownish, sandy clays.........................	6	9
34.	Thin-bedded, sandy clays, rather hard. ....about	20	0
35.	Coarse, pebbly sandstone..................about	8	0
36.	Brownish-grey sandy clay, at base..........................		
		148	1

"At the base, the beds dip at an angle of 12°, further up at 15°, and again begin to dip at a lower angle at the summit. The direction of dip varies from N. 56° E. to N. 26° E. Beyond the highest represented in the above detailed section, a considerable gap occurs, in which the banks show no exposures. When next seen, the beds are poorly exposed; but one bank shows about twenty feet of sandstones and shales like those before met with, and includes two small seams of coal, the lower seven inches, the upper nine inches in thickness. These beds are doubtless the highest found in this locality.

"It would appear, however, that in the sections, but a small portion of the entire thickness of Tertiary beds represented at this place, is seen. Their general character is much like that of those of other localities in the southern part of the province, the sandstones holding, perhaps, more coarse pebbly material than usual. Notwithstanding this, however, there is no appearance of tumultuous deposit, and the coal-seams, though thin, show considerable regularity. The coal-bearing character of the formation appears to persist throughout the section, and a further examination by boring may at some time become desirable. The best locality for a bore-hole would prob-

Diagram XXII



Geological Survey, Canada 1434

Coal Creek *(North Thompson River)* **coal-area**

Miles

1 ½ 0 1 2 3 4 5 6

To accompany Memoir by D. B. Dowling

ably be in the valley of the brook, at the lowest beds of the section."

In 1892, Mr. McEvoy revisited this locality and gives the following note concerning it:[1]

"While in the neighbourhood an opportunity was afforded of visiting the coal mine on the North Thompson Indian Reserve. A tunnel running northward from the creek bed showed the following section:—

Coal	6 inches.
Sandstones	2 feet (variable)
Coal	9 inches.
Sandstone	6 "
Coal	18 "

"Besides these an underlying seam of coal is reported."

The quality of the coal found here is good, and if thicker seams can be found, it would possess an immediate economic importance; on proximate analysis, it yielded the following results to Dr. B. J. Harrington:[2]

	Fast coking.	*Slow coking.*
Hygroscopic water	2·22	2·22
Volatile combustible matter	38·10	32·05
Fixed carbon	46·76	52·81
Ash	12·92	12·92
	100·00	100·00
Coke	59·68	65·73
Ratio of volatile to fixed combustible	1: 1·23	1: 1·65

"Fast coking gave a bright and firm coke, which on burning away left a reddish-white ash. By slow coking the powder was agglutinated only in the bottom of the crucible."

A few fossil plants obtained from the above section in 1877, are thus described by Sir J. Wm. Dawson:[3] "The leaves from this place, in a matrix of gray arenaceous shale, are almost exclusively poplars, referable to *Populus arctica*, *P. genatrix* Newberry, and another species. With these is a species of *Rhus*, allied to *R. rosaefolia*, of Lesquereux."

[1] Summary Report of the Geological Survey, 1892, p. 10.
[2] Report of Progress, Geol. Surv., Can., 1876-77, p. 467.
[3] Trans. Royal Soc., Can., vol. I, sect. IV, p. 34.

NAZCO, BLACKWATER, FORT GEORGE, AND QUESNEL MOUTH COAL AREAS.[1]

(Extracts from report by G. M. Dawson.)

Drift lignite was found in several places along the Nazco river below Cinderella mountain, but was nowhere seen in place. It also occurs in great abundance on the Blackwater, in the upper canyon, and may probably exist in place below the basalt flows west of the range of Lower Cache Creek hills. Large masses of drift lignite were also observed on the Blackwater near the bridge, some of them so compact and pure as to form a fuel of very good quality. Rocks of the Lignite group were seen in several places on this river above the bridge, in small exposures; and though fossil plants occur, beds of lignite were not observed in connexion with them. The rocks are light-coloured, chiefly pale greenish and greyish-white and generally quite fine grained, constituting fireclays, which are sometimes massive but often thin-bedded. Soft sandstones, and occasional beds with small pebbles, also occur. Some layers are highly diatomaceous, a species of *Melosira*, like *M. varians*, being most abundantly represented. All these beds rest unconformably on a rugged surface of Lower Cache Creek rocks, which often protrude through them into the superficial covering of drift-sand and gravel. The beds of the lignite group are for the most part horizontal, but besides slight original irregularities in deposit, are sometimes gently inclined at various angles, in some places dipping as much as 20°. Obscure vegetable impressions, resembling roots or branches, are common, and in one place two stumps evidently standing where they grew, but now tilted with the including beds, were observed. They have been silicified, the wood being represented by a sort of wood-opal of brownish colour, with cavities holding light, yellowish, ashy flakes of silica. The beds turn up round the stumps and thin out towards them. The seed of some species of conifer, with that of a maple and other plant remains, were found in neighbouring exposures.

[1]Report of Progress 1875-76, pp. 255-260.

These beds appear to have been formed in swamps and lakes separated by hills of lower Cache Creek rocks, and no doubt vary much in character in the different basins thus enclosed. They probably underlie a considerable portion of the level country stretching eastward from the hills crossing the Blackwater at the upper canyon; but the whole region is so thickly covered with drift that it is at present impossible exactly to define their area. Some of the lignites found in loose blocks are much superior to those seen about Quesnel mouth, and their appearance, together with the occurrence of stumps in place, gives reason to hope that beds accumulated on the area of growth, and not composed of drift timber, may be found. The actual elevation of these beds above those of Quesnel is about 330 feet.

Much drift lignite also occurs on the bars near the confluence of the Nechako and Fraser rivers. About three miles below Fort George a small exposure of the lignite formation is seen, and it is probable that other patches of its clays and carbonaceous beds are preserved in hollows of the older rocks in several places between Fort George and Quesnel. From Quesnel to Soda creek many good exposures of this formation occur, and, at low water, beds of lignite are seen in several places. These have not been examined.

The lignite-bearing formation of the vicinity of Quesnel mouth has already been noticed in the Report for 1871-72, page 58. Along the foot of the bank of the Fraser river, in front of the town of Quesnel, a considerable thickness of beds is shown. The lowest seen are situated about a mile above the confluence of the Quesnel with the Fraser river, and consist of impure lignites and clays, with layers of soft sandstone and ironstone concretions. These are followed in ascending order by clays and arenaceous clays of pale-greyish, greenish, and yellowish tints, with a general southward or southwestward dip at low angles. These fill the trough of a shallow synclinal over which the town of Quesnel stands. On the south bank of the Quesnel river, the impure lignites and associated beds, first mentioned, rise again to the surface, and in some sections of fifteen or twenty feet the lignite may constitute about one-sixth of the whole. It is not, however, in well-defined beds, but interstratified throughout with clays, and appears to have been deposited in the form of drift-wood by somewhat rapidly flowing water, and is not so pure as to be of any economic importance. Small spots and drops of amber are abundant in some layers.

Half a mile below the mouth of the Quesnel river, on the east bank of the Fraser, a ruined cliff about 100 feet in height is formed by the lignitiferous zone just described, with the addition of some of the overlying beds seen at Quesnel town. The section given on pages 58, 59, in the report above mentioned, was measured near here. From the greater part of the cliff the lignite has entirely disappeared by combustion..............

Plant remains are found in some beds of the Quesnel lignite series, as mentioned in the report above referred to. Additional interest now attaches to the formation, from the discovery of a thin layer, in which the remains of several species of insects are very perfectly preserved. A section is given below showing the beds associated with this insect layer, which occurs in the left bank of the Fraser, at the town of Quesnel, and forms a member of the series overlying the main lignitiferous zone.

