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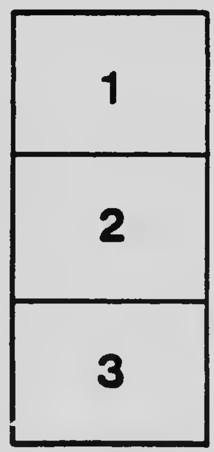
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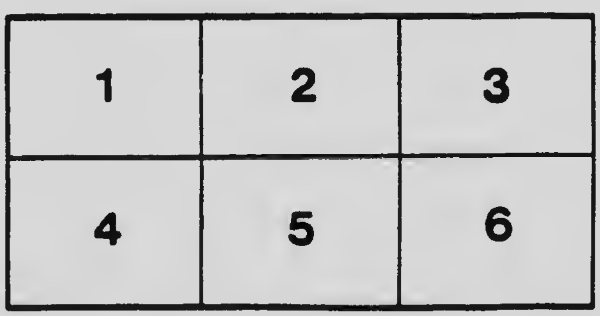
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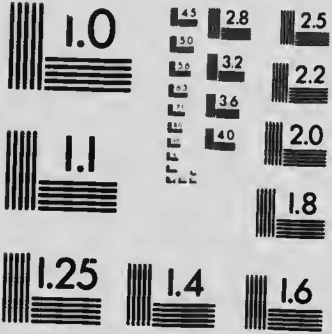

CANADA
DEPARTMENT OF MINES
HON. P. E. BLONDIN, MINISTER; R. G. MCCONNELL, DEPUTY MINISTER.
GEOLOGICAL SURVEY

MEMOIR 88

No. 72, GEOLOGICAL SERIES

Geology of Graham Island, British Columbia

BY
J. D. MacKenzie

OTTAWA
GOVERNMENT PRINTING BUREAU
1916

No. 1622

Bearskin bay and Slatechuck range from Maple island. Queen Charlotte on the right. The high sharp peak is Slatechuck mountain, the highest point on Graham island; the second to the right of it is Mount Genevieve, and the next is Mount Etheline. Note the wave-cut bench at high tide level, and the protecting sea-weed in the foreground. (See pages 24, 118.)

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CHAPTER I.

INTRODUCTION.

GENERAL STATEMENT.

The southern islands of the Queen Charlotte group are known to contain several deposits of metallic minerals, the value of which has not yet been ascertained except in a preliminary way, and Graham island, the subject of this report, has long been considered to have deposits of coal, lignite, and petroleum. The search for workable bodies of these substances has been carried on at irregular intervals since 1859, and has lately been vigorously renewed.

In the year 1912 a short reconnaissance of part of Graham island was made by Dr. C. H. Clapp, then connected with the Geological Survey, and his report made evident the necessity for further and more detailed study. Accordingly, in 1913, the writer was instructed to make a geological examination of Graham island for the purpose, mainly, of determining the extent, structure, and value of the coal deposits. It was found necessary to continue this examination during two months of 1914, with the result that, in addition to a large amount of detailed work, a reconnaissance was made over the whole island. The results of the two seasons' exploration and study are contained in this report.

FIELD WORK.

In 1913, field work was carried on during the three months from June 22 to September 20. For the work done in that year no maps of sufficient accuracy to serve as a base for geological mapping were available, with the exception of the Admiralty chart of Skidegate inlet, No. 48; so that it was necessary to construct a topographical map as the work proceeded. To do this, all trails and the larger streams were surveyed with the telemeter, the traverses being closed, or tied to located posts of the British Columbia Land Surveys. The telemeter surveys, with the coast-line from the chart, and the posts of the land surveys, formed a control of sufficient accuracy for work on a scale of 1 inch to 2 miles. From stations on these surveys, pace-and-compass traverses of the smaller streams were made; and the outcrops along the streams together with a few occurring in interstream areas served to complete the areal geological mapping. As the surveys were completed they were plotted, furnishing a progress outcrop map; and from these plotted surveys the maps accompanying this report have in part been compiled.

During 1914, the two months from June 15 to August 18 were spent on Graham island. In this time the detailed work left unfinished in 1913 was completed and a reconnaissance made over the rest of the island. The district studied in detail comprised portions of townships 6, 7, 8, 9, 11, and 14; and the excellent maps of these townships prepared under the direction of the Surveyor General of British Columbia were of great assistance in the field. They furnished, in part, the base of the maps accompanying this report.

The district studied on a relatively large scale is shown in the map on a scale of 1 inch to 2 miles.

ACKNOWLEDGMENTS.

The writer wishes to express his sincere thanks to the many residents of Graham island who, by their encouragement and assistance, furthered the progress of the work, and especially to Mr. E. M. Sandilands, government agent at Queen Charlotte.

Others who have aided include Mr. G. D. Beattie, Dr. and Mrs. J. T. Wright, and Mr. and Mrs. W. J. Smith of Queen Charlotte; Captain S. Ferguson, Mr. Fred. and Mr. Walter DeLisle, Mr. Mallory, and Mr. Van Valkanburg of Port Clements; Mr. J. M. Campbell, Mr. Henry Edenshaw, Mr. Charles Harri-

son, Mr. James Martin, Mr. F. Nash, and Mr. H. F. and Mr. E. T. Wearmouth of Masset.

Most of the companies prospecting on Graham island have furnished assistance, among them the Graham Island Collieries Company, the Graham Island Coal and Timber Syndicate, the B.C. Oilfields, Limited, and the Western Coal and Iron Corporation, Limited. Mr. Milnor Roberts, in charge of the development work for the latter company, and his assistants Mr. Livingston Wernecke and Mr. J. M. MacDonald have been particularly helpful, both in active co-operation in field work, and by furnishing analyses and other data. Mr. J. H. Dawson, Surveyor General of British Columbia, also, has given valuable assistance by furnishing maps.

In the preparation of this report, the writer has frequently received advice from the members of the Geological Department of the Massachusetts Institute of Technology, Professors Lindgren, Warren, Shimer, and Lahee. In no way, however, are they to be held responsible for any of the statements made.

AREA.

Graham island is the largest of the Queen Charlotte group, and with the exception of Langara or North island, it is the most northerly. Its total area is about 2,500 square miles.

The south-central part of the island, comprising the district between Skidegate and Masset inlets, and containing about 300 square miles, was mapped on a scale of 1 inch to 1 mile. The map on a reduced scale of 1 inch to 2 miles accompanies this report. The portions of this area underlain by coal bearing rocks were carefully examined and, outside of the coal basins, sufficient work was done to determine the structure of the underlying rocks and the absence of coal measures with as much certainty as the outcrops would permit.

Reconnaissance traverses were made through Skidegate channel, and up the west coast nearly to Kano inlet; up the east coast to Lawn hill, and thence westerly across the north-eastern lowland to the valley of the Yakoun river. Hidden creek, Ghost river, King creek, and other creeks west of the

Yakoun were also traversed. The shores of Masset and Juskatla inlets were examined, and from Masset a trip was made in a launch westward along the north coast, and down the west coast as far as Athlow bay. From Dinan bay, in the westward part of Masset lake, a reconnaissance traverse was made by Mr. Dolmage over the trail to Seal inlet on the west coast.

MEANS OF ACCESS.

The Grand Trunk Pacific Steamship Company maintains a regular service between Prince Rupert and the ports of the Queen Charlotte group.

The interior of Graham island is reached by trails, to some degree by the fiord-like inlets which indent the coast, and by the Yakoun river.

From Queen Charlotte a good horse trail leads west about 2½ miles to the mouth of the Honna river, which is the starting point for expeditions to the southern interior. From the mouth a trail, passable for horses after long-continued dry weather only, and usually too soft for use by pack animals, follows up the Honna river for 4 miles to the so-called Fourmile camp. There the trail forks, one branch leading to Camp Robertson, the other to Camp Wilson.

The trail to Camp Robertson runs northwestward for 5 miles over the easternmost spurs of the high hills forming the ridge extending eastward from Mt. Etheline, a very rough and hilly country. This trail has unnecessarily steep gradients and the many ups and downs make it a trying road to traverse. A much better route to Camp Robertson could be provided by building a trail at the base of the hills just mentioned northwestward to the junction of Falls and Wawa creeks and thence up the valley of Wawa creek to Camp Robertson. This road would have much better grades, and would entail vastly less climbing than the present trail.

The trail to Camp Wilson runs almost due north from Fourmile camp for about 5 miles to the Junction where it is joined by a trail coming from Camp Robertson. From there the trail continues north and northwestward about 9 miles to

Camp Wilson, skirting the east shore of Sue lake, crossing the valley of the Tlell river, and passing through the large muskegs on the summit of the highland between that valley and Camp Wilson. From Camp Wilson a trail follows down Wilson creek for about three-fourths of a mile to the Yakoun river, and another trail runs northeastward about 2 miles to the skid road of the Graham Island Coal and Timber Syndicate. This skid road follows a roundabout route of about 30 miles to Port Clements on Masset inlet, and a trail of about the same length follows the east bank of the Yakoun river most of the distance to the same place.

From Camp Robertson a trail leads west about 3 miles to Yakoun lake. Canoes serve for transportation to the opposite side of the lake whence a trail leads to Rennell sound on the west coast; or to the northern end of the lake whence a trail runs north about 2 miles to Hidden creek, continuing north about 2 miles farther to the southern edge of the valley of Ghost river, where it turns eastward for some 600 yards to the Yakoun river.

The Yakoun river furnishes a natural route to the southern interior of the island navigable at almost all stages of water. The river is passable for canoes and river boats to Camp Wilson although many log-jams obstruct the passage. If the jams were wholly removed, the river would be navigable to its source in Yakoun lake.

The west coast may be reached from the northern end of the island by gasoline launches, or by a trail leading from Naden harbour to Otard bay and thence to Tian head. From the head of Dinan bay, on Masset lake, as the large inland expansion of the inlet is termed, a trail leads southward about 1½ miles to Seal inlet on the west coast.

Owing to the thick cover of wet moss and decayed vegetation, the trails are seldom in good condition. Weeds and underbrush obstruct the pathways, and the soft and insecure footing, the roots, snags, and bog-holes make rapid travelling an impossibility. After a few days of rain a trail that is being used much becomes little better than a ditch; and carrying a pack under these conditions is most burdensome. The distance from Camp Wilson to the mouth of the Honna, about 18 miles by the trail, is seldom covered in less than seven hours without packs; and packers carrying only 40 to 50 pounds require two days for the trip. These obstacles make surveying or prospecting slow and costly.

HISTORY.[1]

The Queen Charlotte islands named by Dixon in 1781, were visited by several Spanish expeditions at earlier dates. It is possible that they were visited as early as 1639 by the Spaniard Bartholomew De Fonte, who commanded an expedition fitted out at Callao, Peru. The first well authenticated visit seems to have been that of Ensign Juan Perez, who reached the islands on July 18, 1774. After Perez, the group was visited by Bodega and Maurelle in 1775; La Perouse, Lowrie and Guise, Hanna, and Portlock and Dixon in 1786; Dixon, and Colnett and Duncan in 1787; Duncan, and Douglas in 1788; Gray, and Funter in 1789; Ingraham, and Marchand in 1791; Jacinto Caamano, Haswell, Gray, and Vancouver in 1792; and Vancouver in 1793. Various fur-traders continued to visit the islands, but on the decline of the fur trade, attention was (to quote Dawson)

"withdrawn from the islands until 1852, when the Hudson Bay Company dispatched a party of men in the Brig Una, Captain Mitchell, to discover the locality from which several specimens of gold had been brought by Indians. This was found to be in Port Kuper or Gold Harbour, on the west coast. The gold was found in a small irregular vein, which was soon proved to run out in every direction. . . . . . The enterprise was soon abandoned, but the discovery for a time created quite a *furore*—the first gold excitement of British Columbia—and the locality was visited by a number of miners, but with no better success. . . . . . Mr. Downie (in 1859) appears to have been the first to discover the coal at Skidegate inlet. About this time a Captain Torrens also went with a party to prospect on the Queen Charlotte islands, and narrowly escaped massacre by the Skidegate Indians."

Various surveys of inlets and harbours were made by officers of the Royal Navy, from 1852 to 1886, when D. Pender, R. N., made a careful chart of a large portion of Skidegate inlet.

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[1] For a more detailed account of the early voyages of discovery to the Queen Charlotte islands, see Dawson, G. M., Geol. Surv., Can., Rept. of Prog., 1878-79, pp. 2B-14B, from which this account is taken.

CHAPTER II.

SUMMARY.

SUMMARY OF PREVIOUS GEOLOGICAL WORK.

RICHARDSON'S REPORT.

In 1872, James Richardson made an examination of the shores of portions of Skidegate inlet, and investigated the coal seams then exposed in tunnels at Cowgitz in the western part of that inlet. His report[1] contains the first information in regard to the geology of Graham island.

Richardson divided the Cretaceous rocks of Skidegate inlet into three general divisions, which, under different names, have been adhered to by all subsequent investigators. His division follows:

(1) Upper shales and sandstones.
(2) Coarse conglomerates.
(3) Lower shales with coal and iron ore.

Richardson's description of the coal seams of Cowgitz remains to this day the only authentic information about that locality, as the openings were obscured soon after his visit and are now almost completely obliterated. He considered that the coal was near the base of the measures, failing to recognize the faulting at Cowgitz. He does not clearly state whether the volcanic rocks overlie or underlie the coal measures. He evidently considered all the sedimentary rocks of Skidegate inlet to be Cretaceous, and this confusion of lower Jurassic argillites with Upper Cretaceous slaty shales, which was not detected by Dawson in 1878, caused uncertainty in regard to the age of the Queen Charlotte series until the present investigation was made. Richardson's "Number Two Coal Mine," for instance, occurs in lower Jurassic argillites, and not in Cretaceous rocks. Probably a carbonaceous layer in the argillites was mistaken for a weathered coal seam, a mistake that might easily be made.

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[1] Richardson, James, Geol. Surv., Can., Rept. of Prog., 1872-73, pp. 56-63 and Appendices.

The iron ores, mentioned by Richardson as occurring in the "Lower shales," are probably concretionary bands of dolomitic and calcareous shale, which are sufficiently ferruginous to weather buff and brown.

Appendices to his report deal with the fossils collected, coal analyses, etc.

DAWSON'S REPORT[1].

The report by G. M. Dawson on the Queen Charlotte islands, in so far as it deals with Graham island, is based on a careful examination of the shores and islands of Skidegate inlet (of which a map on the scale of 1 inch to 1 mile accompanies the report), an examination of portions of the east and north coasts of the island, and a short reconnaissance in Masset inlet. With the exception of the detailed work done in Skidegate inlet, the field work was of an exploratory or reconnaissance nature.

The scope of the report may best be indicated by giving the titles of its main divisions. These are:

Position, discovery, and early history of the islands.
General description of the islands.
Geological observations.
  General remarks on the rocks of the Queen Charlotte islands.
  Notes on the map.
    Triassic.
    Cretaceous coal-bearing rocks.
    Tertiary.
  Glaciation and superficial deposits.

The discovery and early history of the islands have already been summarized in the present report. The general description of the group deals with their geography, topography, and scenery, and is a valuable contribution to the knowledge of the islands. Dawson's map, accompanying his report, remained until very recent years the only reliable general map of the group, and parts of the west coast are to this day as little known as when his visit was made.

The table of formations given by Dawson is as follows:

[1] Dawson, G. M., Geol. Surv., Can., Ann. Rept., 1878-79, pp. 1B-239B.

Post-Pliocene.	Sands and gravels. Plastic and boulder clays, etc.

Unconformity, with evidence of some flexure and disturbance of Tertiary beds.

Tertiary, probably Miocene.	Volcanic rocks of the north part of Graham island. Sandstones, with marine fossils and lignites of Skonun point. Shales, clays, and lignites of Mamin river and Chinookundl creek.

Complete unconformity, with evidence of great disturbance. Chief period of mountain making.

Cretaceous.	A. Upper shales and sandstones. B. Coarse conglomerates. C. Lower shales and sandstones. D. Agglomerates. E. Lower sandstones.

Unconformity, but without evidence of great disturbance.

Triassic, but possibly passing below into Carboniferous.	Agglomerates and ash rocks of Logan inlet, etc. (These possibly represent subdivision D., *supra*.) Flaggy calcareous argillites and thin limestones. Massive limestones. Massive dioritic and feldspathic volcanic accumulations, probably including minor limestone beds, occasionally schistose.

A comparison of this table with the subdivisions used in this report is given on page 11.

The rocks called Triassic by Dawson, include limestones and black, calcareous, flaggy argillites, and he mapped a small portion of the south side of Maude island as being underlain by this formation. These rocks, together with other rocks of Skidegate inlet, erroneously supposed by Dawson to be Cretaceous, have been shown through fossils collected by the writer to be lower Jurassic and perhaps Triassic in age, and are termed in this report the Maude formation.

The Cretaceous rocks of Skidegate inlet are described on pages 63B to 77B of his report. Dawson accepts Richardson's subdivision, to which he adds two members, his complete section being:

	Formation.	*Thickness.*
A.	Upper shales and sandstones	1,500 feet.
B.	Coarse conglomerates	2,000 "
C.	Lower shales with coal and iron ore	5.000 "
D.	Agglomerates	3,500 "
E.	Lower sandstones	1,000 ? "
		13,000 "

This subdivision is not entirely correct, as there is a marked unconformity, structural and palæontological, between subdivision C and subdivision D. A, B, and C are Upper Cretaceous in age, D and E are middle and lower Jurassic respectively. That such a minute observer as Dawson considered this unconformity "essentially unimportant" is largely due to the fact that the Cretaceous and pre-Cretaceous beds are in many instances lithologically similar. This is so much the case, that only by the closest attention to the stratigraphy and structure, and by careful labelling of each collection of fossils, was the present writer able to separate them. Dawson, on structural and lithologic grounds, mapped several areas of pre-Cretaceous rocks as Cretaceous. The fossils collected from beds that he supposed to be wholly Cretaceous, on examination proved to be partly referable to the Upper Cretaceous, and some species to the Jurassic. This condition of affairs caused uncertainty in regard to the age of these rocks, which were, until the present examination, supposed to be Lower Cretaceous.

It has been mentioned that Dawson considered the unconformity between subdivisions C and D to be "essentially unimportant." His conclusion was largely based on an examination of the rocks of Alliford bay, which are shaly and tufaceous sandstones, quite similar to those occurring in the Cretaceous. On the east side of the bay an apparent transition between true volcanic tuffs and sandstones occurs, and is figured by Dawson on page 68B of his report. The writer made a careful study of this locality, and fortunately found abundant fossils in the rocks of Alliford bay, which prove them to be wholly Jurassic. Dawson was right, therefore, in saying this unconformity was unimportant, but he did not recognize the much greater and more important unconformity above the rocks of Alliford bay, which, as a matter of fact, are low down in the middle Jurassic.

Apart from the misinterpretation of the structure and stratigraphy above referred to, Dawson's report, as far as the writer could check it, is quite accurate in the descriptions of the formations; and his delineation of these formations on the map is also excellent. The relations of his subdivisions to those used in this report are given in the table below:

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

Eighty-six pages of Dawson's report are taken up with appendices describing the Haida Indians, the natives of the Queen Charlotte islands. This is a most interesting and readable account of this race which is superior to most if not all of the North American aborigines. Plate XIV illustrates the character of one of their villages.

ELLS' REPORT.

In the summer of 1905, R. W. Ells of the Geological Survey made a reconnaissance of Graham island. He traversed the shores of the island completely in a sailing boat, and his assistant ascended Yakoun river to Yakoun lake, and crossed thence by trail to Skidegate inlet. Thus the examination embraced only the coast-line, and one traverse across the island. Two maps accompany the report[1], one of the whole island on a scale of 1 inch to 4 miles, and one of a portion of southern Graham island on a scale of 1 inch to 1 mile. Owing to the incompleteness of the information available these maps are far from accurate.

Ells divided the rocks found on Graham island under four heads:

I. Post Tertiary: including sands, gravels, and clays.
II. Tertiary: comprising shales, sandstone, and conglomerate with beds of lignite, fossiliferous.
III. Cretaceous: shales, sandstone, and conglomerate, with thin limestones and with large deposits of bituminous coal which sometimes passes into anthracite; also fossiliferous.
IV. Igneous rocks: comprising pre-Cretaceous and Tertiary.

Ells' maps differ from Dawson's in that they correctly represent the "agglomerates and lower sandstones" (subdivisions D and E of the latter) as pre-Cretaceous. No clear statement of the relations of these rocks is given in the report, however. Ells considered the Tertiary volcanic rocks of the Slatechuck range to be pre-Cretaceous, and so represented them on his maps.

CLAPP'S REPORT.[2]

C. H. Clapp's report is based on a reconnaissance across Graham island in August, 1912, which lasted seventeen days. His interpretation of the relations of the various formations is almost wholly correct and, considering the short time at his disposal for mapping, the diagram map accompanying his report substantially accurate.

Clapp gave locality names to the subdivisions of the Cretaceous made by Dawson, as may be seen from the following table, taken from his report.

[1] Ells, R. W., Geol. Survey, Can., Ann. Rept., vol. XVI, 1906, pp. 1B-46B.
[2] Clapp, C. H., Geol. Surv., Can., Sum. Rept., 1912, pp. 12-40.

Table of Formations.

Superficial deposits	Pleistocene and Recent.
Tertiary sediments	Upper Miocene or Pliocene.
Tertiary volcanics and intrusives. Dacites, andesites, and basalts	Upper Miocene or Pliocene and probably Eocene.
Queen Charlotte series Skidegate sandstones. Honna conglomerate. Haida sandstones and shales. Image (basal) conglomerates. (May include contemporaneous volcanics).	Middle or upper Jurassic or Lower Cretaceous, and probable Middle and Upper Cretaceous.
Batholithic intrusives Granodiorite, diorite, etc.	Upper Jurassic.
Vancouver group Argillites, slaty shales. Metamorphic volcanics, andesites, and basalts.	Triassic and Jurassic.

He also clearly recognized the important unconformity at the base of the Queen Charlotte series, although he includes in the latter some volcanic conglomerates which more detailed work has shown to be pre-Cretaceous.

As Clapp's descriptions vary only in detail from those in the present report, they are not summarized here.

SUMMARY OF PRESENT REPORT.

For those who are mainly interested in the economic geology of the area, this summary will serve as a sufficiently full description of the general geology. Of necessity, proofs of the conclusions arrived at cannot be given in this summary; for the proofs, and for further details of the geology of the island, the reader is referred to the main part of the report.

GENERAL GEOLOGY.

The oldest formations exposed on Graham island comprise metamorphic sediments and volcanic rocks, of lower Jurassic and perhaps Triassic age, which are correlated in general with the Vancouver group. These basal rocks are divided into two formations, the Maude formation, lower Jurassic and perhaps Triassic in age, and the Yakoun formation, of middle Jurassic age, which conformably overlies it.

The Maude formation is at least 3,8[illegible] feet thick and the lower part is composed of thin, flaggy, fossiliferous argillites and black slates, which, generally, are strongly impregnated with bituminous matter. The upper part of the formation consists of fine, even-grained, grey-green sandstones, with some tuff and agglomerate intercalations. The character of the strata making up the formation, varies somewhat in different localities; and on Langara island, and on the northwest extremity of Graham island there are sandstones and coarse conglomerates which are thought to belong to this formation.

Conformable on the above described rocks is the Yakoun formation, consisting of agglomerates and some flows of basalt, and containing in its lower part greenish-grey tufaceous sandstones, which are in many places fossiliferous, and lithologically resemble the sandstones of the Cretaceous Queen Charlotte series.

These two formations, comprising the Vancouver group, have been strongly folded, the general direction of the axes of the folds being north 30 degrees west, but locally varying. Faulting on a minor scale is common and is especially noticeable in the well banded argillites of the Maude formation.

The rocks of the Vancouver group have been intruded by stocks of granodiorite and associated rocks, which are exposed on the southwest corner of Graham island, and are reported to occur also in the valley of the Tlell river in the eastern part of the island. Dioritic rocks also form the larger portion of Langara island.

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 one or more coal-bearing horizons. The time of their deposition was during the Upper Cretaceous. The surface on which they were deposited was hilly, and in many places very uneven. The general topographical conditions surrounding the basin probably resembled to some extent those found in the vicinity of Skidegate inlet to-day.

The Queen Charlotte series has been subdivided into three members which are, beginning with the oldest, the Haida, Honna, and the Skidegate formations.

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 prevailing. The lenticular character of the various beds renders it difficult to decipher the structure, and there are scarcely any layers in the formation that serve as horizon markers. In thickness, the Haida formation varies from 2,000 to 5,500 feet.

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 and the pebbles which are well rounded form 30 to 60 per cent of the rock. A few of the pebbles at the base of the beds are very large, some of them being 3 feet in diameter; but the average is much less, and many beds do not contain a pebble over 1 inch in diameter. The pebbles have been derived from rocks of many different kinds including diorites, granodiorites and other plutonic rocks, quartzites, argillites and slates, cherts, quartz, and, rarely, Yakoun volcanics. The Honna conglomerate has a sharply gradational contact with the underlying Haida sandstones where exposed at Lina narrows, and the contact with the overlying Skidegate sandstones is also rather abrupt. The thickness of the Honna conglomerate is about 2,000 feet.

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

Structure of the Queen Charlotte Series.

Regional. In preceding pages it has been shown that 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 varying 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 manner in which the basins of Cretaceous rocks occur on the pre-Cretaceous hills, and owing to 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 localized basins.

Numerous dykes and sills, largely of Tertiary age, intrude the Queen Charlotte series, especially the lower Haida member. These bodies range up to 50 feet in thickness, and are particularly abundant in certain places. Some of them have been faulted, and the intrusive period probably covered a long interval. They range from dacite to augite andesite in composition. Following this intrusive epoch came a period of marine sedimentation, in part at least lacustrine or fluviatile, during which the fossiliferous sandstones, shales, conglomerates, and lignites of the Skonun formation were deposited. Overlying these sediments, probably essentially conformably, is a very great thickness of basaltic flows, tuffs, and agglomerates, termed the Masset formation. These rocks underlie the greater portion of Graham island west of Masset inlet and north of Rennell sound, and are found in the Slatechuck range also. In amygdules in some of the basalt flows is found black tarry matter, which has led to considerable prospecting for petroleum.

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[1] Clapp, C. H., Geol. Surv., Can., Sum. Rept., 1912.

The Tertiary rocks have been deformed to some extent, and locally dip at high angles.

Surface formations on Graham island consist of glacial stratified drift, till, and alluvium. Over large areas the bed-rock is deeply buried, rendering the deciphering of the structure difficult.

ECONOMIC GEOLOGY.

The deposits of economic value found on Graham island comprise coal, lignite, clay, building stone and limestone, possibly oil-shale, and gold. Deposits of black tar also are found, but are not considered to indicate the presence of petroleum.

Coal is found in the Haida formation of the Queen Charlotte series, of Upper Cretaceous age. The coal has been exposed at several localities, and the seams show considerable variation, caused by original differences in deposition as well as by later changes. Coal seams have been prospected at Cowgitz and in the Slatechuck valley on Skidegate inlet; at Camps Robertson, Anthracite, Trilby, and Wilson, and near Yakoun lake, all in the interior.

On Skidegate inlet the seams dip at high angles and are much disturbed and the measures are intruded by volcanic rocks, which have changed the coal, which is ordinarily bituminous, to an anthracitic variety. Somewhat similar relations are found near Yakoun lake, where the coal is also altered. At Camp Robertson the coal is well exposed in several prospect openings. One seam is found, which is folded and faulted in such a way that previous investigators have supposed that two or three seams existed. The maximum thickness of this seam is nearly 9 feet, and the maximum thickness of coal it contains is 3 feet 10½ inches, in several bands. The coal is hard and black, and is a low grade bituminous variety, high in ash. The horizon of the seam extends over a considerable area south and west of Camp Robertson, but some parts of this area may not contain coal. At Camp Anthracite south of Camp Robertson, the same seam is also exposed. At Camp Wilson the best seam of the district is exposed in several openings. It is from 4 to

18 feet thick, and in places contains 16 feet of coal. The seam is of much better appearance than the one at Camp Robertson, and the quality of the coal is also superior to the other, although it is rather high in ash.

Lignite occurs in numerous seams at Skonun point, and at other places on the north and east coasts. It is very tough and woody, and its value at present is very low; but it may prove t be a useful fuel in the future.

The clay deposits of Graham island are extensive, particularly in the northeastern part; but, so far as they have been examined, they are of low grade and suitable only for common brick and the cheaper varieties of plastic ware.

Stone suitable for building, should a demand for it arise, could probably be found in some of the more massive bands of the Haida formation on Maude island. Good limestone is found in abundance at the southeast end of South island.

The bituminous rocks of Graham island have attracted considerable attention of late years, and hopes have been entertained that extensive petroleum deposits would be eventually discovered. These hopes are not justified by the nature of the occurrences found and later in this report will appear the reasons for believing that, in spite of apparently favourable indications, Graham island can scarcely be looked to as a future petroleum producer.

The source of the bituminous matter is the organic matter of the fossils found in the Maude formation, of lower Jurassic age. Black, tarry material is also found in Tertiary dykes and basalt flows, usually in the form of amygdules. It also leaks into seams and veins in the basalt, giving rise to tar seepages. There is no reason to suppose that these occurrences indicate a body of liquid petroleum at depth and, furthermore, the structure of the rocks is against such a possibility.

It is possible that some of the finer bands of the Maude formation will prove to be oil-shales of value.

Gold is found on the Southeaster and Beaconsfield claims near Skidegate Indian village, associated with sulphides, in a quartz gangue. It is also found on the east coast of the island in beach placers.

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CHAPTER III.

GENERAL DESCRIPTION OF GRAHAM ISLAND.

TOPOGRAPHY.

GENERAL TOPOGRAPHY.

Regional. The Queen Charlotte islands form part of one of the outer, largely submerged ranges of the northwestern Cordillera, and are generally considered to be the northern continuation of the Vancouver range. The general trend of the islands, which bends from about north 40 degrees west in the southern part to more and more nearly due north in the northern portion, if continued northward would bring them into line with the outer islands of the Alexander archipelago. The pre-Tertiary axes of folding, however, which determined the general configuration of the coast ranges, are not thus bent. The apparent continuity with the northern ranges is caused by the discordance of the axes of folding of the Tertiary rocks of Graham island with the earlier axes. The group is separated from the mainland by Hecate strait which is 30 miles wide at its northern end and widens to 80 miles at the south. From the islands of the Alaskan pan-handle on the north, the group is separated by Dixon entrance, with an average width of 40 miles. The Queen Charlotte islands form a slightly curved triangle, shaped like the truncated end of a crescent, convex toward the Pacific, with its apex to the south. The length of the triangle in a northwesterly direction is about 190 miles, and the width of its base, the northern coast of Graham island, is about 55 miles. The eastern side of Graham island is low and comparatively straight, but the southern islands of the group are high and rugged, with a deeply indented, fiord coast-line. The gently convex western coast-line of the group is more regular than the eastern coast-line, but is indented by several smaller fiords and inlets. Two of these water ways cut across the group, Houston Stewart channel separating Kunghit, the southernmost island of any considerable size, from Moresby island; and Skidegate inlet and channel, separating Moresby and Graham islands. The southern islands lie wholly in the mountains of the Queen Charlotte range which crosses Skidegate channel and forms the western mountains of Graham island.

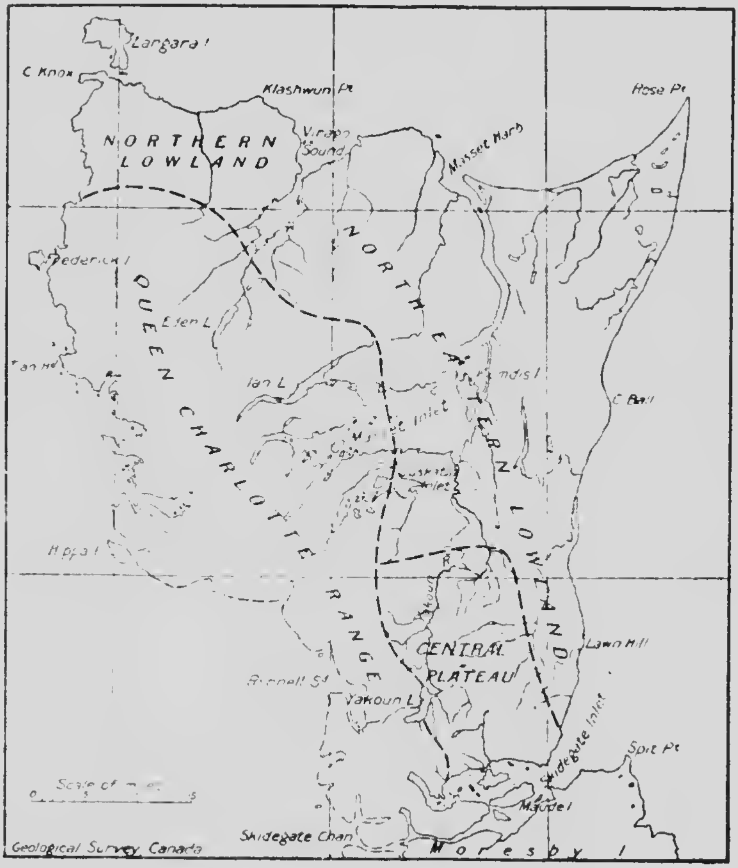

Figure 1. Topographic provinces, Graham island, B.C.

Local. Graha[illegible]nd may be divided into four topographic provinces, each well defined but to some extent gradational into the adjoining ones. These are: the Queen Charlotte range, the Central Plateau province, the Northeastern lowlands, and the Northern lowland. These topographical divisions will be described separately. Their boundaries are shown in Figure 1.

The Queen Charlotte range (Plates I, II, and III) forms the mountainous western portion of the island. These mountains consist of a series of pre-Cretaceous metamorphic and volcanic rocks, with small areas of intrusive plutonic rocks and perhaps occasional basins of Cretaceous sediments, together with overlying Tertiary volcanics. This complex is carved into rugged peaks and ridges, in many places serrate, though not as a rule needle-like, and with many very steep, precipitous slopes. Many of the slopes and some of the summits are glaciated, but glaciation does not appear to have been extensive above the 3,000-foot level. A distinctive feature of the range is the cuesta-shaped peaks, especially prominent in the northern portion, and caused by gently northwestward dipping sheets of Tertiary volcanic rocks. The range is partly cut across by several of the west coast fiords, also by the valleys of Yakoun lake, Rockoun river, Hidden creek, Ghost river, King creek, and other creeks and rivers. The range becomes lower in the northern portion where its height probably does not exceed 2,000 feet, and nowhere on Graham island is the elevation greater than 3,500 feet.

Fringing the Queen Charlotte range, and lying between the mountains and the Northeastern lowland, is the second topographic division, termed the Central Plateau province. Starting at the mouth of Slatechuck creek at Skidegate inlet, the boundary between the mountains and the Plateau province swings northeastward and northward around the eastern flanks of the Slatechuck range, of which Slatechuck mountain is the highest point, and continues in a general northerly direction to the middle of township 8. Near this point the boundary between the Central Plateau province and the northeastern lowlands meets the Queen Charlotte range. This boundary runs east to the eastern part of township 7, whence it turns sharply southeast, reaching the east coast of the island midway between Dead Tree point and Skidegate Indian village.

The Central Plateau province is underlain largely by basins of relatively soft, Cretaceous sediments, separated by higher ridges of pre-Cretaceous metamorphic and volcanic rocks. The name plateau is given to the division because this part of the island—the south-central—is characterized by a number of hills, from 1,000 to 1,500 feet high, with a general accordance of summit level, some of them flat-topped ridges, others plateau-like, as illustrated in Plates IV and V. These higher elevations are composed of the pre-Cretaceous rocks, or, rarely, of the more resistant Cretaceous beds, and are separated by wide valleys carved from the more easily denuded Cretaceous sediments. It thus happens that many of the topographic depressions are underlain by geologic basins. Skidegate inlet and the Honna valley, in part, are instances of such depressions. From the middle of township 8, the boundary of the Queen Charlotte range passes northward through the entrance of Juskatla inlet, crosses Masset inlet, follows up the Ain river, and, curving westward around the head of Naden harbour, reaches the west coast about 6 miles north of Frederick island. It is thus apparent that the Queen Charlotte range does not reach the north coast of Graham island.

This northern portion, west of Naden harbour, is termed the Northern lowland, and is chiefly underlain by Tertiary basalt and pyroclastic rocks, with pre-Cretaceous rocks occurring in the northwestern corner. The Northern lowland (Plate VIII A) has no elevations exceeding 500 feet, although the surface is hilly and irregular.

The Northeastern lowland is a striking feature of Graham island, comprising the district east and northeast of the provinces just described. It is underlain largely by partially or wholly unconsolidated sediments of Tertiary age, with some areas of younger Tertiary volcanics, forming flat-topped hills. Apart from these the district is a low, gently undulating plain, densely forested, except where muskegs, which are of considerable total area, occur (Plate VIIA).

DETAILED TOPOGRAPHY.

Queen Charlotte Range.

In the southern part of Graham island, the Queen Charlotte range consists of a series of very rugged peaks and ridges, many of which, in spite of their steep slopes, are densely tree clad to their summits.

The Slatechuck range, part of the Queen Charlotte range, forms a steep ridge, extending northward between the Slatechuck and Honna valleys, from Skidegate inlet to Yakoun lake. The highest elevation on Graham island, Slatechuck mountain, 3,280 feet, is the summit of the Slatechuck range, which is carved from nearly horizontal bedded volcanic flows (Plate I). The higher portions of these mountains have been modified by the erosive action of local glaciers, a feature which is well shown on Slatechuck and Etheline mountains. The sharp peak of Slatechuck mountain is an important topographical feature, as from it radiate divides controlling the drainage of south-central Graham island. Scenically, it forms the dominating feature of the Queen Charlotte range as seen from Skidegate inlet and from its summit a wonderful view may be obtained over almost the whole of Graham island and a large part of Moresby island.

Very steep mountains, with many needle-like summits, carved from massive granodiorite, overlook Cartwright sound and Kano inlet. Owing to the excessive moisture on the west coast, these peaks are verdure clad except on slopes closely approaching the vertical. The inlets of this part of the coast are very steep walled—noticeably steeper than those carved in less hard and massive rocks—and landings can in many cases be made only where one of the torrential streams, which cascade from the hills, has built a delta of angular blocks of the country rock. The lowering skies, with mist shrouding the hill tops and the heavy and long rains intensify the inhospitable nature of this part of the island. This is accentuated by the roar of the heavy surf, reminding one, even when in the calm waters of a fiord far inside the breakers, that travel along this coast is entirely dependent on the weather.

North of Rennell sound the Queen Charlotte range is almost wholly underlain by Tertiary volcanic rocks and many cuesta-shaped peaks are formed. The mountains are not so rugged as those farther south, and a large number of the mountain tops are bare. Many of these bare summits are rounded as if by glacial action (Plate IIIB); but on examination it is seen that another process is the cause of their subdued character. Everywhere above tre line, which varies in elevation although usually over 1,300 feet, the summits are mantled with an accumulation of sharply angular fragments of the basalt and hard tuffs which form the hills. These fragments are from ¾ inch to 6 inches in size, but average about 3 inches, and in shape remind one of the spalls of rock seen in a stone cutter's yard. The climatic conditions are such that the mist-wreathed and rain-drenched hills at this elevation are subjected to rapid and frequent alternations of freezing and thawing, and it is well known that scarcely any weathering agent is more destructive to rock surfaces. The effect of this action is to rapidly disintegrate all exposed ledges, and to reduce them to a condition where at the highest part the shattered bedrock may be seen projecting from a blanket of debris. The little hollows and irregularities in the surface of the ridges become filled with accumulations of these angular spalls of rock. The slopes leading to the hollows present a curiously streaked appearance, due to the classifying action of moving water on the loose mass of rock fragments. The effect of this process is to smooth out the irregularities of the surface by breaking down the projections and depositing the debris in the hollows. The rounded contours of the crestlines and hill tops is the result. The process is in effect a phase of what had been called equiplanation[1] by Cairnes.

Northern Lowland.

About 6 miles north of Frederick island, the Queen Charlotte range, which to this point has fringed the west coast of Graham island from Skidegate inlet, rather abruptly loses its mountainous character, and is continued, if the term be per-

[1] Cairnes, D. D. Bull. Geol. Soc. America, Vol. 23, 1912, pp. 333-348.

missible, in the Northern lowland. This topographic subdivision extends northward over the remainder of Graham island, west of Naden harbour, and also over Langara island. It has been observed by the writer from the sea only, but it is a district characterized by low ridges, none over 500 feet, and it is said to contain numerous large, open muskegs.

Central Plateau Province.

From the summit of Mount Etheline a good view may be obtained of this province; and its external relations, already described, may be seen. The plateau-like character is not at first apparent; but closer inspection shows a striking accordance in the levels of the hill tops and ridges. This plateau surface extends southward across Skidegate inlet and is visible on the northeastern part of Moresby island, where Table mountain, and other flat-topped hills reach its level. The elevation of the hill tops is not strictly uniform, but varies from 1,000 to 1,500 feet. It seems probable that this general level represents a surface on which there was an approach to base-levelling, after the uplift which followed the deposition of the Upper Cretaceous sediments; but nothing more even than a rolling surface, or perhaps a lowland surmounted by low monadnocks, was developed. On this surface were poured out the floods of Tertiary lavas which were erupted after a period of dyke and sill intrusion. Although the lavas have since been largely denuded from the south-central part of the island, the cap on Mount Genevieve indicates that they once extended some distance eastward from their present position in the Slatechuck range.

East of the Honna valley, a flat-topped range of hills extends northward from Skidegate inlet. Behind Queen Charlotte these hills are 1,200 feet high and they gradually rise, until, east of Camp Wilson, they are about 1,800 feet high. This ridge is cut across by the valleys of Skowkona creek, a large tributary of the Honna, and by the headwaters of the Tlell river, formerly called Threemile creek. About 9 miles from Skidegate inlet these eastern highlands spread westward, and form a marked upland which extends to the Yakoun river, and separates the

Honna coal basin from the Yakoun coal basin. Southward, across the deep valley of Brent creek, this upland is continued in the 1,000-foot hills about Camp Robertson, and rises farther south into the 2,000-foot elevation of Conglomerate peak.

Northeastern Lowland.

More than a third of the area of Graham island is comprised in the Northeastern lowland, which, roughly, is a triangular tract with a base extending from Naden harbour to Rose spit, and the apex between Dead Tree point and Skidegate Indian village. This large area is densely forested except where open muskegs occur, and is dotted with shallow lakes. The district is difficult to traverse, although the elevations are inconsiderable, none being over 400 feet. Conspicuous above the tree-clad plains are Lawn hill, Tow hill, and other flat-topped and forested elevations. These are residuals of volcanic flows, which formerly had a greater extension over the island. From Masset inlet, the contrast between the flat, low, eastern shores in this lowland, and the rugged western shores in the Queen Charlotte range is very striking.

Muskegs.

The features termed muskegs merit a word of description. They are of widely varying sizes and form wherever there is a break in the slope of the land, causing a bench and impeding drainage. Very large ones form on the flat-topped elevations of the Central Plateau province, and on the lowlands. It is not necessary that the bench or flattened area be level, for the surfaces of these muskegs at times slope as much as 15 degrees from the horizontal. The muskegs are open spaces, in many cases dotted with stunted trees in straggly patches as well as single trunks (Plate VI). The surface of the muskeg is a tough, matted, peaty mass of decayed grasses, moss, and plant stems, interlaced with the roots of growing plants. Low, bushy pines, mountain hemlocks, and stunted jack-pines are the usual trees on the muskegs. Scattered irregularly over the surface are stagnant pools of water, filled usually to within about a foot of the general level, and containing immediately below the water surface a flocculent mass of brown decayed vegetable matter, thickening with depth. The depth of these pools is considerable, and it is easy to thrust a pole down 10 feet or more in many of them. It is common to find the water in pools not 5 feet apart standing at levels varying by as much as a foot, owing apparently to the impermeable character of the peaty material. These muskegs, constantly wet as they are, do not allow of rapid walking, but are preferable as routes for trails to the unbroken forest, as the surface is smooth and the impediments of roots and underbrush are lacking. The muskegs are, without doubt, caused by the moist, equable climate, permitting a very rapid growth of vegetation. Some of these open spaces are almost half a mile in diameter, and their wind-swept appearance on a stormy day is desolate and forbidding. In fine weather, however, they form a welcome interlude to the monotony of the forest.

Valleys.

A marked north-south depression runs the length of Graham island; in the north it is submerged, and forms Masset inlet; farther south it is occupied by the Yakoun river, and in the south by the Honna valley. This trench is believed to date back to pre-Cretaceous times, as it is largely occupied by basins of Cretaceous sediments. The depression is at present not a single valley, but is occupied by the valleys of several streams, and while it forms a single depression, its topography is quite diversified.

The Honna river occupies a wide valley, carved from the soft, sandy shales of the Lower Cretaceous sediments on the gently folded eastern limb of the major syncline of the Honna basin, the course of the stream being closely parallel to the strike of the beds. The river itself flows in a narrow trench, in places 150 feet deep and almost canyon-like in some parts. The river was initiated by a more recent uplift than that which caused the main valley to be formed. Its fall in the last 4 miles of its course, from near Fourmile camp to the inlet, is 270 feet, but in its upper reaches the rate of fall is not so great, and the headwaters are rather sluggish streams which are separated in part by a rather low divide from Yakoun River drainage. The tributaries of the upper Honna from the west, crossing the trail between Camps Fourmile and Robertson, are swift little streams, tumbling from the end of the high ridge running east from Mount Etheline. This ridge is composed of massive Cretaceous sandstones and conglomerates, and the influence of the bedrock on the topography is well shown in the way that the drainage radiates from this area of resistant rocks, the trunk streams—Brent creek and the Honna river—flowing in valleys excavated in softer, shaly beds.

Brent creek is a large eastern branch of the Yakoun river and collects the drainage of the highland around Camp Robertson. Rising in the hills nearly 2 miles south of the camp, it flows northeast, north, and finally due west around the base of the highland on which Camp Robertson is situated.

The valleys of Yakoun lake, Baddeck river, and Yakoun river show evidence of topographic readjustment due to glacial action. It may be noted on the map, that Yakoun river, the outlet of Yakoun lake, flows not from the northern end of the lake, but from Etheline bay, on the eastern side, and makes its exit almost at the point at which Etheline creek enters. The lake is surrounded by rock walls, usually steep except around Etheline bay, and at the northern end of the lake. The shores of Etheline bay are low and swampy, and the northern end of Yakoun lake is dammed by low, hummocky, wooded hills apparently of glacial drift, simulating moraine topography. The Baddeck river occupies a wide valley, the direct continuation of the Yakoun River valley, and flows in a braided channel over much of its course. For the upper 3 miles of its course the Yakoun river is crooked and sluggish, but below the grade steepens slightly. The presence of numerous islets in the lake is evidence that it occupies a rather shallow basin.

To explain the origin of Yakoun lake, and the facts given above the hypothesis is advanced that the Yakoun valley below the present north end of the lake was filled with glacial debris, carried down by small local glaciers, the sites of some of which are now represented by cirque-like depressions and hanging valleys west of the north end of Yakoun lake. That the whole lake basin was excavated or even deepened by a glacier is shown to be improbable or impossible by the steep, unglaciated character of the islets in the lake. This damming of the valley, (in pre-Glacial time) occupied by the present Baddeck and Yakoun rivers as one continuous large stream, with Etheline, Delta, and other creeks as tributaries, caused the lake basin to form, shaped the present eastward bend of the Yakoun river, and separated the upper part of the stream, to form the Baddeck river. The glacial filling reduced the grade of the valley, causing the upper part (the Baddeck river) to slacken its rate of cutting and to braid its channel, and the upper reaches of the Yakoun to assume their present sluggish character.

The Yakoun river for the greater part of it slength occupies a wide valley. It flows in a narrow trench that is in places canyon-like, with rock walls rising 50 feet from the water, and maintains a moderate, continuous grade, uninterrupted by pronounced rapids. King creek and the lower parts of Hidden creek and Ghost river also occupy rather wide valleys with moderate, uniform grades.

The valleys tributary to the southwestern end of Yakoun lake, which extends into the Queen Charlotte range, are markedly V-shaped, and little, if at all, modified by glacial erosion. The sides of the valleys are very steep, in some cases sloping at angles as high as 45 degrees. The submerged valleys occupied by Long Arm, and Slatechuck valley are also remarkably steep-sided, narrow, depressions, and seem to have been altered very little by glacial action.

The northern part of the central depression of Graham island is occupied by Masset inlet which is virtually the estuary of the Yakoun river. There is apparently no geologic break along this inlet, which probably represents the submerged lower portion of the Yakoun River valley.

Coast-lines.

The varying effects of subaërial and marine erosion acting on rocks of different characters, are well illustrated on Graham island, where several varieties of rock form the sea coast.

Virtually the whole of the east coast, and the north coast from Rose spit to Masset inlet, present a smooth shore, with shallow water off shore. This is caused by the wearing action of the waves on the soft Tertiary and Pleistocene rocks of this part of the island. The dangerous bar extending northward from Moresby island across the entrance of Skidegate inlet is caused by a northward set of the tides, aided by strong south-east gales that frequently sweep up Hecate straits. The low and dangerous Rose spit, the northeastern extremity of Graham island, famed in Haida legend, is caused by the meeting of currents sweeping northward along the east coast and eastward along the north coast.

The shores of Skidegate inlet and the islands in this water-way are steep and rock bound where they are flanked by the massive agglomerates of the Yakoun formation; where the less resistant sediments of the Queen Charlotte series occur the shores are more gently sloping.

Where massive granitic rocks are found on the coast the shores are extremely steep with the result that in many places, especially where the rocks are glaciated, landing is difficult and in many cases impossible.

The Masset formation, with its alternating, thick, basalt flows and softer, pyroclastic rocks, forms a jagged coast-line, as on the west coast of the island where the headlands are formed of basalt flows, while softer fragmental volcanics underlie the bays. In these bays many remarkable, even, wave-cut benches occur, just below high tide level. One of these benches is illustrated in Plate VIIIB. Caves are not infrequently formed in the agglomerates along the coast.

The most striking single feature on the coast of Graham island is the giant stack of conglomerate from which Pillar bay on the north coast takes its name. This excellent example of a wave-cut stock rears its tree crowned head to a distance of 95 feet above high water mark. It is well illustrated in Plates IX and X.

CLIMATE.

The climate of Graham island, though varying locally, may be described as generally mild. Extremes of heat and cold are seldom experienced and residents state that in the winter, which is by all accounts the most agreeable season of the year, overcoats are seldom necessary.

The west coast, like that of Vancouver island, has an excessive rainfall, and is usually enveloped in mist. The central and eastern parts of the island have considerable rain and much cloudy weather in the early summer, interspersed with bright sunshiny days. August is usually a month of sunshine, and the autumn is wet. In spite of the high latitude, snow does not lie on the ground at sea-level for any length of time in the winter.

FLORA.

Hemlock (Plate XV) is the principal tree and makes up more than half of the forest. Red and yellow cedar and spruce are also plentiful and alder, yew, jack-pine, and mountain hemlock are found. Some of the spruce trees are very large, not infrequently 8 feet in diameter at 5 feet from the ground, and tower 300 feet in the air, carrying their size well up the stem. The yellow cedar is also a wood worth special mention. It is very close-grained and works well with edged tools, owing to its homogeneity, and it takes a good polish. It is well adapted for interior finishing, furniture, and cabinet work.

Undergrowth, except in the valley bottoms, and on coastal lowlands, is not excessively abundant. The uplands are generally open; the principal shrub is a scraggly huckleberry, that delays, but does not seriously impede travel, and even it is sometimes lacking. In the low areas, the bushes which include the huckleberry, salmon-berry, and devil's club grow very thickly, and make travelling slow and arduous. Salal is found only near the coast of the island and in the Northeast lowlands, where dense thickets occur. Occasionally, thickets of young spruce are encountered that are almost impenetrable, but they are not common and on the whole the island is not so difficult of access as it has been reported to be, though it is not easily travelled. The surface of the ground, thickly covered as it is by layers of dead trees and moss, is very rough, and a secure footing is not always obtainable. The trees rise on buttressed roots above the level of the soil and cause hollows to form which serve as traps for the unwary. It is curious, also, to see a prostrate tree trunk forming the site for a row of younger trees, the trees of these parasitic hedges often attaining considerable size. Rank growths of bracken, fireweed, and other weedy annuals are common in the more sunny places, and form in some cases thickets very difficult to penetrate.

Good stands of large hemlock are found in the central part of the island and smaller areas of large clear spruce and of red cedar. Yellow cedar grows on the higher portions of the island, where smaller stands were seen. The timber is virtually uninjured by forest fires, of which only two have been recorded, and these not of great extent.

AGRICULTURE.

The shores in the vicinity of Skidegate inlet are usually too steep to permit of extensive cultivation, but small areas level enough for tilling are not infrequent, and excellent vegetables are raised without difficulty. In the interior no cultivation has been attempted, on account of the dense forest and the thick surface accumulation of dead and decaying vegetation. The Northeastern lowland seems to promise more favourably, since it has a warmer climate and is said to enjoy a greater percentage of sunny weather. Extensive flat or gently sloping areas in the lowland are underlain by stratified sands and clays, covered by a greater or less thickness of vegetable matter. Once these areas are cleared and drained, they should be well adapted to cultivation.

Graham island, in common with some other western communities, has suffered at the hands of unscrupulous real estate boomers, and various misrepresentations, both favourable and unfavourable, have been given publicity. Settlers have been induced to come to the island without being apprised of true conditions, and their inevitable disappointment and loss has reacted against the district. If local conditions in regard to agriculture are intelligently studied, men with ability and some capital to start operations should make a success of farming on the island.

COMMERCIAL POSSIBILITIES.

Apart from the mineral resources, described at length elsewhere in this report, the natural products of Graham island are timber and fish.

The timber should prove of value in the future, and the fisheries, when properly conducted, will also be of value. The whaling industry is being carried on with success by a company with stations at Naden harbour, on Graham island, and at Rose harbour, at the south end of the group. Three steam whaling boats are operated from Naden harbour, and the catch usually consists of sulphur bottoms. Occasionally a sperm whale is captured and in 1914 a specimen of the very rare right whale was taken. This single animal was valued at $20,000.

CHAPTER IV.

GENERAL GEOLOGY.

GENERAL STATEMENT.

Regional.

The Queen Charlotte islands, forming as they do a unit by themselves, can be described only in a broad way with reference to the geology of the northwest coast of America. They lie to the west of the axis of the Coast range, along which denudation has exposed the great batholith, the most impressive geological feature of the northwest coast. As they thus [illegible] position on the flanks of the batholith, it would be supposed that granitic rocks are not abundantly represented in the group, and such is the case. The areas that occur are small relatively, and are to be considered as satellitic stocks and bosses of the enormous mass to the east. The surface rocks of the Queen Charlotte group are, then, largely either pre-batholithic or post-batholithic. The former are found in large areas in the islands of the group south of Skidegate inlet; the post-batholithic rocks being almost wholly confined to Graham island. In a general way, the pre-batholithic rocks are correlated with the Vancouver group.

The geological unity of the Queen Charlotte islands is shown in their fossil fauna, which has provincial characteristics.

Graham island is the northernmost of the group, and a large part of its surface is covered with rocks of Upper Cretaceous and Tertiary ages. In this sense it is geologically the youngest of the islands.

Local.

The oldest rocks exposed on Graham island belong to the Vancouver group. They have been divided into two distinct though gradationally conformable divisions, the Maude and the Yakoun formations. The former is of lower Jurassic and perhaps

Triassic age and the latter is middle Jurassic. The lower members of the Maude formation are very fine-grained, calcareous and carbonaceous mud rocks, associated with bands of limestone. Higher in the formation are pale green, hard sandstones, gradually becoming tufaceous and passing into the conformably overlying Yakoun formation. This formation is largely pyroclastic in its origin, but probably consists in part of flows and sills.

The rocks of the Vancouver group were dynamically metamorphosed and intruded by batholithic rocks. The complex was then eroded, and a thick series of sediments of Upper Cretaceous age, the Queen Charlotte series, was unconformably laid down on the eroded surface. These rocks are composed of the detritus of the older formations, and the lower member contains coal-bearing horizons.

After the formation of the Queen Charlotte series and to some extent during the period of its formation it was extensively injected with numerous dykes and some sills of dacite and andesite, up to 50 feet thick. This volcanic activity extended into the Tertiary period, and the eroded surface of the Cretaceous rocks was deeply buried under the accumulated flows of Tertiary volcanics, with which occur some sediments.

Since the late Tertiary, erosion has been active in shaping the present diversified topography, and deposits of Pleistocene age, stratified and unstratified glacial drift, are widespread.

TABLE OF FORMATIONS.

Pleistocene and Recent	Superficial deposits.	Gravels, sands, and clays. Till.
	Unconformity.	
Pliocene (?)...........	Masset formation........	Basalt flows and agglomerates.
	Unconformity ?	
Pliocene-Miocene ...(?)	Skonun formation........	Conglomerates, sandstones, and shales.

Unconformity.

Eocene (?)............	Etheline formation.......	Dacite and andesite intrusives.

Intrusive contact.

Upper Cretaceous......	Queen Charlotte series:	
	Skidegate formation....	Sandstones and shales.
	Honna formation......	Conglomerate and sandstones.
	Haida formation.......	Sandstones and shales, with coal.

Unconformity.

Upper Jurassic (?).....	Batholithic intrusives:	Quartz diorite, diabase, etc.
	Kano quartz diorite.	
	Langara quartz diorite.	
	Diabase.	

Intrusive contact.

	Vancouver group:	
Middle Jurassic........	Yakoun formation...	Basaltic agglomerates.
Lower Jurassic and Triassic (?)	Maude formation....	Argillites, sandstones, and tuffs.

DESCRIPTION OF FORMATIONS.

In describing the formations in this report, a detailed citation of the localities where they occur is not given in the text, as these can be more readily got from the maps. The places mentioned are those that are important as type localities or for other reasons. A comprehensive summary of the main rock types found in each formation is given here, and detailed descriptions will be found in the chapter on "Petrography."

VANCOUVER GROUP.

Rocks of the Vancouver group make up virtually all of the surface formations on the islands south of Skidegate inlet, and on Graham island are with few exceptions found unconformably underlying the Cretaceous rocks. The Vancouver group is divided into the Yakoun formation, of middle Jurassic age, and the Maude formation, referred to the lower Jurassic, and possibly in part Triassic.

MAUDE FORMATION.

Distribution. The rocks of the Maude formation are typically exposed on the shores of South bay, and on the south side of Maude island in Skidegate inlet. They are also the surface bedrock formation underlying a large area northwest of Camp Robertson in the Yakoun valley, and on the hills between the Wilson trail and the Yakoun river, and are extensively represented west of the latter stream. Representatives of the Maude formation are found on Frederick island, and the sediments of the northwest corner of Graham island also are thought to be of that age.

Lithology. The Maude formation is made up of detrital sediments, with a few bands of pyroclastic material near the top. The lower portion is composed of black and brown, fine-grained, banded slaty and flaggy argillites (Plate XI). These rocks are highly fossiliferous, and are remarkable for the abundant flattened ammonites they contain. Many of the bands are very carbonaceous, and where they have been crushed or slickensided, often simulate coal seams. The "No. 2 coal mine" of Richardson (see page 7) was without doubt situated on a band of this nature in the argillites. A marked characteristic of the flaggy argillites is their strong bituminous odour and films of tar are found on many of the bedding and joint surfaces.

The upper part of the Maude formation consists of fine, even-grained, often well laminated, greenish-grey, feldspathic sandstones. The sandstones are very massive, and tougher and more homogeneous than those found in the Cretaceous, though in general appearance they resemble them. Near the top of the formation, where it begins to grade into the overlying Yakoun, the sandstones contain many tufaceous and agglomeratic beds.

On the southeast end of South island are massive limestones, light grey in colour, partly crystalline, and strongly bituminous. They are provisionally classed with the Maude formation.

At Pillar bay, on the north coast of Graham island, and westward from there along the coast for over 2 miles are exposures of coarse conglomerate (Plates IX and X) greatly resembling the Honna conglomerate of the Queen Charlotte series. The beds underlie apparently conformably, sediments that are almost certainly referable to the Maude formation, and the conglomerates may represent the basal beds of the latter.

Metamorphism. In the field, most of the argillites, especially the banded flaggy varieties, have the appearance of considerably metamorphosed rocks, and this appearance is accentuated by the sharp local folds in which they are frequently disposed. Under the microscope, however, the metamorphism is seen not to have been extreme, and what has taken place seems to be almost wholly the result of pressure unaccompanied by extensive heating or hydrothermal action. Muscovite, chlorite, and calcite, with, perhaps, in one instance, recrystallized feldspar, are the only minerals whose origin is directly traceable to metamorphic processes, and muscovite is not largely developed. The presence of flattened, though otherwise well preserved fossils indicates simple pressure unaccompanied by shearing, except locally, and this static pressure best explains the compactness of the rocks, their fissility along bedding planes, and the slight lamination apart from bedding, but parallel to it, observed in some thin sections.

The thicker and coarser beds at the top of the formation, though thoroughly indurated and hardened, lack the metamorphosed appearance of the finer, flaggy argillites.

Structure.—Internal. The Maude formation has been folded considerably on the whole, and in many cases severely in detail. The general strike of the formation is about north 30 degrees west. The dips are usually high, few under 30 degrees, and generally between 45 degrees and vertical. Localized, recurrent zones are very severely folded and contorted, twisted, and mashed. Those zones, extending for a few score yards, alternate with broader areas in which the folding has not been so severe, and the rocks lie regularly disposed for considerable distances. In the tightly folded zones the mashing and twisting of the beds has been extreme, though faulting, apart from minor slips, is rare. The closeness of the folds, and the sharpness of the turns in them, with the absence of extensive faulting indicates that these rocks were folded under such pressures that they were sensibly plastic. The recurrent zones of severe contortions, separated by less disturbed areas, were caused by the moun-

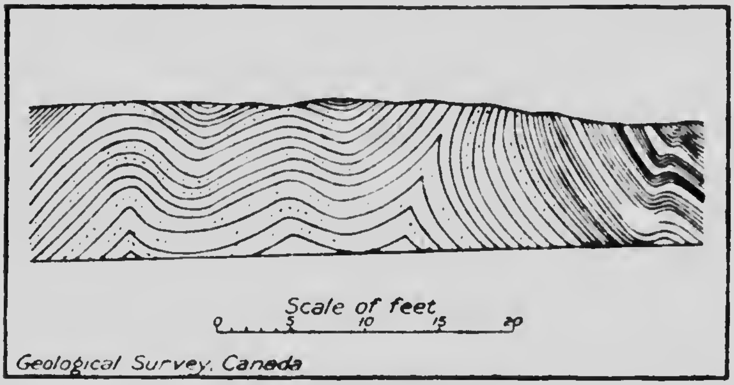

Figure 2. Sketch of low cliff of argillites in the Maude formation on King creek, illustrating typical manner of folding in these rocks. Note parallel folding and carinate anticline.

tain-building stresses having been periodically relieved by failure of the beds in these zones. The types of folds into which the rocks are bent, and typical minor faulting are well shown in Figures 2, 3, and 4 and Plate XIB.

The rocks are extremely jointed, most joints being normal to the bedding, and many containing films of black, tarry matter, which also occurs along bedding surfaces, and in irregular veins of coarsely crystalline yellowish calcite cutting the argillites.

The thickness of the formation is unknown, as the base has not been seen. Dawson[1] describes very similar rocks as occur-

[1] Dawson, G. M., Geol. Surv., Can., Rept. of Prog., 1878-79, p. 55B.

ring in Section cove, with a thickness of about 1,700 feet, so the Maude formation is at least that thick in that locality. Over twice the thickness observed by Dawson is exposed on King creek, a section along which is shown in Figure 5. At least 3,800

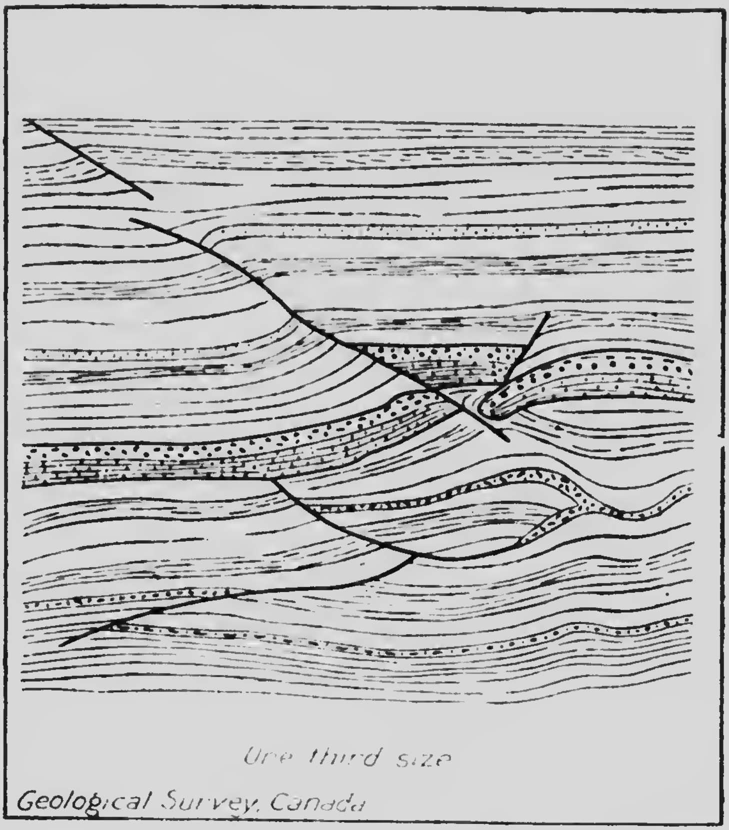

Figure 3. Sketch of a faulted band of laminated argillites in the Maude formation on King creek.

feet of the Maude formation is visible there, with no sign of the basement on which the formation rests, nor any evidence of basal beds. If, as is probable, the basal beds are represented by the thick conglomerates of Pillar bay, on the north coast of Graham island, the total thickness of the Maude formation may reach 9,000 or 10,000 feet.

Structure.—External—Relation to Younger Formations. The Maude formation grades conformably into the Yakoun formation which is the upper member of the Vancouver group on Graham island. This relation is well shown on the south shore of Maude island, and on the opposite shore of Moresby island. Near the centre of the south side of Maude island the rocks are typical, well banded, fine, dense argillites, in part slaty, and are

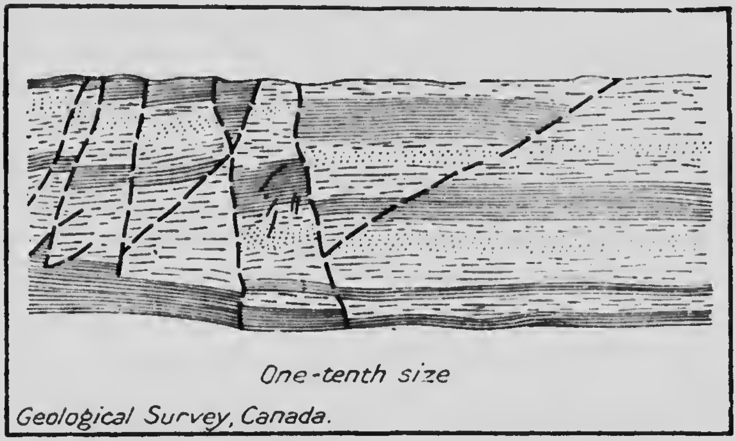

Figure 4. Sketch of faulted band of laminated argillites in the Maude formation on King creek. A photograph of this same band is given as Plate XIB.

fossiliferous. Eastward along the shore, the rocks are well exposed. They occur in moderate folds, and are coarser and thicker bedded. As the horizon of the Yakoun formation is approached, tufaceous material becomes more prominent; but the rocks are still hard, fine, and evenly bedded, and are clearly transitional in character. Farther east massive greenish breccias of the Yakoun volcanics form bold, precipitous cliffs.

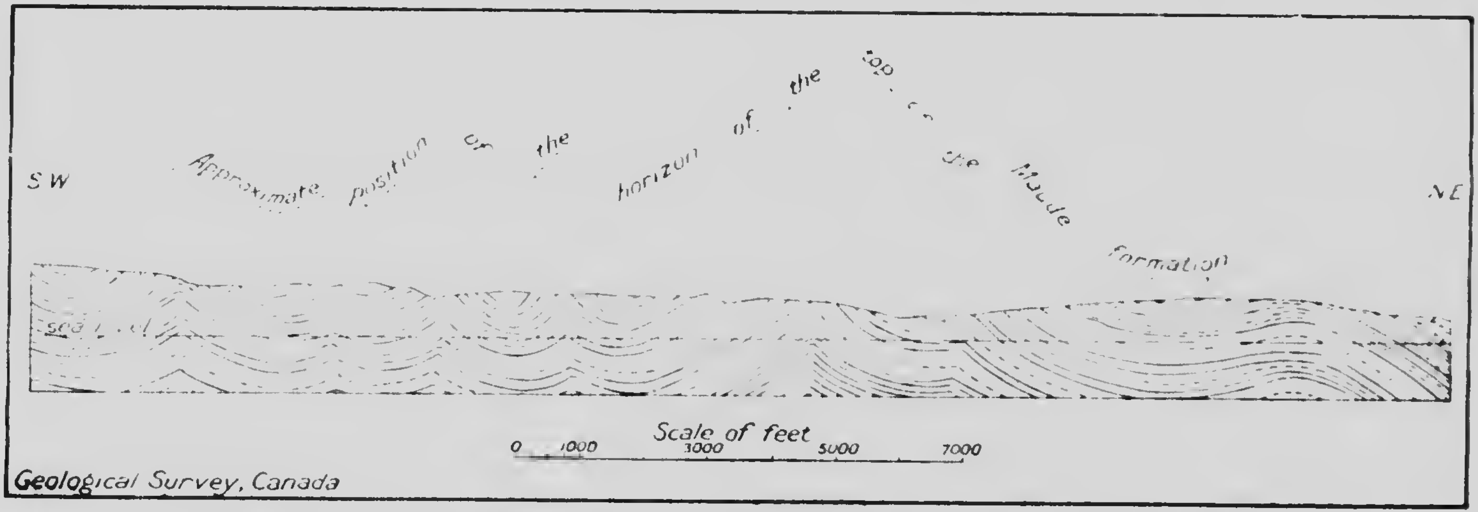

Figure 5. Vertical section in the vicinity of King creek, townships 8 and 9. Length of section is 4½ miles.

The Maude formation is unconformably overlain by the Haida member [illegible] Queen Charlotte series on Yakoun river, Hidden creek, [illegible] river, King creek, Tlell river, north of Camp Robertson and at other localities. Pebbles of the argillites are contained in the Honna conglomerate, and in a basal conglomerate [illegible] ida formation at the southwest end of Yakoun lak[illegible]

The M[illegible] are intruded by coarse-grained green diabase in la[illegible] perhaps of batholithic affinities, along the south sho[illegible] bay.

Origin. [illegible] of the Maude formation clearly shows it to be of mari[illegible] The marine origin is also borne out by the regula[illegible] ell marked banding, and their fine gra[illegible], provisionally correlated with the formation [illegible] me; but largely, if not wholly, detrital in origin. The [illegible] mount of fresh plagioclase throughout the rocks, and the [illegible] eous material in them indicate that parts of the formation at least, and certainly the upper beds, are of pyroclastic origin. Forming, as they do, an intercalation in a thick volcanic series, this origin is not surprising. The fineness of grain, and the abundance of organic remains point to their accumulation in a sedimentation zone of moderate depth. Their present induration has been explained as the result of pressure without shearing, caused by dynamic metamorphism, and their frequently greatly contorted character as the result of localized stresses.

Age. On the basis of the determination of its fossils by Dr. T. W. Stanton, the Maude formation is assigned to the lower Jurassic. Doctor Stanton writes in regard to the list of fossils from the formation given below:

"In my opinion these fossils are of Jurassic age—probably lower Jurassic. They evidently represent the group of fossils, described by Whiteaves, from Maude island, which Dawson referred to his 'Division E.' "

Fossils from the Maude Formation.

Brachiopods.

Rhynchonella maudensis Whiteaves?
Rhynchonella ? sp.
Discina semipolita Whiteaves.

Pelecypods.

Pecten carlottensis Whiteaves.
Avicula, sp. cf *A. whiteavesi* Stanton
Cardium tumidulum Whiteaves.
Ostrea ? sp.

Gastropods.

Several genera, undetermined.

Cephalopods.

Schloenbachia propinqua Whiteaves?
Arniotites ? sp.
Liparoceras ? sp.
Harpoceras ? sp.

On Frederick island are calcareous argillites very rich in the fossil *Pseudomonotis subcircularis*, Gabb. In Lepas bay the same species and a species of *Halobia* were found. E. M. Kindle says that these specimens are probably upper Triassic forms. It thus seems probable that the lower part of the Maude formation is of this age. Until the somewhat provincial fauna from the formation is carefully studied, its age cannot be definitely ascertained.

YAKOUN FORMATION.

Distribution. The Yakoun formation is well exposed on Skidegate inlet and at Yakoun lake, and takes its name from the latter locality. On Skidegate inlet the formation is found along the shore from a mile northeast of Skidegate Indian village to Haida point, underlying the eastern limb of the Cretaceous syncline. The formation is also well exposed at the eastern end of Maude island, at Alliford bay, at Steep point, along the shore west of Saltspring bay, in the western part of the inlet, and along Skidegate channel. Inland, the formations extend northward, in the highlands east of the Honna river, to the vicinity of Camp Wilson, being exposed on several streams, notably the headwaters of the Tlell river. Around Yakoun lake the formation is found in steep, bare cliffs, and is typically exposed in Delta creek. It is also found forming the high steep hill west of the Yakoun river, opposite Wilson creek.

Lithology. The Yakoun formation is formed largely of pyroclastic rocks, and in great part of waterlain agglomerates and tuffs. Effusive types also are found, and possibly sills and dykes. Well rounded conglomerates of volcanic rock fragments in a matrix of similar material are occasionally met with. The formation is dominantly sub-silicic, augite andesites and basalts being the usually occurring varieties both as effusive (or injected) and pyroclastic types. The pyroclastics are virtually always dark greenish or brownish types, and the primary volcanic rocks are characteristically of a purple tint. All types are hard, dense, considerably metamorphosed rocks, and are greatly jointed and sheared (see Plate XIIA).

In the lower part of the formation very well bedded tuffs and tufaceous sandstones occur, which, except for the fossils they contain in abundance, might be correlated with the Haida formation on account of the great lithologic similarity between the two. This similarity led Dawson to map the middle Jurassic rocks of Alliford bay as Cretaceous, and caused confusion in regard to the exact age of the Cretaceous rocks of the Queen Charlotte series, which was not cleared up until the investigation now reported on was completed.

Metamorphism. The Yakoun formation while greatly jointed, and in some places sheared and faulted, is not extremely metamorphosed. Recrystallization is virtually absent; augite alters to chlorite and calcite, instead of to uralite, and much of the feldspar is still quite fresh. Locally, narrow quartz veins are common. As in the case of the Maude formation, the metamorphism may be best explained as the result of pressure during mountain-building, aided by slight hydrothermal action.

Structure.—Internal. Folding in the Yakoun volcanics is apparently not so severe as in the case of the conformably underlying Maude argillites, because the more massive agglomerates deformed by cracking and shearing, rather than by local, complex folding. Jointing in every direction and minor faults are common in the volcanics. On account of the massiveness of the beds, many internal structures as faults, folds, etc., are not readily observed. The top of the volcanics is nowhere seen, and no complete sections of the formation have been obtained; but, from the extent of territory underlain by these beds, it is probable that their thickness may reach 5,000 feet. Dawson estimates it at 3,500 feet.[1]

Structure.—External—Relations to the Maude Argillites. On the south side of Maude island, and on the opposite shore of Alliford bay, the Yakoun volcanics grade conformably downward into the Maude argillites. Near the base of the formation the rocks are very massive, greenish agglomerates, which form bold cliffs on Maude island. The lowest strata definitely referable to the Yakoun formation are very thick beds of bright green agglomerate, made up of angular fragments 1 or 2 inches across, in a tufaceous green matrix, often replaced by calcite. These beds are underlain by thinner bedded, finer strata, the whole clearly waterlain, and gradually passing into the beds referred to the upper Maude.

Structure.—Relation to the Queen Charlotte Series. The Yakoun volcanics are unconformably overlain by the basal marine sediments of the Queen Charlotte series. This relationship is well exposed at Haida point, in the Channel islands, and at the eastern end of Maude island. At these localities an irregular surface, developed on the hard, resistant agglomerates of the Yakoun formation, is seen to be covered by the coarse, arkosic sediments of the basal Cretaceous. These soft, easily disintegrated, younger beds fill the cracks and irregularities in the surface of the older rocks, and include fragments of them. Believing, as he did, that the sediments of Alliford bay were Cretaceous, it is not difficult to see how Dawson was led to say that this unconformity was unimportant.[2] The "passage beds" on the east side of Alliford bay, on which he lays stress,[3] while truly transitional in nature, are wholly middle Jurassic in age, and the passage is between two layers of agglomerate, not from the Yakoun formation to the Cretaceous. As a matter of fact

[1] Dawson, G. M., Geol. Surv., Can., Rept. of Prog., 1878-79, p. 69B.
[2] Dawson, G. M., Geol. Surv., Can., Rept. of Prog., 1878-79, p. 68B.
[3] Idem, p. 67B-68B.

these beds are very low down in the Yakoun formation.

Further discussion of the relations of these formations has been given in Chapter II.

Origin. The foregoing facts make it clear that the Yakoun volcanics were largely formed by the subaqueous accumulation of sub-silicic volcanic ejecta of various sizes. These pyroclastic rocks are associated with lava flows and probably with intrusive, volcanic sills and dykes. The size of the fragments in the breccias, their angularity, aggregate volume, and heterogeneity show that volcanic action took place on a very large and violent scale. The well stratified and fossiliferous nature of many of the beds indicates a subaqueous origin for the formation, and the presence of local, well rounded conglomerates may be explained by supposing islands of flows and agglomerates to have been built up by eruptions, and in part or wholly destroyed by wave action. Pipes or necks and vents, other than rare dykes, have not been seen. The marine origin of the lower part of the formation is well illustrated by the fossiliferous, well sorted sediments of Alliford bay. As has been mentioned, these rocks are lithologically not distinguishable in the field from many bands of the Haida formation of Cretaceous age.

Age. Doctor Stanton states regarding the fauna of the Yakoun formation:

"The fossils attributed to the "Yakoun volcanics" are not numerous, but their character indicates Jurassic age, and the ammonites in two lots suggest correlation with a part of the Tuxedni sandstone (middle Jurassic) of Alaska."

Fossils from the Yakoun Formation.

Brachiopods.

Rhynchonella ? sp.
Terebratula skidegatensis Whiteaves ?

Pelecypods.

Pecten ? sp.
Nemodon ? sp.
Thracia ? sp.
Pholodomya ? sp.
Avicula ? sp.