The beds are as follow, in descending order:—

		Feet	Inches
1.	Sands and arenaceous clays, light coloured and whitish, regularly bedded..........................	20	0
2.	Grey sand....................................	1	0
3.	Grey arenaceous clay, thin-bedded................	11	9
4.	Ferruginous sandstone, nodular and irregular......	1	0
5.	Fine grey clay, distinctly bedded..................	2	0
6.	Fine yellowish-grey clay..........................	0	2½
7.	Very fine greyish and greenish-white fireclay, in thin layers, with coniferous and angiospermous leaves, seeds, and insect remains........................	0	8½
8.	Carbonaceous clay, or impure lignite, in many places seen to be composed of matted leaves, mingled with clay..	0	2
9.	Arenaceous clay, yellowish-grey, and much divided by rusty cracks, pretty distinctly bedded, but in thick layers..................................	13	0
10.	Coarse yellowish-grey arenaceous clay.............	4	0
11.	Grey arenaceous clay with small siliceous pebbles, probably derived from rocks of the Lower Cache Creek group.................................	1	6

		Feet	Inches
12.	Grey arenaceous clay............................	2	0
13.	Coarse grey sand, with occasional flattened masses of lignite 6 inches to..............................	1	0
14.	Coarse sand and gravel. A rusty irregular layer, about..	0	6
15.	Yellowish clay.................................	2	6
16.	Greyish clay...................................	4	0
		65	4

The section is traversed by two small faults, and similar unimportant dislocations occur in other parts of the lignite formation of this vicinity. The highest beds of the section dip at an angle of about 22° in a direction oblique to that of the bank. The upturned edges of the beds have been eroded, and are covered by the gravel and sand deposits of the river valley.

Such a section as this cannot be affirmed through any considerable thickness of beds to represent an unbroken sequence in time; but supposing those layers immediately surrounding the insect and plant bed to do so, the analogy of the deposits with those which might represent a single season, in the present condition of the country, is striking. In some oozy creek, or estuary, of one of the existing lakes, the coarser deposits of the summer flood—consequent on the melting snows of the mountains— might be succeeded by a mass of the fallen leaves of autumn, which, as the season became more severe, reducing the flow of water and, at the same time, the quantity and size of the constituent particles of the sediment, would be followed by the few recognizable. The insects from bed No. 7 of the above section were transmitted to Mr. S. H. Scudder, of Cambridge, Mass., who had kindly consented to examine them.

Principal Dawson, who has kindly examined the plants from Quesnel and Blackwater, furnishes the following list and notes:—

PLANTS FROM QUESNEL.

Acer. Species represented by a leaf, resembling a small leaf of *A. grossedentatum* Heer, of the European Tertiary. To this species it may not improbably belong.

Juglans nijella Hr. This plant is also found in Alaska, and is near ally of *J. Bilinica* of the European Tertiary, and of the modern *J. nigra*, or black walnut.

Juglans, sp. Nuts found in association with the above, and probably its fruits. They are allied to those of *Juglans nigra*, and resemble those called *J. nux-tauriensis* by Brogniart, which are found with remains of *J. Bilinica*.

Carya, sp. A nut, probably representing an undescribed species.

Castanea Ungeri Hr. Found also in the Tertiaries of Alaska and Greenland, and a near ally of the modern C. *pumila* of North America.

Dombyopsis Islandica Hr. This plant is found also in Iceland, but may eventually require to be referred to some other genus.

Fagus Feroniae Unger. Found also in the Miocene of Europe and Alaska.

Plantanus aceroides St. Known also from the Miocene deposits of Europe, Greenland, Mackenzie river, and Spitzbergen.

Quercus pseudocastanea Goep. Found also in European and Alaska Miocene.

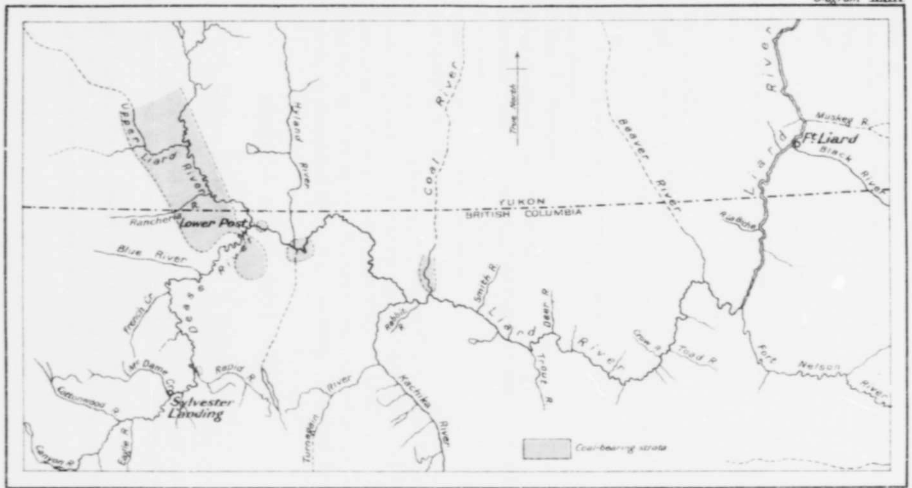
Quercus, sp.

Betula, sp. Nearly agreeing with *B. prisca*, Ettings., but with slightly cordate base; perhaps the same species as that identified by Heer with *B. prisca* in Alaska. Many specimens of the samara of a birch are associated with this leaf. The outline is round, emarginate at apex, with two mucros, seed slender, inflated above; width about 3 mm. A trilobed bract, with the central lobe much the longest, also occurs.

Fagus antipofi Abich. Found also in Alaska.

Nordenskoldia borealis Hr. Found in the Spitzbergen Miocene A plant of uncertain affinities, which may, perhaps, eventually be included in the genus *Diospyros*, represented in the Tertiary of Greenland. Fruit.

Diagram XXIII



Geological Survey, Canada

Liard River coal-areas

Miles

To accompany Memoir by D.B. Dowling

Populus arctica Hr. ?
Rhamnus, sp.
Rhamnus, allied to *R. alaternoides* Hr., but an undescribed form.
Nyssidium. ?
Taxodium. ?

Plants from Blackwater.

Acer, sp. Represented by a large winged seed, about two inches long, but very imperfectly preserved. Probably *A. macropterum* Hr., a species found in the Alaska Miocene.
Sequoia Langsdorfii.
Taxodium occidentale Newberry.
Thuja. Not determinable, but allied to *Th. interrupta* of Newberry.
Pinus. Two species represented by small winged seeds.
Castania Ungeri ?
Fagus like *F. Feroniæ*.
Diospiros Alaskana Sch. ? A leaf.

The collections are not large, nor the specimens very perfect. It may, however, be considered certain that the formations of Blackwater and Quesnel containing these plants are Tertiary and probably not very different in age. The plants from the Quesnel beds are, to a great extent, identical with those from the "Miocene" of Alaska, as described by Professor Heer, and they also have points of resemblance with those of Bellingham bay, as described by Newberry. Whether the age of these beds is Miocene or somewhat older, may, however, admit of doubt.

BOWRON RIVER COAL AREA.[1]

(From paper by C. F. J. Galloway.)

This promising field is situated about 45 miles due east of Fort George, and 80 miles north of Barkerville. Bowron[2] river

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[1]The Canadian Mining Journal, May 15, 1912, p. 335.

[2]Bowron river is the new name for Bear river which enters the Fraser river east of Fort George and rises near Barkerville.

flows through the field in a northwesterly direction in its course from near Barkerville to the Fraser.

The coal-measures lie in a flat basin surrounded by hills consisting of crystalline rock, which define its limits in certain directions, but its actual extent cannot be definitely determined except by extensive drilling, as the ground is entirely covered by alluvial sand, gravel, and clay, and bed-rock is only exposed in a few places in the bed and banks of the river.

Igneous intrusions occur in a few places, locally disturbing the measures, but the greater part of the area seems to be entirely free from such disturbance.

An area of fourteen sections of one square mile each is held by Mr. A. E. Hepburn, of Vancouver, B.C., and within this an area of ten and a half square miles is probably underlain by the coal-measures in an undisturbed condition.

A very limited section of the measures is exposed; but at one place three workable seams outcrop in the bank of the river.

Some development work has been done on these, proving them to have the following sections:—

	Total thickness.	Total coal.
Upper seam................	10 ft. 4 in.+	9 ft. 2 in.+
Middle seam...............	5 ft. 0¾ in.	4 ft. 2¼ in.
Lower seam................	11 ft. 11½ in.	7 ft. 8¾ in.
Total coal............................		21 ft. 1 in.+

The two lower seams, and the lower portion of the upper one, are to a certain extent interbedded with sandstone and shale, as is seen from the above sections; but the upper seven feet of the upper seam contains only one band of four inches of sandstone. A farther thickness of three or four feet of clean coal is reported as existing in this seam above that measured. This the writer could not see, the open-cut in which it was exposed being filled with mud, and being so little above the level of the river that the mud could not be removed. This additional thickness must, therefore, be added to that given above, which represents the measurements acutally made by the writer.

In the measures immediately below these, numerous thin seams of coal occur, up to three feet in thickness, separated by thin bands of shale and sandstone, and it is quite possible that some of these will come together, forming workable seams under portions of the area. Other thin seams appear elsewhere, apparently on a slightly higher horizon.