Ostrea ? sp.
Lima sp. cf. *L. gigantea* (Sowerby).
Trigonia sp. cf. *T. Dawsoni* Whiteaves.
Pleuromya laevigtata Whiteaves.
Pleuromya carlottensis Whiteaves.
Thracia semiplanata Whiteaves.

Cephalopods.

Stephanoceras sp. a.
Stephanoceras sp. b.

BATHOLITHIC ROCKS.

KANO QUARTZ DIORITE.

Distribution. The name Kano quartz diorite is applied to a series of rocks of batholithic origin which are found in the vicinity of Kano inlet, on the southwest coast of Graham island. Between Lawn hill and Skidegate inlet "granite" is reported on good authority as occurring on one of the branches of the Tlell river. Elsewhere on southern Graham island no batholithic rocks have been seen; but they are found in many places on the southern islands of the Queen Charlotte group.

Lithology. The rock that apparently makes up the greater bulk of the Kano quartz diorite is light grey, whitish weathering, and medium even-grained. It consists largely of a whitish-grey plagioclase, abundant glassy quartz, and between 5 and 10 per cent of an altered hornblende. Some varieties are coarser, and others contain more hornblende and less quartz, grading into diorites. The formation has not been carefully studied, and the relations and proportions of the various types are not certainly known; but they represent without doubt different facies of a stock or small batholith.

Structure. The internal structural relations of the batholithic masses have not been determined, and the areal distribution and relative volume of the various types are not known.

Although no detailed work has been done in this area, it is fairly certain from the general relations that the Kano quartz diorite cuts the rocks of the Vancouver group in an intrusive manner.

Origin. From its mode of occurrence and lithologic character it is inferred that the Kano quartz diorite must have consolidated under batholithic conditions, in magma chambers, where slow cooling and favourable conditions for a high degree of crystallinity and medium sized granularity prevailed.

LANGARA QUARTZ DIORITE.

Distribution. The rock forms somewhat over half of Langara island, in its northern part, and is well exposed on the coast.

Lithology. The quartz diorite is a grey to dark-grey, fine to medium even-grained rock, with a slight porphyritic structure in some exposures. It is largely composed of plagioclase feldspar, with small amounts of a black mineral, difficult to determine in the field, but which the microscope shows to be biotite. At the contact of the quartz diorite and conglomerate, dykes of the former, lighter in colour and finer in grain than the usual rock, cut the conglomerate.

Structure. The Langara quartz diorite is very clearly intrusive into the conglomerates forming the lower member of the sediments on the southern portion of Langara island. This contact is very well exposed on the east coast, north of Egeria bay. The quartz diorite penetrates irregularly between the pebbles of the conglomerate, and encloses both pebbles and fragments derived from it. Dykes, related to the quartz diorite, but intruded after the consolidation of the main mass, cut both the quartz diorite and the conglomerate.

Dawson considered this quartz diorite to be older than the conglomerates, basing his statement on the fact that pebbles "like those of the north end of North (Langara) island,"[1] are found in the sediments. This evidence, based on a superficial similarity noted in the field, he would, of course, have rejected, had he observed the contact as described above.

Origin. No detailed observations have been made on the Langara quartz diorite from which a statement in regard to its origin may be made, other than that it is essentially similar in its genesis to the Kano quartz diorite.

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[1] Dawson, G. M., Geol. Surv., Can., Ann. Rept., 1878-79, p. 84B.

DIABASE.

Distribution. Along the north coast of Moresby island, and on the southeast end of South island there are considerable areas in which outcrops of diabase are found.

Lithology. The diabase is a dark, greenish-grey medium-grained rock, usually massive, and altered in appearance. Its diabasic texture is not always apparent in the field, and it might there be called a diorite or gabbro.

Structure. The diabase as seen in outcrops is a massive, jointed rock, which gives no evidence of internal structures. Small rounded darker patches occur in it, and are probably segregations of the dark minerals.

Contacts of the diabase with the Maude formation were observed in several localities. Most of these contacts showed discordant relations between the diabase and the sediments; but at one locality for several feet the relations were concordant. The diabase is finer-grained near the sediments and includes fragments of the argillite and limestones; it is, therefore, intrusive into the Maude formation. The form in which it occurs is not known, but the contacts and the texture seem to indicate that it may be laccolithic.

Origin. This diabase is a hypabyssal, igneous rock, formed by the cooling of molten magma at a moderate depth in the earth's crust.

AGE AND CORRELATION OF BATHOLITHIC ROCKS.

In regard to the age of the batholithic rocks of Graham island it can only be said that they are post-middle Jurassic, and pre-Upper Cretaceous. They are thus upper Jurassic or Lower Cretaceous in age. As the rocks bear a general resemblance to the granitic rocks of the Coast Range batholith, they may be correlated with this great intrusive mass with a considerable degree of certainty. The Coast Range batholith is generally considered to be of upper Jurassic age.

The batholithic rocks of Graham island occur in relatively small, separated areas as they do on Vancouver island.[1] It has

[1] Clapp, C. H., Geol. Surv., Can., Mem. 13, 1912, p. 113.

been already mentioned that this is a mode of occurrence to be expected because of the situation of the Queen Charlotte islands on the flanks of the batholith.

QUEEN CHARLOTTE SERIES.

The Queen Charlotte series comprises the detrital sediments of Cretaceous age on the Queen Charlotte islands. This series has been divided by Clapp[1] on lithologic grounds, into three formations, the Haida, the Honna, and the Skidegate. He also included a basal conglomerate as a fourth member, but more detailed work has shown that these basal beds belong to the Yakoun formation.

The three members will be first described separately, and then the structure and correlation of the Queen Charlotte series as a unit will be taken up.

HAIDA FORMATION.

Distribution.

The Haida formation is typically exposed in many localities about Skidegate inlet, and the devious channels of this waterway afford several sections of these rocks. Areally it is the most extensive member of the Queen Charlotte series. A band 2 or 3 miles wide extends northwestward from Bearskin bay up the Honna valley, and, in the vicinity of Camp Robertson, expands westward nearly to Yakoun lake. This expansion is caused by low, undulating folds. Basal beds of the formation are exposed at Yakoun lake, and in several small, separate basins in the Yakoun valley. A small area also occurs on the Tlell river, between Camp Robertson and Camp Wilson. Other areas doubtless occur throughout the Queen Charlotte range, as Haida fossils have been found in stream drift from these mountains.

The Haida formation forms the only representative of the Queen Charlotte series in the so-called Yakoun basin, which contains the coal seam of Camp Wilson.

[1] Clapp, C. H., Geol. Surv., Can., Sum. Rept., 1912, p. 18.

Lithology.

The Haida formation is largely composed of sandstones, though many beds of shale occur in some localities, and strata coarse enough to be called conglomerate or breccias are found. The basal beds are well exposed at Haida point, the east end of Maude island, and at other localities in Skidegate inlet. They are pale yellow and buff, coarse sandstones and fine conglomerates largely quartzose, and containing in varying amount angular and subangular fragments of the Yakoun volcanics. Carbonized stems of trees, partly replaced by calcite, and bits of bright, coaly matter up to several inches in diameter are not uncommon near the base. Higher in the formation, in the exposures on the shores of Bearskin bay, are green chloritic and feldspathic concretionary sandstones, in massive layers, containing fossil pelecypods and ammonites in abundance. These sandstones exfoliate in scaly sheets. Dark-grey, very fine, thin-bedded, argillaceous sandstones, to which the term shale may be applied, outcrop between Queen Charlotte, and Lina narrows. With these are associated buff-weathering hard, dense, calcareous, siliceous, and ferruginous concretionary bands.

Inland, especially near Camp Wilson and on the Tlell river, the lowest beds are composed of re-sorted, angular fragments of the Yakoun volcanics, in a matrix of similar, finer material, so that it is frequently difficult to tell the Haida beds from the rocks on which they lie.

In the Slatechuck valley there are thick beds of black very fine-grained, massive, hard shale, which is highly carbonaceous, and breaks with a conchoidal fracture. It is used by the Haida Indians for carving small models of totem poles and other distinctive ornaments. This shale is very like that in which the coal seams in the Slatechuck valley are found.

This rock was analysed by B. J. Harrington[1] from samples collected by Mr. Richardson in 1872. The analysis follows:

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	H_2O
44·78	36·94	8·46	trace	trace	7·15
	Carbonaceous matter—3·18		=	100·51	

[1] Geol. Surv., Can., Rept. of Prog., 1872-73, p. 62.

Marine fossils occur throughout the Haida formation, sometimes in great abundance.

Stratigraphy and Structure.

The Haida formation varies in its internal stratigraphy from place to place, and cannot well be described as a whole.

On Skidegate inlet several sections of the rocks are found some of which are complete. The Bearskin Bay section extends from Haida point, where the basal beds rest unconformably on the Yakoun volcanics, westward beyond the mouth of the Honna river, where the Haida is conformably overlain by the Honna conglomerate. The rocks dip westward at moderate angles, undulating somewhat in the upper portion. The lower half of the formation consists of massive and flaggy, greenish and greyish sandstones and arkoses, with shaly interbeds. From Queen Charlotte westward the upper half of the Haida is much finer and the beds are thinner and more shaly. Concretions and concretionary layers abound, and weather in relief, simulating sills. False bedding is frequently seen, especially in the lower beds.

On Maude island another complete section is exposed. The basal beds fringe the eastern end of the island and form a band across the central part, with a westerly dip, surrounding an old projection of the Vancouver group. False bedding is remarkably well shown on the southeast end of Maude island. Several hundred feet of the lower part of the formation are composed of a very massive, fine-grained, greyish-green sandstone, with shaly interbeds, well exposed on the northern side of Maude island, and in part on the southern side of Lina island. This massive band has not been recognized in the Bearskin Bay section, less than 2 miles distant.

The Haida formation exposed in the vicinity of Camp Robertson is different from either of the above sections, and is clearly divisible into two members, the lower about 3,000 feet and the upper averaging 2,300 feet in thickness. The Robertson coal seam occurs about 200 feet below the base of the upper division. The lower member is made up of alternating beds of fine grey shales, medium-grained sandstones, and arkosic conglomerates, a great deal of the detrital material having been derived from the Yakoun volcanics. These rocks are best exposed in Robertson creek, but a fair idea of their character may be obtained from the following columnar section measured in a small creek northeast of Camp Robertson:

	Feet	Inches
Fine grey sandstone	..	
Coarse grey sandstone	66	
Massive, fine grey sandstone	20	
Mostly concealed, probably coarse light grey sandstone	60	
Fine, laminated, crushed shale	0	1
Very fine, drab, jointed sandstone	8	
Laminated, red shale	0	1
Coarse pebbly sandstone	20	
Medium-grained sandstone	0	1
Laminated, grey sandstone	3	
Fine, drab sandstone	10	
Coarse pebbly sandstone		4
Light grey sandstone		1
Laminated, grey sandstone		2
Dark grey sandstone		4
Light grey sandstone		4
Dark grey sandstone		8
Light grey sandstone		3
Dark grey sandstone	6	0
Fine-grained, drab sandstone, partly concealed	45	
Finer-grained, drab sandstone	12	
Medium-grained, grey sandstone	50	
Total	302	5

The upper member is much more homogeneous, and consists of very massive fine, even-grained, bluish and greenish, quartzose, grey sandstone, often beautifully laminated, and occasionally showing signs of irregular current bedding. Interbeds of thin bedded, flaggy sandstone occur. Throughout the area in which the thick-bedded sandstone is found, the dips are flat or gentle. The recognition of this massive band of sandstone is important for prospectors, for the known coal horizon is found about 200 feet below its base.

In the part of the Yakoun basin exposed on the Tlell river the beds are coarse arkoses derived from the underlying volcanics, with shales, some bands of massive sandstone, and a great deal of fine quartzose conglomerate.

Farther north in the same basin the rocks are variable in their nature, at the base consisting of volcanic arkoses, overlain by shales and about 250 feet of fine massive sandstone. The sections are not constant even over small areas. The section found in the bore-hole of the Graham Island Coal and Timber Syndicate, in the eastern part of section 36, is given in the appendix, together with other partial sections of the formation obtained from cores of bore-holes.

East of Alliford point in Skidegate inlet a narrow sandstone dyke was found cutting fine dense black shaly sandstones of the Haida formation. The dyke, which is 4 inches wide in places, is lenticular and splits into ramifying branches. It is vertical in attitude and has a very sharp contact with the shales.[1]

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 nearly 5,500 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 thickness exposed in the Yakoun basin is probably under 1,000 feet.

Folding and Faulting. Folding in the Haida formation, while locally severe, is gentle on the whole. Near the base and in the vicinity of the coal seams and without doubt elsewhere, close folds are found representing the relief of stress in the less competent beds. Faulting is also a local phenomenon, and several small faults, usually reverse, have been noted in the coal openings at Camp Robertson and Camp Wilson (See Figures 12 and 22).

Relation to the Vancouver Group. The Haida formation rests unconformably on the rocks of the Vancouver group and includes fragments of these rocks. This relationship was noted at Haida point, the Channel islands, and Maude island in

[1] Cf. Clapp, C. H., Geol. Surv., Can., Mem. 51, p. 75.

Skidegate inlet; on the Yakoun river; at Yakoun lake; on the Tlell river and Wilson creek, and elsewhere. The surface on which the Haida sediments were laid down was a very irregular one, and projections of the older rocks are found in the lower beds of the formation.

Relation to the Honna Formation. At Lina narrows in Skidegate inlet, the Haida formation is conformably overlain by the Honna conglomerate. The upper beds of the Haida are fine, sandy shales, and at the very top are coarse, calcareous and concretionary sandstones, grading in a short distance into coarser, pebbly sandstones that may be considered the basal beds of the Honna formation. While the actual contact has not been observed elsewhere, structural evidence makes it seem probable that the two formations are closely conformable throughout, though local disconformities may occur.

Relation to the Tertiary Formations. Dykes and sills of the Etheline formation intrude the eroded and uptilted Haida formation and flows of the Masset volcanics overlie it.

HONNA FORMATION.

Distribution.

The Honna formation outcrops at Lina narrows in Skidegate inlet; it forms the western parts of Lina and Maude islands and the northern part of South island; and is well exposed in the vicinity of the mouth of the Dina river on Moresby island. A broad band of the Honna conglomerate crosses Nose point and many of the islands in the western part of Skidegate inlet are of this rock; also it is exposed along the shore from South point to the east of the mouth of Slatechuck creek. Inland a ridge of the conglomerate extends due north from Lina narrows and culminates in the highlands south of Camp Robertson, the strike of the measures changing from north-south, with a westerly dip, to nearly east-west. This strike, with a southerly dip, is maintained as far as Mount Etheline, where the conglomerate is overlain by flows of Tertiary volcanics. Structural relations in the overlying measures make it evident, however, that the rocks regain their north-south strike with an easterly dip, forming the western limb of a syncline, and that they extend southward under the Tertiary volcanic veneer to Skidegate inlet, west of the mouth of Slatechuck creek. The Honna formation thus forms a horseshoe-shaped outcrop on Graham island.

Lithology.

The Honna formation is mostly composed of conglomerate with some sandstones and sandy shales. Some of the conglomerates at the base are coarse, with pebbles up to 3 feet in diameter but averaging much less. The most common conglomerate is composed of about 60 per cent of well rounded pebbles, from ¼ inch to 6 inches in diameter but averaging about 1½ inches, in a coarse sandy matrix. Most of the pebbles are plutonic rocks—light grey diorite, dark grey diorite or gabbro, fine black diorite, granodiorite both even granular and gneissic, fine porphyritic diorite, etc. Coarse quartzites, fragments of argillites of the Maude formation, chert, and quartz also are found, but recognizable fragments of the Yakoun volcanics are rare or absent.

The sandstone interbeds in the conglomerate are generally pinkish, medium-quartzose varieties, and the shaly beds are black, fine-grained, hard slaty rocks.

Stratigraphy and Structure.

The lowermost beds of the formation exposed at Lina narrows are coarse sandstones, transitional from the upper Haida; then come 6 feet of very coarse conglomerate, with well rounded pebbles averaging over 6 inches. Above this are bands of medium conglomerate with thin, cross-bedded and lenticular intercalations of sandstones. These conglomerate beds form the lower few hundred feet of the formation and above them are softer shales and crossbedded sandstones, forming the middle half, while conglomerates make up the upper 500 feet or so of the formation.

On the south side of Nose point, dark grey, slaty shales of the Honna formation are cut by a 5-inch, medium-grained, sandstone dyke, with a marked platy jointing normal to its walls.[1] The dyke strikes east-west and dips south at an angle of 80 degrees.

The Honna formation is about 2,000 feet thick.

Relation to the Haida Formation. The Honna conglomerate lies conformably on the sandstones and shales of the upper Haida; this relation between the two is seen at Lina narrows in Skidegate inlet. Although no evidence for it has been seen, it is possible that the Honna lies in part disconformably on the Haida.

Relation to the Skidegate Formation. The Honna formation is conformably overlain by the sandstones and shales of the Skidegate formation. A contact showing the relationship is seen about three-fourths of a mile west of Lina narrows and elsewhere in the series structural evidence leads to the same conclusion.

Relation to the Tertiary Formations. Dykes of the Etheline volcanics cutting the Honna formation have been noted and on Mount Etheline flows of the Masset volcanics unconformably overlie the conglomerate.

SKIDEGATE FORMATION.

Distribution. The Skidegate formation is well exposed along the north shore of the western part of Skidegate inlet, and from there extends inland, northward, in a roughly rectangular area about 4 miles north and south and 3 miles east and west. It is also exposed on the northeast side of Nose point, but has not been found elsewhere on Graham island.

Lithology. The Skidegate formation is composed of sandstones and shales with concretionary bands of hard, tough, buff-weathering, siliceous and calcareous material.

The rocks are mostly coarse to medium, cross-bedded arkoses interbedded with black, fine shales.

Stratigraphy and Structure.

The basal beds of the Skidegate formation, as exposed on Skidegate inlet, are feldspathic, concretionary sandstones,

[1] Cf. Clapp, C. H., Geol. Surv., Can., Mem. 51, p. 75.

overlain by finer sandstones, above which are shales with thin sandy bands. Inland, as exposed on Tarundl creek and elsewhere, the Skidegate beds are mostly black and dark grey, very fine, carbonaceous, massive, and laminated shales.

The exposed thickness of the Skidegate formation is at least 2,000 feet, and the formation may have been considerably thicker.

Relation to the Honna Formation. The Skidegate formation conformably overlies the Honna conglomerate in several localities around Skidegate inlet, and the actual contact is exposed about three-fourths of a mile west of Lina narrows.

Relation to the Tertiary Formations. Dykes and sills of the Etheline volcanics penetrate the Skidegate beds, and the formation is unconformably overlain by volcanic flows of the Masset formation in the Slatechuck range and elsewhere. Dykes are not as abundant in the rocks of this formation as in the older Haida beds.

METAMORPHISM.

The sediments of the Queen Charlotte series are thoroughly compacted and indurated. They are dense; but the rocks are not metamorphosed in the ordinarily accepted sense of the word. The cement is usually calcite, accompanied by chloritic, argillaceous, and tufaceous materials which are not products of recrystallization. In the vicinity of the dykes and sills, it is common to find finely granular pyrite impregnating the sediments and, in some localities, small concretions containing concentric layers of whitish pyrite are found. The sills and dykes have in nearly all cases baked and hardened the sediments into which they have been forced, and the effects of the intrusions have been more severe in the shales then in the sandstones.

STRUCTURE.

The Queen Charlotte series occupies several complex, synclinal basins.

The largest of these basins underlies Skidegate inlet, and extends northward on Graham island for about 9 miles, to Yakoun lake and beyond Camp Robertson. It is complicated by several smaller folds (as illustrated in the sections accompanying the map) and the folding is more severe in the western than in the eastern limb. The portion of the syncline underlying Skidegate inlet is an irregularly warped sheet of sediments of variable thickness, in which strikes at all azimuths, and dips up to vertical are found. The main extension of the Skidegate Inlet basin is found in the syncline occupying the Honna and Slatechuck valleys and other territory northward beyond Camp Robertson and covered to the west by Tertiary volcanic flows. This syncline is on the whole a broad open fold hereafter termed the Honna basin. The western part of the Honna basin, in the Slatechuck valley and around Yakoun lake, is severely folded, in places overturned, and also faulted. The more severe folding is doubtless due to the proximity of the underlying massive rocks of the Vancouver group, which formed a buttress against which the softer sediments were compressed. Westward from Camp Robertson the rocks lie flat or in undulations, but to the eastward there are severe local folds, accompanied by faults. The structures at Camp Robertson are illustrated in the sections given in connexion with the description of the coal seams there. These sections give evidence that the beds have been affected by intense folding with slight faults, probably due to the soft and yielding nature of the coal seams and associated beds.

The Haida formation occurs in the vicinity of Camp Wilson in the Yakoun valley in a basin-shaped syncline, warped into several open folds complicated by minor crumplings and some faulting. The detailed structure of this basin has not been deciphered owing to the obscurity of the evidence given by the meagre outcrops.

Further details in regard to the faults affecting the Queen Charlotte series will be found in Chapter VI.

IGNEOUS INTRUSIONS.

Dykes of the Etheline volcanics are found cutting the Queen Charlotte series in great numbers. They are particularly common in the Haida formation, especially in the Honna basin.

The dykes range from a few inches to 50 feet or more in width. Sills of the volcanics are frequently found, but are not nearly so numerous as the dykes. South of Lake Stanley, near the uppermost exposed beds of the Skidegate formation, very thick sills or laccoliths, some up to 200 feet, intrude the sediments. Perhaps the lessening weight of the superincumbent rocks rendered it easy for the magma to penetrate between the beds here.

ORIGIN.

The foregoing descriptions of the various formations making up the Queen Charlotte series show it to be formed of sediments rapidly accumulated in shallow water. The fossils found throughout the series are marine, while the coal which is found at a single horizon in the Haida member, was probably laid down at a time when shallow estuarine or lagoon conditions prevailed over considerable portions of the area subject to sedimentation. The topographic irregularity of the surface on which the basal sediments of the series were laid down and the varying character of the lower beds of the Haida formation indicate that the first accumulations of detrital material took place in more or less separate basins. These basins were gradually filled, and deposition, after the period of coal formation, took place in a single widespread depression.

The large amount of poorly assorted undecomposed feldspathic and volcanic rock fragments in the sediments is evidence of rapid erosion and accumulation of the detrital material.

The locality from which the plutonic rocks found in the Honna conglomerate were derived is at present unknown, although they may have come from the Queen Charlotte range on Moresby island. So far as is now known, however, only small areas of batholithic rocks are exposed in the range, and it may be that some of the materials of the Honna conglomerate were accumulated from a more distant source. The well assorted character of the Honna beds, and the rounded pebbles indicate transportation from a distance, and the cross-bedded and lenticular nature of the layers is evidence of the deposition of the Honna conglomerate under the influence of currents.

It is probable that the Queen Charlotte series was formed in estuarine basins, by the sudden influx of a large amount of sediments carried in by rapid streams, and that the series as a whole represents a delta deposit, reassorted and modified by the waves and currents of a shallow sea.

AGE.

The fossils from the Queen Charlotte series show these rocks to be of Upper Cretaceous age, and Dr. Stanton states that most of them, judged by European standards, are not older than Gault. A single species of Inoceramus, closely resembling if not identical with *I. labiatus* Schlotheim, suggests a higher horizon, represented by the Benton shale of the Rocky mountains and the Turonian of Europe.

The fossils of the Queen Charlotte series, determined by Dr. T. W. Stanton, follow:

Skidegate Formation.

Pelecypods:

Inoceramus sp. cf. *I. labiatus* Schlotheim.
(From the uppermost beds exposed).

Honna Formation.

Pelecypods:

Inoceramus sp. cf. *I. labiatus* Schlotheim.

Haida Formation.

Plants:

Fern pinnule.

Echinoids:

Spines with imprint of fragment of test.

Brachiopods:

Rhynochonella ? sp.

Pelecypods:

Trigonia diversicostata Whiteaves ?
Trigonia maudensis Whiteaves ?
Cytherea subtrigona Whiteaves.

Thetis affinis Whiteaves.
Inoceramus sulcatus Parkinson.
Inoceramus moresbyensis Whiteaves.
Inoceramus sp. cf. *I. quatsinoensis* Whiteaves.
Inoceramus sp. cf. *I. labiatus* Schlotheim.
Anomia linensis Whiteaves.
Pecten (Ectolium) lenticularis Whiteaves?
Tellina skidegatensis Whiteaves.
Nucula (Acila) truncata Gabb?
Thracia ? sp.
Nemodon sp.
Pecten sp.
Cucullaea sp.
Nucula sp.
Trigonia sp.
Cyprina sp.
Teredo ? sp.
Corbula ? sp.
Astarte ? sp.
Pleuromya ? sp.
Cytherea ? sp.
Undetermined pelecypods.

Gastropods:

Amauropsis tenuistriata Whiteaves.
Undetermined gastropod.

Cephalopods:

Desmoceras (Puzosia) planulatum ? Sowerby as identified by Whiteaves.
Desmoceras (Puzosia) perezianum Whiteaves.
Lytoceras (Tetragonites) timotheanum (Mayer).
Lytoceras sacya (Forbes).
Perisphinctes skidegatensis Whiteaves?
Desmoceras sp.
Belemnites sp.
Undetermined ammonites, one possibly *Prionatropis*.

TERTIARY FORMATIONS.

ETHELINE FORMATION.

The Etheline formation consists of dykes, sills, and probably laccoliths of volcanic rocks intrusive into the rocks of the Vancouver group and the Queen Charlotte series. The effusive basalts of Mount Etheline were in 1913 thought to belong to this formation, and the name was given for this reason, in the writer's Summary Report for that year. Field work in 1914, aided by study of the rocks in thin section, made it evident that the basalt flows of Mount Etheline and elsewhere in southern Graham island are to be correlated with the Masset formation, of later Tertiary age. The formation name Etheline is thus restricted to intrusive volcanic rocks. No effusive types have been recognized as belonging to this formation, although it is possible that they may occur.

Distribution. Dykes and sills are of frequent occurrence over virtually all of southern Graham island. They are particularly abundant in the rocks of the Vancouver group, so that in some localities as on King, Canyon, and other creeks, the intrusive rocks occupy areas as large or larger than does the intruded formation. There is thus a marked tendency for the older formations to contain the intrusive rocks in greater abundance than the younger ones; and this is the case even in the Queen Charlotte series, where few dykes or sills penetrate the Honna conglomerate.

In the vicinity of Parry passage, between Langara and Graham islands, are numerous intrusive rocks, which on account of lithological similarity are correlated with the Etheline intrusives. Lucy island, and the larger part of Cape Knox consist of one of these intrusions of biotite andesite, in the shape of a huge dyke, which is at least a mile wide, and 5 miles long.

Lithology. In composition the dykes range from dacite to basalt, and virtually all the volcanic rocks of the series are represented in dyke form, while all but the dacites are represented as sills.

The determination of the several types is next to impossible in the field. The dacites and quartz-bearing andesites are light coloured rocks, generally pale grey, and are characterized usually by phenocrysts of quartz and plagioclase. The andesites are similar, but lack the quartz. The augite andesites and basalts are darker grey rocks. All the rocks show porphyritic facies and the groundmass is in every case very fine-grained. Most of them are characterized by finely divided, disseminated pyrite.

More detailed descriptions of these rocks will be found in Chapter V.

Structure.—Internal. The widths of the dykes vary from a fraction of an inch to 50 feet or more. Sills up to 200 feet thick have been met with, but they are exceptional, and may be

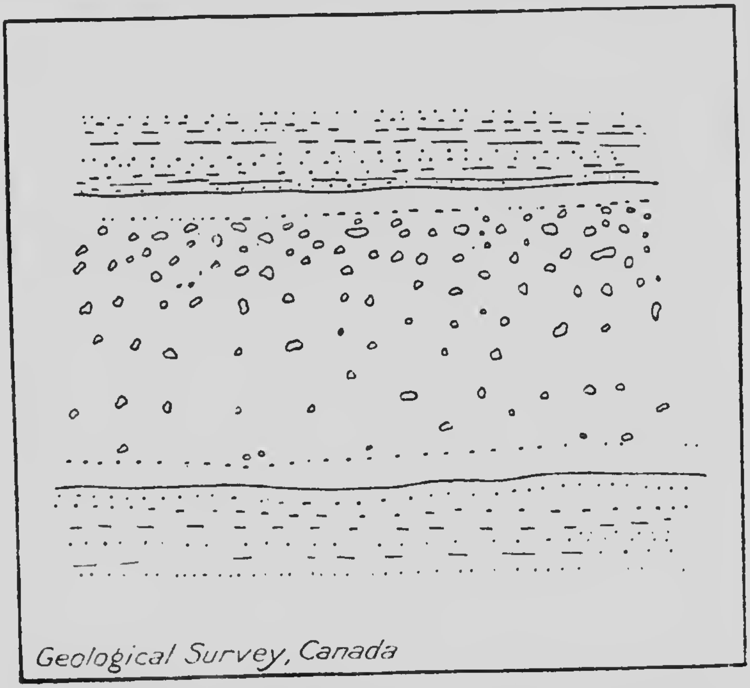


Figure 6. Vertical section of andesite sill on north side of Triangle island, Skidegate inlet, cutting shaly sandstones. Illustrates chilled contacts, and upward translation of vesicles. Sill is 3 feet 6 inches thick.

laccoliths. The average width of the dykes, excluding two of 30 and 50 feet respectively, is about 5 feet. There is little variation in the internal structure of the injected bodies. Many show chilled contacts in varying degrees, but it is not uncommon to find the grain uniform throughout. Some of the bodies are vesicular and amygdaloidal, and a sill on the north shore of Triangle island contains vesicles so distributed as to indicate their translation toward the top of the sill under the influence of gravity, as shown in Figure 6. On the south side of Lina island there is a composite sill of andesite, with later augite andesite porphyrite occupying the same cavity. Aplitic stringers up to an inch wide, irregularly disposed, and grading into the rest of the rock, were found in a hornblende andesite dyke, a rare type containing small phenocrysts of hornblende. The aplitic veinlets are much less altered than the andesite containing them. The same dyke contains an irregular altered shale xenolith about 3 feet in diameter. The severe heating which the xenolith has undergone has not altered it appreciably and virtually the only change it has suffered is a partial replacement by pyrite. Other smaller xenoliths of shale are commonly found near the margins of the dykes, where they have been stoped from the walls.

Structure.—External. The most striking external action of the injected bodies is their baking action on the rocks they intrude. A hardened, resistant zone is found bordering the dykes and sills in almost every case, but there seems to be no definite relation between the width of the zone and the thickness of the intrusive, indicating a varying amount of superheat in different dykes. The zone is up to 2 feet thick, and weathers in relief, generally adhering strongly to the dyke walls. This is illustrated in Plate XIIB. The actual contacts of the dykes and sills with the shales are linear in the main, but remarkably irregular in detail. A zone one-fourth to one-half inch in thickness occurs paralleling the dyke, in which there is an intimate interpenetration of intrusive and enclosing rock. This gives the surfaces of the dyke walls an irregularly pimpled appearance when exposed.

The sills are not in every case strictly concordant bodies, some of them cut across the strata for short distances, and return to the bedding planes. In places a gap appears between different portions of the same sill, as illustrated in Figure 7. This is analogous to the dykes described and figured by Harker[1].

[1] Harker, A., "Tertiary Igneous Rocks of Skye," 1904, p. 303.

Some of the dykes show a similar structure, and particular cases are illustrated in Figures 8 and 9. In the case of Figure 9 there seems to have been an excess of magma at the point illustrated and the overflow forced its way irregularly into the sandstone.

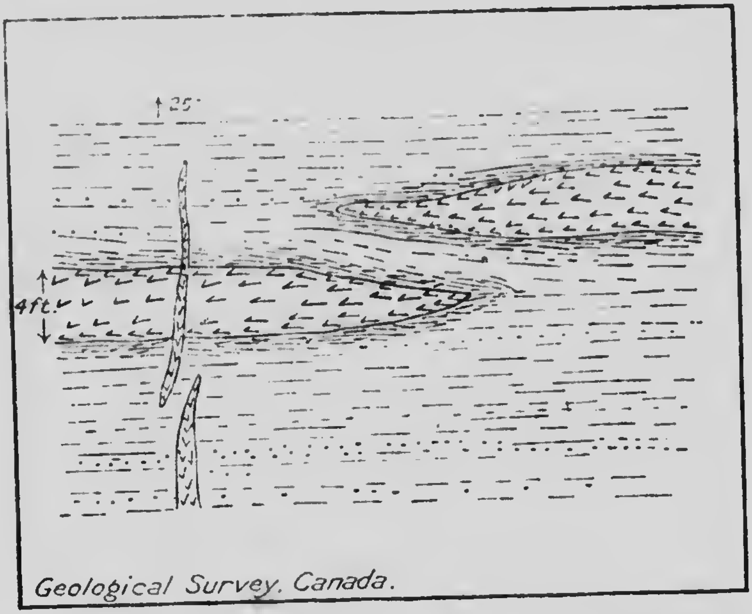


Figure 7. Plan of 4-foot andesite sill on east end of Lina island, Skidegate inlet, illustrating intrusion *en echelon*, baking of sediments, and later, finer grained andesite dyke.

That some at least of the dykes and sills were injected before deformation ceased is shown by the tightly folded sills occurring in the tunnel of the British Pacific Coal Company, and by the folded and faulted dyke in the tunnel at Camp Robertson, Figure 12.

Method of Intrusion. It will later be shown (page 113) that the dykes occupy almost exclusively fissures belonging to one of four systems of joints. The joints of this system, therefore, must extend to considerable depths and they are considered on this account to be the master joints of the region. Into these deep fissures the magma was forced under enormous pressure, filling them with great rapidity. The fact of the occurrence of

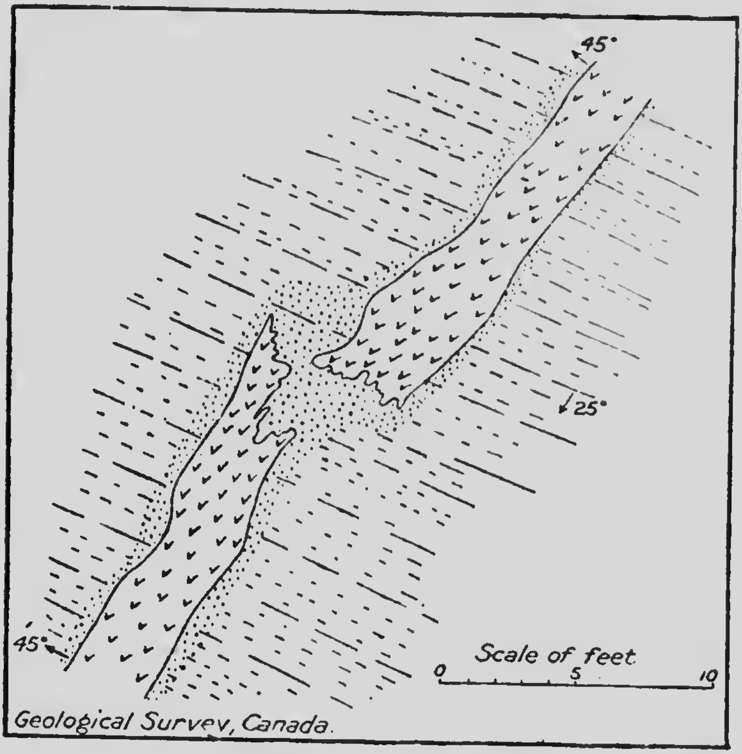


Figure 8. Irregular andesite dyke cutting shaly sandstones on beach west of Haida point, illustrating also the baking of the sediments.

such thin bodies of igneous rock so far from their source proves two things: a large amount of superheat in the magma, and a very rapid intrusion.

Age. The Etheline sills and dykes cut the Upper Cretaceous beds of the Queen Charlotte series, and are, therefore, younger than these beds. Some of them are found in folded strata, and it seems probable, therefore, that they were intruded before the folding took place. Others are faulted. This evidence although

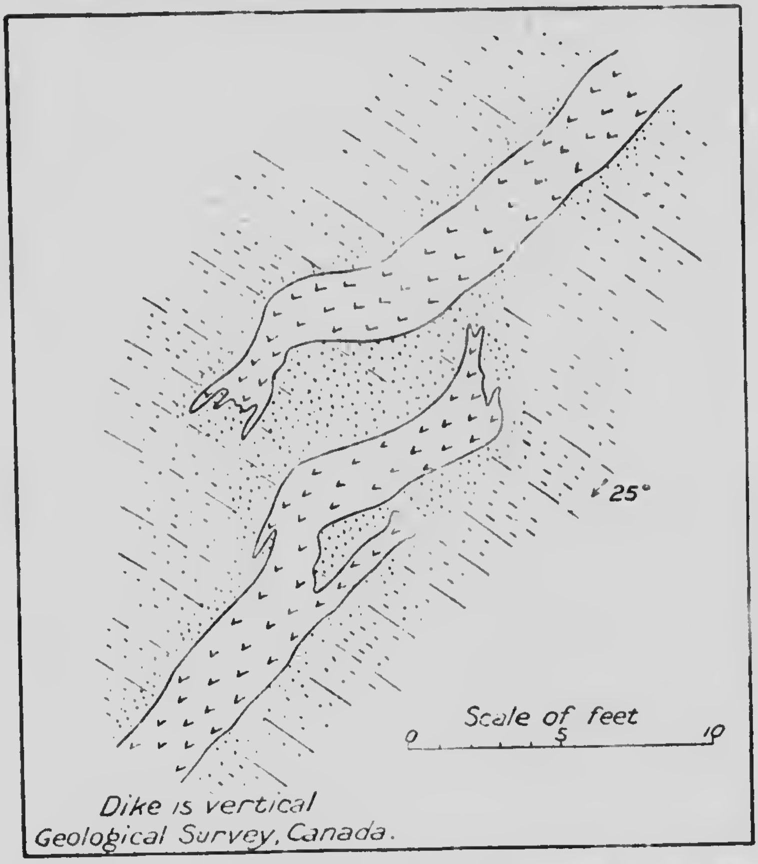


Figure 9. Irregular andesite dyke cutting shaly sandstones on beach west of Haida point, illustrating also the baking of the sediments.

not altogether satisfactory, indicates that the intrusives are not very much younger than the Upper Cretaceous. They are nowhere found cutting the Masset or Skonun formations and, therefore, are older than these beds which are at least as old as mid-Miocene.

It seems best to consider the Etheline formation as of Eocene age and probably early Eocene.

SKONUN[1] FORMATION.

The name Skonun is given to a sedimentary formation included in the Tertiary rocks of the Queen Charlotte islands.

Distribution. These sediments have been observed in section 1 of township 7, on the lower Yakoun river, on the Mamin river, and at Skonun point on the north coast. They are reported to occur at the mouth of Miller creek, about 8 miles north of Skidegate post-office, at Meyer lake, at Tow hill, and at other localities in the northeast lowland. Although these are only a few outcrops scattered over a large expanse of territory, it is believed on topographic evidence (See Chapter III) that the Skonun formation underlies the greater part of the northeast lowland.

Lithology. The character of this formation varies from place to place, exhibiting differing degrees of consolidation at different points. On the Yakoun river, the formation is made up of flat lying, slightly cemented sand and fine gravel, and tough, soft, grey clay. The sand which is on the whole coarse is white to light grey in colour, and largely composed of quartz. At Skonun point on the north coast, similar beds occur dipping at angles up to 60 degrees, but there they are quite hard and well cemented by calcite (see Plate XIIA.) Lenticular bands of grey limestone up to 2 inches thick are also found in these sandstones. Conglomerates occur there, and also thick beds of lignite. Lignite has been reported to occur also at Miller creek, Mamin river, Naden harbour, and various points on the east coast. It is evidently wide-spread through the formation.

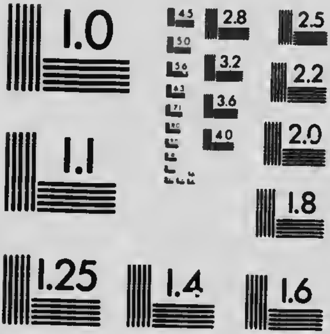
Fossil shells and leaves have been found in the clays on the Yakoun river, and shells are very abundant in the sandstones of Skonun point.

Structure. The sediments on Yakoun river and at Skonun point are in layers from 1 foot to upwards of 10 feet thick, and

[1] Named from Skonun point.

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



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the sandstones are frequently cross-bedded. At Skonun point the beds are disposed in an east-west anticline, apparently faulted on the crest, and with dips up to 60 degrees. Most of the exposures seen were flat lying, or nearly so. The formation as a whole appears to have a gentle northeast dip, and is unconformable on the rocks of the Vancouver group in township 7.

The total thickness of the Skonun formation is unknown. A bore-hole put down at Skonun point for the American-Canadian Coal Company is reported to have penetrated to a depth of 1,003 feet, at an angle of 45 degrees. Owing to the dip of the measures, this nearly represents the true stratigraphic thickness passed through, so the formation may be considered to be over 1,000 feet thick.

The writer has not seen the contact between the overlying Masset and the Skonun formations, but from the general areal distribution of the Tertiary rocks, it is thought that the Masset formation overlies the Skonun with overlap or unconformable relations. The alternating sediments and basalt flows on the Mamin river may indicate that the upper part of the Skonun formation contains intercalated basalt, but the relations are not clear.

Origin. The variable character of the sediments and their cross-bedded structure points to a shallow water place of origin. The fossil leaves indicate a location near shore, while the marine fossils show that the water was at least brackish. The beds of lignite, though derived in part probably from transported material, hints at a freshwater origin for part of the formation at least. On the whole, it seems best to consider the Skonun sediments as beds formed in shallow estuarine basins, parts of which were at times cut off from the sea and converted into freshwater lakes or swamps, and at times reverted to estuarine or marine conditions.

Age. The fossils collected from Skonun point by Dawson were examined by Whiteaves, and his determinations and remarks are given here in full.[1]

[1] Geol. Surv., Can., Rept. of Prog. 1878-79, p. 87B.

"Gasteropoda.

Mangelia ? sp. undt. One worn specimen.
Nassa, sp. Unlike any of the living species on the N.W. coast.
Lunatia ? sp. Test exfoliated.
Trochita, or *Galerus*. Test exfoliated.
Crypta adunca, Sby. One specimen; undistinguishable from the living species. Mr. Gabb (Pal. Cal. vol. 2, p. 82,) says that this shell occurs in the Pliocene and Post Pliocene of California.

Lamellibranchiata.

Solen, sp. One fragment of a large species.
Siliqua—Possibly the young of *S. patula*, Dixon. Two examples.
Standella—Very like *S. planulata*, Con., and *S. falcata* Gld., but smaller than either.
Several specimens.
Macoma nasuta, Conrad. Two or three specimens. According to Gabb. (Pal. Cal. vol. 2, p. 93) this recent species occurs also in the Upper Miocene, Pliocene, and Post Pliocene of California.
Mercenaria—Mr. W. H. Dall thinks this shell is closely related to his *M. Kennicotti*, from Alaska.
Chione, sp. undt. Two specimens.
Tapes staminea, Conrad. The most abundant shell in the collection. It is abundant, in a living state, on the N.W. coast, and Mr. Gabb says that in California it is found in the Post Pliocene, Pliocene, and Miocene.
Saxodomus, species undistinguishable. The outer layer of all the specimens, which are not numerous, is entirely exfoliated.
Cardium, one exfoliated valve. Appears to resemble *C. Islandicum*.
Cardium. Several valves of a species, which may be referable to *C. blandum*, Gld.
Arca microdonta, Conrad. An extinct species, found so far only in the Miocene and Pliocene of California. Two specimens.
Axinaea. Possibly a form of *A. patula*, Conrad, but barely distinguishable from the smooth form (var. *subobsoleta* Carpenter) of the living *A. septentrionalis*, Middendorf, of the N.W. coast. Four single valves."

From this list it would appear that the Skonun formation is either Miocene or Pliocene in age. Arnold and Hannibal[1] correlate the Skonun sediments with the Empire formation, of middle Miocene age.

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[1] Proc. Am. Phil. Soc. vol. LII, 1913, p. 592

The following Miocene fossils from Skonun point were collected by the author and were determined by Dr. Ralph Arnold:

Paphia sp. C.
Caesia sp. K.
Cryptonatica clausa B. and S.
Hemimactra cf. *albaria* Conr.

MASSET FORMATION.

Distribution. The Masset formation is a name applied to the late Tertiary volcanic rocks of Graham island, which form virtually all of the surface rocks west of Masset inlet and north of Rennell sound, and which occur in other parts of the island as well. These rocks are well exposed along the north and west coasts, around Masset lake in the interior, and in the Slatechuck range in the southern part of the island.

Lithology. The Masset rocks are almost wholly basaltic. Bedded flows and coarse agglomerate beds (Plate XIIA) make up nearly all of the formation. The basalts are characteristically dark grey or black, heavy rocks, and range in texture from glassy to highly porphyritic types. Amygdaloids are abundant, the amygdules being filled with chalcedony, quartz, calcite, and occasionally black sticky tar. Basaltic glass or tachylyte has been found on Ship Kieta island, in Masset inlet, and in some of the streams entering Athlow bay on the west coast. It is reported also from the west side of Juskatla inlet. Agglomerates in bewildering varieties of shape, size, and proportion of fragment to matrix, occur interbedded with the flows. Fine-grained, bright greenish and bluish, curiously banded tuffs are found near Tian head on the west coast and elsewhere in that vicinity. These are the rocks in which it is hoped by some to find petroleum by drilling.

Besides the pyroclastic rocks, sediments of detrital origin make up a part of the Masset volcanics. They were seen on the southeast slope of Slatechuck mountain, but were not carefully studied. Some of the beds are conglomerates, composed of pebbles of volcanics up to 6 inches in diameter, in a dense tufaceous matrix. A large exposure of brillant red, soft, argillaceous sediments was seen several hundred feet below this conglomerate. These beds are at least 100 feet thick, and may be much thicker. The lower 40 feet includes some sills or flows.

Some of the hills east of Otard bay and Port Louis on the west coast are formed of bright red, bedded rocks, perhaps sedimentary and similar to those just described.

These ferruginous rocks, occurring in a great volcanic series, recall the deposition of hematite mud at the present day in the Hawaiian islands,[1] another region of basaltic rocks, and may be worth while prospecting for beds of sedimentary iron ore.

Structure.—Internal. The Masset formation is formed of bedded flows and agglomerates usually not exceeding 100 feet in thickness, both of which may be considered as thin and relatively extensive lenses. This bedded nature of the formation is well seen in the Slatechuck range and at Lawn hill and in fact in every exposure of the volcanics except those of very small size. Many of the flows show well marked columnar jointing. This jointing has been noted on Mount Etheline and in a high degree of perfection on the west coast (Plate XIIIB). Flow structure, so beautifully illustrated in thin section, is well brought out by weathering in several localities, notably at Lawn Hill beach.

Chalcedony and calcite veins intersect the rocks at Lawn hill and Tian point, on the east and west coasts respectively, at both localities carrying tar.

Structure.—External. The actual contact of the Masset volcanics with the underlying Cretaceous rocks was observed at two localities on the southeast slope of Slatechuck mountain. The contact is very sharp; the basalt is chilled for several inches above its lower surface, and exhibits a distinct columnar and rude platy jointing, the former perpendicular to this surface, and the latter parallel to it. This lower surface is generally smooth, but in deta[illegible] [illegible]newhat mammillary, with projections reaching

[1] Lindgren, W., "Mineral deposits," McGraw-Hill Book Co., New York, N.Y., p. 200.

heights of one inch and corresponding hollows. The only alteration in the shales is a slight softening which may be ascribed to percolating water. Angular blocks of shale are found in the lower portion of the flow, and the surface of the shale, where overflowed by basalt, is as clean as if it had been subjected to erosive water action.

The lower contact of the formation has not been sufficiently observed to determine the character of the surface on which the basalts were extruded.

It can be stated that the Masset formation has been acted on by deforming forces to a considerable extent, though, as the work done in the areas underlain by this formation was largely of a reconnaissance nature, the structure has not been worked out in detail.

In the Slatechuck range, the formation is about horizontal, with possibly a low westerly dip. At Lawn hill, the strike of the flows is east and west, dipping 10 to 15 degrees south. This east-west trend of the folds is seen in many places, although much of the formation on the west coast strikes from north 20 degrees west to north 20 degrees east, in low folds. In some cases local folding has been severe, and is accompanied by minor faulting, but dips of over 20 degrees are uncommon. The only fault of any magnitude noted is one crossing Frederick island in an east-west direction, and bringing the Tertiary basalt flows, which in the northern part of the island dip 20 to 30 degrees south and southwest, sharply against the lower Jurassic Maude argillites, also dipping south, but at higher angles.

Thickness. In the Slatechuck range 1,600 feet of piled up basalt flows are visible in Slatechuck mountain. On the west coast upwards of 2,500 feet are to be seen in steep hill-sides and from the folding observed the formation at present is estimated to be upwards of 5,000 feet thick.

Method of Extrusion. From the description of the rock types in the formation, it is evident that they were formed during an extensive period of vulcanism, when great explosive vents vomited forth masses of so-called ash and fragments of hot lava to form the tuffs and agglomerates. Concurrently great flows of basalt were poured out, and the formation was built up in this way. None of the actual vents from which this great basaltic accumulation came were seen, and it is improbable that any volcanic cones now remain. The tachylyte of Ship Kieta island is, however, evidence that one at least of the vents was in that vicinity. From the well stratified nature of some of the tuffs it is inferred that their accumulation was subaqueous.

Origin. From the character of the rocks, it is plain that the Masset formation is the result of extensive explosive volcanic action, accompanied by the extrusion of great flows of lava. What is now Graham island, may be conceived to have been an archipelago in this volcanic epoch, or an upland with large lakes, as many of the tuffs and agglomerates are clearly water-lain. Into these water basins were also carried ferruginous detrital sediments, derived from the subaërial decomposition of the basalts, in a way analagous to the hematitic deposits of the Island of Molokai in the Hawaiian group.[1]

Age. The Masset formation is younger than the Skonun sediments, which may in part be Pliocene in age, and is probably conformable with them. It is older than the Glacial epoch, as many of the outcrops are glacially scoured and the basalts of the Slatechuck range have been greatly sculptured by ice action. Until the age of the Skonun sediments is definitely determined, the Masset formation may be considered Pliocene in age.

COMPARISON OF THE YAKOUN AND MASSET FORMATIONS.

A comparison of igneous rocks of different ages in the same district is always interesting from the scientific view-point, and, in the case of the Masset volcanics of Tertiary age and the Yakoun volcanics of Jurassic age, there is an important economic reason why these two formations should be compared and clearly distinguished. Between them lies the coal-bearing Queen Charlotte series, resting unconformably on the Yakoun volcanics, and unconformably overflowed by the Masset volcanics. To the prospector the ability to recognize which formation of volcanics—

[1] Lingdren, W., "Mineral deposits." McGraw-Hill Book Co., New York, N.Y., 1913, p. 250.

underlying or overlying—he is dealing with is of the utmost value. At least one case is known where several hundred feet of useless drilling was done in the Yakoun volcanics, on the mistaken assumption that they were the overlying rocks.

This mistake may in part have arisen because the outcrops occurred on a hill-side, above outcrops of the Haida formation, which were not recognized as basal. The determination of the fact that the coal measures were laid down on an uneven surface is thus seen to have a direct economic bearing. Erosion has in some degree bared the pre-Cretaceous topography, exposing the hills against which the sediments of the Queen Charlotte series were accumulated. It very often happens that the stratigraphically underlying Yakoun volcanics are, topographically, above the stratigraphically overlying coal measures, owing to normal processes of erosion having exposed the ancient topography. It is essential to intelligent prospecting that these peculiar structural relations be borne in mind, and it is largely on account of them that the prospector and geologist must fall back on petrological criteria for distinguishing which formation of volcanics he has encountered.

Fortunately there are distinct megascopic differences, and only occasionally need there be any uncertainty as to the identity of the formation in the field. In these cases of doubt the powerful aid of the microscope may be invoked, for the microscopic characteristics of the two series of rocks are even more distinctive than the megascopic.

For convenience in reference the two formations are contrasted in detail under the same headings.

Yakoun Formation.	*Masset Formation.*
Age.	
Middle Jurassic	Pliocene (?)
Stratigraphic Position.	
Unconformably underlying the coal-bearing Queen Charlotte series.	Unconformably overlying the coal-bearing Queen Charlotte series.

Structural Relations.

Highly jointed, sheared and broken, veined with calcite and quartz, and brilliant jasper.	Columnar joints, and otherwise jointed but not to such an extent as the Yakoun formation.

(See also page 80.)

Lithological Character.

Basalt and andesite tuffs and agglomerates. Rarely diabase.	Basalts, agglomerates, and tuffs.

Middle Colour.

Purplish, greenish, blackish, and dark grey; altered looking, and stained with epidote, chlorite, and limonite. A dull, mottled purplish and green tint is very common.	Dark grey or black; usually fresh looking and unstained. Agglomerates often rusty.

Texture.

Typically fragmental rocks, tuffs, and very dense agglomerates. Fragments angul[illegible], and of all sizes up to several feet. In some cases well bedded, in layers of varying thickness. Dense, porphyritic, and amygdaloidal flows, and injected rocks are found. Frequently highly [illegible]orphyritic.	Typically massive, dense, devitrified or sparingly porphyritic flow rocks, occasionally amygdaloidal. Fragmental rocks are abundant, and a few bright red interstratified clay sediments are found. Columnar structures common. Agglomerates loose textured.

Microscopic.

Essential m[illegible] [illegible]bradorite, $Ab_{35}An_{65}$-[illegible] [illegible] rarely-andesine; [illegible] [illegible]ubordinate minerals: [illegible] titanite, rarely biot[illegible] [illegible]ary chlorite, calcite, etc.	Essential minerals: labradorite, $Ab_{30}An_{70}$-$Ab_{50}An_{50}$; augite. Subordinate minerals: magnetite. Secondary minerals: chlorite, calcite, epidote, etc.

Microscopic Texture.

Wholly crystalline, finely even granular or porphyritic; feldspar equidimensional; texture intersertal or ophitic; flow structure rare.	Wholly or partly crystalline; finely even granular, frequently porphyritic; feldspar markedly lath-shaped; texture intersertal, rarely ophitic; highly developed flow structure universal. Vitreous rocks found.

Alteration.

Considerable; feldspar always partly or wholly kaolinized; augite altered to chlorite, etc.	Very slight; small amounts of kaolinization; much of feldspar and augite quite fresh.

SUPERFICIAL DEPOSITS.

GLACIAL DRIFT.

Glacial drift, both stratified drift and till, occurs in abundance on Graham island. The relative distribution and amounts of each cannot be determined with any degree of accuracy owing to the absence of exposures.

Lithology. The stratified drift is composed of laminated fine blue clays, sand, and gravel. Much of the clay is suitable for brickmaking.

The unstratified till is made up of angular, subangular, and rounded boulders of varying sizes up to about 3 feet in diameter, embedded in a matrix composed of sand and gravel in varying amounts. The boulders consist of several varieties of igneou rocks and of rocks of the Queen Charlotte series, and many of them show glacial scratches and striations.

Origin. The stratified glacial drift has been laid down in water and probably was formed in lakes or estuaries caused by glacial damming, as it seems improbable that a sufficient uplift has occurred to make it possible that the stratified drift seen can be of marine origin. The unstratified drift has all the characteristics of boulder till, and was formed by the usual accumulation of heterogeneous material. Some of the till is slightly sorted, and perhaps modified by water action.

DAWSON'S DESCRIPTION OF THE SUPERFICIAL DEPOSITS.

The following description of the superficial deposits as exposed in the cliffs on the east coast of Graham island is taken from Dawson's report.[1]

[1] Dawson, G. M., Geol. Surv., Can., Ann. Rept., 1878-79, pp. 91B-93B.

"The long lines of wasting cliff on the eastward-facing shore present excellent sections of the deposits of which this low land is composed, and these appear with scarcely any exception to be those of the glacial or even yet more modern periods.

A few miles north of Lawn point, at the entrance to Skidegate, the most southern exposure is found in a low cliff or bank, in which deposits evidently of glacial ag are cut off above by a gently undulating surface of denudation, and overlain by ten or fifteen feet of superficial material which shows no sign of blending with that below. The upper deposit consists of sand and well rounded gravel, in regular and often nearly horizontal layers. It has become in places quite hard, being apparently cemented with ferruginous matter. Its lower layers hold some small boulders, a few of which measure eighteen inches or two feet in diameter. The lower deposit at the north end of the exposure—which may be in all about two hundred yards in length— is a typical boulder clay, with many half-rounded and subangular stones and occasional boulders of some size. The matrix is bluish-grey, hard and somewhat arenaceous. The whole is irregularly mingled, and shows no sign of bedding. The boulders were not observed to be striated, but smaller stones now loose on the beach were so. Among the fragments pieces of lignite from the Tertiary formation, which there is good reason to believe underlies all this region, are quite abundant. When followed a few yards southward this boulder clay begins to show bedding and to become interstratified with hard clayey gravels composed of well-rounded pebbles. The bedding of these is undulating and rather irregular, and there is, as may be supposed, some local unconformity by erosion between the different layers. A few paces further on these become interbedded with, and are eventually replaced by, hard bluish-grey arenaceous clays, which hold only occasional pebbly layers, but contain in abundance imperfect and broken specimens of several species of molluscs, among which *Leda fossa* is the most common. A small *Cardium*-like shell and fragments of a *Balanus* were also observed, but all broken, and tender from partial decomposition.

In general appearance with their relation to the sea level, and the shells found in them, these beds resemble very closely those previously described as occurring in the vicinity of Victoria, on the south-eastern extremity of Vancouver Island.

Ten miles north of Cape Ball the last exposures of the clayey beds forming the lower part of the section were observed. The clay is here very hard, and in some places distinctly bedded, with occasional gravelly layers, but these are not nearly so prominent as in the last described localities. No shells were found, but fragments of wood partly converted to lignite—but still quite distinct in appearance from the more highly altered wood found in the underlying Tertiary formation—were noticed in several places. The junction with the overlying sands is generally sharp, and forms as before in many places an undulating plane. The sands are in thin and regular layers of pale yellowish colours, with some beds of well rounded gravel. In consequence of the undulating upper surface of the clays, these rise considerably higher above the water level in some places than in others, and where the hard clays are most largely developed, the more prominent points of the coast are found. Above both the clays and sands banks of wind-blown sand are occasionally seen in section.

In the narrow sound leading to the wide southern expansion of Masset inlet, eleven miles above Masset, at the mouth of a small stream called Watoon, are some interesting exposures probably referable to the upper part of the clay beds, or to the sands overlying them. The bank here rises about eight feet above high-water mark, its upper half being composed of regularly bedded coarse sands and fine gravels of general yellowish colour. Below this, and usually meeting it at a pretty well defined line, is a hard bluish-grey sandy clay, thickly packed with rounded pebbles, generally about the size of walnuts, but in some instances having a diameter of several inches. One small fragment of Tertiary lignite was also observed. This lower part is filled with marine shells, but all the specimens are tender and being imbedded in a hard matrix, difficult to preserve entire. Several inches of the upper part of the shell-bearing layer has been so affected by atmospheric waters, that the shells have been completely removed leaving hollow casts. This part of the bed has also been changed to a yellowish colour.

Mr. J. F. Whiteaves has examined the collection from this place, and enumerates the following species:—

Hemithyris psittacea Linn.
Modiolaria nigra Gray.
Saxicava rugosa Lamarck.
Puncturella galeata Gould.
Balanus – ?

and fragments of bivalves, which are scarcely determinable.

In several other places on this sound, similar sandy beds were seen generally when near the water level well compacted, but were not again found to hold shells. At Echinus Point, on the south shore of the first great expansion of the inlet, at low tide, a very hard sandy clay almost like stone is exposed. It is charged with pebbles and boulders, some of which appear to be ice marked.

Deposits of this character probably underlie the whole flat country between Masset Inlet and the east coast, while on the southern and western margins of the expansions of the inlet superficial deposits other than boulders, which are evidently derived from the mountains of the immediate vicinity, are wanting, and ice marking was observed in many places on the rocky sides of the valleys."

Along the north coast of Graham island, from the entrance of Masset inlet to Rose spit, an almost continuous wall of white dune sand borders the beach. In many places the dunes have migrated several hundred yards inland (Plate VII).

A curious effect of the great quantities of loose sand caused by the abrasion of these loose deposits by the waves may be seen in several creeks entering Hecate strait from the northeastern lowland. These creeks, of which only a few were examined, turn abruptly north on nearing the water and flow for some distance parallel to the shore, before entering the sea. The Tlell river is the most notable example of this, as can be seen from the map. This northward translation of the mouths of the streams is attributed to the effect of the waves caused by the heavy southeast storms which pile up the sand, and shove it northward along the shore.

CHAPTER V.

PETROGRAPHY.

INTRODUCTION.

In this chapter will be found detailed descriptions, both megascopic and microscopic, of the typical rocks found in each formation. Space limits forbid the description of each of the hundreds of specimens collected, nor would it serve any useful purpose. Instead, the specimens have been divided into groups under each formation, and the group is described as a whole.

MAUDE FORMATION.

Quartzitic Rocks. These are pale greenish and bluish light grey, very fine-grained, compact, arenaceous rocks, occurring in flaggy layers up to a foot thick, with a blocky fracture.

Under the microscope they are seen to be excessively fine-grained rocks, and much of the material is not clearly resolved. They are characterized by quartz in irregular grains, sometimes rounded, up to 0·1 mm., and also fewer grains of plagioclase. Subordinate minerals are recrystallized muscovite, together with granular calcite and matted chlorite. The texture is finely even granular, and the minerals are in part recrystallized. Alteration consists of recrystallization of argillaceous material to muscovite and chlorite, with later introduction and replacement by calcite.

Calcareous Feldspathic Argillites. Rocks best classed under this name form much of the lower part of the formation. They are well laminated, fine-grained to dense, thinly banded sediments, nearly always black or dark grey, the adjacent layers often presenting a striking appearance in weathered exposures, owing to the brilliant yellow, orange, and black colours of alternating bands. This type is referred to locally as "the ribbon rocks." These rocks are frequently highly fossiliferous, and specimens from virtually every outcrop emit a strong bituminous odour when rubbed together or struck with the hammer. On seams and on bedding planes black, hardened bituminous matter is frequently found, also in gash veins of calcite which intersect the rocks. Actual seepages of oil have not been observed from these rocks, nor from any rocks in the Maude formation.

Microscopically they are seen to consist of alternate laminæ made up of grains of varying sizes and of different materials. The calcareous bands are composed of equidimensional calcite grains with ragged outlines, as if secondary calcite had been added to them, in a matrix of fine fresh plagioclase and other, finer detritus, in part not resolved by the microscope. Pyrite occurs in minute, rounded, concretionary replacements, and brownish bituminous matter is found between the grains.

The finer bands are more argillaceous, containing fragments of oligoclase, $Ab_{75}An_{25}$ to andesine $Ab_{60}An_{40}$ in a very fine matrix, also bituminous. A little muscovite is developed, but sparingly.

These rocks are extremely dense, but the alteration is the result of induration by pressure alone, with little or no shearing, and little high temperature action.

Tufaceous Sediments. In places and especially near the top of the formation, the rocks are more thickly bedded, coarser, and tufaceous in appearance. Various shades of dark grey and green occur, and the textures vary from fine even grained, to rather coarse, unevenly fragmental. The rocks are made up of fragments of various basic effusive volcanics, feldspar, etc., and are usually more or less calcareous.

In thin section they vary considerably, and are greatly replaced by calcite, but originally they consisted of fragments of basalt and andesite porphyrites in a tufaceous matrix, with fragments of feldspar, augite, etc. Many of the porphyrites are completely replaced by granular calcite, even the albite twinning and zonal growths in the plagioclase being faithfully preserved. Chlorite in matted granular areas, and as pseudomorphs after augite commonly occurs, and also large amounts of limonite.

Slaty or Shaly Argillites. These rocks, the most highly fossiliferous of the formation, are black, carbonaceous, paper-thin, slaty shales, cleaving in fissile plates parallel to the bedding. They occur in bands up to several feet thick, and at times may be readily mistaken for some of the more indurated bands in the Haida shales. The rocks are characterized by the great number of fossils they contain, the fossils consisting of flattened impressions of the shells of ammonites and often crowding the laminæ in great profusion.

Limestones. The limestones of the southeast end of South island are provisionally classified with the Maude argillites. They consist of massive beds of light grey, partly crystalline limestone, cut by irregular veinlets of recrystallized calcite, from paper-thin sheets to 2 inches or more in thickness. They are strongly bituminous, and give a markedly foetid odour when struck.

Under the microscope the rock is seen to be made up of rounded and sub-rounded granules of calcite, averaging 0·02 mm., without any appreciable matrix. Occasional grains of detrital plagioclase are to be seen. Between the grains and in little veinlets is black bituminous matter, and this also occurs along suture-like cracks. Bitumen is almost wholly lacking in the recrystallized veins.

On the south shore of Maude island, near the top of the formation, bands of buff and grey, partly crystalline limestones occur in beds up to 8 inches thick, containing, scattered through them, groups of striated cubes of pyrite.

YAKOUN FORMATION.

Basalts.

These basalts are typically dark, purplish, or greenish, fine-grained rocks, frequently porphyritic and sometimes amygdaloidal. Their altered nature is evident, even in hand specimens, from the abundance of chlorite and other secondary minerals developed.

Some of them have been recognized as flows or sills, but many of the specimens examined were from fragments in agglomerates.

In thin sections the primary minerals seen are labradorite, varying from $Ab_{35}An_{65}$ to $Ab_{50}An_{50}$, colourless augite, magnetite, and a little biotite and titanite. Secondary minerals are abundant, chiefly chlorite and calcite, with sericite, magnetite, limonite, hematite, and perhaps serpentine and epidote. The labradorite is typically developed in equant crystals, more rarely tabular or lath shaped. The texture varies, either dense, porphyritic, intersertal, or occasionally ophitic being found. Phenocrysts of both labradorite and augite occur. Alteration is considerable, the mafic minerals usually being replaced by chlorite and calcite, in varying degrees up to completion, but the feldspars are often little changed. When amygdules occur, they are filled with chlorite, calcite, and quartz.

Augite Andesite.

The augite andesites are rocks similar to the basalts, and clearly related to them, differing only in having andesine instead of labradorite feldspar. In colour, textures, mode of occurrence, etc., they resemble the basalts.

Pyroclastic Rocks.

The bulk of the Yakoun volcanics on Graham island are bedded tuffs and agglomerates, clearly pyroclastic in their origin, and in large part accumulated under water. The lower beds of the formation are well stratified, rather fine-grained tuffs, weathering rather readily, but for the most part coarse, indurated, tough agglomerates prevail, in massive beds showing little or no stratification.

Basalt Tuffs. These tuffs vary in the hand specimen from light grey, porous rocks, to dark brownish and greenish varieties, usually very hard and dense, and clearly showing their clastic nature on the weathered surface.

Under the microscope angular fragments of basalt or augite andesite, as well as individual pieces of labradorite, augite, biotite, etc., are visible. The matrix is of finer fragments, apparently very fine volcanic material. Alteration varies greatly, and some specimens are almost wholly replaced by chlorite and calcite.

Pyrite is frequently found impregnating the tuffs.

Basalt Agglomerates. These are coarsely fragmental types, well exposed along the government road and on the shore east of Skidegate village. They are purplish and greenish, massive rocks, consisting of angular fragments of effusive types, basalt, amygdaloids, and porphyries, in a dense tufaceous matrix. The fragments sometimes attain a diameter of 5 feet, though this is not common.

These pyroclastic rocks are clearly related to the primary types occurring interbedded with them, and were derived from the same magmas by explosion instead of extrusion or injection.

BATHOLITHIC ROCKS.

Kano Quartz Diorite.

Under this head are classified a number of rocks of plutonic habit which appear to make up the bulk of the batholithic rocks of southwestern Graham island. They are in general light grey, speckled, whitish weathering, and medium even grained.

In thin section the rock is seen to be composed largely of andesine and quartz, with subordinate amounts of hornblende, perhaps orthoclase, and magnetite and titanite. Secondary minerals are biotite, chlorite, calcite, magnetite, epidote, and hematite.

In some varieties the andesine is present in two generations of crystals. The first average 1·5 to 2 mm. diameter, and are mostly equant (some of them tabular) and euhedral. In size and shape they partake of the nature of phenocrysts. The composition of this andesine is about Ab_{55} An_{45} as determined by index of refraction, optical character, the statistical method, and by measurements on Carlsbad twins and albite twinning. In addition to these twins, pericline twinning has been observed. In several instances the polysynthetic twinning after the albite and pericline laws is so complete and minute that the mineral was at first mistaken for microcline. However, the indices of refraction (about those of quartz) and the optical character negative this. Zonal structure has been noted. The centres of the larger andesine crystals are frequently more decayed than the exterior portions, but decay has not progressed greatly.

The second generation of andesine averages 0·75 mm. diameter, and is mostly tabular to equant, and sub- to euhedral. Its composition does not differ appreciably from the larger crystals, and the same varieties of twinning have been observed, though pericline twins are less common. Slightly broader albite lamellæ may indicate that the second generation of andesine is more calcic. The alteration seems less than in the phenocrystic andesine.

Orthoclase, whose determination is doubtful, if present at all is in small amount.

Quartz is up to 1·5 mm. diameter, and quite anhedral, moulded on the other crystals. It contains strings of minute doubly refracting crystals, and possesses faint wavy extinction.

The hornblende is the common variety, exhibiting pleochroism in green and yellow shades. It varies greatly in size and shape, from equant grains 0·1 mm. across to prismatic crystals 2 mm. by 0·5 mm. It is euhedral, forms the usual rhombic cross sections, and is occasionally prismatically twinned. In some specimens studied the hornblende is quite fresh, in others it is partly or wholly altered to biotite, chlorite, magnetite, calcite, and epidote.

In texture the quartz diorites vary from fine even subhedral grained to those somewhat coarser and of a porphyritic tendency. In one thin section studied the order of cessation of crystallization was magnetite (some), andesine (phenocrystic), magnetite, (most) hornblende, andesine (interstitial), quartz.

Alteration is not great, on the whole, though as noted above certain minerals have been partially attacked.

In the same region are found diorites clearly related to the quartz diorites, as they contain andesine of similar habit, similar hornblende, and titanite. Their colour is whitish grey, and the hornblende and feldspar are in nearly equal amounts. The hornblende has a strong prismatic development and is euhedral. These dioritic rocks are differentiation facies of the quartz diorite stock.

Langara Quartz Diorite.

The Langara quartz diorite is a grey, fine, even-grained, plutonic rock.

In thin section the essential minerals are seen to be andesine and quartz, with subordinate biotite and perhaps orthoclase and secondary kaolin and chlorite. The andesine has the composition Ab_{65} An_{35}, and is in euhedral to subhedral grains, showing Carlsbad, albite, and pericline twins. Zonal development has been noted. The mineral is usually fresh. Quartz is clear, forming equant irregular grains, containing strings of microscopic cavities. The biotite is characteristically changed to chlorite.

Some varieties of the rock possess an almost phenocrystic development of the andesine.

As only a small area of this quartz diorite was studied, it is impossible to say how well the above description fits the rock as a whole. The specimens from Langara island have a distinct resemblance to the Kano quartz diorites. The composition and habit of the feldspars are virtually identical, but instead of hornblende, the chief mafic mineral is biotite, which appears primary. The hornblende of the Kano quartz diorites alters to biotite, so the Langara biotite may represent a late magmatic change.

Diabase.

This is a dark, greenish grey, medium-grained rock, usually altered in appearance. In thin section it is seen to be composed of labradorite, Ab_{50} An_{50}, and a colourless augite, with accessory magnetite. Secondary minerals are usually present, and chlorite, calcite, and kaolin are greatly developed in the more altered varieties. The texture is ophitic, and augite crystals up to 3 mm. with a rectangular tendency poicilitically enclose short prismatic grains of labradorite, averaging about 0·3 mm Augite also forms smaller grains, interstitial to and wrapping around the labradorite.

HAIDA FORMATION.

Coarse Quartzose Sandstone. This rock, a typical variety occurring near the base of the formation, is light yellowish buff medium to coarse-grained, and disintegrates readily. It is characterized by a large percentage of well rounded, milky quartz grains with a few dense black rock fragments.

Under the microscope its composition is seen to be quartz and white chert, with a good deal of decomposed plagioclase, and fragments of the argillites of the Maude formation and the Yakoun volcanics cemented by chlorite and argillaceous matter stained with limonite.

Feldspathic Arkoses. The arkoses are green, fine to medium grained, fairly hard rocks, and make up a large part of the formation.

In thin section the minerals are seen to be: quartz, in angular to sub-rounded grains, generally less than 40 per cent of the fragments; almost as much plagioclase as quartz, usually fresh, and quite angular, ranging from oligoclase to labradorite; chlorite and calcite in grains, augite, biotite, and decomposed rounded fragments of the Yakoun basalts. Chlorite and calcite form the cement. Glauconite may be present, but could not be distinguished from chlorite. Pyrite is sparingly found, probably as an impregnation. The textures are usually fine, grains averaging from 0·15 mm. to 0·25 mm., and the rocks are on the whole moderately well sorted.

Quartz Sandstones. Some of the finer, more massive sandstones are largely composed of quartz fragments.

Under the microscope, besides quartz, appreciable amounts of plagioclase, biotite, augite, chlorite, etc., are seen to be present. The cement is usually calcite, with a small amount of argillaceous matter and chlorite. These rocks are more even grained and better sorted than are the arkoses.

Tufaceous Sandstones and Breccias. In the lower part of the formation beds composed almost exclusively of fragments of the Yakoun volcanics are found. They are poorly sorted, and the fragments are often very angular, usually less than an inch in size, and embedded in varying proportions of a tufaceous matrix.

As seen in thin section, these rocks are not so compact as the agglomerates from which they were formed, and there is more calcite, limonite, and chlorite present. Fragments of various basalts, usually decomposed, make up the bulk of the rock, with pieces of augite, altered plagioclase, biotite, etc., in a chloritic matrix of finer detrital volcanic material. These rocks are plainly the product of rapid weathering and hasty deposition, and give little evidence of transportation.

Carbonaceous sandstones have been seen—soft black rocks, containing finely divided carbonaceous sediment.

SKIDEGATE FORMATION.

Sandstone. The only specimen examined microscopically from the Skidegate formation was one from the basal beds of dark reddish, grey, uneven-grained sandstones. In thin section, angular quartz, with some plagioclase and decomposed volcanic rocks, was seen to be embedded in a granular calcite matrix and calcite also replaces feldspar in some instances.

The shales found in the formation are fine, dark grey to black, massive, and banded carbonaceous rocks.

ETHELINE FORMATION.

In composition the Etheline formation, which consists only of injected rocks, ranges from dacite to augite andesite.[1] All the types are represented as dykes, and all but dacite as sills. Basalt dykes occur on Graham island, but their general appearance and lack of alteration indicates that they belong to the later Masset formation which is almost wholly basaltic, so far as is known.

Dacite. The dacites are dense rocks of light grey colour, showing green, blue, and more rarely pink tints, and virtually all characterized by yellowish or brownish weathering. They are porphyritic in places. Phenocrysts occur in some of the rocks in small amounts, and are usually chalky white plagioclase, under 5 mm.; more rarely they are quartz. Small, irregu-

[1] The sill and dyke rocks of Graham island were first described petrographically by C. H. Clapp (Geol. Surv., Can., Sum. Rept., 1912, p. 25). He supposed them to be connected with the effusive types, so did not use the nomenclature proper to their position as hypabyssal rocks. It has seemed preferable to retain the original nomenclature, rather than to cause confusion by introducing such names as "granodiorite-porphyrite," "diorite-porphyrite," etc., for rocks here called "dacite" and "andesite" respectively.

lar replacements of white calcite are frequently seen, and most of the dacites are impregnated by finely divided pyrite.

Under the microscope the essential minerals are seen to be andesine and quartz, with subordinate augite and rarely magnetite, biotite, and apatite. Secondary minerals are, chlorite and calcite in large amounts, kaolin, sericite, and an irregular scaly alteration product which may be zeolitic. The andesine is, without exception, greatly altered to kaolin and sericite, so that a close determination of its composition is not practicable; it is lath shaped with irregular ends, and averages less than 1 mm. long. Quartz is not very abundant, usually from 10 to 15 per cent, and is in anhedral grains, interstitial to the andesine. A matrix of fibrous, radiated, and scaly, pale green, faintly pleochroic chlorite surrounds the andesine and quartz. This is an alteration product from the original mafic mineral, not a trace of which now exists. As augite occurs in the closely related andesites, it is probable that it was the mafic mineral in the dacites also. The change to chlorite and the recrystallization have been so complete that the original relations of the augite and andesine are obscured. The dacites are completely crystalline, and the lath shaped, occasionally tabular, andesine is divergently arranged in the matted chlorite matrix. Alteration is extreme in every rock examined and the great development of chlorite, the alteration of the feldspars and impregnation by pyrite, afford evidence of strong hydrothermal action on these dykes.

Quartz Bearing Andesite. These rocks are very similar to the dacites, differing from them only in containing a smaller amount of quartz. They are clearly transitional between the andesites and the dacites.

Andesite. Andesite is the most abundant type represented among the injected rocks. The andesites are closely related to the dacites and resemble them in texture and colour, the same varying shades of grey being seen. Some of the andesites are porphyritic, and amygdaloids are occasionally found, both in dykes and sills.

In thin section the essential minerals are andesine, forming 60 to 80 per cent of the rock, and augite. Subordinate minerals are magnetite and apatite; and secondary chlorite, calcite, sericite, kaolin, and the probably zeolitic mineral noted in the dacites, occur. The andesine varies from $Ab_{65}An_{35}$ to $Ab_{60}An_{40}$, is often almost unaltered, and has a lath shaped, divergent habit as in the dacites. The augite is often considerably altered to chlorite, but much less so than in the dacites. Completely crystalline, finely granular, intersertal textures prevail, the augite in small equant grains being interstitial to the divergent laths of andesine or, it may be, in some cases including them poicilitically. Pyrite and calcite impregnations are common.

Andesite Porphyrite. These rocks are very similar to the andesites, differing only in texture. They have been observed as dykes only. Phenocrysts of chalky white, equant, euhedral plagioclase occur and make up in some cases 10 per cent of the rock.

Examined under the microscope, the phenocrysts are andesine, greatly altered to calcite, kaolin, and sericite embedded in a groundmass resembling the nonporphyritic andesites in composition and texture, except that in some cases it is almost a devitrified glass. Ilmenite and leucoxene have been noted.

The thick sills, some of them possibly laccoliths, that occur near the uppermost exposed beds of the Skidegate formation south of Lake Stanley, are mostly andesite porphyrite. They are light, bluish-grey rocks, with phenocrysts forming a much higher proportion of the rock than usual. One of them, studied in thin section, vas found to contain euhedral to subhedral phenocrysts of andesine, $Ab_{55}An_{45}$ (about 20 per cent of the rock) in a groundmass composed of more acid andesine, $Ab_{60}An_{40}$ (about 60 per cent of the rock) the rest being augite almost wholly altered to chlorite.