Taking the thickness of workable coal in the three seams exposed, the area controlled by Mr. Hepburn may be estimated to contain on a very conservative basis 150 million tons of coal.

The coal is bituminous, bright, and fairly hard and, in the crucible assay, yielded an excellent hard and firm coke.

The following analyses were made by Mr. J. O'Sullivan, F.C.S., of Vancouver:—

	"A."	"B."	No. 1.	No. 2.
Hygroscopic water	3·5	3·5	6·0	4·0
Volatile combustible matter	37·5	40·8	37·3	44·4
Fixed carbon	54·0	48·3	54·3	46·9
Ash	4·0	6·0	1·0	3·5
Sulphur	1·0	1·4	1·4	1·2
	100·0	100·0	100·0	100·0

At the point where the three workable seams are exposed the measures dip at an angle of about 43 degrees; but this appears to be on the flank of an anticlinal roll, and the dip moderates towards the northeast, so that the measures may reasonably be expected to lie comparatively flat under the greater part of the area.

As the ground underlain by the coal-measures is all flat bench land, the coal will have to be worked entirely from shafts, practically none being above drainage level.

The ground is well timbered with black pine and spruce suitable for mining purposes.

An inexhaustible supply of water is furnished at all seasons by the Bear river.

This coal-field lies within about fourteen miles of the line of the Grand Trunk Pacific railway in the valley of the Fraser, above the canyon, being separated from it by Seymour pass, a low divide, only some 300 feet higher than the coal exposures, the construction of a railway over which will offer no difficulties.

NECHAKO COAL AREA.[1]

(Extract from report by G. M. Dawson.)

The Cheslata Lake stream joins the Nechako from the west, not far below the first great bend. From this point, for some distance northward—as ascertained by Mr. Bowman, who ascended the river in a canoe—the basalts are underlain by an extensive sedimentary formation, including lignites, of which one bed of very good quality was found to be four feet in thickness. The rocks accompanying the lignites appear to be arenaceous clays of the usual character, but are associated with conglomerates in greater proportion than usual. These contain well-rounded fragments of silicified volcanic rocks, like those described on a former page, as probably representing the Mesozoic series on this part of the river. The basaltic and other later igneous rocks seem here, as in other instances, to have flowed out into pools and lakes containing the earlier Tertiary deposits; and are in consequence, in their lower parts vesicular, and sometimes earthy. No exposures occur in the reach of the Nechako flowing due north toward Fraser lake, but the underlying rocks are, in all probability, those of the Tertiary series.

Analysis of Nechako Coal by B. J. Harrington.[2] A specimen of lignite, from a four-foot seam occurring at this place, has been given to me for examination by Mr. G. M. Dawson. It is black, and most of it has a distinct woody structure, although portions of it have lost all trace of this structure, becoming highly lustrous and divided up by numerous reticulating cracks, precisely as is the case with some of the Tertiary lignites east of the Rocky mountains.

It also contains occasional specks of mineral resin. Analyses by fast and slow coking gave as follows:—

	Fast coking	Slow coking
Hygroscopic water	10·46	10·46
Volatile combustible matter	41·44	35·01
Fixed carbon	43·21	49·64
Ash	4·89	4·89
	100·00	100·00
Ratio of volatile to fixed combustible	1:1·04	1:1·41

[1]Report of Progress, 1876-77, Geol. Surv., Can., p. 82 et seq.

[2]Report of Progress 1876-77, pp. 467-468.

By rapid heating a portion of the powder was sintered together into a friable silvery-grey coke. The ash was of a brick-red colour.

KOHASGANKO COAL AREA[1].

(Extract from report by G. M. Dawson.)

On the Kohasganko stream (a branch of Dean river) south of Tanyabunkut lake the ordinary clays and arenaceous-clays of the Tertiary appear from below the igneous material. The line of junction is marked by a series of peculiar rocks, evidently produced by the flow of molten matter on soft wet clays, perhaps under water. The basalts and dolerites, which in the upper part of the section are blackish or greyish in colour, and compact in texture, become dull, whitish, opaque-wacke, or tuff-like materials, sometimes still showing vesicles like those of some of the overlying beds, but often confused and structureless. In the upper compact beds, zones are characterized by numerous hardened and in some cases almost porcelainized fragments of the lower slaty clays. Some of the vesicles, in both the compact and earthy basaltic rocks, contain minutely crystallized zeolitic minerals. From thirty to forty feet below the lowest basalt, occurs a bed of lignite, which appears to be of excellent quality. About four feet in thickness was visible at the time of our visit, the base being covered by the high water. This measurement, however, includes a few shaly partings. In one place, a remarkable, brown, almost greasy clay, is seen, which appears to represent a hardened peaty material. The sedimentary beds holding the lignite, rest on the surface of the intrusive granitic mass already described (page 64), which, where they have been lately removed by denudation, is rotten and decomposed to a considerable depth. The lignite bed and overlying basalts dip S. 34° E., to S. 19° E., at angles of from 13° to 18°. The direction is toward the central region of the Tsitsutl range, and shows slight folding subsequent to the close of the Tertiary

[1]Report of Progress 1876-77, Geol. Surv., Can., p. 76.

volcanic period, or a subsidence toward the centre of volcanic emission.

The exposures of the lignite-bearing beds are here quite small, and occur only in the banks of the brook. From the soft and crumbling character of these beds, and the tendency of the basalts, when bared in cliffs or escarpments, to break off in columnar or angular fragments which form a rough talus concealing all below, the actual appearance of the lignite-bearing portion of the formation is very rare, even though it may underlie a great area of country. The lignite bed in the Kohasganko might easily be exposed with a little labour, at low water, in August, and the thickness and extent of the basin determined by boring through the basalt capping to the south. No beds seem to intervene between the Tertiary basalts and unconformably underlying porphyrites, on the south side of the range.

Analysis of Coal by B. J Harrington from Kohasganko Stream, British Columbia[1].—This specimen was brought by Dr. G. M. Dawson from a seam of lignite occurring on the above-named stream. It was dull brown to black, and on drying fell into small fragments, often with highly lustrous surfaces. It showed distinct lamination and a good deal of mineral charcoal between the layers. The powder was blackish-brown and coloured the potash solution very strongly. By slow and rapid heating the following results were obtained:—

	Slow coking	Rapid coking
Water (at 100°-115°C).....................	9·90	9·90
Volatile combustible matter................	37·71	42·61
Fixed carbon..............................	38·85	33·95
Ash (pale grey)...........................	13·54	13·54
	100·00	100·00

[1]Report of Progress, 1877-78, p. 48G.

PARSNIP RIVER[1].

(Extract from report by A. R. C. Selwyn.)

Except in a small exposure on the left bank of the Parsnip, close to the mouth of Pack river, no beds of lignite were seen after leaving Quesnel; but both in the valley of the Blackwater, as mentioned by Mr. Dawson, and as observed by myself, and also from the highest point to which we ascended the Parsnip river down to the mouth of Nation river, ample evidence is afforded, by the frequent occurrence of large sized loose blocks, that a lignite formation, similar to that seen on the Fraser river at Quesnel, underlies a very large area of country, both in the vicinity of Blackwater, and also, probably, at intervals from the Giscome portage to the valley of Nation river.

Some of the blocks found along the shores of the Parsnip were of large size and sufficiently pure and compact to be of value as fuel if found in thick seams. At about three miles below Nation river, a steep cliff rises on the right bank from the water's edge to seventy or eighty feet. At the base, stiff blue clays are seen and these are overlaid by layers of sand and fine gravel. This is probably near the northern limit of the Parsnip River lignite-Tertiary basin, as a short distance farther a rocky ridge crosses the river and crops out in both banks, the country then rising rapidly, on one side to the Rocky mountains, and on the other to the watershed between Omineca and Parsnip rivers.

LIARD RIVER COAL AREAS.