On the whole, the alteration of the andesites and andesite porphyrites, while considerable, is much less marked than in the more silicic dacites. Much of the andesine is scarcely altered at all and many rocks contain fresh colourless augite.

Augite Andesite. The augite andesites are usually porphyritic rocks, with phenocrysts of chalky white plagioclase or augite in a finely crystalline grey, greenish, or dark grey groundmass. Phenocrysts in some cases make up as much as 15 per cent of the rock

Examined microscopically, andesine or andesine-labradorite and augite are seen to be the essential minerals; sometimes phenocrysts of labradorite are found. Apatite occurs in small amounts, and chlorite, calcite, sericite, kaolin, etc., are the secondary minerals. The andesine is as calcic as $Ab_{55}An_{45}$, approaching labradorite, and some of the labradorite phenocrysts have the composition $Ab_{45}An_{55}$. The plagioclase is only slightly altered, and the augite, which is colourless, is often quite fresh. Alteration is much less noticeable than in the andesites and dacites.

Biotite Andesite Porphyrite. Rocks classified under this type were found only in two localities, on upper Hidden creek, where it is probably intrusive, and in the vicinity of Parry passage, where a very large dyke of this rock forms all of Lucy island, Cape Knox, and probably the reefs far to the west of Cape Knox.

The rock from Hidden creek is a light greenish-grey porphyry with about 10 per cent of plagioclase phenocrysts up to 4 mm. and averaging 2 mm. in diameter, and a few, scattered, dark brown phenocrysts of biotite.

Studied under the microscope, the phenocrysts prove to be calcic andesine and biotite in a groundmass made up of finely crystalline plagioclase laths, presumably andesine, with a small amount of chloritic material. The composition of the plagioclase phenocrysts is andesine, near labradorite, $Ab_{55}An_{45}$, and they are much replaced by kaolin and calcite. The phenocrysts of biotite are euhedral and of varying shapes, some rectangular, others rounded-hexagonal, triangular, etc. They vary in size up to 2 mm., but are mostly smaller. The fresh crystals are strongly pleochroic, pale green to deep brown, and have a very small axial angle, with an almost uniaxial interference figure. Most of the biotite is completely altered to a very finely granular greenish substance, probably chloritic, with disseminated magnetite dust. Various stages of alteration are present, but the change is usually abrupt, varying amounts of fresh biotite lying in abrupt contact with the granular chlorite.

The rock from Parry passage is a light grey porphyry, with brown biotite phenocrysts of ragged outlines and up to 2 mm. across, forming less than 10 per cent of the rock.

Under the microscope the biotite is strongly pleochroic, and often partly replaced by chlorite, and phenocrysts of sodic andesine also occur. Augite is very rarely found as a phenocryst. The groundmass is probably andesine, apparently slightly more calcic than the phenocrysts, and is considerably altered to chlorite and calcite. Apatite and magnetite are accessory minerals.

In composition, texture, and alteration this rock shows its kinship with the Etheline intrusives.

General Petrology. The Etheline formation is characterized by a complete gradation from dacite to augite andesite—a rock near a basalt in composition—and the series possesses a few peculiarities common to all the types. The textures of the rocks are remarkably similar and are in sharp contrast to the textures both of the Jurassic Yakoun volcanics, and of the later Tertiary Masset flows. The minerals forming the rocks are strikingly similar, and a complete gradation of plagioclase feldspar of similar habit is observed. The augite is very much the same throughout the series. The consanguinity is shown not only in the presence of certain minerals, but in the absence of others. Thus, biotite has been noted in three instances only and hornblende in one only. Subordinate minerals are characteristically rare. Magnetite, ilmenite, and apatite only have been noted.

The general family resemblance of the rocks is also shown in their alteration. The characteristic change is a chloritic replacement of augite, and a replacement of the minerals and rocks as a whole with calcite. Impregnations with finely granular pyrite are also characteristic.

Alteration. A striking feature of the Etheline formation is the progressive alteration exhibited, this being greatest in the most silicic rocks, the dacites, and uniformly becoming less as the sub-silicic end of the series is approached. There are, of course, exceptions; but the general rule seems to hold for most of the specimens studied.

The very great alteration of augite and other ferro-magnesian minerals to chlorite, in these Tertiary intrusives, is a strong indication that processes more intense than usual have affected them. This is the more apparent when we recall the small degree of alteration undergone by the very much older Yakoun basalts.

The evidence bearing upon the question, what these processes probably were, may be summed up here.

The noticeable amount of superheat in many of the intrusives at the time of their injection is proved by the strong baking action they have had on the enclosing sediments, as well as by the very fact of the occurrence of thinly tabular bodies in a highly liquid condition (Figures 7, 8, and 9) so far from their sources.

The finely divided pyrite, found as impregnations—that is replacements—in the dykes and sills and in the adjoining rocks, for instance, the pyritic nodules near the intrusives, is evidence of the presence of hot pyritic solutions.

Finally, the great development of chlorite is to be considered. While chlorite can doubtless be formed under rather low temperature conditions, its frequent occurrence in high temperature ore deposits[1] and in chloritic schists shows that its formation readily takes place under rather high temperature conditions.

The great degree of alteration of the feldspars in the Etheline intrusives, compared with the less degree of alteration of the same mineral in the much older Yakoun volcanics indicates also that the Etheline rocks are exceptionally affected.

With the above facts in mind, the decomposition of the rocks of the Etheline formation is best explained by supposing them to have been acted upon by large amounts of heated magmatic water which may well have been wholly or in part in gaseous form.

MASSET FORMATION.

The Masset formation is wholly basaltic except for a single occurrence of a trachyte of bostonitic habit, an unusual rock type. Wherever examined, with this single exception, basalts of all varieties of texture, both primary and pyroclastic, were

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[1] Lindgren, W., "Mineral deposits," McGraw-Hill Book Co., New York, N.Y., 1913, pp. 617, 627, etc.

Spurr and Garrey, Econ. Geol. vol. 3, 1908, pp. 688-725.

McConnell, R. G., "The Whitehorse copper belt, Yukon Territory," Geol. Surv., Can., 1909, pp. 21, 22, 23. (In this case the clinochlore is clearly a primary mineral.)

encountered, piled up in a great succession of flows and in agglomerate and tuff beds, over 5,000 feet thick, and covering an area of over 1,000 square miles.

The various types of basaltic rocks examined in thin section can be considered only as samples of the formation, although their unvarying composition is good testimony to the general homogeneity of this great mass of volcanics.

Basalt Dykes. Basalt is rare as an injected type, but a few dykes have been noted. They are dark grey, very finely crystalline rocks.

Under the microscope the essential minerals are labradorite and augite, with subordinate magnetite, and secondary chlorite and calcite. The labradorite has the composition $Ab_{40}An_{60}$, and is in sharply crystallized, lath shaped, and tabular finely twinned forms. It forms about 60 per cent of the rock, averages 0·12 by 0·04 mm. in size, and is very fresh. The augite has a violet tinge, and is faintly pleochroic. It is usually fresh, but is occasionally altered to chlorite. Magnetite forms individual grains, and is often in parallel and reticulate strings of octahedra. The texture is intersertal, the augite in small equant grains filling the interstices between the labradorite laths. Labradorite and augite crystallized in part simultaneously, but the latter kept on forming after the labradorite had ceased to grow.

Both in composition and habit the dyke basalt is clearly related to the effusive basalt, and the dykes are doubtless the feeders for the flows, in part at least.

Basalt Flows. These flows are fresh-looking rocks, varying in texture from almost vitreous to very finely, but distinctly granular. This type is of very wide distribution and, with the basalt porphyrite, makes up by far the larger part of the formation.

Under the microscope the essential minerals are labradorite and augite, with subordinate magnetite and perhaps olivine. Some rocks contain small amounts of residual glass, and these form a link with the vitrophyric type. Secondary minerals are chlorite, calcite, kaolin, limonite, hematite, epidote, and probably serpentine. The labradorite is usually in sharply crystallized, unaltered, rectangular laths, from 0·05 by 0·005 mm.

to 0·5 by 0·07 mm., finely twinned after the albite law, sometimes after the Carlsbad as well. It forms from 40 per cent to 85 per cent of the rock. Augite is colourless, pale greenish or violet, faintly pleochroic or not at all. It is often almost entirely unaltered. In some rocks it varies greatly in size from 0·02 mm. to 1·5 mm., the larger grains being oikocrysts poicilitically enclosing chadacrysts of labradorite. The smaller grains are interstitial between the feldspars. Alteration of the augite, when present, is to chlorite, calcite, and finely granular magnetite. Augite makes up 15 to 30 per cent of the rock. Primary magnetite (ilmenite?) is in considerable abundance in some specimens, in single and grouped euhedral grains.

The texture is in most cases intersertal, but in some it is ophitic, and others exhibit both fabrics. In all cases a marked fluidal development of the labradorite laths is manifested, even in the poicilitic basalts the labradorite chadacrysts in the augite oikocrysts being arranged parallel to the general direction of flow.

Basalt Porphyrite. Several varieties of this type of flow rocks have been studied, which vary only in texture. In the field they are black or dark grey, heavy rocks, differing in the amount of phenocrysts they contain, and in the granularity of the groundmass, which ranges from glass (forming the vitrophyre, a variety described below) to distinctly, though finely crystalline.

In thin section labradorite appears as a phenocryst, usually accompanied by augite, in a groundmass composed of the same minerals with magnetite (ilmenite). In some cases, badly altered grains, of the general size of the phenocrysts, are seen, which were probably originally olivine. The labradorite varies in size from 0·25 mm. to 1·0 mm., and is frequently equant, though sometimes tabular. Its composition is from $Ab_{30}An_{70}$ to $Ab_{40}An_{60}$. Augite is generally smaller than the feldspar phenocrysts, and is usually equant and euhedral. In many rocks the phenocrysts have a marked glomeroporphyritic tendency. The groundmass consists of labradorite and augite with magnetite, the feldspar being typically lath shaped and often arranged in marked flowage lines, while the augite is usually equant and intersertal, indicating crystallization after flowage had ceased.

Alteration varies in these basalt porphyrites, some being almost wholly unaffected while others have cloudy feldspar and chloritized augite. Decomposition is never comparable with that in the Etheline volcanics.

In the thin section made from one of the basalt porphyrites collected by C. H. Clapp, several of the labradorite phenocrysts exhibited a peculiar regular mottling, the cause of which is not clear.

The phenocryst best exhibiting this mottling is cut nearly normal to 010 and 001. The composition is $Ab_{30}An_{70}$ (determined by index of refraction, optical character, and by the statistical method). It contains numerous inclusions of augite up to 0·3 mm. long, usually under 0·1 mm., and generally altered to chlorite and magnetite.

The peculiar mottling consisting of connected, rectangular or square areas, and forming a net work throughout the section, gives the impression of a crystalligraphically intergrown substance. This substance has a slightly higher index of refraction than the rest of the phenocryst, and is probably plagioclase, more calcic than $Ab_{30}An_{70}$. No satisfactory explanation of this unusual texture in labradorite occurs to the writer.

Basalt Amygdaloid. Amygdaloids are of frequent occurrence in various parts of the Masset formation, and are most interestingly developed at Tian point, on the west coast where highly amygdaloidal basalts have the cavities filled with chalcedony, quartz, calcite, and black sticky tar, the latter a substance of great rarity in such a connexion. These rocks have not been studied in thin section owing to the unfortunate loss of the specimens by shipwreck, but their field appearance is that of the ordinary basalt as described above, modified, of course, by the texture. They are further treated of in the description of the tar occurrence in the chapter on "Economic Geology."

A specimen of basalt amygdaloid, collected from a talus at the foot of a high cliff of flows on Tarundl creek, is a light greenish altered looking rock, composed of about 5 per cent of somewhat elongate, fluidally arranged amygdules up to one-half inch long and filled with chlorite, calcite, and common opal.

In thin section the essential minerals are plagioclase and augite, both greatly altered, though with the habit of those minerals as in the other basalts. Secondary minerals are chlorite and calcite in large amounts, limonite, sericite, kaolin, etc. The texture of the massive portion of the rock is very finely granular and the alteration, in contrast to the other basalts, is great.

A boulder found in the Baddeck river consists of a dark green, highly amygdaloidal rock, crowded with spherical amygdules of chlorite, some of them concentrically arranged.

Under the microscope, the original minerals of the rock are seen to be entirely altered and recrystallized to a finely granular mass of euhedral to subhedral epidote and chlorite. The amygdules originally filled with chlorite have been recrystallized and are more intimately bound up with and gradaal into the solid portion of the rock. Not a trace of any primary mineral was noted. Besides epidote and chlorite, limonite and probably magnetite dust occur. The alteration is, of course, extreme; and it is significant that the only cases of considerable alteration seen in the basalts have taken place in these, originally porous rocks. The high degree of recrystallization in this rock, which is probably a surface flow, is evidence that hydrothermal action acted in an especially severe manner; and the rock may belong to the Yakoun formation, though found in an area underlain by Masset basalt flows.

Quartz Basalt. A specimen collected from the east shore of Yakoun lake is remarkable on account of the quartz it contains. It is a grey, dense rock.

In thin section, labradorite and augite are the essential minerals, with subordinate quartz and magnetite. The usual calcite, chlorite, etc., are found secondary. The labradorite forms laths with irregular ends, averaging 0·4 by 0·05 mm. The mineral is so unaltered that only a little kaolin has been noted. The augite, on the other hand, is virtually all altered to a scaly and granular mass of calcite with a little chlorite. Quartz is found in equant, irregularly anhedral grains, filling the last spaces left by the crystallization of the other minerals. Into these spaces the ends of the other minerals projected and are now surrounded by quartz. The quartz is estimated to form nearly 5 per cent of the rock.

Tachylyte. This rare[1] type, a glassy basalt, was found forming fragments in an agglomerate on the west side of Ship Kieta island in Masset inlet, and fragments were found in streams entering Athlow bay on the west coast. A large mass of it is reported to occur on the west side of Juskatla inlet.

The tachylyte is a black, glassy rock, with a brilliant lustre, speckled with white, rectangular phenocrysts of feldspar up to a millimetre in size.

In thin section the phenocrysts are seen to be labradorite, about $Ab_{40}An_{60}$, in euhedral, equant, and tabular forms, quite clear and unaltered. Carlsbad twins are combined with albite twinning. A few phenocrysts of fresh augite are also present. The groundmass is a brownish, perfectly isotropic glass, containing disseminated grains of a fine black mineral, probably magnetite, and extremely minute, hair-like crystals, probably feldspar. The phenocrysts exhibit a glomeroporphyritic tendency. The alteration of this rock is very slight indeed, which is remarkable considering its unstable condition as a glass.

Tuffs are abundantly represented on the west coast and are of several varieties, some of which are described in the part of the chapter on "Economic Geology" treating of the bituminous rocks in the Masset formation.

Basalt Tuff. On Baddeck river, the Masset flows contain a number of bright, brick-red, intercalated beds, most of which are tuffs. The specimen examined is a mottled, bright and dark red, very dense highly ferruginous rock, clearly of clastic origin.

Studied in thin section, it is seen to consist of sub-rounded fragments of dense and vitreous basalts, containing phenocrysts of labradorite closely crowded together. Fragmentary fresh andesine occurs. The whole rock is permeated and in part replaced by hematite, giving the red colour and rendering the rock almost opaque in thin section.

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[1] Harker, A., "Petrology for Students," Univ. Press, Cambridge, 1908, p. 207.
Iddings, J. P., "Igneous Rocks," vol. 1, Wiley and Sons, New York, N.Y., 1909, p. 378.

Trachyte. On the west side of Harrison island, in Juskatla inlet, prospecting work has been done on a large mass of light coloured, variegated, dense rock, occurring intercalated in the basalt flows and agglomerates, which form the remainder of the island. The rocks of the vicinity strike north 45 degrees east and dip 70 degrees southeast, in some places slightly contorted, and the mass of light coloured rock is clearly interbedded with them. Where it has been blasted, 30 feet of the bed is visible with no indication of the total thickness. Mr. Arthur Robertson, owner of the claim, reports that the rock outcrops over an area several hundred feet wide, crossing the island in a southerly direction, so that the thickness and lateral extent may be considerable.

The rock varies in appearance in the field. In general, it is light, creamy white, chalky white where weathered, and pale bluish or pale sea green where apparently quite fresh. A marked characteristic of the coloration is the reddish irregular mottlings which extend throughout the rock in all directions, and make up varying proportions of it at different places. This colouring varies from a chocolate red to a light brick red. On joint planes are brilliant yellow stains of limonite.

The rock shows various gradations in texture from very dense to fairly porous; and much of it shows a variable lamination suggestive of flow-structure. The reddened areas mentioned above are to some degree controlled by this banding. In various parts of the rock are small cavities, usually under one-fourth of an inch across, and of no particular regularity of shape, which are lined with minute crystals and, in rare instances, spherical concretionary masses of chalcedony have been noted in them. Disseminated sulphides, like marcasite, are found sparingly.

In general appearance the rock in the field is like a cherty sediment or silicified tuff, and its true nature was not suspected until a microscopic study was made. The silicified or cherty appearance of the rock is enhanced by a slightly vitreous lustre.

Studied in thin section the rock is seen to be composed almost wholly of feldspar, which is apparently orthoclase. The texture of the rock is distinctly trachytic, and very fine-grained, the laths of feldspar averaging 0·03 by 0·003 mm. in size. They have parallel sides, and indefinite, irregular ends. They show parallel extinction; and crushed fragments were determined by the immersion method in liquids of known indices of refraction to have indices very close to those given for orthoclase. Scattered phenocrysts of orthoclase have been noted, up to 0·5 mm. by 0·4 mm. Besides orthoclase, a minute grain of a mineral that may be augite was noted in thin section, also small amounts of what appears to be pyrite, in very minute, sometimes cubic grains, frequently arranged in bead-like strings up to 0·03 mm.

Viewed with a binocular microscope, the cavities are seen to be lined with tabular, clear crystals which apparently are feldspar. When these crystals, which are not over 0·25 mm. across, are crushed and observed with the polarizing microscope, they are seen to be microcline, with excellent grating structure, and enclosing minute reddish and deep orange grains of hematite. In these cavities, which are miarolitic in their nature, is also found a colourless, almost isotropic mineral with poor or no cleavage, and an index of refraction considerably less than 1·495. This may be sodalite or analcite.

The texture as seen in thin section is also interesting. The main mass of the rock has the typical divergent texture of the bostonites or trachytes, markedly fluidal in the slides studied. Sections cut from parts of the rock full of the miarolitic cavities show these to be of all shapes and sizes, ranging from a slight disturbance of the usual even-grained texture to a cavity several millimetres in diameter. These cavities are lined with an encrusting rim made up of radial fibres, inside of which a vacant space occurs, or the space is in some cases filled with feldspar or the mineral noted above as being probably analcite or sodalite. The encrusting radial rims are probably needles of orthoclase or microcline. One or two instances of spherulitic development have been noted, as well as an extension of the radial rims into plumose growths.

The minerals are almost absolutely fresh. The only decomposition noted was a slight oxidation of the pyrite in specimens near the surface. The reddish colouring of the mottled areas appears to be due to submicroscopic matter, probably hematite, enclosed in the feldspar.

The mode of occurrence and texture of this rock indicate that it is a flow, and not an injected type. In composition and texture it is decidedly of the bostonite type.

The name bostonite has been used by Rosenbusch[1] for a dyke rock, but the type occurrence, at Marblehead Neck, near Boston, Massachusetts, is considered by some of those who are familiar with the locality to be an effusive and not an intrusive rock.

In the absence of analyses, it seems best to designate the rock by the more general term trachyte, and to call attention to its bostonitic habit and probable composition.

Where prospected, the trachyte is reported to carry values in gold. No free gold was seen and samples of the exposure were unfortunately lost.

The occurrence of this alkaline rock in the midst of a great basaltic series is analagous to the bostonite found in the Island of Skye.[2]

ORIGIN OF THE TERTIARY IGNEOUS ROCKS.

The Tertiary igneous rocks of Graham island exhibit certain relationships that throw light on their origin, and on the history of the magma from which they were derived. These igneous rocks are naturally divisible into two series; the earlier Etheline intrusive rocks, and the later Masset effusive and explosive types. Some of the facts in regard to these Tertiary rocks are summarized below, and a discussion of them follows.

In the intrusive rocks of the Etheline formation dacite has been found only as a dykerock, and never as a sill. Andesite forms both dykes and sills, the former in much larger number. Basalt has not been recognized in this formation, for all the basalt dykes that occur in association with it show marked affinities with the Masset rocks.

The rocks of the Etheline formation are all highly altered types, differing in this respect from the Masset formation even more than their greater age would lead one to expect. The period of eruption of the Masset formation, which is almost

[1] Rosenbusch, H., "Elements der Gesteinslehre," 1910, p. 269.
[2] Harker, A., "Tertiary Igneous Rocks of Skye," 1904, pp. 327, 239-290.

wholly basaltic, was separated from the earlier more silicic intrusions by a considerable lapse of time during which the Skonun sediments accumulated.

The Tertiary volcanics are believed to have originated by processes of magmatic differentiation in a sub-crustal reservoir, and from that source to have been intruded into the upper portions of the crust, finally reaching the surface. The facts given under the preceding heading are best explained by this hypothesis, which we may now elaborate somewhat.

The consanguinity of the various types of the Etheline intrusives, which is evident from the descriptions given, indicates a common parent magma which seems to have been an olivine free basalt of felsic nature. This common parent magma is supposed to have differentiated by gravitative adjustment so that a gradational stratified condition was reached, with dacites at the top, underlain by andesites, in turn resting on basalts. This differentiation and stratification took place during the long period of quiescent subsidence during which the Cretaceous sediments were accumulated. The movements causing the folding of the sediments disturbed the equilibrium of the magma chamber and part of its filling was injected into the roof. The intrusions began gradually, consequent on the slow but powerful forces deforming the region and extended over a considerable period, as shown by the folding of sills and dykes with the Queen Charlotte series. The first material to leave the chamber was the uppermost dacite magma, and this was forced into the first cracks penetrating the crust. It will be recalled that dacite occurs only as dykes. There are a number of reasons for this: first, the marginal rock was the coolest or possessed the least degree of superheat and, therefore, was most viscous and incapable of penetrating to the surface; second, the silicic character of the magma would render it viscous; third, the first fissures may well be supposed to have been of less magnitude than the later ones; and fourth, the surface was at a greater distance in this early period of intrusion owing to a less amount of erosion having taken place. In the case of the andesites, the same causes operated but in less degree; so we have many andesite dykes and some sills, necessitating a more superheated rock. The greater number of andesites is what would be expected according to the hypothesis of differentiation from a basalt or an augite andesite magma.

The tapping of the upper portions of the magma chamber seems to have sufficed to relieve the pressures that tended to cause eruption; so that a quiescent period of considerable duration ensued during which the Skonun formation accumulated. Then came an era of tremendous volcanic activity and explosions and effusions of lava took place in great number. During this period the main basaltic sub-crustal reservoir was in direct communication with the surface.

It is thus seen that the various igneous rocks of the Tertiary period may best be explained as the result of magmatic differentiation by gravitative adjustment. This general explanation, however, does not suffice to explain the exceptional alkaline trachyte associated with the basalts of the Masset formation; and it can only be said here that owing to its unique occurrence in the series, and its relatively small volume, it is apparently a local differentiate, in, or near a vent. That it was near a vent is indicated by the tachylyte as well as the agglomerates found in its vicinity. Surrounded as it is by enormous masses of basalt the field relations of this trachyte afford further proof that it is a differentiate of the basaltic magma.

CHAPTER VI.

STRUCTURAL GEOLOGY, HISTORICAL GEOLOGY, AND CORRELATION.

STRUCTURAL GEOLOGY.

Folding. The structure of the Queen Charlotte series has already been discussed in some detail in the description of those rocks. A more general treatment of the structural features of the district as a whole follows.

The pre-Cretaceous rocks are affected by a series of folds with a general strike of north 30 degrees west, corresponding with the trend of the islands south of Skidegate inlet. The general structure of these rocks is not wholly evident, as the Cretaceous and Tertiary covering obscures them, but there is good evidence that they are disposed in a broad, major anticline, with the above strike. The central part of this anticline is occupied by the Maude argillites, which are flanked on both sides by the overlying Yakoun volcanics. This general anticlinal structure is complicated by many smaller folds, especially in the less competent argillites of the Maude formation. These thin bedded and relatively plastic rocks readily yielded to deforming stresses, and were bent into close, often isoclinal folds. While the information is meagre, it is the writer's opinion that the folding on a major scale was not as intense as might be imagined from a study of locally plicated areas of the argillites. These fine-grained beds, although thin, are remarkably uniform over wide areas, and, as already explained, allowed stresses to accumulate to a certain point, when zones in the argillites were intensely deformed, giving the close folding already described. In these argillites the type of folding is that termed parallel. In the massive, more competent volcanics, the strains caused shear zones and faults, instead of folds. The orogenic movements causing the upheaval and deformation of these rocks manifested themselves as compressive stresses acting in a direction north 60 degrees east, and may be correlated with the disturbance concomitant with the intrusion of the upper Jurassic batholiths of the Coast ranges.

The subsequent erosional shaping of the uplifted mountain ranges of the upper Jurassic caused valleys to form parallel to the folds, that is, with a general north 30 degrees west direction; and it was in these valleys, after their subsidence and invasion by the sea, that the Cretaceous sediments were accumulated. Erosion has now laid bare once more portions of the upper Jurassic land-surface where Cretaceous sediments rest on pre-Cretaceous rocks, and it is evident that the outlines of the basins of Cretaceous rocks are controlled largely by the topographic depressions of upper Jurassic time.

The general strike of the folds in the Cretaceous synclines is not, however, parallel to the outlines of the basins. A parallelism of internal strike and general outline holds near the margins of the synclines, where they rest on the older rocks, but the main folding inside the synclines is in a direction only a few degrees west of north, at an angle of 20 to 30 degrees with the direction of the earlier folds. It is thus clear that the orogenic forces causing the second mountain building period recorded in the rocks, acted in a more nearly due easterly direction than did the first forces. The evidence of the dyke filled fissures in regard to the divergence in direction of these two stresses will be later mentioned. This second mountain building period may be correlated with the Laramide revolution, as it uplifted rocks of Upper Cretaceous age. A third period of folding affected the island after the Masset formation had consolidated. The date of eruption of the Masset rocks has been placed in the Pliocene, so that this folding probably took place in the late Pliocene.

The direction of the stresses causing this folding has not been thoroughly worked out, but many of the folds seen run more nearly east and west than those in the pre-Tertiary rocks, and these stresses may well have acted from a southwest or southerly direction.[1]

Faulting. A considerable amount of faulting accompanied

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[1] Compare the east-west axes of Tertiary folding in southern California. Arnold, R., U.S. Geol. Surv., Bull. 321, 1907, Plate 1.

Arnold, R. and Anderson, R. M. U. S. Geol. Surv., Bull. 322, 1907, Plates 1 and 7.

each deformation of the rocks of Graham island. The earliest recognized fault is the one which forms the western boundary of the Queen Charlotte series at South point in Skidegate inlet. This fault is clearly in evidence on the east side of the point, where Honna conglomerate is in close juxtaposition to the Maude formation, proving an easterly downthrow. It is not clear whether the fault is normal or reverse, but it is probably normal. The direction is somewhat conjectural, but the fault may well be the same one that affects the coal seam at the old Cowgitz mine, and it has been so mapped. Cutting this fault and displacing it, and, therefore, later than it, is an east-west break, the effects of which are plainly visible from Steep point to Lina narrows. This is probably a normal fault with a northerly downthrow, and in its westward continuation may pass through the marked east-west valley between the mouth of Long arm and North arm.

In the vicinity of the mouth of Slatechuck creek there are areas of the Maude formation which bear relations to the later sediments that can be most readily explained by the faults shown on the map. By this assumption of a fault block of the Maude in the lower Slatechuck valley the absence of the Honna conglomerate in this vicinity is explained.

A fault with a general east-west direction crosses the southeast end of South island. It has a northerly downthrow, bringing Haida shales sharply against the Maude formation, and, therefore, may be of considerable displacement.

The attitudes of the formation on Nose point and on the adjacent ends of Maude and Lina islands are best explained by supposing a normal fault to occur in the Channel between these islands and Nose point. This fault has apparently a direction a few degrees west of north, and a westerly downthrow of about 500 feet.

Faulting in the interior of the island is almost impossible of detection on the surface on account of the rarity of exposures. On a minute scale the flaggy argillites of the Maude formation are known to be extensively fractured, and minor faults have been detected in prospect openings at various places in the Haida formation of the Queen Charlotte series.

From the foregoing description of the faults that occur there, it is apparent that Skidegate inlet is an area of marked fracturing mostly east-west in direction, and with considerable downthrows to the north. For this reason the inlet forms, in general, a geological boundary between the pre-Cretaceous rocks of the southern islands of the Queen Charlotte group and the Cretaceous and Tertiary rocks of Graham island. The division is not complete, for small areas of Cretaceous rocks are found on the northern end of Moresby island, and rocks of the Vancouver group are the surface formations over portions of Graham island.

Jointing. There is no apparent regularity in the directions of jointing affecting the rocks. They are broken by planes in great number and at all azimuths, and on account of the limited size of the exposures major jointing cannot be distinguished from minor breaks. A significant clue to the directions of major jointing is obtained, however, from the directions of the many dykes cutting the rocks. It may fairly be supposed that these dykes occupy fissures extending to great depths, which may be considered the major joints of the region. Of the many hundred dyke-filled fissures only a few have been recorded, but in these few there is a coincidence of direction that is deemed worthy of remark. This coincidence consists of a marked grouping of strikes about four principal directions, so that, in virtually every instance, a dyke may be referred to one of these four directions. The relations are shown in Figure 10, and it is evident that there are two sets nearly at right angles, the resultants of one set striking north 24 degrees west and north 76 degrees east, and of the other set, north 53 degrees west and north 45 degrees east. In explanation of these relations it is suggested that each set represents strike and dip joints nearly at right angles, and that the two sets are caused by the two periods of severe orogenic movement which affected the region before the intrusion of the dykes. It is true that the direction of the two resultants of the strikes of the dykes are not parallel to the general strike of pre-Cretaceous and post-Cretaceous folds; but it is significant that the resultants are separated by the same angular distance, 30 degrees, that separates the general directions of the two periods of major folding. The fissures are thus not strictly parallel to the general strike of the pre-Cretaceous and post-Cretaceous folding; but it should be pointed out that the dykes plotted are nearly all from the vicinity of Skidegate inlet, and there is reason to suspect a bending of the folds towards the west in this region.

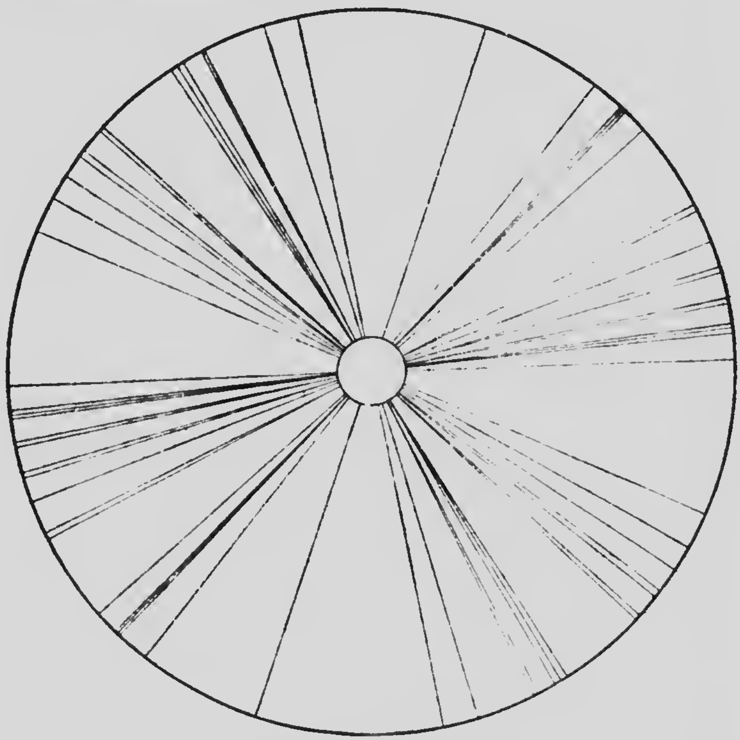

Figure 10. Chart showing strikes of thirty-three dykes (Etheline), mostly around Skidegate inlet.

HISTORICAL GEOLOGY.

The first geological event of which there is any record in the rocks studied on Graham island was a long stage of marine sedimentation. This sedimentation took place under very quiet, uniform, apparently widespread conditions, and at moderate depths, in lower Jurassic time, or perhaps it began in upper Triassic time. In this epoch the Maude formation was accumulated. If the classification of the conglomerates of Pillar bay and that vicinity as basal Maude is correct, then the lowermost Jurassic (upper Triassic) was a time of littoral sedimentation on a large scale, and these shallow, turbulent water conditions gave way to the quiescent conditions outlined above.

Towards the close of the lower Jurassic epoch, an uplift caused slightly coarser sediment to be deposited and about the same time explosive volcanic action began. This volcanic epoch, which began gradually, continued with great violence through middle Jurassic time, and gave rise to the Yakoun formation. The region now occupied by Graham island was then the scene of violent volcanic activity and vast amounts of basaltic ejecta were accumulated, at first under marine conditions, and later probably on the land platform built up by the eruptions. Lava flows were apparently not a large feature of the eruptions. The length of this stage of vulcanism is unknown as the volcanics are everywhere removed or truncated by the surface of pre-Cretaceous erosion. That there was a considerable covering over the formations now exposed at the surface is evident from the fact that they are intruded by batholithic rocks, requiring at least several hundred feet of cover.

After their accumulation and consolidation the lower and middle Jurassic rocks were folded to a considerable degree, and intruded by masses of igneous rocks in the form of batholiths and probably laccoliths. As the gap in the time scale represented by the unconformity at the top of the middle and lower Jurassic rocks extends to the base of the Upper Cretaceous, there is obviously no means of fixing the date of this intrusive epoch exactly; but it may be correlated with the intrusion of the Coast Range batholith, generally supposed to be upper Jurassic in age.

The late Jurassic folding and uplift raised the region, so that the rocks of the Maude and Yakoun formations, together termed the Vancouver group, formed a range of mountains with axes striking about north 30 degrees west. These mountains were reduced to a subdued topography and a rather rapid subsidence initiated the Upper Cretaceous sedimentation.

This region at the beginning of the Upper Cretaceous epoch consisted of a land of moderate relief intersected by a number of bays and estuaries in which marine sediments were being deposited. The variation in the material of the sediments, their rapid lateral and vertical gradation, and their similarity to directly underlying terranes show that the Cretaceous rocks were rapidly accumulated in great part in localized basins. After the initial Cretaceous sinking the sediments rapidly filled up the marine depressions, and shallow water conditions favourable for coal accumulation prevailed. These conditions appear to have been wide, shallow estuaries bordering land masses on the west, and deepening into true marine basins on the east. After the coal beds had accumulated, the interrupted sinking continued; and the massive fine-grained sandstones of the upper Haida were accumulated under quieter, more widespread conditions than had previously prevailed. These conditions were followed by a period during which rapid sedimentation just balanced sinking, and the Honna conglomerate was formed. The Skidegate formation represents a time of accumulation of variable sediments made up for the most part of fine sand or mud; and these beds form the last record of Cretaceous sedimentation.

The general orogenic disturbance which affected the whole Cordilleran region at the close of the Cretaceous period, the Laramide revolution, folded and upraised the rocks of the district under consideration, without much deformation, except locally; and following this uplift, the Cretaceous sediments were largely stripped from the underlying rocks, remaining only in synclinal basins protected by walls of the older, more resistant formations. The land surface at this time may have been fairly even, as the accordance of level of flat-topped ridges over considerable areas indicates conditions of this sort.

After this interval of erosion, and perhaps in part while the Cretaceous rocks were being folded, dacite dykes, and andesite dykes and sills were injected extensively. The main injection probably took place in the Eocene and there are no evidences of extrusive rocks having been formed in this epoch. In the

Miocene epoch, perhaps extending into the Pliocene, the northeastern portion of Graham is and was the scene of littoral sedimentation which was, as in the Upper Cretaceous, in part estuarine and fresh water; so that vegetable accumulations formed, now represented as beds of lignite. This sedimentation was cut short by a resumption of volcanic activity on a tremendous scale, by which the Masset formation was built up.

It is probable that at this time several volcanoes were in action, vomiting showers of fragments and floods of lava. This vulcanism is best placed in the early or mid-Pliocene, and the close of this epoch was marked by a recurrence of deforming forces which have locally severely flexed the Tertiary formations, but in general have disposed them in broad open folds. This deformation uplifted the sediments of northeastern Graham island a few score feet to their present position a short distance above sea-level and is probably responsible for the narrow trench which the Honna river now occupies in its broad valley.

Since the close of the Tertiary, the area has been subjected to subaërial erosion which in a large measure shaped the present topography. During the Pleistocene, the Queen Charlotte range was covered in part at least with an ice cap; and glaciers flowed from the range along the fiords of the west coast and also through Skidegate inlet, where strong glacial scouring has been noted. That ice occupied at least part of the lowlands also is indicated by the occurrence of [illegible] so many localities. The well stratified glacial sands an[illegible] found in several places indicate lacustrine conditions du[illegible]t of the glacial occupation.

There are some evidences of a recent uplift having affected Graham island. Near the mouth of the Yakoun river, in a bank of stratified clay and gravel, numerous recent shells were found, identical with those now living below high tide level in Masset inlet. The highest position of these shells in the bank was from 15 to 18 feet above high tide. Dawson[1] describes similarly uplifted shell banks at Naden harbour and on the Mamin river. He also[2] mentions seeing terraces i[illegible]kidegate and Masset

[1] Geol. Surv., Can., Ann. Rept., 1878-79, pp. 94-95B.
[2] *Loc. cit.*

inlets up to 20 feet above sea-level, but the present writer could not convince himself that these were present. The very marked wave-cut benches seen in Skidegate inlet, Masset inlet, and on the west coast (Plates I and VIIIB) which are now virtually at high tide level, may indicate a recent uplift; though Dawson[1] considers them to have formed at this level owing to the protection of the rocks below high tide mark by sea weeds.

Around Skidegate inlet were noted several of the heaps of recent shells mixed with soil, decayed sea-weed, and gravel, that are such a common feature of the Puget Sound region.[2]

These shell heaps contained numerous shells and many single and broken valves. It seems quite probable that the heaps represent an upraised beach deposit.

CORRELATION.

The following table of the formations of Graham island, compared with those of neighbouring districts, will show at a glance the relations between them. The close geological relations of Graham island and Vancouver island are well brought out, also the absence from this insular province of the upper Jurassic and Lower Cretaceous stratified formations of the Alaska province.

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[1] *Loc. cit.* p. 98 B.

[2] Arnold and Hannibal. "The marine Tertiary stratigraphy of the north Pacific coast of America",, Proc. Am. Phil. Soc. vol. LII. 1913, p. 597. The name "Saanich" had been applied (previous to this usage for a Pleistocene formation), to a body of granodiorite on southern Vancouver island by C. H. Clapp in 1912 (see Geol. Surv., Can., Mem. 13, 1912, p. 36).

Mesozoic

Cenozoic

Table of Formations of C

[illegible]	Graham island[1]		Southeastern Alaska[2]		Iliamna region[3]		Cook inlet and Alaska peninsula[4]		
	Formation	Lithological character	Formation	Lithological character	Formatioo	Lithological character	Formation	Lithological character	
[illegible]		Glacial till, and stratified gravels, sands, and clays.		Gravels, sands and clays, glacial drift. *Unconformity*		Recent volcanic material. Beach and flood-plain deposits. Terrace gravels Glacial deposits.			
Pliocene	Masset formation	Basaltic flows, tuffs, and agglomerates.				Basaltic flows and tuffs.			
Miocene	Skonun formation *Unconformity*	Sandstones, conglomerates, and shales, with marine fossils and lignite.				Sedimentary beds.	Kenai formation		E
Eocene	Etheline formation	Intrusive dacite and andesite.	Kenai series	Friable sandstones, conglomerates, shales, and coal seams.			*Unconformity*		C
Upper Cretaceous	Queen Charlotte series *Unconformity*	Fossiliferous sandstones, shales, and conglomerates, with coal.		Sandstones, shales, and coals (Kuiu island). *Unconformity*			*Unconformity*	Like the Kenai, but with some marine shales and sandstone.	
Lower Cretaceous			Gravina series; (Mesozoic ?) Kasaan Greenstone (Mesozoic ?)	Conglomerates and shales. *Unconformity* Intrusives and extrusives. *Unconformity*			*Unconformity*	Shales and sandstones with *Aucella crassicolis*.	
Upper Jurassic	Batholithic intrusives, etc.	Quartz diorite, etc.	Coast Range intrusives (Probably Jurassic)	Diorites, granodiorites, and granites.	Naknek formation Chisic conglomerate.		Naknek formation	Conglomerate, sandstone, arkose, and shales with andesitic flows.	
Middle Jurassic	Yakoun formation	Agglomerates, tuffs, and flows			Chinitna shale Tuxedni sandstone.		Enochkin formation *Unconformity*	Shales and sandstones with some conglomerate beds.	
Lower Jurassic	Maude formation	Dark coloured, fine-grained, thinly laminated fossiliferous argillites, grading upward into tuffs and agglomerates. Possil[illegible] detrital conglomerates at base.			Granitic rocks. Porphyries and tuffs.		*Unconformity*	Tuffs and sandstones	
Upper Triassic					Kamishak chert. Limestone			Thin-bedded cherts, limestones and shales, base not seen.	
Lower Triassic									

[1] This report. [2] A. H. Brooks, U.S.G.S. Prof. Paper 45, p. 206. [3] G. C. Martin and F. J. Katz, U.S.G.S. Bull. 485, p. 30. [4] F. W. Stanton and G. C. Martin, Bull. Geol. Soc. America, vol. 16, 19[illegible]

[9] C. H. Clapp, Geol. Surv., Can., Mem. 13, pp. 36-37. [10] W[illegible]

...sations of Graham Island and Neighbouring Districts

...ula[4]	Matanuska valley, Alaska[5]		Fairbanks quadrangle, Alaska[7]		Skeena river, B.C.[8]		Vancouver island[9]		Southwestern Alberta[10]	
...racter	Formation	Lithological character	Formation	Lithological character	Formation	Lithological character	Formation	Lithological character	Formation	Lithological character
	Unconformity	Alluvium Terrace gravels Morainic deposits	*Unconformity*	Till, sands, and gravels.	*Unconformity*	Glacial deposits.		Glacial till and unconsolidated gravels, sands, and clays, mostly stratified.		
	(?) *Unconformity*	Basaltic lavas, breccias, and tuffs.	Tertiary (?)	Basalt						
	Eska formation	Conglomerate			Oligocene ? *Unconformity*	Sandstone, conglomerate, shale, and coal.	Sooke and Carnanah formations (Oligocene ?)	Conglomerates and sandstones.		
	Chickaloon formation[6]	Shale and sandstone, coal bearing; arkose and conglomerate	Eocene (?) *Unconformity*	Conglomerate, sandstone, and shale, with some lignitic coal beds.	Tertiary ? Bulkley eruptives	Granodiorite, diorite-porphyrite.				
...with some ...sandstone.		Shale and sandstone		Carbonaceous shales, sandstone, and conglomerates.			Nanaimo series	Conglomerates, sandstones, and shales, with coal.	Allison (Belly River) ? Benton ? Crowsnest volcanics. Dakota (?) formation	Soft light grey sandstones. Chiefly dark shales. Analcite pyroclastics. Chiefly greenish sandstones.
...nes with		Limestone			Skeena series	Shales, sandstones, conglomerate, and coal.			Kootenay formation	Sandstones, shales, and coal seams.
...tone, ar- ...n andesitic		Shale, sandstone, and conglomerate			Jurassic Hazelton group	Andesite flows and sandstone, shales, and tuffs.	Batholithic and dyke intrusives.	Granodiorites, quartz diorites, etc.		
...with some		Sandstone and shale					Sicker series (Jurassic or Triassic).	Andesitic flows and tuffs; schistose slaty tufaceous and quartzose sediments.		
		Andesitic greenstone, tuffs, agglomerates, and breccias; rhyolites.					Suttoo formation, Vancouver volcanics.	Crystalline limestones, metamorphic andesites, and pyroclastic rocks.	Fernie formation	Dark shales with a few thin sandstone beds.
...imestones ...seen.										
							Nitinat formation (?			

..., vol. 16, 1904, pp. 391-410. [5] G. C. Martin and F. J. Katz, U.S.G.S. Bull. 500, p. 15. [6] Carries Kenai flora. [7] L. M. Prindle, U.S.G.S. Bull. 525, p.34. [8] W. W. Leach, Geol. Surv., Can., Sum. Rept., 1910, p. 93.
...87. [10] W. W. Leach, Twelfth Inter. Geol. Cong., Guidebook No. 9, p. 23.

CHAPTER VII.

ECONOMIC GEOLOGY.

The substances to be considered in discussing the economic geology of Graham island are coal, lignite, petroleum, oil-shale, clay, building stone and limestone, and gold. These materials are treated in the order given.

COAL.

Coal, of Cretaceous age, is found in the Haida formation of the Queen Charlotte series. The coal occurrences may be grouped on structural grounds in two basins; the Honna basin in the southern part of the island, and the Yakoun basin in the north-central part. In the Honna basin, anthracitic coal is found at Cowgitz and in the Slatechuck valley in the vicinity of Skidegate inlet; and coal of a somewhat similar kind occurs near Yakoun lake. At Camp Anthracite a coal is found resembling bituminous in appearance, but more like a low grade anthracite in composition. The most important location in the Honna basin is at Camp Robertson, where one seam of bituminous coal has been exposed.

In the writer's summary report for 1913, pages 36 and 48, the statement was made that the exposures represented outcrops of the same horizon, repeated by folding. Further work has made it appear more probable that the horizon of Camps Robertson and Anthracite, which doubtless are on the same seam, is higher in the Haida formation than the horizon of the exposures at Skidegate inlet and Yakoun lake.

Coal has been found at only one locality in the Yakoun basin, at Camp Wilson, and the coal there is also bituminous.

Material of a coaly nature is recorded from the south shore of Saltspring bay by Richardson,[1] and on the south shore of Skidegate channel,[2] by Dawson. These occurrences are in an

[1] Richardson, James, Geol. Surv., Can., Rept. of Prog., 1872-73, p. 60.
[2] Dawson, G. M., Geol. Surv., Can., Rept. of Prog., 1878-79.

area underlain by the lower Jurassic Maude formation, and the so-called coal in probably a carbonaceous shale band in these rocks which contain no coal.

HONNA BASIN.

Cowgitz and Vicinity.

The first discovery of coal in the Queen Charlotte islands was made by a Mr. Downie in 1859, at Cowgitz near the headwaters of Hooper creek,[1] and in 1865 a company was formed in Victoria, B.C., to exploit the deposit. At the request of those interested in the coal, James Richardson of the Geological Survey examined the property, and his account may be found in the Report of Progress of the Geological Survey for 1872-73. At the present time the workings are caved and obscured by undergrowth, so that the following account is largely taken from Richardson's report.

The measures containing the coal are nearly vertical, and the existence of faults is suspected. Three seams have been supposed to be present, and they are rather lenticular in character. In one of the prospect tunnels the coal was found in contact with trap rock; and the seam which was called good anthracite, increased from 2 to 3 feet, where it was first struck, to over 6 feet and, to quote Richardson, "continued so for 60 or 70 feet. It then became mixed with black shale and ironstone for seventy or eighty feet, and in this portion the coal had to be separated by hand picking. The tunnel continued for about fifty feet farther, but I could not convince myself that any coal at all was present towards the extremity. This bed is called the 'six feet seam.'" Apparently stratigraphically above this seam, and perhaps the same one repeated by faulting, are two seams as shown in the following section:

	Feet	Inches
Coal, good anthracite	0	6
Black argillaceous shale	4	6
Coal, good anthracite called the "three feet seam"	2	5
Black argillaceous shale, with nodules of clay ironstone	11	0
Grey trap, or it may be altered sandstone	8	8

[1] Dawson, G. M. Geol. Surv., Can., Rept. of Prog., 1878-79, p. 13B.

The coal seams at this locality are not far above the underlying volcanic rocks, and it is probable that this relationship is due to faulting, as elsewhere the coal occurs well above the base of the Haida formation. In appearance the coal found on the dumps is a semi-anthracite, and it seems quite unaffected by its forty years' exposure to the atmosphere. Analyses are quoted on page 126.

A coal seam was seen by the writer on King creek, about a quarter of a mile northeast of the openings on Hooper creek. The seam is not well exposed. It dips at a high angle, and is directly on the line of strike of the coal horizon between Hooper and Slatechuck creeks. The coal is anthracitic in appearance and the seam is fairly clean. It is at least 5 feet thick, and over 500 feet above the base of the measures. This seam is either a continuation of one of the Hooper Creek or Slatechuck seams, or is another seam lying at or near the same horizon.

Slatechuck Creek.

In the Slatechuck valley two exposures of the coal, which there also is anthracitic, have been prospected. On Coal creek, a small tributary of the Slatechuck from the west, the coal is exposed in the stream bed about half a mile above the junction of . . :eks. At that point an adit has been driven for 757 feet acr... .ie measures by the British Pacific Coal Company. A number of specimens of the coal were collected from the dump in front of this opening, but the adit, on account of its gassy condition, was not examined. Clapp states[1] that three seams of over a foot in thickness, called the A, B, and C seams, were encountered in the adit. The A seam is nearest to the entra..ce and apparently the lowest, but this apparent position is probably due to over-folding, as the base of the measures is reached on Coal creek in the same general direction as the adit. To quote Clapp: "The seams are associated with slaty shales, usually carbonaceous, intrusive into which are at least two sills of altered dacite porphyrite. The sills do not appear to have broken across the bedding, and may have been folded with the shales. In the

[1] Clapp, C. H., Geol. Surv., Can., Sum. Rept., 1912.

length of the 'tunnel' the measures are involved in a sharp syncline with a corresponding broader anticline. The rocks and seams are also broken by one or two small transverse faults.

The A seam is six feet thick and consists of a somewhat crushed coal, which has the appearance of being graphitic.

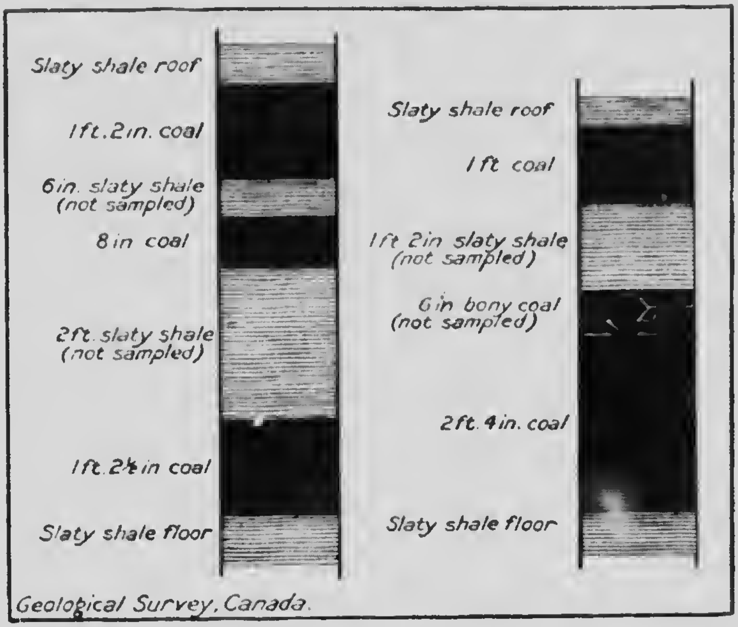

Figure 11. Sections B and C seams exposed in tunnel of British Pacific Coal Company, section 4, township 11, Graham island, B.C.

The B seam is 5 ft. 6½ in. thick, and the C seam is 5 feet thick. The coal from these seams is not greatly crushed."

Detailed sections of these seams are given in Figure 11.

In appearance the coal is of two principal kinds: a dull, somewhat lustreless variety, which is crushed; and a brilliantly black, hard, anthracitic looking material. The two varieties form alternating layers. Some of the bands of brilliant coal which are up to 3 inches thick possess a rude parting in sensibly parallel planes, at right angles to the bedding. These parting planes are often marked like the "augenkohle" of the Germans,[1] as illustrated in Plate XVIA. The coal is harder than ordinary Pennsylvania anthracite and is a little harder than calcite. It is of a rather more steely, grey-black colour than anthracite.

The material is evidently a member of the coal series that has undergone greater metamorphism than ordinary anthracite. It is without question closely allied to anthracite, but has not been metamorphosed to nearly the same extent as the graphitic variety of Rhode Island[2] coal or the schungite from near Lake Onega, Russia. The latter substance has been described in detail by A. Inostranzeff[3] under the title of "A New, Extreme Member in the Amorphous Carbon Series."

Schungite is found interbedded in black clay slates cut by greenstones. Four varieties of the schungite are noted, of different degrees of purity, varying from nearly pure carbon to carbonaceous slate. Inostranzeff concludes that schungite is an extreme member of the coal series, intermediate between anthracite and graphite, and from its properties, which he describes in detail, he places it nearer graphite than anthracite.

The Graham Island coal is also an "extreme member," and is doubtless also intermediate between anthracite and graphite; but, unlike schungite, it is nearer anthracite than graphite, and may be regarded as a connecting link between anthracite and schungite. Although intermediate between anthracite and schungite, the coal is closely related to both; and while perhaps deserving of a specific name, the writer prefers to wait until more detailed tests are made of the substance.[4] Analysis 11 on page 125 gives the composition of this material as determined by proximate analysis.

One of the specimens of this coal collected from the dump exhibits an unusual and interesting texture. It consists of com-

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[1] Stutzer, O. Die wichtigsten lagerstätten der Nicht—Erze; Berlin, 1914, vol. 2, p. 171.

[2] As illustrated by specimens in the collection of the Massachusetts Institute of Technology, Boston.

[3] Inostranzeff, A. Neues Jahr. 1880, Bd. 1, pp. 97-124, and 1886, Bd. 1, pp. 92-93.

[4] Specimens of this coal were in the possession of Mr. W. Fleet Robertson at the time of the visit of the International Geological Congress to Victoria, B.C., in 1913. Some of the visiting German and Russian geologists when shown the coal said it resembled schungite closely.

pressed and folded irregular layers of hard, brilliant coal, alternating with layers whose appearance varies. Some of these are wholly dense black, lustreless material, in sharp contrast with the bright variety. These dead black layers have a gradational relationship into the brilliant coal, and it is in these intermediate bands that the peculiar texture is seen. The intermediate layers consist of spherical grains of dull black material embedded in a matrix of the brilliant coal. The spherical bodies average about 2 mm. in diameter, and are occasionally rod-like in shape. The relative amounts of these bodies and of the matrix of brilliant coal vary; the spheres are usually closely packed together, and grade on the one hand into dense layers of dull coal penetrated at the margins by films of bright coal; and on the other, rather sharply, into the layers of brilliant coal.

In order to determine if possible any structure that the spheroids might possess, highly polished fragments of the coal were examined with the aid of a metallographic microscope used for examining opaque substances by reflected light. No particular structure was visible even with the highest magnifications. The dull spheroids were seen to contain minute irregular specks of bright coal embedded in the dull material. In various portions of the surface examined, the bright patches increased in amount, and formed ramifying veinlets, marking off the surface of the coal into circles of dull material and intercircular areas of bright coal (Plate XVI B).

The composition of the brilliant coal is given in analysis 11 on page 125 and, as already stated, it is that of a rather pure anthracite. The composition of the duller bands and dull spheroids, as shown by blow-pipe and qualitative tests, is that of clay ironstone or ferrous carbonate mixed with carbonaceous matter.

The iron carbonate probably was formed by the iron of the ferruginous solutions from the surrounding basic igneous rocks being precipitated as ferrous carbonate by the carbonaceous matter of the coal seams, then in process of accumulation. On account of the abundance of carbon, siderite, and not limonite or bog iron ore, formed.

The peculiar texture is regarded as being of inorganic and also of secondary origin. It is supposed that while such chemi-

Analyses of Coals from Cowgitz and the Slatechuck 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.............	Noncoherent		88·25 Noncoherent	87·04	87·72	86·72					

[1] Loss at 105° C.

1. Six-foot seam at Cowgitz, and
2. Two-foot five-inch seam at Cogwitz. Collector J. Richardson, analyst B. J. Harrington, Geol. Surv., Can., Rept. of Prog., 1872-73, p. 81.
3. Five-foot seam on King creek. Collector J. D. MacKenzie, analyst F. G. Wait, Department of Mines.

4, 5, and 6. Tunnel, British Pacific Coal Company, Coal creek. Collector C. H. Clapp, analyst F. G. Wait, Geol. Surv., Can., Sum. Rept., 1912.
4. Coal from A seam.
5. Coal from B seam.
6. Coal from C seam.

7, 8, 9, and 10. Different benches from B seam, tunnel of British Pacific Coal Company. Collector Alexander Faulds, analyst Noble E. Perrie, Geol. Surv., Can., Sum. Rept., 1912.

11. Picked sample, best clean bright coal, British Pacific Coal Company tunnel. Collector J. D. MacKenzie, analyst Edgar Stansfield, Department of Mines. This is the material described above as intermediate between anthracite and schungite.

cal and physical changes were taking place in the accumulated vegetable matter that caused the formation of anthracite, there was a tendency for the pure carbonaceous substance to separate from the iron carbonate. This separation took place by a sort of concretionary action, causing the clay ironstone to segregate in globular forms.

Camp Robertson.

Location. Camp Robertson is situated in the western part of section 20, township 5. It is distant 11 miles from Queen Charlotte, is over 11 miles from Camp Wilson, and about 3 miles from Yakoun lake, in each case by the trail. The first prospecting work of value was done in the spring of 1893, and prospecting has been carried on at intervals to the present time. A number of openings are the result of this work, and the coal is well exposed. A topographic map of the vicinity of Camp Robertson is given as Figure 17.

Stratigraphic Position. The measures in the vicinity of Camp Robertson in which the coal seam occurs, are near the middle of the Haida formation, about 200 feet below the fine-grained, massive sandstone of the upper Haida. A good section of the lower Haida is obtained on Wawa creek from the trail crossing down to near its junction with Brent creek. Sections showing the central third of the formation are exposed on Falls and Anthracite creeks, south of Camp Robertson.

Coal Openings. The coal is exposed in a number of prospect shafts, slopes, etc., the location of which is shown on the accompanying large scale map.

These openings were made at various times from March, 1893 to the summer of 1913. A careful examination of the more important ones was made and two are illustrated in Figures 12 and 13.

Coal Seam. In various public and private reports, the number of coal seams at Camp Robertson has been stated to be from two to three, and the estimates of the thickness of the individual seams also vary. In the investigation now reported on, the writer had the pleasure and advantage of the co-operation of Dean Milnor Roberts; and our careful measurements and examinations have proved beyond reasonable doubt that there is only one coal seam exposed in the present openings.

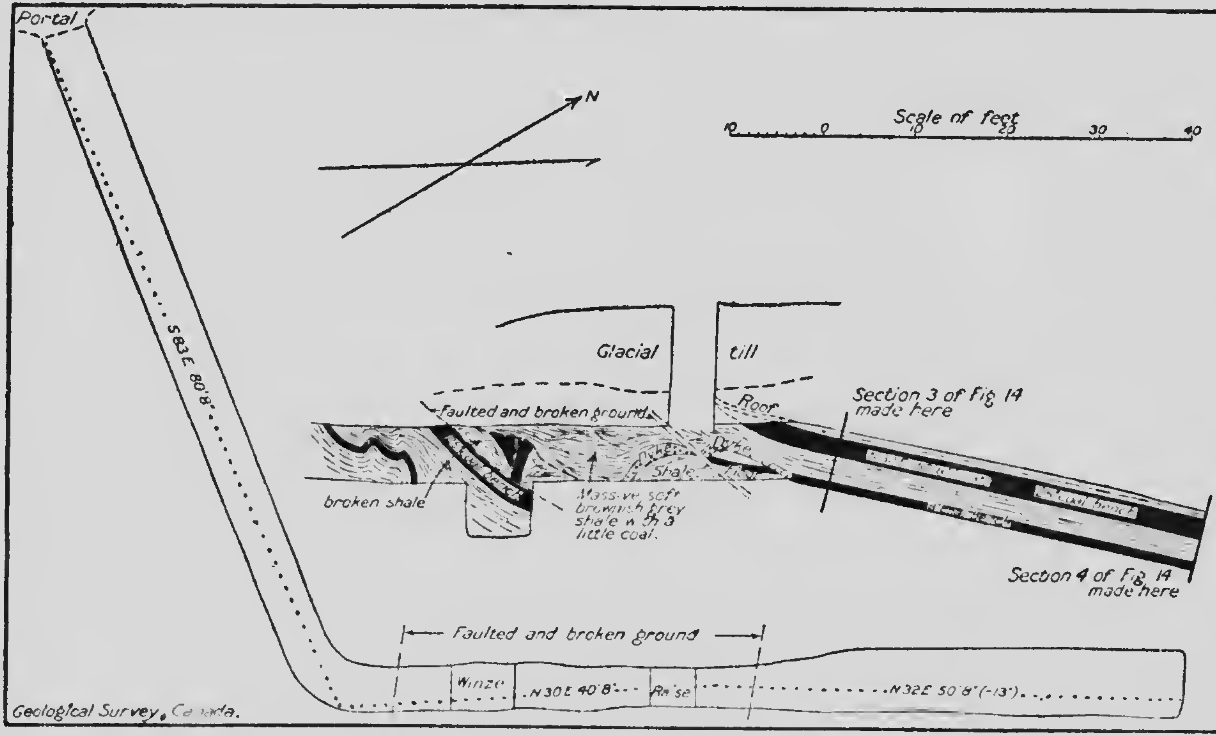

Figure 12. Camp Robertson. Plan and sections of the rock tunnel (see Figure 17), showing relations of faulted coal seam.

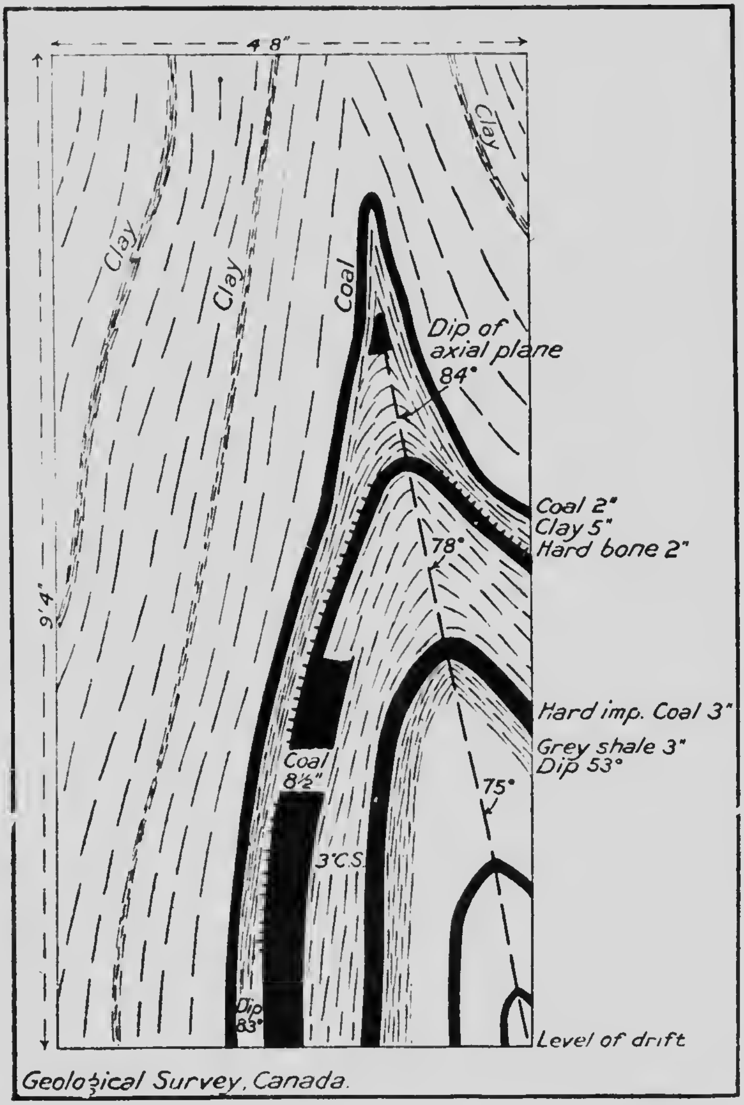

Figure 13. Sketch of folded coal seam, No. 1 shaft, Camp Robertson. Only the upper portion of the Robertson seam is here shown.

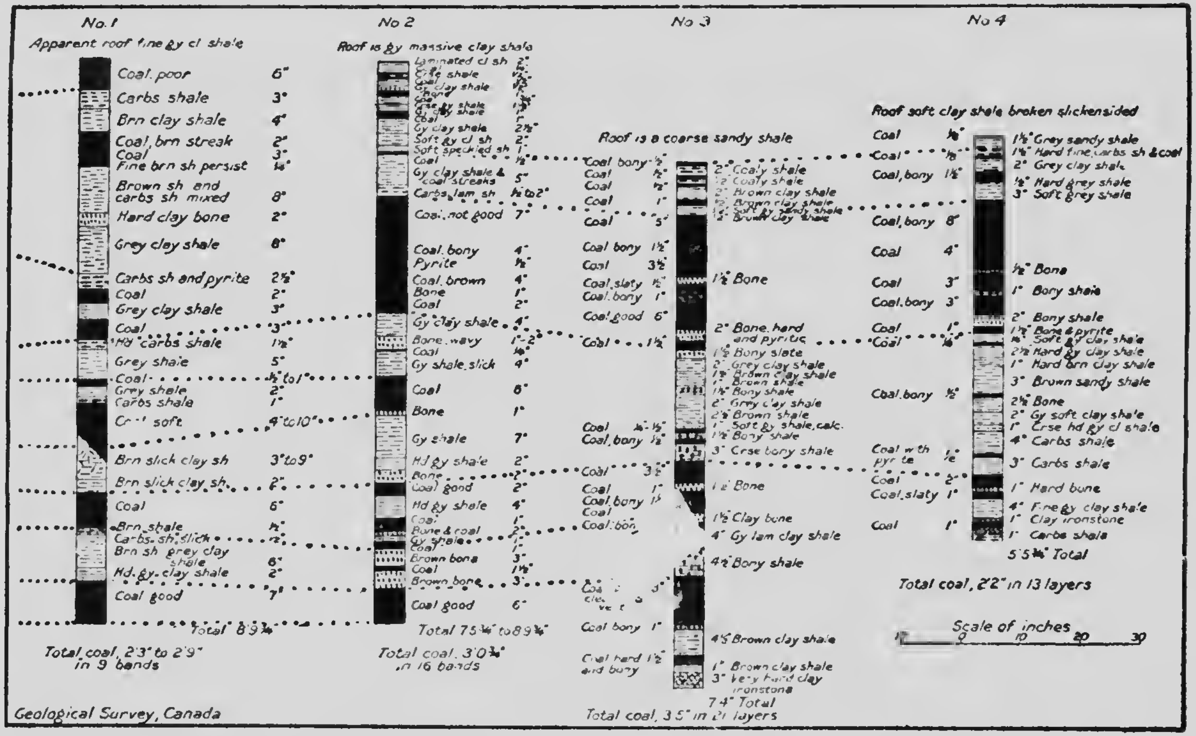

Figure 14. Sections of the Robertson coal seam. (For location of openings, see Figure 17). No. 1. Seam as exposed in No. 1 opening. No. 2. Seam as exposed in No. 3 opening. No. 3. Section in slope shown in Figure 12, q.V. No. 4. Section at face of slope shown in Figure 12. In all the sections the floor of the lower 6-inch 8-inch bench of coal is kept at the same level.

This seam, of which several complete and partial detailed sections are given in Figure 14, averages about 8 feet thick; and its total coal content, in several separate layers, varies from 2 feet 3 inches to 3 feet 10½ inches in the sections measured. The seam is characterized by variation in detail in the superposition and relative amount of coal and impurities, but there is, nevertheless, a marked similarity between the various sections. The floor on which the seam rests is grey or brownish grey shale, varying slightly from fine to coarse in different openings. The shale is soft, massive, and not laminated, breaks with a blocky fracture, and in places carries veinlets of calcite up to one-fourth of an inch wide. The upper surface of the shale, on which the lowest band of coal in the seam was deposited, is slightly wavy and irregular. The coal parts cleanly from the massive shale, and the contact is a little slickensided. There is not the slightest appearance of underclay, and no trace of rootlets penetrating the floor. The coal has in small degree an appearance of disconformity with the floor, in that it fills up the minor irregularities and then builds up an evenly laminated seam. The lowest band of the seam itself, which consists of 6 to 8 inches of bright, clean, somewhat crushed coal, is the best looking part of the seam, and this appearance of superiority is borne out by the analyses. This band is very constant, and appears in all the sections measured which reach the floor of the seam. Above this coal are alternate bands of brown and grey, fine clay-shale of varying degrees of hardness, together with layers of dark brown or black, hard, tough, fine, carbonaceous and siliceous material, termed bone. With these impurities are various thin seams of coal, in places impure and bony. They are lenticular in form and can be only approximately referred to a general position in the lower part of the seam. In the lower part of the upper half of the seam is a constantly reappearing coal bench, averaging about 25 inches in thickness, and carrying locally, thin streaks of shale and bone. This coal has films of pyrite on joints and bedding planes, and is not of such good quality as the lowest bench. It is hard and splintery, and has a higher average specific gravity than is usual. Above this 25-inch bench are other lenticular bands of shale, bone, and coal, the latter in places attaining a thickness of 6 inches. The roof of the seam, like the floor, is of grey, fine to coarse, massive clay shale.

About a quarter of a mile west of Camp Robertson and a few yards south of the trail to Yakoun lake, thin seams of coaly shale are exposed in the south bank of Wawa creek. These seams are of no value in themselves, but serve to illustrate the tendency for coal to form when these measures were being laid down. Figures 15 and 16, from a sketch by Mr. Milnor Roberts, show the relations of these coaly seams.

Analyses of the coal from the Robertson seam are given below. The samples collected by the writer were carefully taken, and material that could be rejected by hand picking in mining operations was not included in the sample.

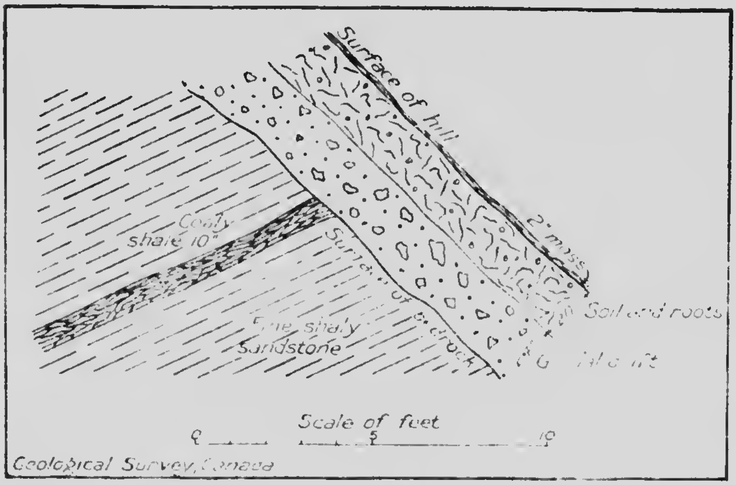

Figure 15. Vertical section through A—A′ on right wall of open-cut (see Figure 16), looking north 70 degrees west. Illustrates typical occurrence of glacial drift resting on cleanly eroded surface of bed-rock. No coal blossom is found in the drift material near the outcrop of the seam.

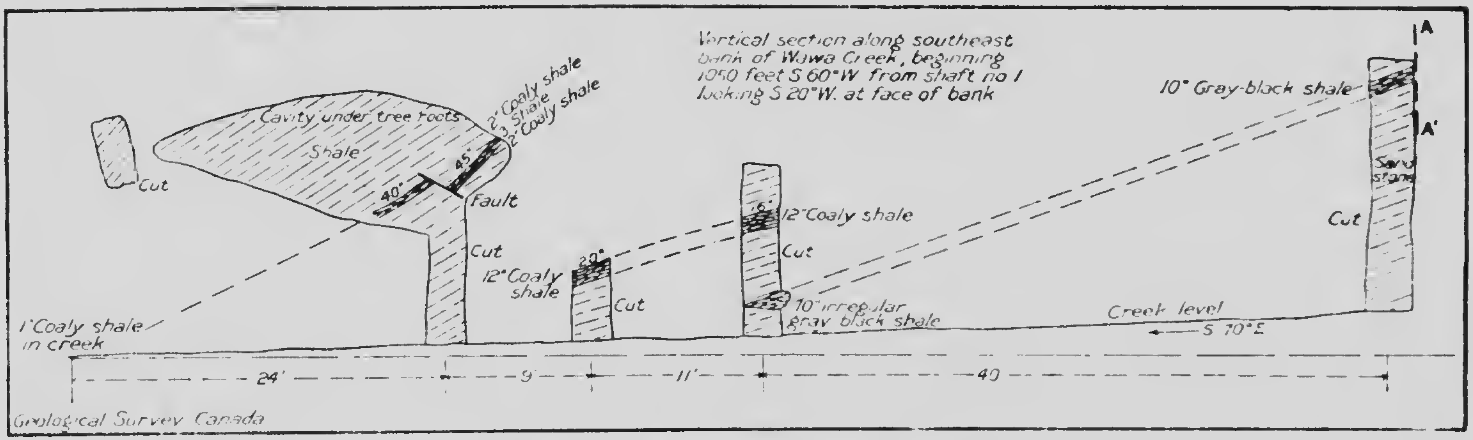

Figure 16. Coaly seams west of Camp Robertson.

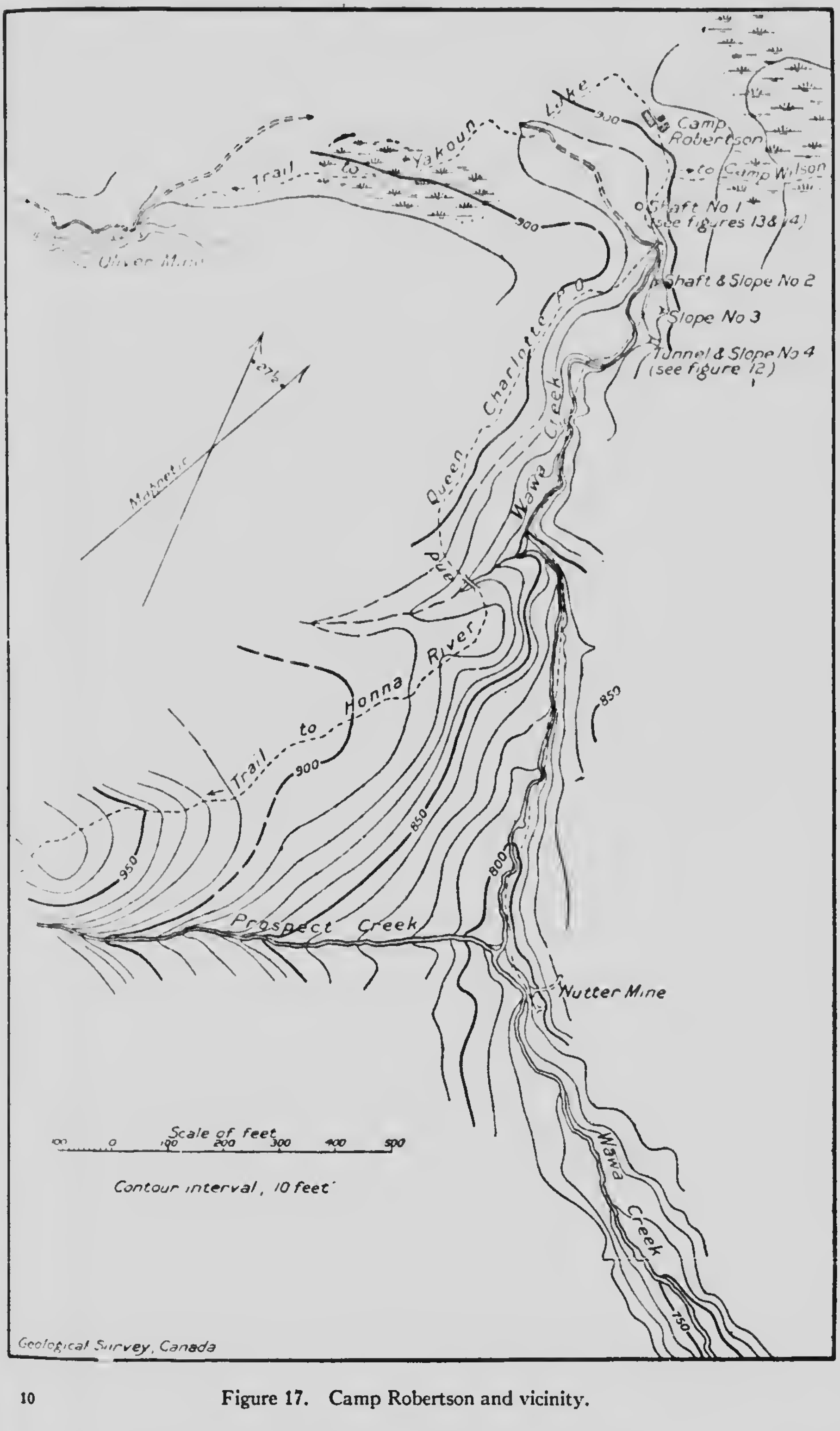

Figure 17. Camp Robertson and vicinity.

Analyses of the Coal 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 inches from drift from No. 1 shaft. Collector J. D. MacKenzie, analyst F. G. Wait, Department of Mines.

2. Same as No. 1, duplicate sample. Collector Milnor Roberts, analyst C. R. Corey, University of Washington.

3. Thirty-three inches of upper bench, slope at end of tunnel, northwest wall, 14 feet from face of slope. Collector J. D. MacKenzie, analyst F. G. Wait, Department of Mines.

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 inches beginning 12 inches below roof. Collector J. D. MacKenzie, analyst, F. G. Wait, Department of Mines.

6. Same as No. 5, duplicate sample. Collector Milnor Roberts, analyst C. R. Corey, University of Washington.

7. Lowermost 8 inches best coal on southeast wall, 5 feet from turn of tunnel. Collector J. D. MacKenzie, analyst F. G. Wait, Department of Mines.

8. Same as No. 7, duplicate sample. Collector Milnor Roberts, analyst C. R. Corey, University of Washington.

9. Eight-inch 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. Surv., Can., Ann. Rept., vol. VI, 1895, p. 12R.

11. Collector R. W. Ells, analyst J. T. Donald, Geol. Surv., Can., Ann. Rept., vol. XV, 1906, p. 43B.

12. Collector R. W. Ells, analyst M. F. Connor, Geol. Surv., Can., 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.