(*See Diagram XXIII.*)

Our knowledge of the coal-bearing possibilities of the rocks of this region is confined to very hasty traverses of the stream. Mr. R. G. McConnell observed two Tertiary basins on the Liard near the mouth of the Dease river and float lignite in a tributary on the western side of the Rocky mountains. Cre-

[1]Report of Progress, Geol. Surv., Can., 1875-76, p. 71.

taceous rocks, possibly coal-bearing, are found east of the mountains both in the disturbed area of the foothills through the various canyons and in the undisturbed beds of the east. The following extracts from Mr. McConnell's report refer to the portion below the mouth of the Dease river[1]:—

"Rock exposures are infrequent in the valley of the Liard between the mouth of the Dease and the Little Cañon, but those observed will be described in order. Three miles below the mouth of the Dease is a small exposure of somewhat soft dark shales associated with friable sandstones and conglomerates. A second exposure of the same beds was observed about a mile farther down the river, where they dip N. 60° W. < 20°, beyond which they disappear. These rocks are unfossiliferous, but from their lithological characters, and the fact that they overlie unconformably the hard quartzites, slates and limestones of the neighbourhood, were referred to the Tertiary. At the mouth of Highland river, on a small island is an exposure of hard whitish sandstone, passing into quartzite. This rock weathers yellow and dips N. 50° E. < 50°. Six miles farther down, at a bend which the river makes to the north, is a cut bank showing unconsolidated sands, sandy clays and gravels, and holding some small beds of impure lignite. Below this, with the exception of rolled river gravels, no further exposures were seen until near the Little Cañon, when black shales appear in a couple of places."

From Little canyon to Whirlpool canyon the rocks are mainly limestones, but shales and conglomerates are occasionally seen.

"From Whirlpool cañon the river flows swiftly around a sharp bend, at the extremity of which it received Coal river and after a clear course of less than four miles, plunges over the rapids at Portage Brule.

"Coal river is a small, clear stream about a hundred feet wide, and is interesting on account of the quantity of lignite which it brings down. At the time of our visit a bar at its mouth was thickly strewn with angular and apparently little-travelled blocks of this mineral. The fresh appearance of the lignite

[1]Annual Report, G.S.C., Vol. IV, 1888-89, pp. 36-37D.

induced me to spend part of a day, while the men were packing across Portage Brule, in exploring for the bed from which it originated, but a walk of several miles up the stream failed to reveal its presence *in situ*, although an abundance of drift fragments was everywhere noticed. The lignite is of inferior quality. It is soft and shows a well marked woody structure. The banks of Coal river, as far as my examination extended, are low and consist of uncemented sands, clays and gravel, like those holding the lignite beds above the Little Cañon. This formation is of irregular thickness, but of wide distribution, as it was observed filling depressions in the older rocks all the way from the mouth of the Dease to the passage of the Rockies."[1]

The Upper Liard was traversed by Dr. G M. Dawson who notes Tertiary rocks on the Dease river and again on the Upper Liard and Frances rivers and on his map joins them all into one rather large area. His description of the rocks in the Liard is here incorporated[2]: "Six miles from the cañon Tertiary clays of whitish and grey colours, and associated with impure lignite, are first met with, and these continue to appear here and there along the river as far as the Frances. The thickest bed of lignite observed was about three feet, four miles below the Frances. The lignite is generally impure and often very distinctly laminated. It resembles in character the lignites of the Miocene of British Columbia, and the associated clays and soft shales are similar in character to those of that formation. Numerous boulders of basalt are found along this part of the river, and the basalt was observed to form a mural cliff, at a height of about 300 feet above the river, at a place just below the mouth of the Rancheria river. This rock evidently overlies the lignite-bearing beds. The shaly clays and lignites show evidence of considerable disturbance, and dip in some places at rather high angles. This may be due to the action of old land-slides along the banks of the river; but appears to be rather too constant to be satisfactorily accounted for in this way."

These rocks were noted crossing the Dease river and Dr.

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[1]Ibid. p. 41D.
[2]Ann. Rep. G.S.C., Vol. III, 1887-88, p. 101B.

Dawson's comments are again inserted.[1] "Overlying these old rocks, in several places at about eight miles from the mouth of the Dease, are shaly clays and coarse, soft sandstones, associated with which a thin bed of lignite was observed. These are evidently Tertiary, and referable to the series found more extensively developed in the Liard, above the mouth of the Dease. Some very obscure remains of leaves were noticed, but none were collected. The beds dip at various angles, sometimes as high as 15° and thus appear to have been, to some extent, affected by flexure subsequent to their deposition. It is not improbable that a considerable part of the higher plateau by which the river is here bordered on both sides, is composed of these newer rocks resting upon the upturned edges of the schists."

Lignite is also reported on a branch of the Dease, Rapid river which enters below Sylvesters landing, but no definite information was given.

FRASER DELTA COAL AREA.

As described by Mr. Camsell[2] in the guide book for excursion C1 of the Twelfth International Geological Congress, the delta is compound in structure and was built up at different times, beginning with the Eocene.

"The topography of the delta is in the main low and fairly level, with elevations ranging from sea level to about 400 feet above it. However, here and there in the upper part an isolated hill stands above the general level, reaching an altitude of about 1000 feet above the sea. Sumas and Chilliwack mountains are typical examples of the higher eminences.

"The oldest exposed rocks are the granitic rocks of the Coast Range batholith, which border and underlie the delta on the north.

"Remnants of once more extensive Lower Cretaceous rocks form some of the hills in the upper part of the delta, and around these the more recent deposits were laid down.

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[1]Ann. Rep. G.S.C., Vol. III, 1887-88, p. 95B.

[2]Twelfth International Congress Guide Book No. 8, pp. 271-272.

"Virtually the whole of the delta, with the exception of those parts covered by the Cretaceous remnants, is believed to be floored by stratified rocks of Eocene age, which are referred to in the literature as the Puget group. They consist of little disturbed beds of conglomerate, sandstone and shale which were laid down by the ancient Fraser river in an estuary of the sea. They have a thickness of about 3,000 feet in Canada, but are much thicker in the State of Washington. They contain a variety of plant remains and some small seams of lignite.

"The Eocene beds suffered erosion throughout the remainder of Tertiary times, but towards the close of the Glacial period were overlaid throughout by sands, gravel and till. These deposits now constitute broad, flat-topped plateaus about 400 feet high, which were once continuous as the late Glacial delta of the river. They have, however, since been dissected by the present stream, as a result of post-Glacial elevation. This process of dissection is related to the strong terracing of the Glacial deposits in the upper part of the Fraser river."

The economic importance of these Eocene beds lies not only in the valuable fireclay beds that are known but also in the possible coal seams that these beds may contain. As yet no very definite results have been obtained from prospecting; but attention is here called to the field as a possible reserve in which local areas may probably be supplied with a domestic fuel. The continuity of the seams is doubtful and it may be that the deposits are in the form of lenses. The information gleaned by the officers of the Geological Survey, which is in large part not available to the general public, is here inserted in the following extracts.

"[1]The Tertiary coal measures of Puget Sound and Bellingham Bay are continuous north of the 49th parallel, and must underlie nearly 1,000 square miles of the low country about the estuary of the Fraser and in the lower part of its valley. Lignite has been found in connection with these rocks at Burrard Inlet and other localities, and specimens of a fuel resembling true bituminous coal (and coking on the application of heat) have been obtained near the Fraser above New Westminster. The

[1]G. M. Dawson, Geol. Surv., Can., Report of Progress 1876-77, p. 126.

remarkably good specimen of coal from the River Chilliwack, of which an analysis by Dr. Harrington is given on page 99 of the Geological Survey Report for 1873-74, is probably from this series. The seams, so far as known, are quite thin, but the low country underlain by the formation is deeply covered with drift and alluvium, and exposures are few. Mr. Richardson has made a slight examination of the coast sections on the shores of Burrard Inlet; but the rest of this district has not been worked out. A geological examination, embracing all the known outcrops, would probably have to be supplemented by boring operations in well-chosen localities before the value of the coals, and lignites of these rocks can be ascertained."

"[1]Mr. John Jessop, superintendent of schools in British Columbia, sent a sample of coal from the mainland, accompanied by a note in which he states that the sample was taken from a seam recently discovered in the Chilliwack district about one mile from the Chilliwack river, and less than five miles from the Fraser; but that the seam had not been sufficiently examined to ascertain its thickness or extent. The sample has been examined by Dr. Harrington with the following results:—

"A clean, bright, bituminous coal. By rapid coking it gave—

Volatile matter	35·73
Fixed carbon	63·86
Ash	0·41

"It coked, but the coke was non-coherent and brittle. The remarkably small amount of ash which it contained was of a dark red colour."

"[2]Rocks somewhat resembling those of the Cretaceous coal series were also observed on the south side of the entrance to Burrard inlet, where they form cliffs of from seventy to eighty feet high. They consist of grey sandstones and arenaceous shales, both of which decompose readily on exposure to the weather. In some beds, fragments and lenticular seams of lignite were met with; but no fossils were observed, so that we have no

[1]Jas. Richardson, Geol. Surv., Can., Report of Progress, 1873-74, p. 99.