Notes on Mining. The tunnel and slope, Figure 12, give an opportunity of judging as to the qualities of the seam for mining purposes. Unless the whole seam is mined and the product washed free from dirt, the coal to be depended on is that in the so-called 25-inch bench, in the upper part of the seam. The lower 10 inches of this are noticeably the better, and more free from bone, some streaks of which occur in the upper part; but the good part of this 25 inches cannot be mined separately. From the bottom of this bench, at least 40 inches must be mined above to the roof, which would readily stand, with props and lagging every 4 or 5 feet. The roof holds well, and nowhere in the tunnel it had sagged more than one foot. No caps are bent, and there is little or no weight on the lagging, except for occasional spalls due to slickensiding. Pillars in the seam could doubtless be robbed with safety, as the roof now stands 8 feet wide rib to rib. There is no slumping from the sides, nor any trace of swelling in the floor. The condition of the coal is the same in the portion under water as in that exposed to the air. The coal is as firm on the rib as at 2 feet in, and evidently does not carry any extra weight of roof on account of the openings having been made, as the roof supports itself right across. Water comes into the opening only through occasional joints, and it is probable that a mine on the seam would be dry and perhaps dusty.

Structure. Although only exposed in the streams and prospect openings, enough outcrops have been observed to allow of the general structure of the rocks in this vicinity being made out fairly accurately. Wawa creek flows along an anticlinal axis, on which close local folding accompanied by some overthrust faulting has taken place. The compressed anticline exposed in the northwest and southeast walls of No. 1 shaft is sketched in Figure 13. The axis of this fold may be traced in the roof of the drift from this shaft and is seen to bend in a flat S curve. It is quite possible that minor faulting further complicates the seam.

In the opening shown in Figure 12, consisting of a tunnel, slope, winze, and raise, it is shown clearly that the two apparent seams are parts of the same seam repeated by faulting. The geological section sketched in the figure is well exposed on the northwest wall of the tunnel, slope, and winze, and requires little explanation. The width of the area occupied by faulted and broken ground has doubtless contributed to the error of former investigators in considering [illegible] there were two seams at this location. The bent and [illegible] dyke is evidence of the intrusion of some of the dykes at least [illegible] movement had ceased. The sharp differential folding of the lower part of the downthrow section of the seam, where the [illegible] coal bench resting on the floor is bent into sharp [illegible] worthy of notice.

East of the Wawa Creek [illegible] is a sharp canoe-shaped syncline, with a [illegible] probably about a mile in length, and an east-west axis [illegible] thought not to exceed 300 yards. West of Wawa creek the measures are not well exposed, but the general structure west to the high ridge near Yakoun lake is a flat syncline, modified by low, undulating folds. The approximate position of the outcrop of the coal bearing horizon in this syncline is indicated on the map.

Camp Anthracite.

Location. Camp Anthracite is situated on the creek of the same name, an eighth of a mile above the trail crossing, and about a mile southeast of Camp Robertson.

Stratigraphic Position. Camp Anthracite is probably at the same horizon as Camp Robertson, near the middle of the Haida formation, but apparently nearer the base of the massive sandstone of the upper Haida.

The opening is an adit on the right bank of the creek driven for 45 feet across the measures. The roof of the coal seam is cut at 12 feet from the portal, and at this point a drift goes 30 feet southeast in the seam (Figure 18).

Coal Seam. The seam at Camp Anthracite bears a resemblance to the one at Camp Robertson, and is with little doubt the same. It is 9 feet thick, perhaps thickened by minor faulting, and contains several bands of coal, 4 feet 5 inches in all, separated by bands of shale and bone. Next the floor there is a 4-inch layer of crushed coal, as in the case of the seam at Camp Robertson. The roof is a medium to fine grey sandstone. The seam is illustrated in Figure 19.

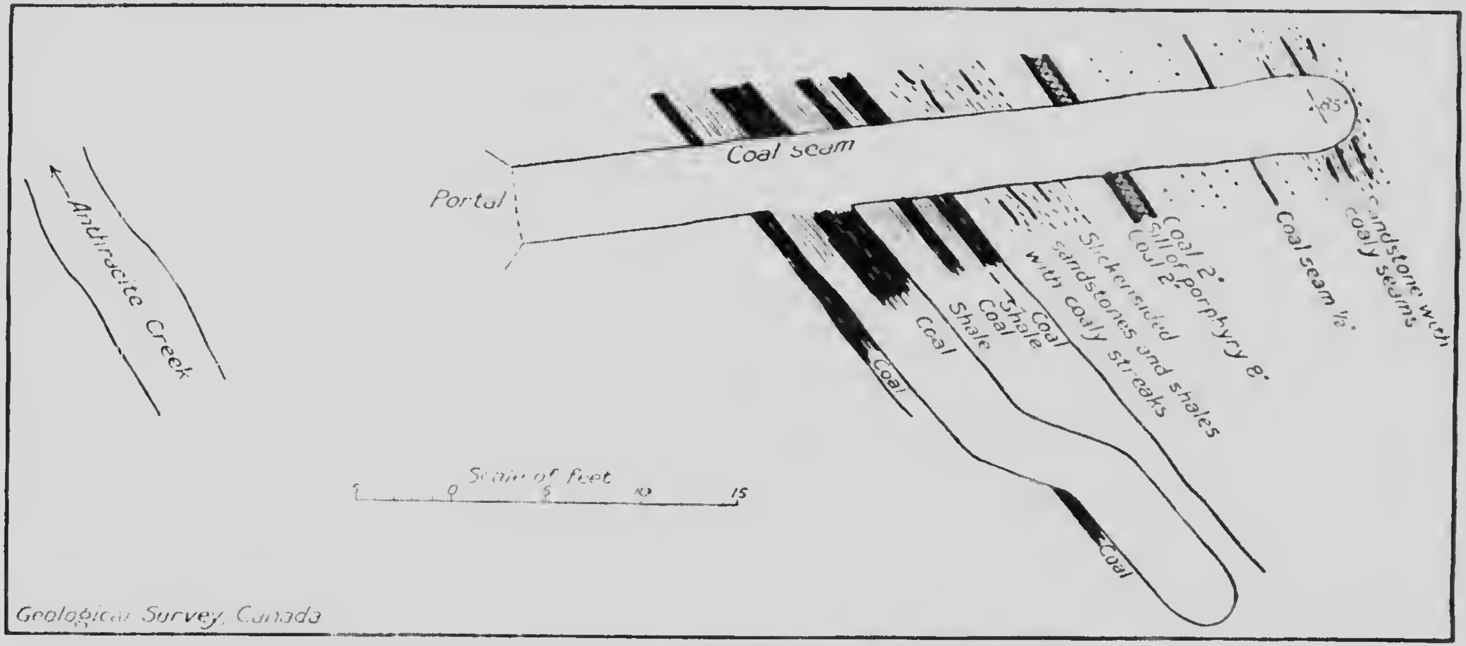

Figure 18. Camp Anthracite. Plan of drift and crosscut showing geology.

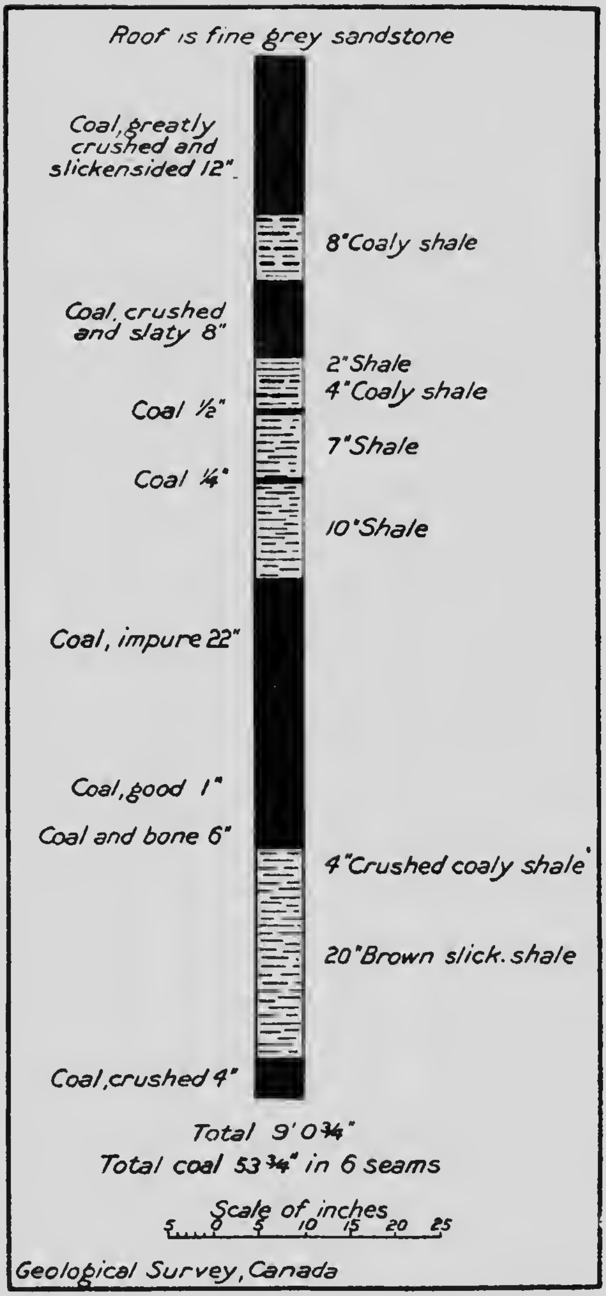

Figure 19. Camp Anthracite, section through coal seams.

The analysis of the coal collected by the writer was made from a sample taken from the 29-inch bench in the lower part of the seam; and, except for the low percentage of volatile matter, resembles the analyses of the coal from Camp Robertson. In appearance the coal is crushed and rather slaty; it is bituminous in aspect, and in no way resembles anthracite. The low volatile matter is ascribed to the influence of the dykes and sills of andesite and dacite so prevalent in the region, and a thin sill of volcanic rock is exposed in the adit, beyond the coal seam.

In the sandstones and shales underlying the coal seam there are several thin streaks and seams of coal, none exceeding 4 inches in thickness. They are quite unimportant as economic factors.

Analyses of the Coal from Camp Anthracite.

	1	2	3
Water....................	5·69	1·52	2·55
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 feet in from mouth. Collector J. D. MacKenzie, analyst F. G. Wait, Department of Mines.
2 and 3. Collector W. A. Robertson, analyst G. C. Hoffmann, Geol. Surv., Can., vol. VI, 1895, p. 13R.

Structure. The measures are considerably disturbed in the immediate vicinity of Camp Anthracite, and the structure has not been worked out in detail. In the adit the measures are seen to strike north 32 degrees west, and to dip about 85 degrees southwest. This high dip is only local, however, and is probably due to minor faulting, as a short distance up Anthracite creek, the massive fine sandstones of the upper Haida lie flat or at low angles. These beds form part of the large, flat syncline already mentioned as underlying the country west and southwest of Camp Robertson.

Yakoun Lake.

Location. Yakoun lake is situated in the southern part of the island, about 3 miles from Camp Robertson, and 14 miles from Queen Charlotte by trail. Near the southeast corner of the lake, where it bends sharply to the west, some prospecting has been done, and about 2½ miles by trail south-southeast of that point Camp Trilby is located.

Stratigraphic Position. The exposures in this section of the island are few and little time was available for their study, so that the stratigraphy and structure have not been worked out thoroughly. From the data available, however, it is probable that the coal seam southeast of Yakoun lake occupies a narrow, north-south, closely folded syncline, pitching to the north. It is separated from the wider, main syncline of the Honna basin by an anticline of the older Yakoun volcanics. The relations are further obscured by Tertiary volcanic flows, but the areal relations and the structure are believed to be essentially as delineated on the maps and sections.

The coal seam is apparently not as far above the base of the Haida formation as it is at Camp Robertson, and the coal probably represents a lower horizon. It is fairly certain that the coal of Cowgitz, Slatechuck, and Yakoun lake represents the same horizon.

Coal Seam. The opening nearer the lake is an adit on the left bank of a small creek, driven south 60 degrees east for 50 feet across the measures. In it are exposed black carbonaceous shales, cracked and slickensided, containing lenticular veinlets of hard, altered, coaly matter one-fourth of an inch thick. At about 40 feet in from the portal a 3-inch seam of anthracitic or coky coal is exposed. Above the adit in the creek bank a 4 to 5-inch seam of altered coked coal is exposed, probably the extension of the 3-inch seam in the adit. Just outside the adit are impressions of small tree trunks in black shale. The coal itself to some extent resembles the material from Cowgitz and Slatechuck valley, but instead of being dense and heavy, it is porous and light, of a coky, rather than of an anthracitic nature, and with a lustrous, jet black colour. Some of the coal shows well marked columnar structure, the individual columns being about the size of the lead in a pencil and arranged normally to the bedding.

Camp Trilby, the other locality near Yakoun lake, was not visited by the writer; but S. E. Slipper of the Geological Survey, who visited it, states that the occurrence is similar in a general way to that just described, though he was unable to carefully examine the workings.

As in the case of the occurrences near Skidegate inlet, the metamorphosed condition of the coal is ascribed to the heating action of dykes and sills of the Etheline volcanics. Sills are found in proximity to the seams and there are doubtless many that are not visible. The coked appearance of the coal is strong evidence that direct application of heat caused the metamorphism.

Structure. In general structure this coal basin seems to be a close folded syncline, pitching north. The opening nearer the lake is on the western limb of the fold, and the measures there dip steeply northeast, while Camp Trilby is situated on the eastern limb, and the rocks dip steeply southwest. This syncline is in part covered by flows of Tertiary volcanic rocks.

Extent of the Coal-bearing Horizon.

The accompanying areal map shows the supposed outcrop of the horizon of the Robertson seam, definitely located only at Camps Robertson and Anthracite, and elsewhere traced by means of its relations to the massive sandstone of the upper Haida. Away from the high ground on which these two camps are situated the outcrops are few and in certain areas lacking, so that the location of the line representing the horizon on the map is based, along portions of its course, more on inference than on direct evidence. The line shows at least approximately, however, the area which is underlain by the coal horizon. The sections, constructed from surface exposures, indicate that the probable depth of the coal horizon is not great over a considerable area between Camp Robertson and Yakoun lake.

The probability of a coal seam being found at this horizon throughout the Honna basin, remains to be considered. The evidence on which the conclusions are based will in part be summed up later. There appears to be no good reason to expect that a seam of better quality than the one now known will be found. The measures on the whole are variable and made up of hastily accumulated material; and the coal seam bears evidence of rapid changes in conditions of deposition. These conditions in the Honna basin do not appear to have been favourable for the extensive accumulation of vegetable deposits. The finding of coal seams in various localities, already enumerated, in different parts of the western and northern portions of the Honna basin, is good evidence that a single seam, or a series of overlapping seams occur there. The western portion of the seam or seams has been so altered by volcanic agencies that it cannot at present be economically mined, even in the few localities where the coal is of sufficient thickness.

About Camp Robertson the seam is at its best as far as quality goes, but the structure is complicated by folds and faults. Between Camp Robertson, Yakoun lake, and the ridge surmounted by Mount Etheline there is a considerable body of coal which apparently is fairly regular in its structure; but, from the character of the seam at Camp Robertson, the quality of this coal cannot be expected to be high.

The question of the extension of the Robertson seam down the Honna valley is a difficult one to answer. No trace of the seam has been seen on any of the creeks in the territory in which the horizon outcrops, except on Honna river, where some coaly shale occurs. The massive sandstones of the upper Haida do not extend down the Honna valley, and in this valley and on the west shore of Bearskin bay the upper half of the Haida formation is shaly and thin bedded, and more fossiliferous than around Camp Robertson. The evidence is unsatisfactory because the actual conditions of the accumulation of the coal are not known; but conditions of deposition were different in the eastern part of the syncline and, apparently, deeper water conditions prevailed. It is scarcely possible to draw safe conclusions; but the probability that coal was not deposited in the southeastern part of the syncline and that the Honna valley and Maude and Lina islands may be barren of coal seams cannot be ignored.

This hypothesis should not be accepted as fact, however, and the careful prospecting of the small eastern tributaries of the Honna river is recommended.

YAKOUN BASIN.

Camp Wilson.

Location. Camp Wilson is located on Wilson creek, in the N. W. ¼, sec. 25, tp. 7. It is distant over 11 miles from Camp Robertson and about 20 miles from Queen Charlotte by the trail. A trail about three-fourths of a mile long leads from Camp Wilson to the Yakoun river, which is navigable for river boats at most stages of water from where the trail meets it to its mouth at Masset inlet 32 miles distant.

Stratigraphic Position. The strata in which the coal seam at Camp Wilson is found belong to the Haida formation and the seam has been found by boring to be about 400 feet above the base of the formation.

The rocks in this portion of the Yakoun basin are on the whole coarser than those in the Honna basin; and are composed of more angular, less sorted debris of the Yakoun volcanics.

Coal Openings. The coal openings at Camp Wilson are three in number. No. 1 opening, on the right bank of Wilson creek, consists of an adit on the seam for a distance of 50 feet from the portal. At 8 feet from the entrance a winze 11 feet 6 inches deep gives access to a drift on the seam. From the winze this drift extends 20 feet south, and 24 feet north. Near the end of this northern portion a narrow crosscut exposes the full width of the seam.

No. 2 opening is a shaft 14 feet deep from which a drift runs south on the seam for 20 feet.

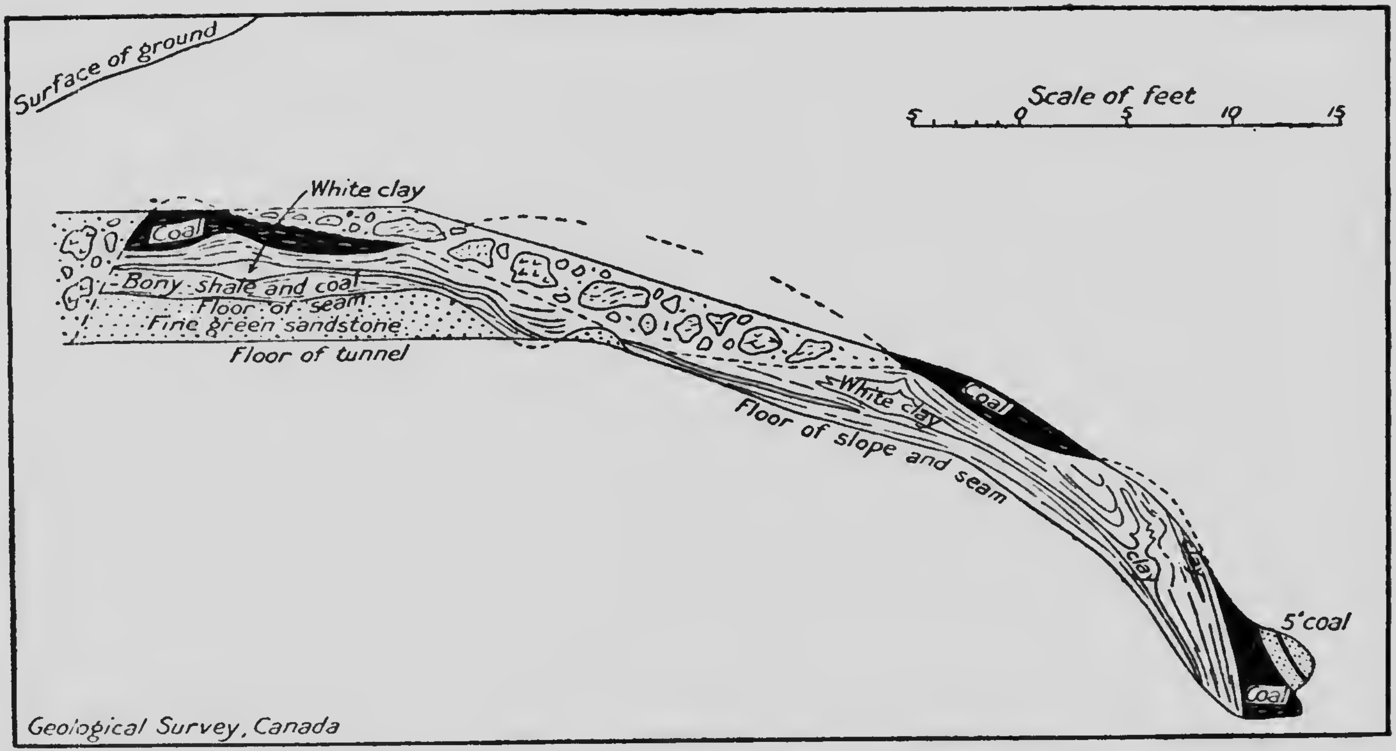

Figure 20. Sketch of part of the wall of No. 3 Prospect opening at Camp Wilson, showing warping of coal seam due to folding, and swelling of clay bands in the seam caused by surface waters. Till overlies part of the seam as shown.

No. 3 opening started as an adit, partly on the seam and partly in the glacial till, but with the increasing dip of the coal the adit developed into a slope, as shown in Figure 20.

Coal Seam. The Wilson seam varies from 4 feet to 18 feet in thickness where measured, but it is not certain that the full thickness is exposed where the smaller measurement was obtained. It is certain, however, that the seam is of varying thickness, and that the maximum figure given above does not represent the true average.

The floor is a green, fine to medium-grained sandstone, containing scattered, well rounded pebbles up to an inch in diameter. Under the microscope the sand grains are seen to consist of rounded volcanic fragments, with quartz and decomposed feldspar grains, in a calcareous cement.

The seam itself, of which a diagrammatic section is given in Figure 21, is best exposed in No. 1 opening, and was there sectioned and sampled. It is divided into two benches by a 5-inch band of soft, grey sandstone, occurring about 5 feet above the floor. At the base of the seam are usually found lenticular bands of granular, yellowish-grey, soft clay shale; but in some places the coal rests directly on the sandstone, or is separated from it by a layer of bone or by a bedded vein of calcite. In other places, bands of the same soft, plastic, clay shale occur in the lower part of the seam. The lower bench is dirty and of inferior quality, as shown by the analyses of the coal. The upper bench, about 12 feet thick, is composed almost wholly of coal in several layers, not all of the same quality. The upper part of the upper bench is crushed, dirty, and poor looking, and the analysis of this portion runs 37 per cent ash.

The roof of the seam is a greenish, medium-grained sandstone, more pebbly than the floor, and in places almost a conglomerate.

In this opening (No. 1) the seam shows no evidence of local thickening due to folding, the laminations being continuous and even; but a slight amount of thickening due to faulting occurs. The type of faulting is illustrated in Figure 22. The seam shows strong, continuous slickensides, parallel to the bedding, which are probably due to slight differential movements caused by the

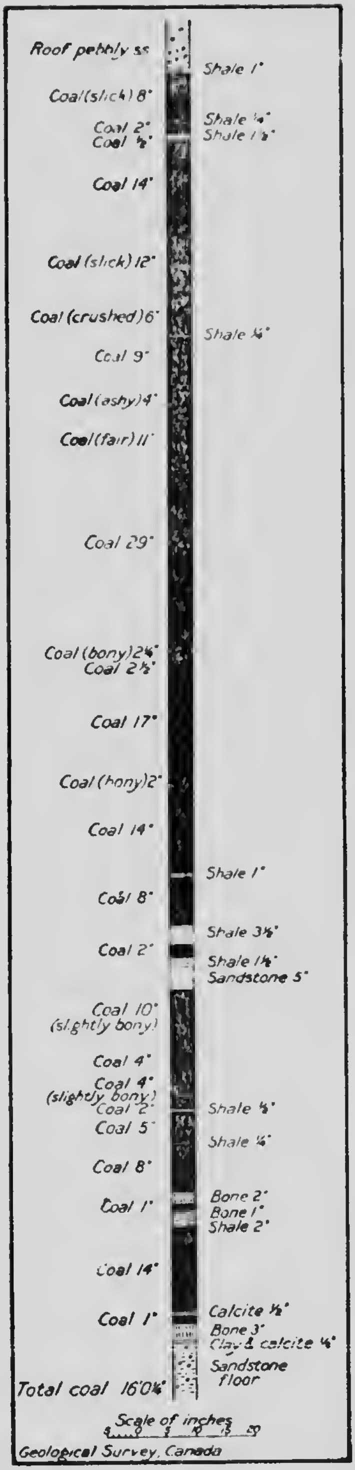

Figure 21. Section of Wilson coal seam.

severe folding. If it were considered advisable to mine the upper bench separately, the 5-inch sandstone parting between the two benches would make a satisfactory floor.

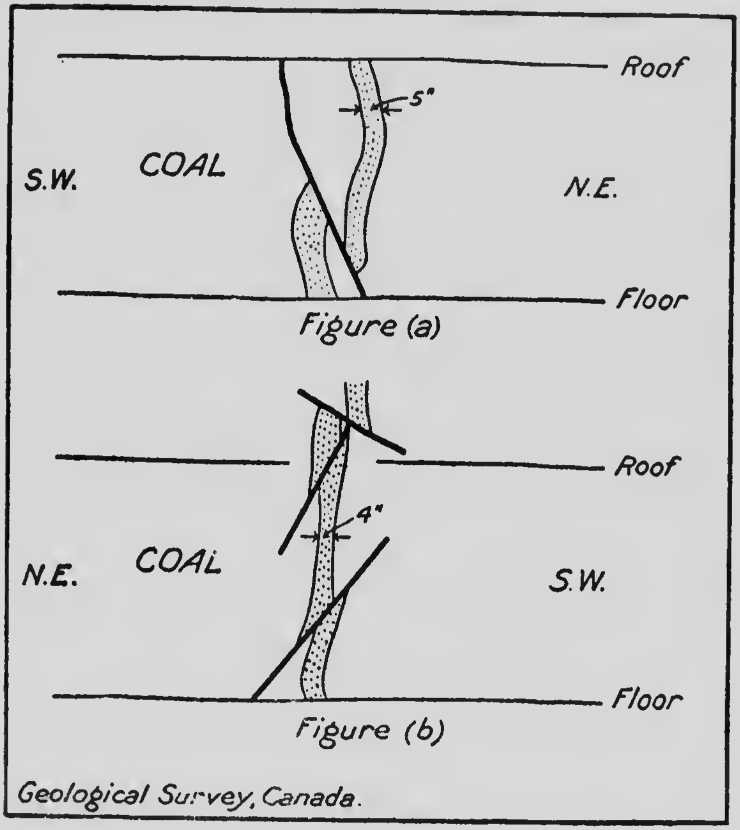

Figure 22. (a) Sketch of northwest wall of crosscut in vertical Wilson seam, showing faulted sandstone parting 4 to 6 inches thick.
(b) Sketch of southeast wall showing same fault. This wall is 2½ feet distant from the one sketched in Figure 22a.

In No. 2 opening the seam is cut off by a fault at the end of the drift; but an apparently complete section in the shaft gave 9 feet 5 inches in the seam, with a total thickness of coal of 6 feet 2 inches.

In No. 3 opening it is not certain that the whole of the seam has been cut. The 5 feet of coal exposed are shown in Figure 20.

The seam as a whole is very different from the Robertson seam, both in its greater freedom from impurities, and in the appearance and composition of the coal. The coal is greatly jointed by lenticularly intersecting surfaces, which cause it to break up in mining, but which will probably disappear to a large extent in the less disturbed parts of the seam. The coal is light in weight and burns freely with a smoky flame. It forms a light, flaky, white, or pinkish ash, and does not clinker until all but the last vestiges of carbon are burned. The coking qualities are excellent, judging from tests on one or two pounds, pulverized, and coked in a coal fire.

About three-fourths of a mile north 12 degrees west from No. 1 opening at Camp Wilson a dirty seam of coal and shale, about 7 feet thick, is exposed. This seam is about on the strike of the Wilson seam; and, although the two are vastly different in their constitution, the structural evidence, together with the well recognized variation of the coal seams on the island, point to the conclusion that this seam represents the Wilson seam. This interpretation can only be proved or disproved by careful prospecting, as the intervening country is virtually barren of exposures.

A section of the seam, for which the writer is indebted to Messrs. Milnor Roberts and Livingston Wernecke, is as follows:

Roof of seam is clay shale with coal lenticles.

	Thickness.	
	Feet	inches
Coal		½
Clay	1	
Coal, shaly	1	½
Coal		½
Shale	1	
Coal		¼
Shale		½
Coal		¼
Shale	3	½
Coal		¼

	Thickess. Feet	inches
Shale	2	¼
Coal	2	
Shale	5	
Coal	1	
Shale and coal	3	
Red clay shale	4	
Coaly shale, in part replaced by a thin sill	1	½ to 3
Light grey shale	2	½
Soft sandstone with thin coaly bands	6	
Grey shale	12	
Coal	3	
Coaly shale	8	
Clay shale	4	
Coal	1	
Coaly shale	3	
Green shaly sandstone	5	
Coal, variable character	8	
Shale		¼
Coal, shaly	6	¾
	7 ft. 5½ in. to 7 ft. 7 in.	

Floor is of sandy shale.

Structure. The Yakoun basin is an irregular, elongate syncline, extending from the Tlell river in township 6, about 6½ miles north to near the east-west centre line of township 8. Except locally, it does not exceed 2 miles in width.

The syncline is complicated by a number of minor folds which make prospecting uncertain and which are difficult to work out on account of the variable character of the rocks, and the lack of horizon markers.

The rocks in the vicinity of Camp Wilson are poorly exposed, and Wilson creek and the prospect openings afford the only data from which to determine the structure. The seam is on the western limb of a narrow syncline, apparently canoe-shaped and pitching slightly to the north. This western limb is complicated by a small anticlinal wrinkle at Camp Wilson, accompanied by faulting, and this increases the difficulty of prospecting. The structure can not be completely diagnosed from the outcrops and openings at present available, but Figure

Analyses of the Coal from Camp Wilson.

	1	2[3]	3	4	5	6	7	8	9	10	11	12	13
Water........	1·8[1]	1·22[2]	2·2[1]	1·82[2]	2·02[2]	1·6[1]	1·35[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	12·26	5·43	9·45	2·92	3·46
Sulphur.......	......	1·00	......	0·50	......	......	1·20	......	0·80	......	......	......	......
	100·0	101·00	100·0	100·50	100·00	100·0	101·20	100·0	100·80	100·00	100·00	100·00	100·00
Coke.........	Barely cokes	Firm coherent	Barely cokes			Barely cokes			61·60 Firm coherent	Firm, coherent			Non-friable

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

1. Upper bench, No. 1 opening. Collector J. D. MacKenzie, analyst Edgar Stansfield, Department of Mines.
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, Department of Mines.
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 inches of coal, beginning 27 inches below roof, No. 1 opening. Collector J. D. MacKenzie, analyst F. G. Wait, Department of Mines.
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, Department of Mines.
9. Collector C. H. Clapp, analyst F. G. Wait, Department of Mines, Geol. Surv., Can., Sum. Rept., 1912, p. 36.
10. G. C. Hoffmann, analyst, Geol. Surv., Can., Ann. Rept., vol. III, 1887-88, p. 17T.
11. Collector W. A. Robertson, analyst G. C. Hoffman, Geol. Surv., Can., Ann. Rept., vol. VI, 1892-93, p. 12R.
12. Collector R. W. Ells, analyst J. T. Donald, Geol. Surv., Can., Ann. Rept., vol. XVI, 1904, p. 40B.
13. Collector R. W. Ells, analyst. M. F. Connor, Geol Surv., Can., vol. XVI, 1904, p. 44B.

20 shows the anticlinal nature of the seam, and Figure 22 some of the small faults seen in No. 1 opening. At the end of the adit at No. 1 opening the seam is cut off by a north-south fault, and in No. 2 opening the seam is also cut off by a fault virtually on the strike of which the details are not completely worked out.

An interesting case of the swelling and local minor folding of a coal seam due to exposure to weathering agents is seen in No. 3 opening, shown in Figure 20. Most of the thickening and contortion of the lenses of white clay and of the seam as a whole appears to be due to the expansion of the seam caused by the action of surface water.

Extent of the Coal-Bearing Horizon.

From the data obtained by boring at Camp Wilson it is known that the coal seam occurs about 400 feet above the base of the Haida formation at that point. The horizon of the seam, that is, the stratum at which the seam would occur if present, must, therefore, underlie a considerable area in the Yakoun basin as indicated on the accompanying map. That the seam is absent in at least part of this area, however, may be indicated by the failure to find coal in the boring put down near the eastern edge of section 36, township 9; although it is probable that this hole was started below the horizon of the coal seam. It is evident that until the area indicated on the map is thoroughly prospected, it will be impossible to say that the seam does not occur in any given part; but the possibility of its absence over perhaps most of the district should be kept in mind.

That the seam itself is irregular in its thickness is strongly hinted at by the known irregularity of the enclosing sediments and their poorly sorted character, also by the absence of the seam in the bore-hole noted above. To determine the extent to which this irregularity affects the value of the coal, recourse must be had to carefully made borings.

The uneven nature of the seam recalls those of the Nanaimo[1]

[1] Clapp, C. H., Geol. Surv., Can., Mem. 51, p. 106.

district; but the Graham Island seams differ from those at Nanaimo in being irregular on account of differences in the amount of material originally deposited, while the Nanaimo seams were affected by movements in the rocks after they were partially consolidated.

ORIGIN OF THE COAL.

The problem of the origin of the coal seams naturally is divided into two parts: the question of the mode of accumulation of the seams, and the question of the formation of the different grades of coal. The first question is the more general and, so far as the evidence goes, applies with equal force to the different occurrences; but the origin of the different types of coal, such as the bituminous of Camp Wilson, the coked coal of Yakoun lake, or the anthracitic material at Cowgitz, is a problem to be treated separately in each case.

In the discussion of the origin of the Queen Charlotte series it was brought out that those sediments are supposed to have been formed in estuarine basins bordered by land of at least moderate relief. In order that vegetable strata might accumulate in these basins a number of conditions must be fulfilled. It is evident from the character of the rocks associated with the coal that they were laid down under uniform, quiet, shallow water conditions; such conditions might obtain after an estuary or bay was largely filled with detritus, and when the heavier seas and stronger currents were prevented from disturbing the water by seaward bars, shoaling water, vegetable growth, or all three. It is almost axiomatic that the plants that formed what we know as the coal seams of the present day, grew in fresh or at most brackish water.[1] It is concluded, therefore, that on Graham island, marshes, consequent on the filling of the basins by sediments, allowed vegetation to obtain a foothold along the shore, and this fringe was rapidly pushed seaward over the muds of the estuary. It is further generally conceded that plant growth in former geological periods was on a vastly greater scale than

[1] White, D. and Thiessen, R., "The origin of coal," U. S. Department of the Interior. Bureau of Mines, Bull. 38, 1913, p. 61.

at present.[1] The rapidly accumulating vegetable matter would of itself prevent salt water from penetrating far into its mass, except occasionally. These incursions of sea water are now represented by the sand and shale partings in the seams.

A point to be emphasized in regard to the coal seams of Graham island is the total absence of rootlets in the floors of the seams. In fact, except locally, so-called underclays are absent as well; and the coal rests directly on shale or sandstone beds, in some instances several feet thick. In no case were rootlets observed, though search for them was made at every opportunity. Neither have stems nor trunks been found penetrating the roof or otherwise occurring in the measures. With the single exception of the coaly trunk near Yakoun lake, no stems, leaves, or fronds of any description have been seen in connexion with the seams. It is only fair to state that there are no extensive mining operations to expose large areas of the seams, yet in none of the widely scattered prospect openings were any of the above features seen. The high percentage of ash in the coal, even of the cleanest type, is to be recalled.

The facts given in the preceding paragraph point to the conclusion that much of the vegetable matter now forming coal in the seams was accumulated by transportation, and did not grow directly where now found.

While much of the surrounding terrane was doubtless hilly, a considerable extent of land immediately bordering the areas of sedimentary deposition was probably low; so that while the vegetation was accumulating, sedimentation from adjoining areas was largely checked. On these coastal lowlands, plants grew in profusion, and in part contributed their quota to the seams.

To sum up: it is considered that during the coal-forming period or periods—there may have been as many as three—shallow, estuarine basins became choked with vegetable material, in part growing in place forming marshes and in part rafted in by the currents of sluggish streams. Frequently the sea inundated the otherwise freshwater marshes, carrying in the clay and sand now represented by shale and sandstone partings.

The conditions as outlined above are believed to be appli-

[1] *Ibid.* pp. 68 *et seq.*

cable in general to the Cretaceous coals of Graham island. Whether the various seams are identical, or occur even at nearly the same horizon remains to be considered.

In the Honna basin, there were probably two coal-forming periods, during the earlier of which coal in the western part of the basin at Cogwitz, Slatechuck, and Yakoun lake was accumulated. During this period deeper water conditions seem to have prevailed over the central and eastern portions of the basin, as there appears to be no coal in them. Later, the shoal water extended as far east as the central part of the basin and the seam at Camps Robertson and Anthracite was formed. This seam does not appear to extend east or south as already mentioned.

From the different character of the sediments of the Yakoun basin, including both the enclosing rocks and the coal itself, it appears probable that the Wilson seam is distinct from the seams in the Honna basin. While the Cretaceous sedimentation was doubtless continuous over what is now south-central Graham island, the preponderance of evidence seems to favour the theory that the coal seams were accumulated in localized, relatively small basins, and that it is vain to search for the Wilson seam in the Honna basin or the Honna Basin seams in the Yakoun basin.

It is not planned in the present report to consider the processes that have acted to form the bituminous coal of Camps Robertson and Wilson. A consideration of them may be found in various papers on the origin of coal, and no new facts bearing on this stage of coal formation have been noted on Graham island. Certain observations and deductions, however, with regard to the formation of carbonite or natural coke and of the anthracitic coal of Slatechuck valley and Cowgitz, will be set forth here. Other facts on which the theory is based in part have been already stated.

The appearance of the anthracitic material of the Slatechuck valley, Cowgitz, and other places, together with its analyses and mode of occurrence have been already described. It is to be emphasized that this is a true bedded, syngenetic deposit, a coal seam to all intents and purposes, and differing from anthracite essentially only in being unable to support combustion under ordinary conditions.

Intersecting the shales in which the coal is found are several dykes and sills of the Etheline volcanics, like those shown in Figures 8 and 9 on pages 71 and 72. The metamorphosing action of these igneous rocks, through the application of heat, is believed to have deprived the coal of its volatile constituents, and, to have left it in its present condition.

That molten igneous rocks intersecting coal seams exert a strong devolatilizing action on the coal is well known,[1] and also that this action is effective only locally.[2] This localization of the metamorphosing effect will explain why only a part of the Cretaceous coals on Graham island are anthracitic.

In the anthracitic district of Graham island, the intrusive bodies have been shown to be particularly abundant and some are of considerable size (the 50-foot dyke near Anchor cove for instance); and the intrusives in general have been accompanied by considerable volumes of heated waters. It is thought that these heated waters, in part perhaps in the gaseous state, have permeated the strata and devolatilized the coal seams to the extreme extent now seen.

The hot waters or gases are believed to have been even more potent in their action, through their transference of heat by convection, than through the baking of the coal by conduction. The latter process is very slow,[3] while any contact metamorphic deposit gives evidence of the efficiency of heat transfer by heated waters.[4]

In place of the above theory, that contact metamorphism was the effective agent, the regional metamorphism hypothesis deserves consideration. This hypothesis in brief considers the degree of anthracitization to be proportional to the degree of deformation of the enclosing strata. This hypothesis seems in-

[1] Willis, Bailey., Tenth Census U.S.A., vol. 15, 1883, p. 765.
Lee, W. T., Cited by D. White, U. S. Bureau of Mines, Bull. 38, p. 103.
Newberry, J. S., Sch. of Mines Quart., vol. 8, 1886-87, p. 334.
Taff, J. A., Science, N.S., vol. 23, 1900, p. 696.
Storrs, L. S., 22nd Ann. Rept., U.S. Geol. Surv., vol. 3, p. 430.