[2]Jas. Richardson, Geol. Surv., Can., Report of Progress, 1876-77, pp. 188-190.

guide as to their age. Judging, however, from the nearly horizontal attitude of the strata, and their resemblance to those of Sooke (page 190), in which Tertiary fossils have been found, it is not improbable that they are also Tertiary, and may spread over a great part of the flats at the mouth of the Fraser river, and for many miles up its valley, as well as southward into Washington Territory.

"The details in the following section are from a bore-hole put down by Mr. John Dick, who kindly furnished me with the information. The bore is on the sea beach, about three-quarters of a mile west of the Company's saw mills.

"Journal of No. 1 bore on the British Columbia Coal Mining Company's land at Burrard inlet. The beds passed through are as follows, in descending order:—

	Feet	Inches
Surface (clay)	8	10
Light grey sandstone and shale	9	11
Parting	0	6
Light-grey sandstone	27	7
" "	8	6
" "	6	2
Dark-grey shale, with coal plies (that is thin seams of coal)	0	5
Light-grey shale, with sandstone plies	7	8
Light-grey sandstone	7	2
" " harder	3	0
Parting with pebbles in it	0	7
Hard, grey sandstone	0	11
Soft, light-grey sandstone	12	3
Very hard, grey sandstone	1	10
Soft, grey sandstone	13	0
Hard, grey sandstone	1	2
Soft, grey sandstone	15	4
" "	3	0
Light-blue shale	9	10
Light-brown shale	16	5
Light-grey sandstone	2	0
Light-brown shale and sandstone	21	7
Dark-red shale	10	2
Light-grey shale and sandstone	3	0
Dark-grey sandstone	5	1
Light-blue shale and sandstone	11	10

	Feet	Inches
Light-grey sandstone	8	0
" "	6	3
Light-blue shale and sandstone	9	0
Light-grey sandstone	6	5
Dark-red shale	14	4
Light-brown shale	9	9
Light-blue shale	16	4
Dark-grey sandstone	1	2
Soft coal	0	8
Dark-blue shale	1	11
Soft coal and shale	1	4
Light-blue shale	3	8
Light-grey sandstone	14	4
Hard, light-grey sandstone	50	0
Light-blue shale	0	3
Hard, light-grey sandstone	16	2
Dark conglomerate	8	7
Light-grey sandstone	3	1
Dark-blue shale	9	3
Dark-grey sandstone	2	3
Dark-blue shale	0	10
Soft, blue shale, mixed with brown	0	7
Light-grey sandstone	14	0
Light-blue shale	39	0
Dark-grey sandstone	2	9
Hard, grey sandstone	0	10
Dark-blue shale mixed with coal	0	4
Light-blue shale	7	8
	466	6

"[1]In this region are situated the cities of Westminster and Vancouver. It includes the delta of the Fraser, and also the much larger pleistocene delta of that stream. A considerable expanse of lignite-bearing Tertiary, and also of bituminous coal-bearing rocks of Cretaceous age, occur in this region, the two series presenting a system of outliers and ranges flanking the higher coast mountains of granite.

"Workable beds of lignite and coal, in the older as well as in the newer series of rocks, are believed to exist, and will be

[1]A. R. C. Selwyn. Summary of work by Amos Bowman for 1888, Geol. Surv., Can., Annual Report, Vol. III, 1887-88, pp. 66-69A.

developed when prospecting for them by boring, or drifting to depths beyond atmospheric influence, is undertaken. In the adjacent United States territory the same rocks have been more extensively prospected, and in several places, where exploited, show every indication of the prevalence and continuance of favorable coal, making conditions along the whole eastern or mainland side of the Puget sound and Fuca strait, from the southern extremity of the former as far northward as the valley of the Fraser—in other words, on the Westminster side of the trough as well as on the opposing Vancouver Island side. The older or Cretaceous series of rocks are extensively developed in Canadian territory in the Harrison Lake district, and in the south-eastern portions of the field described.

"The quantity of Tertiary coal or lignite, which may be developed by means of judicious boring operations in the vicinity of Westminster and Vancouver, can only be conjectured by the experience at Bellingham bay, which furnished one of the earliest examples of profitable coal mining on the Pacific Coast; the basin there and its rocks being continuous, it may be fairly inferred that the coal seams are so also.

"Although coal has been found in very many localities north of the International Boundary line in the Tertiary delta of the Fraser, in only two instances have attempts been made, by sinking or boring, to ascertain the thickness of the same at depths where they would be uninfluenced by atmospheric weathering, and in both instances without adequate capital—at Coal harbour (Vancouver) by a boring, and at Sumas mountain by an incline. The results, so far as they go, are by no means discouraging.

"The quality of this Tertiary coal is somewhat superior to that of Mount Diable in California, which has there served a most useful purpose.

"The conditions now existing, which justify prospecting by boring operations, and mining lignite for local use, are its cheapness, and a local market greatly extended beyond that heretofore existing; which would enable it now to successfully compete for many purposes with coal transported from Vancouver island.

"Proximity to croppings of seams known and considered to be more or less promising, so as to test these at a distance from the surface, would be the first consideration in selecting sites suitable for boring operations. Otherwise located, a bore-hole might be put down very widely astray, and might succeed only in testing a theory; but thus guided the bore could not fail to test the ground in association with the seam or seams in question to the depths explored.

"The thickness of the measures desirable to be tested in the same connection will of course govern the depth of the bore in any given locality. The entire series exposed in the vicinity of Burrard inlet is not far from 3,000 feet in thickness. But all these beds, except some unknown, possibly underlying ones, come to the surface; those exposed nearest to the Inlet being at the bottom and those nearest to Fraser river at the top of the series. A bore near Port Moody, say at the terminus of the "North Road," would test the lower series; but could reveal nothing respecting the next overlying strata, which at that place have been removed by denudation. To test these it would be necessary to go as far up the coal ravine of the "Gravel Pit" (nearly opposite the north arm of Burrard inlet, known also as camp No. 2, and the "Italian Camp," on the railway) as it would be possible to haul the boring machinery. The same rocks would be far below the surface at Burnaby lake, and probably several thousand feet beneath the city of Westminster.

"A very short incline, shaft or tunnel, might test the ground satisfactorily in one place, while a bore of several hundred feet might suffice at another; the choice being determined by the contract price. Sinking by shaft, necessitating pumping of water, would be undertaken only after the ground has been tested, and proved to justify that expense.

"Cretaceous coal measures already referred to, lie probably too deep in the littoral district under consideration to be reached by boring, except possibly in certain localities along the south shore of Burrard inlet, where a bore would probably go through some shore edges of the Cretaceous before reaching the underlying granite; such as opposite the valleys of the North Arm and of Pitt river, both of which may represent arms of the Cretaceous sea.

"Any point between the smelting works and the terminus of the "North Road," would be suitable for a bore to search for the deep lying Cretaceous coal measures in this vicinity. That of the coal croppings on Hastings townsite, half a mile west of Hastings, is as favorable as any other; and presents, in addition, the inducement of connected and interesting developments in the Tertiary series.

"At Sumas mountain, and at the Warnock-Kanaka Creek mountain, the Tertiary coal, so far as known, lies near the bottom of the series. Kanaka creek presents a favorable locality for test by boring in the line of the ancient valley of the Lillooet river.

"Two series of coal seams come to the surface on opposite sides of the city of Vancouver. The coal measures occupy the whole of Stanley park, and also immediately underlie the city. By means of a bore of over 400 feet put down near Granville Hotel, Vancouver, nearly twenty years ago, some lower beds of the series coming to the surface in Stanley park have been proved to be either noncontinuous or barren. But the seams which have given Coal harbour its name more probably escaped the investigation of the prospectors altogether, from the circumstance that the locality selected appears to have presented only strata overlying the coal. The upper coal croppings of Brewery creek, and other localities on the south side of False creek, do not anywhere extend to the northward of False creek. They could be conveniently intersected by a bore on the line of the False Creek trail to Fraser river, which could be so located as to reach the coal at any desired depth below the surface."

SOOKE COAL AREA.[1]

(Extract from report by C. H. Clapp.)

Fringing the west coast of Vancouver island is a group of marine sediments of Tertiary age. This group has been subdiv-

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[1]Memoir No. 13, Geol. Surv., Can., p. 136, and Summary Rep. Geol. Surv., Can., 1912, pp. 52-53.

ided by Merriam[1] on palæontological evidence into the Carmanah and Sooke formations. The two formations cannot be subdivided on lithological or structural evidence, and the fossils collected by the writer have not yet been determined

The Tertiary sediments occur in small, isolated basins, which fringe the west coast, between Pachena bay to the northwest and Becher bay to the southeast. They underlie relatively low, flat areas, 150 to 200 feet above the present sea-level. The larger basins extend for several miles parallel to the coast, but rarely extend inland for much over a mile. Besides the larger basins, there are a great number of very small basins, a few of which are shown on the map, which occur between promontories of the underlying crystalline rocks.

The sediments are fairly well exposed along the shore, where they usually form a young cliff 100 to 150 feet high. The larger basins are partially covered with stratified drift, exposed at the shore in steep, wave-cut cliffs, except where eroded to the present sea-level by the larger streams, where coarse boulder beaches occur. The sediments, except in one or two instances, were not traced inland, but their inner boundary can be located fairly well from the shore as the underlying crystalline rocks surmount steeply the low areas underlain by the relatively soft sediments.

The Sooke formation along the southwest coast has been considered as a possible source of coal and oil, and has been prospected at Sooke, Muir creek, and Kirby (Coal) creek. The only indications of coal are thin seams of lignite and lignitic sandstones, with occasional cigar-shaped lenses and cylindrical masses of lignite. The Sooke formation consists largely of coarse detritus, which was deposited rapidly off a rather mountainous coast under marine conditions. These conditions are very unfavourable for the formation of coal. It seems as if the carbonaceous matter present was largely of drift origin, that is, composed of logs and other vegetable waste, which accumulated along the shores of the Tertiary ocean during the deposition of the Sooke formation. The small seams of lignite that occur

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[1] J. C. Merriam. Bull. Univ. Cal. Geol., Vol. II, No. 3, pp. 101-108, 1896.

are very impure, the following being an analysis of the thickest seam known, 8 inches thick, exposed on Kirby (Coal) creek, near the Jordan River road bridge. The sample was collected by W. L. Uglow and was analysed in the laboratory of the Mines Branch, Department of Mines.

Water	7·70 %
Volatile combustible matter	29·37 "
Fixed carbon	23·11 "
Ash	39·82 "
	100·00

In the Sooke formation there is no thick shale horizon rich in organic matter from which oil might have been derived, although some of the sandstones contain large numbers of marine organisms, from which the small amount of oil forming insignificant seepages has probably been derived. Since the rocks are coarse grained and porous, without impervious layers, and not folded, but broken by many small faults, the structural conditions are unfavourable for the accumulation of oil. Also the individual basins of the Sooke formation are small, and the thickness of the rocks, except locally, is probably less than 500 or 600 feet. It is, therefore, with a great deal of assurance that any extensive attempt at prospecting for coal and oil in the Sooke formation is discouraged.

GRAHAM ISLAND TERTIARY COAL AREA.[1]

(Extract from report by C. H. Clapp.)

The Tertiary coals, which, as stated, are all lignites, occur in the Tertiary sediments, which are confined to the northeastern part of Graham island. Lignite is known to occur at several localities, the best known of which is Skonun point on the north shore. This was the only locality visited by the writer, and will be described in more detail. Dawson[2] describes

[1]Summary Rep. Geol. Surv. 1912, pp. 38-39.
[2]Rept. of Progress 1878-79, Geol. Surv. of Can., pp. 85B-89B, 1880.

briefly the occurrence of lignite at a few other localities. In Chinukundl brook, which empties into Hecate strait 8 miles north of Image point, are a few thin, impure seams. North of Chinukundl brook, between Lawn hill and Cape Fife, numerous fragments of lignite are found on the beach, suggesting that lignite may outcrop in the vicinity possibly below low-water mark. At Yakan point on the north shore, about 10 miles east of Skonun point, irregular masses of lignite are found in sandstones and shales. Six miles up the Mamin river, which empties into Tsuskatli arm of Masset Inlet expansion, lignite occurs in thin seams. In the bed of a stream emptying into the east side of Naden harbour, pieces of lignite abound, and they have probably come from some outcrop not far up the stream. Also, the writer has seen samples of a good grade of black lignite with an irregular coaly structure and conchoidal fracture, that probably came from the northeast part of the basin underlain by the Queen Charlotte series near the head-waters of Tlell river.

At Skonun point at low tide there are exposed more than ten seams of varying persistency, of a tough woody lignite, which is curiously more resistant to wave erosion than the sandy shales with which it occurs. The seams range from 1 to 15 feet in thickness. The lignite-bearing measures have been considerably deformed, the structure apparently being a small anticline with a general east-west strike, broken along the crest by a nearly true strike fault. The southern limb of the anticline contains the lignite seams, which dip inland at angles varying from 25 to 60 degrees. An inclined bore-hole has been put down to a depth of 1,000 feet in the property, which is controlled by the American-Canadian Coal company. It is reported that thirteen seams of lignite of more than a foot in thickness were struck in this distance. Near the surface, the lignite is of the same woody nature as that exposed in the beach; but it is said that the lignite found in depth is of a more coaly nature.

The character of the lignite exposed at the surface is shown by the following proximate and ultimate analysis of a thoroughly air-dried sample collected by the writer from the thickest seam. The proximate analysis was made by F. G. Wait in the laboratory of the Mines Branch, Department of Mines, and the ultimate analysis was made by E. Stansfield in the Fuel Testing laboratory of the Department of Mines.

Proximate analysis:—

Water	11·03 %
Volatile combustible matter	49·75 "
Fixed carbon	35·94 "
Ash	3·28 "
Coke	39·22 "
Its character	coherent, but tender.
Fuel ratio	0·72
Split volatile ratio	2·33

Ultimate analysis:—

Carbon	56·3 %
Hydrogen	5·9 "
Nitrogen	0·3 "
Oxygen	33·1 "
Sulphur	0·3 "
Moisture	10·0 "
Ash	4·1 "
Carbon hydrogen ratio	9·5 "

Two other analyses of the Skonun Point lignite are published in the prospectus of the American Coal company, September, 1911, the analyses being made by J. O'Sullivan, of Vancouver.

Water	22·0	22·5
Volatile combustible matter	45·5	37·5
Fixed carbon	31·5	36·5
Ash	1·0	3·5
	100·0	100·0

The actual coal reserve at Skonum point is large. The seams are exposed for a distance of half a mile along the beach, as far as any outcrops are observed, and they undoubtedly extend much farther. If the area underlain by the lignite is estimated, very conservatively, as being 2 square miles, the reserve, taking 30 feet as the average thickness of workable seams of lignite, is 60,000,000 long tons. The lignite reserve of a fair degree of probability, on Graham island, is much greater. The areas underlain by Tertiary sediments, which almost assuredly contain more or less lignite, throughout the northeastern part of the island, may be conservatively estimated as totalling 136 square miles, and the probable lignite reserve is at least 1,000,000,000 long tons. It is, therefore, not a question of the quantity of the lignite, but of its quality and commercial possibilities.

Although some of the lignite is of a high grade, coaly character like the lignite described as probably coming from near the head-waters of Tlell river, most of it will doubtless be a lower grade character, like that exposed at Skonun point. However, the lignite that has been seen by the writer is strong and does not slack on exposure to the air like the lignites of the prairie regions. It is, therefore, capable of being transported and of being used directly as a fuel. Also many of the lignites, certainly those of Skonun point, are low in ash. The high water or oxygen content is, of course, a great drawback, since these substances greatly reduce the calorific (heat) value of the lignite. Nevertheless, of late years a great deal of attention has been given to the lignites of North America, and economical processes for their use have been developed. Hence, the lignites of Graham island are of great future value.

STIKINE RIVER AREA (TUYA RIVER).

Note by Provincial Mineralogist.[1] The following is from a report by Mr. R. D. Featherstonhaugh for the Atlin-Tuya Coal Prospecting Syndicate, upon certain coal lands situated on the Tuya river:—

"The property is situated on the Tuya river, in the Cassiar District, Province of British Columbia, about 25 miles upstream from where the Tuya empties into the Stikine river and about 35 miles from the village of Telegraph Creek. At the latter place are stores, hotels, post-office, and telegraph office. The property consists of 13 leases, each one mile square, or over 8,000 acres.

"The country for about 15 miles along the Tuya river is of sedimentary formation, consisting of carboniferous conglomerate, sandstone and shales, the general trend being northeast and southwest, the contact on the north being principally granite

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[1]Report of the Minister of Mines, B.C., 1904, pp. 97-98.

and on the south basalt and other eruptive rocks. The sandstone and conglomerate apparently extend in a westerly direction, a distance of nearly 50 miles, to the Nahlin river, where the same formation with the same plant fossils can be easily seen.

"Lying between the strata are large seams of coal. Outcrop No. 1 is a seam of coal 38 feet thick lying on a bed of clay and shale, capped by a stratum of conglomerate of varying thickness, then a stratum of coarse sandstone, on top of which has been deposited by ice at a later period about 20 feet of coarse gravel composed of granite and syenite boulders. This coal seam strikes approximately N. 30° W. and S. 30° E., and has been tilted to an angle of about 40°, and has been cut through by the river for a depth of 35 feet, thereby saving a large amount of prospecting to get the information which has been obtained at this point. An analysis made by the Provincial Assayer at Victoria, B.C., from samples, last November, gave the following results:—

"Moisture	11·35%
Volatile matter	28·36%
Fixed carbon	49·22%
Ash	9·92%
Sulphur	1·15%
Heating value in British thermal units	11,401

"Outcrop No. 2 is a seam of coal 26 feet thick and about one-half mile down stream from out crop No. 1, dip and strike corresponding with No. 1, but a distinctly separate seam, and can be traced for a long distance on the surface.

"Outcrop No. 3 shows up on Coutts creek about 400 yards up stream, on the right-hand side going up. Coutts creek is a large creek running nearly east and west, emptying into the Tuya river about one and a half miles below No. 1 outcrop. This outcrop is over 40 feet wide, dipping at an angle of 35° to the north, and strikes more with the trend of the country, namely, easterly and westerly. A great deal of coal can be found in the wash in the creek bottom.

"The whole area is fairly well timbered with spruce, affording sufficient supply for mining and construction purposes.

"A practically unlimited water power can be obtained at a reasonable cost from the Tuya river and Coutts creek.

"Of course railway facilities for the handling of the coal is an absolute necessity. The proposed line from Kitimat harbour or Hazelton to Dawson would pass through the property within a few miles of the present outcrop of coal, following the old survey of the Cassiar Central Railway."

INDEX.

A.

ERRATA.

In this index references to pages 70 to 90 inclusive will be found on the preceding page of text; *e.g.*, "Benson Mt." stated in the index to be on page 76 will be found on page 75.

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INDEX.

A.

B.

D.

E.

H.

I.

J.

K.

N.

O.

P.

S.

T.

Y.

Z.

LIST OF RECENT REPORTS OF GEOLOGICAL SURVEY

Since 1910, reports issued by the Geological Survey have been called memoirs and have been numbered Memoir 1, Memoir 2, etc. Owing to delays incidental to the publishing of reports and their accompanying maps, not all of the reports have been called memoirs, and the memoirs have not been issued in the order of their assigned numbers and, therefore, the following list has been prepared to prevent any misconceptions arising on this account. The titles of all other important publications of the Geological Survey are incorporated in this list.

Memoirs and Reports Published During 1910.

REPORTS.

Report on a geological reconnaissance of the region traversed by the National Transcontinental railway between Lake Nipigon and Clay lake, Ont.—by W. H. Collins. No. 1059.

Report on the geological position and characteristics of the oil-shale deposits of Canada—by R. W. Ells. No. 1107.

A reconnaissance across the Mackenzie mountains on the Pelly, Ross, and Gravel rivers, Yukon and North West Territories—by Joseph Keele. No. 1097.

Summary Report for the calendar year 1909. No. 1120.

MEMOIRS—GEOLOGICAL SERIES.

MEMOIR 1. *No. 1, Geological Series.* Geology of the Nipigon basin, Ontario —by Alfred W. G. Wilson.

MEMOIR 2. *No. 2, Geological Series.* Geology and ore deposits of Hedley mining district, British Columbia—by Charles Camsell.

MEMOIR 3. *No. 3, Geological Series.* Palæoniscid fishes from the Albert shales of New Brunswick—by Lawrence M. Lambe.

MEMOIR 5. *No. 4, Geological Series.* Preliminary memoir on the Lewes and Nordenskiöld Rivers coal district, Yukon Territory—by D. D. Cairnes.

MEMOIR 6. *No. 5, Geological Series.* Geology of the Haliburton and Bancroft areas, Province of Ontario—by Frank D. Adams and Alfred E. Barlow.

MEMOIR 7. *No. 6, Geological Series.* Geology of St. Bruno mountain, province of Quebec—by John A. Dresser.

MEMOIRS—TOPOGRAPHICAL SERIES.

MEMOIR 11. *No. 1, Topographical Series.* Triangulation and spirit levelling of Vancouver island, B.C., 1909—by R. H. Chapman.

Memoirs and Reports Published During 1911.

REPORTS.

Report on a traverse through the southern part of the North West Territories, from Lac Seul to Cat lake, in 1902—by Alfred W. G. Wilson. No. 1006.

Report on a part of the North West Territories drained by the Winisk and Upper Attawapiskat rivers—by W. McInnes. No. 1080.

Report on the geology of an area adjoining the east side of LakeTimiskaming—by Morley E. Wilson. No. 1064.

Summary Report for the calendar year 1910. No. 1170.

MEMOIRS—GEOLOGICAL SERIES.

MEMOIR 4. *No. 7, Geological Series.* Geological reconnaissance along the line of the National Transcontinental railway in western Quebec—by W. J. Wilson.

MEMOIR 8. *No. 8, Geological Series.* The Edmonton coal field, Alberta—by D. B. Dowling.

MEMOIR 9. *No. 9, Geological Series.* Bighorn coal basin, Alberta—by G. S. Malloch.

MEMOIR 10. *No. 10, Geological Series.* An instrumental survey of the shore-lines of the extinct lakes Algonquin and Nipissing in southwestern Ontario—by J. W. Goldthwait.

MEMOIR 12. *No. 11, Geological Series.* Insects from the Tertiary lake deposits of the southern interior of British Columbia, collected by Mr. Lawrence M. Lambe, in 1906—by Anton Handlirsch.

MEMOIR 15. *No. 12, Geological Series.* On a Trenton Echinoderm fauna at Kirkfield, Ontario—by Frank Springer.

MEMOIR 16. *No. 13, Geological Series.* The clay and shale deposits of Nova Scotia and portions of New Brunswick—by Heinrich Ries assisted by Joseph Keele.

MEMOIRS—BIOLOGICAL SERIES.

MEMOIR 14. *No. 1, Biological Series.* New species of shells collected by Mr. John Macoun at Barkley sound, Vancouver island, British Columbia—by William H. Dall and Paul Bartsch.

Memoirs and Reports Published During 1912.

REPORTS.

Summary Report for the calendar year 1911. No. 1218.

MEMOIRS—GEOLOGICAL SERIES.

MEMOIR 13. *No. 14, Geological Series.* Southern Vancouver island—by Charles H. Clapp.

MEMOIR 21. *No. 15, Geological Series.* The geology and ore deposits of Phoenix, Boundary district, British Columbia—by O. E. LeRoy.

MEMOIR 24. *No. 16, Geological Series.* Preliminary report on the clay and shale deposits of the western provinces—by Heinrich Ries and Joseph Keele.

MEMOIR 27. *No. 17, Geological Series.* Report of the Commission appointed to investigate Turtle mountain, Frank, Alberta, 1911.

MEMOIR 28. *No. 18, Geological Series.* The Geology of Steeprock lake, Ontario—by Andrew C. Lawson. Notes on fossils from limestone of Steeprock lake, Ontario—by Charles D. Walcott.

Memoirs and Reports Published During 1913.

REPORTS, ETC.

Museum Bulletin No. 1: contains articles Nos. 1 to 12 of the Geological Series of Museum Bulletins, articles Nos. 1 to 3 of the Biological Series of Museum Bulletins, and article No. 1 of the Anthropological Series of Museum Bulletins.

Guide Book No. 1. Excursions in eastern Quebec and the Maritime Provinces, parts 1 and 2.

Guide Book No. 2. Excursions in the Eastern Townships of Quebec and the eastern part of Ontario.

Guide Book No. 3. Excursions in the neighbourhood of Montreal and Ottawa.

Guide Book No. 4. Excursions in southwestern Ontario.

Guide Book No. 5. Excursions in the western peninsula of Ontario and Manitoulin island.

Guide Book No. 8. Toronto to Victoria and return *via* Canadian Pacific and Canadian Northern railways: parts 1, 2, and 3.

Guide Book No. 9. Toronto to Victoria and return *via* Canadian Pacific, Grand Trunk Pacific, and National Transcontinental railways.

Guide Book No. 10. Excursions in Northern British Columbia and Yukon Territory and along the north Pacific coast.

MEMOIRS—GEOLOGICAL SERIES.

MEMOIR 17. *No. 28, Geological Series.* Geology and economic resources of the Larder Lake district, Ont., and adjoining portions of Pontiac county, Que.—by Morley E. Wilson.

MEMOIR 18. *No. 19, Geological Series.* Bathurst district, New Brunswick—by G. A. Young.

MEMOIR 26. *No. 34, Geological Series.* Geology and mineral deposits of the Tulameen district, B.C.—by C. Camsell.

MEMOIR 29. *No. 32, Geological Series.* Oil and gas prospects of the northwest provinces of Canada—by W. Malcolm.

MEMOIR 31. *No. 20, Geological Series.* Wheaton district, Yukon Territory—by D. D. Cairnes.

MEMOIR 33. *No. 30, Geological Series.* The geology of Gowganda Mining Division—by W. H. Collins.

MEMOIR 35. *No. 29, Geological Series.* Reconnaissance along the National Transcontinental railway in southern Quebec—by John A. Dresser.

MEMOIR 37. *No. 22, Geological Series.* Portions of Atlin district, B.C.—by D. D. Cairnes.

MEMOIR 38. *No. 31, Geological Series.* Geology of the North American Cordillera at the forty-ninth parallel, Parts I and II—by Reginald Aldworth Daly.

Memoirs and Reports Published During 1914.

REPORTS, ETC.

Summary Report for the calendar year 1912. No. 1305.

Museum Bulletins Nos. 2, 3, 4, 5, 7, and 8 contain articles Nos. 13 to 22 of the Geological Series of Museum Bulletins, article No. 2 of the Anthropological Series, and article No. 4 of the Biological Series of Museum Bulletins.

Prospector's Handbook No. 1: Notes on radium-bearing minerals—by Wyatt Malcolm.

MUSEUM GUIDE BOOKS.

The archæological collection from the southern interior of British Columbia—by Harlan I. Smith. No. 1290.

MEMOIRS—GEOLOGICAL SERIES.

MEMOIR 23. *No. 23, Geological Series.* Geology of the Coast and islands between the Strait of Georgia and Queen Charlotte sound, B.C.—by J. Austen Bancroft.

MEMOIRS—ANTHROPOLOGICAL SERIES.

MEMOIRS—BIOLOGICAL SERIES.

Memoirs and Reports Published During 1915.

REPORTS, ETC.

Summary Report for the calendar year 1913, No. 1359.

Report from Anthropological Division. Separate from Summary Report 1913.

Report from Topographical Division. Separate from Summary Report 1913.

Museum Bulletin No. 6. *No. 3, Anthropological Series.* Pre-historic and present commerce among the Arctic Coast Eskimo—N. Stefansson.

Museum Bulletin No. 9. *No. 4, Anthropological Series.* The glenoid fossa in the skull of the Eskimo—F. H. S. Knowles.

Museum Bulletin No. 13. *No. 5, Biological Series.* The double crested cormorant (*Phalacrocorax auritus*). Its relation to the salmon industries on the Gulf of St. Lawrence—P. A. Taverner.

MEMOIRS—GEOLOGICAL SERIES.

MEMOIR 58. *No. 48, Geological Series.* Texada island—by R. G. McConnell.

MEMOIR 60. *No. 47, Geological Series.* Arisaig-Antigonish district—by M. Y. Williams.

MEMOIR 67. *No. 49, Geological Series.* The Yukon-Alaska Boundary between Porcupine and Yukon rivers—by D. D. Cairnes.

MEMOIR 59. *No. 55, Geological Series.* Coal fields and coal resources of Canada—by D. B. Dowling.

MEMOIR 50. *No. 51, Geological Series.* Upper White River District, Yukon —by D. D. Cairnes.

MEMOIR 66. *No. 54, Geological Series.* Clay and shale deposits of the western provinces, Part V—by J. Keele.

MEMOIR 65. *No. 53, Geological Series.* Clay and shale deposits of the western provinces, Part IV—by H. Ries.

MEMOIR 56. *No. 56, Geological Series.* Geology of Franklin mining camp, B. C.—by Chas. W. Drysdale.

MEMOIR 64. *No. 52, Geological Series.* Preliminary report on the clay and shale deposits of the Province of Quebec—by J. Keele.

MEMOIR 57. *No. 50, Geological Series.* Corundum, its occurrence, distribution, exploitation and uses—by A. E. Barlow.

Memoirs and Reports in Press, May 8, 1915.

MEMOIR 62. *No. 5, Anthropological Series.* Abnormal types of speech in Nootka—by E. Sapir.

MEMOIR 63. *No. 6, Anthropological Series.* Noun reduplication in Comox, a Salish language of Vancouver island—by E. Sapir.

MEMOIR 46. *No. 7, Anthropological Series.* Classification of Iroquoian radicals with subjective pronominal prefixes—by C. M. Barbeau.

MEMOIR 70. *No. 8, Anthropological Series.* Family hunting territories and social life of the various Algonkian bands of the Ottawa valley—by F. G. Speck.

MEMOIR 71. *No. 9, Anthropological Series.* Myths and folk-lore of the Timiskaming Algonquin and Timagami Ojibwa—by F. G. Speck.

MEMOIR 69. *No. 57, Geological Series.* Coal fields of British Columbia—by D. B. Dowling.

MEMOIR 34. *No. 63, Geological Series.* The Devonian of southwestern Ontario—by C. R. Stauffer.

MEMOIR 73. *No. 58, Geological Series.* The Pleistocene and Recent deposits of the island of Montreal—by J. Stansfield.

MEMOIR 68. *No. 59, Geological Series.* A geological reconnaissance between Golden and Kamloops, B.C., along the line of the Canadian Pacific railway—by R. A. Daly.

MEMOIR 72. *No. 60, Geological Series.* The artesian wells of Montreal—by C. L. Cumming.

MEMOIR 74. *No. 61, Geological Series.* A list of Canadian mineral occurrences—by R. A. A. Johnston.

MEMOIR 75. *No. 10, Anthropological Series.* Decorative art of Indian tribes of Connecticut—Frank G. Speck.

MEMOIR 76. *No. 62, Geological Series.* Geology of the Cranbrook map-area—by S. J. Schofield.

Summary Report for the calendar year 1914.

Museum Bulletin No. 10. *No. 5, Anthropological Series.* The social organization of the Winnebago Indians—by P. Radin.

Museum Bulletin No. 11. *No. 23, Geological Series.* Physiography of the Beaverdell map-area and the southern part of the Interior plateaus, B.C.—by Leopold Reinecke.

Museum Bulletin No. 12. *No. 24, Geological Series.* On Eoceratops canadensis, gen. nov., with remarks on other general of Cretaceous horned dinosaurs—by L. M. Lambe.

Museum Bulletin No. 14. *No. 25, Geological Series.* The occurrence of Glacial drift on the Magdalen islands—by J. W. Goldthwait.

Canada
Department of Mines
GEOLOGICAL SURVEY
LEGEND
Areas of coal bearing strata
Coal occurrences
I XXIII
Numbers relating to Diagrams contained in Memoir
DIAGRAMS
I. Crowsnest and Elk River coal areas
II. Flathead coal areas
III. Cowichan Basin and Nanaimo coal field
IV. Comox coal area
V. Suquash coal area
VI. Quatsino Sound coal area
VII. Koskeemo coal area
VIII. Graham Island coal areas
IX. Kispiox and Skeena coal areas
X. Telkwa River coal areas
XIX. Nicola and Quilchena coal areas
XX. Kamloops Lake coal areas
XXI. Hat Creek coal areas
XXII. Coal Creek North Thompson River coal area
XXIII. Liard River coal areas
YUKON
BRITISH COLUMBIA
ROCKY MOUNTAINS
ALBERTA
COAST RANGE
QUEEN CHARLOTTE ISLANDS
VANCOUVER ISLAND
PACIFIC OCEAN
DIXON ENTRANCE
UNITED STATES
VANCOUVER
VICTORIA
CALGARY
SKAGIT
CLALLAM
SNOHOMISH
Longitude West 123 from Greenwich
MAP 139 A
(Issued 1915)
Coal fields
of
BRITISH COLUMBIA
Scale, 1/2,217,600
Miles
Kilometres
35 MILES TO 1 INCH