[2] White, D., U. S. Bureau of Mines, No. 38, p. 104.

[3] Ingersoll, L. R., Econ Geol. vol. 8, 1913, p. 230.

[4] Lindgren, W., Econ. Geol. vol. 9, 1914, p. 290.

applicable to the Graham Island deposits, for at both Camps Robertson and Wilson, severe folding accompanied by minor faulting has not caused anthracite to form.

Campbell's hypothesis,[1] that anthracite formation is facilitated by the escape of gases through greater permeability of the enclosing rocks, is no more helpful in this case; for the measures enclosing the anthracitic coal are very dense shales, much more impermeable than the coarser beds of Camps Robertson and Wilson.

LIGNITE.

Location. Lignite is of widespread occurrence in the Skonun formation, of Tertiary age. The most westerly locality where it is reported to be in place is on Lignite creek which enters Naden harbour near its southeast corner. Lignite has been reported from near Parry passage, at the northwestern extremity of Graham island; but Mr. Henry Edenshaw, who is thoroughly familiar with the district, states that the lignite found there was not in place. It was probably carried by waves and currents from the outcrops to the east. At Skonun and Yakan points on the north coast of Graham island, there are several seams of lignite. On the Mamin river entering Juskatla inlet, in the interior of the island, Dawson[2] reports lignite as occurring 6 miles up stream from the mouth. Along the east coast of the island as far south as Spit point on Moresby island, fragments of lignite are occasionally cast on the beach after storms, and are presumably torn from submarine outcrops. Clapp[3] reports having seen lignite said to have come from the headwaters of the south branch of the Tlell river.

Lignite of Skonun Point. At Skonun point there are several seams of lignite which have attracted considerable attention of late years. This was the only lignite seen in place by the writer; but, unfortunately, the tides at the time when the locality was visited were not low enough to allow of a careful examination being made. The following account of the occurrence is, therefore, taken from Clapp's report.[4]

[1] Campbell, M. R., Econ. Geol. vol. 1, 1905, p. 26.
[2] Dawson, G. M., Geol. Surv., Can., Rept. of Prog., 1878-79, pp. 85B-89B.
[3] Clapp, C. H., Geol. Surv., Can, Sum. Rept., 1913, p. 38.
[4] *Ibid.* p. 38.

"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 due east 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
Vol. combustible	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
Vol. combustible	45·5	37·5
Fixed carbon	31·5	36·5
Ash	1·0	3·5
	100·0	100·0

The lignite is plainly seen to be composed of woody stems and tree trunks pressed into a tough, black, and brown mass and is remarkably similar to Tertiary lignite from the Flathead valley, British Columbia. The feeble resistance to erosion offered by the enclosing sandstones is probably due to their calcareous cement which is readily dissolved by the sea water.

The lignite, if not allowed to dry too rapidly, will stand transportation fairly well, though it slacks or checks to some extent.

At Skonun point there appears to be a large amount of this lignite available, though, with few exceptions the seams are thin. As a future resource the material has undoubted value.

No other occurrences of lignite came under the writer's observation, but the known wide extent of the material renders it probable that valuable deposits may yet be found.

Origin. As detailed studies have not been made of the lignite, little can be said in regard to its origin. In general, the conditions may have been similar to those obtaining when the Cretaceous coals were formed, except that the conditions were not so widespread.

PETROLEUM.

In the following description of the so-called petroleum deposits of Graham island, the various occurrences are taken up according to the formation in which they are found, beginning with the oldest; there follows a brief statement of the theories in regard to the origin and accumulation of petroleum deposits of commercial value and an application of these theories to the occurrences under consideration, with conclusions.

While material that can properly be called petroleum has been found only in a single instance, and that in minute quantities, it is thought best to retain the heading, petroleum, for the description of the various bituminous substances, exclusive of oil-shale, found on Graham island.

MAUDE FORMATION.[1]

Virtually all of the finer grained sediments of the Maude formation contain bituminous matter, in varying amounts. This is quite apparent in the field, where the rocks give off a bituminous odour when struck or rubbed; and pulverized fragments ignited at a low heat in a closed glass tube give a marked foetid odour as well, even when rubbing does not produce this effect. In almost every exposure of the formation, search will reveal thin sheets of black, sticky, odourless, tarry matter on bedding planes, and in many on joint surfaces. At several localities, notably on Hidden creek, calcite veins have been found filling irregular, usually short and branching fissures in the banded argillites of the Maude formation. They occur in the localized zones of crumpling already described (page 41) where cracking in the rocks has been most pronounced. In these veins there are many irregular open spaces. Brownish organic matter and tar encrust the surfaces of many of these cavities and, in places are enclosed in the calcite. Pulverized calcite from these veins, when heated in the closed tube gives off water coloured brown by organic matter which has an oily smell.

Origin. It is to be recalled that the argillites of the Maude formation are very fossiliferous—literally crowded with flattened impressions of ammonites and other forms, the substance of which has practically all disappeared. This fact, in connexion with those given above, renders it unnecessary to look elsewhere for the source of the bituminous matter. It is thought

[1] Full descriptions of the lithology of the Maude, as well as of the other formations in which bituminous matter is found, are given in chapters IV and V, and need not be repeated here.

that the soft parts of the marine animals, now represented by the impressions in the rocks, furnished the bitumen by slow distillation during the compression and induration of the beds. The same waters that carried calcite dissolved from the rocks into the gash veins also carried the black tarry matter. The hypothesis that the bitumen may have originated elsewhere and later was concentrated in the argillites is negatived by their very impervious character. It is in these, the least porous rocks of the formation, that the bitumen is found in most abundance. That they are its original home seems certain.

This occurrence of bituminous matter in connexion with fossils from which it almost certainly is derived is analagous to the occurrence of petroleum in the diatomaceous beds of California,[1] in the fossil beds from Egypt,[2] etc. It is to be emphasized that no seepages of oil have anywhere been observed or reported from the Maude formation. The distillation has been carried so far that only the black tar, in the nature of an asphaltic residue, has been left; and while there are undoubtedly considerable quantities of bituminous matter locked up in the argillites, it cannot be released short of actual distillation by retorting the rocks.

HAIDA FORMATION.

In the calyx drill hole put down in the eastern part of section 36, township 7, through the lower part of the Haida formation of the Yakoun basin, brown stains of oily material were found in the cores at about 465 feet from the surface. As in some of the occurrences in the Maude formation, the bitumen was in calcite veinlets. The amount found was very small, no one stain being over an inch across; and no oil was observed.

The diamond drill holes bored at Camp Wilson in 1914 gave a considerable flow of gas, both during the drilling, and after it had ceased. The gas was colourless and odourless, and burned with a yellow flame that seemed to be of low heat intensity. The flow was estimated to be less than a cubic foot per minute.

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[1] Arnold and Anderson, U.S.G.S. Bull. 322, 1907, p. 110.
[2] Fraas, cited by Clarke, U.S.G.S. Bull. 491, 1911, p. 699.

A slight seepage of gas is reported to take place on the shore of Bearskin bay, west of Queen Charlotte, but this seepage was not seen by the writer.

ETHELINE FORMATION.

The Etheline formation, composed as it is wholly of intrusive igneous rocks, would not be expected to prove a container of bituminous matter. A single occurrence has been noted where bitumen fills some of the vesicles in an altered andesite dyke. The dyke is on King creek about 2 miles above its mouth and cuts finely laminated, strongly bituminous argillites of the Maude formation. It strikes north 35 degrees east and dips 40 degrees northwest. The argillites at this point strike north 75 degrees west and dip 60 degrees southwest. The dyke averages 15 inches in width and is somewhat irregular in outline. It is dense and in part amygdaloidal; the amygdules are spherical, up to three-sixteenths of an inch in diameter, and filled with pale, bluish chalcedony, calcite, or black, hard, tarry matter. Some of them contain pale brown, viscous oil; and fragments of the dyke falling in water cause strong iridescent films to form.

The amygdaloidal portion of the dyke is irregularly distributed through it, generally near its lower contact, and forms less than 40 per cent of its volume. Where the amygdules are found the rock is stained pale brown by bitumen; and brownish streaks and patches penetrate the remainder of the rock, which is a pale purplish-grey. These streaks are controlled by cracks, formed after the dyke had consolidated, and the bitumen probably found its way along them while the rock was still heated. Very similar brownish stains have been noted in dykes of the same kind from Skidegate inlet, and their cause was obscure until this dyke was found.

This is a clear instance of petroleum occurring in an igneous rock; but it is just as evident that the home of the oil is the bituminous argillites, from which the heated dyke distilled and absorbed the organic matter.

MASSET FORMATION.

Bituminous matter has been found in the Masset formation in several localities, which will be described separately.

Lawn Hill.

At Lawn hill, on the east coast of Graham island, black, dense, fluidal basalts, some of them with well developed columnar structures, are exposed on the shore. One outcrop of these rocks is seamed with several calcite veins filling joint cracks, which also contain tar. The veins are usually less than an inch wide and many of them are as thin as paper; they are filled with white and yellowish calcite, more rarely with quartz, and exhibit comb-structure, often with a channel in the middle of the vein. Black tarry matter exudes from the veins on warm days when the rocks are heated by the sun. The tar is odourless and sticky, and slightly softer than is pitch under ordinary summer temperatures. The fact that the supply of tar does not seem to diminish, and has been continuous for some years at least, indicates that it is supplied from a natural source below. Apparently exposure to the air hardens the tar; for the material beneath the surface, although at a considerably lower temperature (that of the enclosing rocks) than that of the atmosphere, is sufficiently fluid to travel through the cracks. The total amount of tar is small, and the quantity exuding from the cracks is dependent on the amount of sunshine.

In some of the loose basaltic agglomerates which in part form the eminence called Lawn hill, irregular patches contain similar black tar in the interstices of the rock. This tar doubtless is from the same source as that exuding on the beach.

On the ranch of Edgar Ashton, about 2 miles inland from the occurrences noted above, similar tar is reported to have been found within a few feet of the surface of the ground, in a grey soft clay.

Tian Point.

Black tar like that described above is found at several localities on the west coast of Graham island, notably at Frederick island, Tian point, and Otard bay. At Frederick island films of tar are found in the flaggy argillites of the Maude formation, a type of deposit which has been already described.

The occurrence at Tian point (to which that at Otard bay is essentially similar) is of a different type to any yet described, though related to some of them. The present home of the tar in this case is in amygdules and lenticular fissure veins in basalt and basalt agglomerate.

Country Rocks. The rocks in the vicinity of the bituminous deposits are agglomerates and tuffs—locally termed shale—with which are interbedded numerous and thick flows of basalt, often amygdaloidal. Many of the basalt flows are very thick—up to 100 feet—and in many instances they possess well developed columnar structures, as illustrated in Plate XIIIB, individual columns being 3 or 4 feet in diameter. These flows are much more resistant to weathering and erosion than are the pyroclastic rocks; and they form jutting headlands continued seaward in dangerous reefs. while the softer fragmental rocks are found in the coves and bays.

Many of the tuffs are pale bluish, fine-grained, soft, fragmental rocks and to these the term shale is applied by the prospectors. Other tuffs are light green, banded, and curiously contorted. They are light in weight, rather porous, and break readily, leaving a rough, harsh surface.

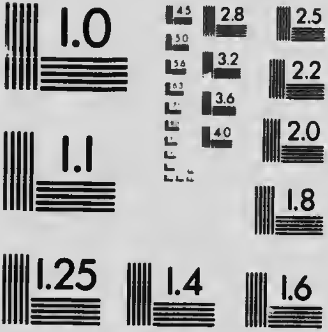
Structure. The general structure in the vicinity of Tian point is monoclinal. Details of structure were not worked out, but minor deviations in strike and dip have been observed. The general strike is north 20 degrees west with moderate southwesterly dips.

Occurrence. The bitumen at Tian point is found in veins traversing the basalts and agglomerates, and in amygdulesi n the basalt. It is also found seeping from cracks in the basalt which in most cases can be proved to be connected with one or the other of the above occurrences, and probably are so connected in all cases.

The amygdaloids of Tian point vary greatly in their habit. In some the number of filled cavities is large, in others they are fewer; and the size of the individual amygdules varies greatly. In one commonly occurring type about 40 per cent of the volume is made up of evenly distributed amygdules averaging less than one-fourth inch across, and spherical or regularly almond-shaped. Another type contains fewer, irregularly spaced cavities of large

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



size up to 2 or 3 feet across, and irregularly flat in shape. The groundmass of the rock is in all cases dense, and in many cases considerably altered.

The filling of the amygdules is made up of various minerals, in varying proportions. Some contain pale bluish-grey, chalcedonic silica only; and these, when weathered from the rocks and rounded on the beach, form the agates for which the locality is noted. Others contain only calcite and, in the altered rocks, chlorite. The fillings composed of single minerals are usually the smaller amygdules, under an inch in diameter. A very common type of filling, perhaps the most common, and one to which the larger amygdules belong, consists of an outer rim of banded, bluish-grey chalcedony lined with a concentric layer of inwardly projecting quartz crystals which in some amygdules fill the whole space and in others leave a cavity. It is in this central cavity that the tar is found, filling the whole space; so that when the amygdule is broken open on a cool day, the tarry, internal mould may be seen to bear the imprint of the crystalline facets of the quartz. One pint of tar has been taken from a single one of the larger amygdules. In some of the smaller amygdules tar forms the sole filling.

In the agglomerates tar occurs with calcite and quartz, which form irregular replacement masses up to a foot or so across, the tar filling cavities in the masses.

In both the amygdaloids and the agglomerates tar is found in fissure veins. The vein filling is mostly chalcedony, quartz, and calcite, usually with a symmetrically banded structure. White, pale blue, or grey laminated chalcedony occurs on each wall of the vein, the middle portion of which is composed of clear quartz or white calcite crystals projecting inward; and tar is found in the vacant space between the ends of the crystals. The occurrence is thus seen to be essentially similar to that in the amygdules. The veins are from a fraction of an inch to 3 feet or more wide, and occasionally over a score of feet long, though usually not attaining such length. They branch and reunite and in general are irregular.

Liquid oil is said to occur in some of the agates from this vicinity and in these a bubble can be seen to move through its translucent container. A. A. MacPhail of the B.C. Oilfields showed one of these agates to the writer, and said that they were occasionally found at Tian point, though considered more or less of a rarity.

Figure 23 is a generalized diagram illustrating the various ways in which the tarry matter is found.

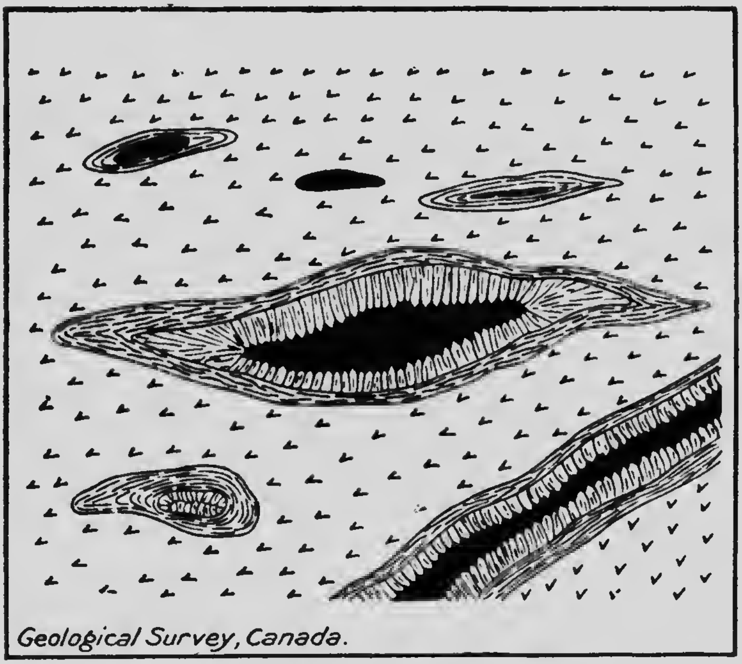


Figure 23. Generalized diagram illustrating the mode of occurrence of tar in chalcedony-quartz amygdules and veins in basalt.

Origin. It is not proposed to give here an account of the theories that have been advanced to explain the origin of petroleum. Excellent summaries with abundant references are given by Clarke[1] and Höfer.[2] In general it may be said, that petroleum

[1] Clark, F. W., U.S. Geol. Surv., Bull. 491, pp. 681-704.
[2] Höfer, Hans. Das Erdöl, Leipzic, 1906, pp. 160-229.

is supposed to have originated through one of two main processes, (1) by inorganic, and (2) by organic agencies.

Perhaps the strongest argument that the upholders of the inorganic theory put forth is the well known occurrence of hydrocarbon gases in volcanoes, and coincidently, in volcanic rocks.[1] The bitumen in the Graham Island basalts, it will no doubt be argued by some, is of inorganic origin, and perhaps this cannot be absolutely disproved. However, the occurrence of similar bitumen in the sediments of the Maude formation, where it is clearly of organic origin,[2] the fact that the Masset basalts have penetrated these sediments, and that an amygdaloidal dyke cutting the bituminous argillites of the Maude formation has been found to contain oil and tar, point irresistibly to the conclusion that the bitumen has been absorbed from the Maude formation by the passage through these rocks of the basalt together with heated waters and gases connected with the intrusion, and that it is, therefore, primarily of organic origin.

The physical chemistry of the process would be analogous to that involved in the case of the gases dissolved in metals, which are given up on cooling.[3]

"OZOCERITE."

Paraffin wax in a high state of purity has been found at a number of localities on the coast of Graham island; and it has been supposed by some to be ozocerite or natural paraffin, and to be an indication of petroleum deposits at depth.

The wax has been found on the west coast, in the neighbourhood of Frederick island and Tian point and on the north coast, near Parry passage. It is reported to have been found also on Kumdis island, in Masset inlet. The wax has never been found in veins or cavities in the rocks; in other words, it has not been seen in place, and has been found only as cakes on the beach, evidently cast up by the waves. Those who main-

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[1] For summary of this subject see:
Becker, G. F., U.S. Geol. Surv., Bull 401, 1909.

[2] *Ante*, p. 264.

[3] Hofman, H. O., "General Metallurgy," McGraw-Hill Book Co., N.Y., 1914, p. 20. Many references are given here on this subject.
Sieverts, A. Revue de Met. Extraits. vol. 5, 1908, p. 10.

tain that its origin is natural say that it is formed in the rocks below sea-level and has broken from them and floated to shore.

In appearance the wax is translucent, pale yellow, homogeneous, and evidently of a high degree of purity. It is found in cakes which are usually rectangular, up to 18 inches square and 2 to 3 inches thick. Although somewhat abraded by rough treatment on the beach, and occasionally having sand embedded in its surface, the wax has without question been moulded by artificial means; and the pieces seen are very similar to the paraffin cakes sold for household purposes.

A sample of the wax was tested in the laboratory of the fuel testing station at Ottawa by Fred. E. Carter, who reports as follows:

"Paraffin wax, recovered from the residue left after distilling petroleum, and ozocerite, the residue left by nature from petroleum deposits, have striking similarities rather than dissimilarities; and it is rather difficult to determine the origin of a sample (by laboratory tests). The melting point and the solubility in alcohol indicate that the sample submitted is impure paraffin wax rather than ozocerite."

In view of the mode of occurrence of the wax, its appearance, the shape of the cakes, and its high purity, the theory that it is of natural occurrence is so improbable as to be fantastic. Furthermore, while the bitumen of natural occurrence on Graham island is of an asphaltic nature, this wax is what would be derived from an oil with a paraffin base, and cannot serve as an indication of asphaltic oil.

The paraffin is thought to have floated ashore from a ship, having been thrown into the water, or to have come there by shipwreck[1]. The west coast of Graham island is swept by currents that bring material of many kinds to land; redwood from California or Puget sound has been found there, as has oak and other dressed lumber from localities unknown. In July, 1914, great quantities of white, purple-stained pumice were washed ashore, for the first time according to several men familiar with

[1] Compare the beeswax found at Nehalem bay, Oregon, U.S.A., and described by C. W. Washburne, U.S. Geol. Survey, Bull. 590, p. 65. As in the present case, this wax has been held to be ozocerite, and called an indication of oil.

the coast. This pumice could hardly have come from Alaska, or it would have been observed long before. The supposition that it comes from the Japanese volcanoes in eruption early in 1914, though it seems far-fetched, is the only explanation that occurs to the writer. At any rate, various materials from distant sources find their way to the Queen Charlotte islands by ocean currents, and it is most probable that this is the way the paraffin came. Its occurrence in conjunction with the asphaltic bitumen found in place in the basalts must be looked upon only as a coincidence.

ACCUMULATION OF PETROLEUM.

Whatever may be the disagreement among geologists in regard to the origin of petroleum, there is essential accord in postulating conditions for its accumulation in bodies of commercial value. These necessary geological features may be listed under four headings.

(1). *A Supply of Liquid Oil.* It is obvious, that in order that petroleum may be extracted from the rocks by drilling, it is necessary to have the oil in a liquid condition at the temperature prevailing in the strata in which it is contained.

(2). *A Porous Container.* The bed or stratum in which the oil is contained is called the "oil sand" irrespective of its true lithological character. It may be a porous sandstone, a dolomitic limestone, a layer of fractured chert or hard shale, or some other container. It is necessary, however, that there be a considerable area that is porous, to allow flow of oil toward the hole.

(3). *An Impervious Cover.* In order that a mobile liquid like petroleum shall not escape from the porous container, the latter must be covered or "capped" with some impervious bed. This impervious cap is usually wet clay or shale, which imprisons the oil until it is penetrated by the drill.

(4). *Favourable Structure.* It is conceded by everyone that the structure of the rocks containing the oil has a most important influence on its accumulation. There are many different types of structure that contain oil, and the subject has been treated at length by Clapp[1] and others.

[1] Clapp, F. G., Econ. Geol., vol. 5, 1910, p. 503.
Griswold and Munn, U.S. Geol. Surv., Bull. 318, p. 15.

It is to be expected that in saturated rocks, petroleum, a liquid lighter than water, will rise to the highest part of its container, the oil sand. For this reason, oil is frequently found at or near the crests of anticlines in saturated rocks; but it is also found along flat areas in the sand, or where changes of dip from flat to steep occur. Other apparently anomalous occurrences may be explained as due to varying porosity of the sand or caused by varying conditions of saturation by water and groundwater movement.

It is to be emphasized that without the conjunction of these four conditions in an individual area, no search for oil can hope to meet with success.

CONDITIONS ON GRAHAM ISLAND.

It now remains to critically examine the occurrences of bituminous matter in the various formations and districts of Graham island, in the light of the facts given above, in order to arrive at a conclusion in each case as to the probability of workable deposits of petroleum being found by drilling. As in the descriptive portion of this report, the formations will be taken up in the order of their age, beginning with the oldest.

In the Maude formation conditions 1, 2, and 4 are not fulfilled. No liquid oil has ever been observed or reported from this formation, and the tar which does occur is so viscous that it flows only when heated by the sun. None of the beds of the formation, except some of the tuffs at the top, are at all porous. Elsewhere in it are found only dense partly metamorphosed argillites and fine tufaceous sandstones. Finally, the rocks, though the structure perhaps may be locally favourable, are on the whole so extremely broken up and traversed by joints and faults that it is extremely doubtful that any large body of petroleum could be confined in them. The types of structures found in this formation are illustrated by Figures 2 and 5.

In the Haida formation, where the last three conditions as given above may in some places be fulfilled, there is almost no sign of petroleum of any sort occurring in the rocks. It is true that small oil stains have been observed in some of the drill cores, and that gas has escaped from some of the holes; but these in themselves are not sufficient indications that workable bodies of oil exist to warrant drilling. These instances of small quantities of oil and gas being found in a fossiliferous series of sediments is quite in keeping with other well known occurrences, and does not necessarily indicate large reservoirs of petroleum at depth. Nearly all sedimentary rocks contain bituminous matter in some degree[1] and it is to be expected that it will occasionally manifest itself as oil or gas. A slight flow of gas is not unusual from boreholes drilled in sediments and, taken alone, scarcely warrants further prospecting.

Fire damp in dangerous amounts is found in the tunnel of the British Pacific Coal Company near Slatechuck creek, where it collects after exuding from the shales and coal seam. It is here no more an indication of petroleum than the fire damp so commonly found in coal mines.

The occurrence of liquid oil in the amygdaloidal dyke of the Etheline formation remains the only instance in which this substance has been found on Graham island. It is hardly necessary to say, howe er, that oil pools are not to be looked for in connexion with dykes and sills of igneous rocks.

In the Masset formation the necessary condition, viz., the presence of liquid oil, is not fulfilled; and while the other three may be present to some extent, it has not been so ascertained in any instance as yet. If liquid oil did occur, there are tuffs and agglomerates among the basalts that might readily form a porous container, and impervious cappings might be found as well. The fact, however, that no oil nor real indications of oil (the tar and paraffin cannot be considered such) have been found negatives the hope of finding workable bodies of petroleum in this formation.

CONCLUSIONS.

In view of the facts and their interpretation as given above, it seems unnecessary to add that the possibility of workable bodies of petroleum being found is regarded as extremely remote.

[1] Orton, E., Geol. Surv. Ohio, First Ann. Rept. 1890, p. 87.

That they may occur is not regarded as impossible; but nothing to indicate their existence has been seen by the writer; and until some further and more satisfactory natural indications are found, prospecting blindly with the drill is discouraged.

OIL-SHALE.

The fact that many bands in the Maude formation are rich in bituminous matter suggests that some may be oil-shales of value. Oil-shale is a rock containing bitumen that can be extracted by distillation in retorts. The "shale oil" industry is well established in Scotland, and extensive tests have been made there on Canadian oil-shales from New Brunswick[1].

In general, oil-shale is dark brown or black in colour, usually rather light in weight, with a "curly" or a massive structure. Many of the bands of argillite seen in the Maude formation resemble some of the New Brunswick shales, especially those from Albert Mines of which the analysis is given under No. 3 on page 17, Part I, of Ells' report. The Graham Island shales are denser and heavier, however.

The writer was shown a sample of typical curly oil-shale by a prospector, which was said to have come from the vicinity of Rennell sou[illegible] [illegible]t was markedly lighter in weight than any rocks elsewhe[illegible] [illegible]t it is possible that such shales occur.

A 3-pou[illegible] of argillite from the Maude formation on Hidden c[illegible] [illegible]sed for the Northern Oil Company by the Vancouver assay office, gave 2·8 per cent of "aqueous extract." What this extract consisted of was not stated in the copy of the analysis furnished the writer—presumably it was hydrocarbons, etc.

To compensate for the disappointing prospects of deposits of liquid petroleum being found on Graham island, the attention of prospectors is directed to the Maude formation as the probable home of commercial oil-shales.

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[1] Ells, R. W., "Joint report on the bituminous, or oil-shales of New Brunswick and Nova Scotia, also on the oil-shale industry of Scotland," Department of Mines, Canada, 1909.

CLAY.

Clay, of glacial origin, and of low grade, is found in abundance in the Honna valley, Yakoun valley, underlying the northeast lowland, and in other localities. It is usually grey, very plastic, and is suitable for common brick manufacture and perhaps the lower grades of pottery. High grade clays have not been observed on Graham island. Some of the clays from the Skonun formation on the Yakoun river have been tested in the kilns of the Clayburn Brick Company, but have been found to melt at low temperatures.

The shales of the Haida formation are usually too sandy for use in clay industries; but some shales from the tunnel of the British Pacific Coal Company nea Slatechuck creek were collected by Clapp[1] and tested by Dr. H. Ries. These shales are found beneath the "A" seam. The upper one is a dark carbonaceous dense slaty shale, similar to that quarried by the Indians on Slatechuck creek for carving, and it is 15 feet thick. The lower shale, 30 feet thick, is a lighter coloured and much softer rock, and is locally termed fire-clay. Doctor Ries reports on these clays as follows:

"The plasticity of the lower shale is fair, that of the upper shale very poor. A mixture of the two shales in equal proportions is fairly plastic. The air shrinkage of the mixture averages 4·5 per cent, and the tensile strength averages 50 pounds. At cone 010 (1742 degrees F. or 950 degrees C.) the burnt mixture has a little ring, poor colour, an absorption of 14 per cent, and a fire shrinkage of minus 1 per cent. At cone 05 (1922 degrees F. or 1050 degrees C.) the mixture has a light grey buff colour and an absorption of 13 per cent. At cone 1 (2102 degrees F. or 1150 degrees C.) the colour is still the same and the fire shrinkage 1·6 per cent. At cone 7 (2318 degrees F. or 1270 degrees C.) the mixture shows no sign of failing by fusion. These tests show that the mixture could be used for common and face brick, although there was not sufficient material supplied to test it in a stiff-mud die. The lower shale clay alone behaves similarly, but is more plastic and burns a little denser."

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[1] Clapp, C. H., Geol. Surv., Can., Sum. Rept. 1912, p. 40.

BUILDING STONE AND LIMESTONE.

Although the possibility that a demand for these materials will arise is remote, it is well to note places where they may be obtained.

The massive beds of the Haida formation on Maude island would probably furnish sandstone of good quality, though little is known regarding the jointing, and the dressing qualities of the stone. It is probable that some of the areas on the west coast underlain by granitic rocks would furnish granite at tidewater. The basalt of the Masset formation of northern Graham island, Lawn hill, etc., would furnish inexhaustible quantities of excellent stone for surfacing roads.

Limestone, suitable for use in plaster and probably cement manufacture, may be obtained in large quantities on the southeast end of South island in Skidegate inlet.

GOLD.

At several places along the east coast of Graham island, from Lawn hill to Rose spit, gold has been obtained by washing the black sands of the beach. The east coast of Graham island is underlain by unconsolidated or soft Tertiary sediments, covered with stratified glacial drift. Long continued action of the waves and currents on these deposits has developed a nearly straight, low, flat beach, with very shallow water off-shore. The sorting effect of the waves has concentrated the heavier minerals in the quartz sands at [illegible] in places; and it is in reddish, brownish, or black streaks of sand that the gold is found. The writer has not examined the deposits carefully, nor has he been able to get any detailed information about them. At Masset, however, deposits of a similar nature were seen, and were said by Mr. James Martin to be like those of the east coast in all respects but size.

The Masset black sands occur in the ordinary white quartz beach sand as layers of a reddish to black colour, from one-fourth to one inch thick. They are a few square feet in area, and irregular in outline. The location of the layers is not permanent as they shift with every storm. A sample of the Masset black sands was collected and subjected to a sizing test, with the following results:

The whole sample passed a 20-mesh sieve.

	On	40 mesh	=	0·63	per cent by weight.	
Through	40 "	60 "	=	31·0	"	"
"	60 "	80 "	=	50·5	"	"
"	80 "	100 "	=	16·6	"	"
"	100 "	120 "	=	1·2	"	"
"	120 "	140 "	=	0·15	"	"
"	140 "	160 "	=	0·08	"	"
"	160 "	180 "	=	0·01	"	"
"	180 "	200 "	=	0·005	"	"
"	200 "	220 "	=	0·0025	"	"
"	220			0·0025	"	"
				100·0		

The sand was also mineralogically examined, and found to consist of (besides quartz) magnetite, ilmenite, pink garnet, epidote, zircon, with a few grains of chlorite, serpentine, and biotite.

The gold occurring in the sands of the east coast is said to be in extremely small particles, as the so-called "flour" or "float" gold. The absence of any natural head of water along the shore makes extraction expensive.

The ultimate source of the gold has not been determined. Gold occurs at Gold harbour on the west coast of Moresby island, as free gold in quartz; and it is possible that the placer gold was derived from veins of a similar nature now buried by the Tertiary and later rocks. The high degree of comminution of the gold in the beach sands indicates that the gold was transported a considerable distance; and it seems most probable that the gold now obtained from the beach placers has been reconcentrated in them from the Pleist[illegible] gravels of the northeast lowland.

Gold is found on the Southeaster and Beaconsfield mining claims, situated about a mile northeast of Skidegate Indian village. Through the courtesy of John MacClellan, Esq., part owner, the writer had the opportunity of visiting the property, and the following information was largely obtained from Mr. MacClellan.

The deposit consists of a vein averaging 9 feet thick, striking north 40 degrees west and with a vertical dip. The vein is slightly irregular, and apparently faulted off at the southeast end. The vein material is almost wholly milky quartz, occurring as a replacement of a brecciated zone in the Yakoun volcanics. Irregularly distributed through the vein are bunches of sulphides, containing galena, sphalerite, pyrite, and chalcopyrite. The gold occurs in the galena, which carries up to 30 ounces in silver, and also with an unknown yellow mineral encrusting some of the specimens in thin films. Occasionally, free gold may be seen with the naked eye, but usually it can not be thus made out. Specimens of galena gave assays as high as $2,600 to the ton, but the bunchy nature of the ore necessitates thorough prospecting before the value of the property can be definitely established.

Gold is reported to occur in the flow of bostonitic trachyte on the west side of Harrison island in Juskatla inlet. Mr. Robertson, owner of the claim, states that free gold is sometimes visible in the rock, and that assays from nothing to several hundred dollars to the ton have been obtained. Pyrite is found disseminated in very minute crystals throughout the rock, and pyrite or marcasite form infrequent films on small joint surfaces. It is possible that these minerals carry gold.

CHAPTER VIII.

BORE-HOLE RECORDS.

In this chapter are given records of several of the bore-holes which have been put down on Graham island in search of coal or lignite.

Graham Island Collieries.

Bore-hole No. 1. Put down on left bank Yakoun river in the N.W. ¼, S.E. ¼ sec. 30, tp. 7. Depth of hole, 1,100 feet (?). Diamond drill used.

The core of this hole, which was started in slaty argillites of the Maude formation whose attitude is north 65 degrees east, dip 15 degrees northwest, consisted of black dense slaty argillites, much intersected by dacite and andesite dykes of the Etheline formation. No other rocks were observed, and the core was not measured in detail.

Bore-hole No. 2. Put down 35 feet in a north 75 degrees east direction from southwest corner post of sec. 18, tp. 7. Depth of hole, 1,500 feet. Diamond drill used. Size of core, 2½ inches.

Description of Core.	Thickness feet. (*Approximate*).	Depth feet.
Light greenish-grey, fine, hard, even-grained, tufaceous sandstone with some coarser and softer tuff layers	157	157
Green, uneven-grained, angular agglomerate, irregular fragments up to 1½ inches in a large percentage of matrix, much replaced by calcite. Beds are up to 10 feet thick, and vary slightly in texture. Several intrusions of andesite up to 5 feet thick occur	500	657
Light greenish-grey, very massive, and homogeneous tuff and feldspathic sandstone, with a few coarser layers, up to 2 feet thick, and dacite or andesite sills	250	907
Grey, massive, feldspathic sandstone, or tuff, rather coarse, seamed with calcite veins	50	957

Description of Core.	Thickness feet.	Depth feet.
	(*Approximate*).	
Grey, massive, fine, even tuff, very dense and hard, with thin coarser-grained beds, and a few markings like belemnites....................	200	1,157
Grey, massive, fine, even tuff, very similar to above, but finer on the whole, some layers argillite-like. Contains intrusives..........................	150	1,307
Greenish and purplish, coarse, angular agglomerate, fragments up to 3 inches, in a tuff matrix greatly replaced by calcite..........................	100	1,407
Light grey, fine, massive tuff.....................	33	1,440
Green, medium-grained, agglomerate or tufaceous sandstone................................	60	1,500

These beds are typical of the upper portion of the Maude formation, and represent in part its transition to the Yakoun formation.

Graham Island Coal and Timber Syndicate.

Bore-hole No. 1. Put down near the northeast corner post sec. 4, tp. 7. Depth of hole, 400 feet (?). Davis shot drill used.

The core of this hole consisted of greenish and purplish agglomerates of the Yakoun formation, with many intrusive andesite and dacite porphyrites of the Etheline formation.

Bore-hole No. 2. Put down near the south ¼ post of sec. 4, tp. 7. Depth of hole, 390 feet. Davis shot drill used.

The core[1] for 15 feet consisted of dacite porphyry and the rest of agglomerate with green matrix and red fragments or occasionally red matrix and green porphyry fragments. The rocks are veined with calcite and quartz. These agglomerates belong to the Yakoun formation.

Bore-hole No. 3. Put down 19·75 chains west of east line of sec. 36, tp. 9, and 1·97 chains south of east-west centre line of sec. 36. Passes through the Haida formation of the Yakoun basin into the Yakoun formation. Depth of hole, 860 feet. Davis shot drill used. Size of core, 2½ inches.

[1] Description from notes of C. H. Clapp.

Description of Core.	Thickness feet.	Depth feet.
Drift	112	112
Greenish-grey, soft, argillaceous sandstone with occasional pebbles	40	152
Greenish-grey, coarse angular sandstone, mostly volcanic detritus, much seamed with calcite veins, contains finer bands	8	160
Dark grey fine argillaceous sandstone	5	165
Dark greenish medium to coarse angular sandstone, layers from 2 inches to 6 inches, seamed with calcite	11	176
Greenish-grey, medium to fine sandstone	2	178
Greenish, fine sandstone, well rounded grains	4	182
Greenish, coarser sandstone, alternating with finer layers	19	201
Greyish and greenish-grey, very fine, irregularly textured, well-laminated sandstone (dip not over 10 degrees).	4	205
Greenish-grey, medium to coarse sandstone, a few pebbles to one-fourth inch, finer near base	21	226
Greenish and greyish sandstones alternating beds coarse and fine	15	241
Dark grey, fine argillaceous sandstone, sub-conchoidal fracture	7	248
Grey, fine laminated sandstone, coarser at base	10	258
Grey, medium to fine even-grained, slightly argillaceous sandstone, seamed with calcite veins (especially between 270 and 273 feet)	28	286
Grey, fine sandstone, rare slickensides and coarser layers	51	337
Grey, fine to medium sandstone, rare sub-angular pebbles to $\frac{3}{32}$ inch. Fragments of black, grey, and bright red chert found; laminations horizontal	6	343
Grey sandstone, medium to coarse, with red jaspery fragments	18	361
Alternating bands of grey, fine to coarse sandstones of volcanic detritus	25	386
Grey, fine, even-grained, well laminated, massive sandstone, considerably cut by narrow calcite veins. Horizontal lamination	88	466
(At 466 are stringers of calcite up to one-eighth inch thick containing brownish bituminous matter, smelling strongly when ignited)		
Grey, fine argillaceous sandstone	4	470

These are probably the lowest measures in the Haida formation. Below here the rocks are agglomerates of the Yakoun formation.	Thickness feet.	Depth feet.
Grey, medium to coarse grit	14	484
Greenish, fine, dense tuff, coarser at base	9	493
Greenish, coarse tuff	29	522
Greenish, angular, very coarse grit, mostly volcanic fragments	11	533
Greenish tuff finer near base, with tarry matter seen in one place	24	557
Greenish, fine to medium tuff	23	580
Greenish, coarse, angular tuff	5	585
Light greenish, fine, tufaceous sandstone	18	603
As above, but coarser	9	612
Green, coarse, volcanic sandstones, coarser at base	39	651
Greenish-grey, coarse tuff	7	658
Grey, fine, even-grained tuff	7	665
Greenish, coarse sandstone	7	672
Greenish, alternating coarse and fine sandstone or tuff	28	700
Greenish-grey, fine, even-grained tuff	9	709
Green, fine, tufaceous sandstone with fossil imprints at 730 feet	26	735
Grey, fine sandstone	10	745
Grey, fine to medium, angular, tufaceous sandstones	25	770
Greenish and purplish, coarse grits, clearly volcanic material	30	800
Whitish-grey soft sandstone	15	815
Below here the rocks are purplish and greenish, coarse, angular, hard agglomerates, fragments up to 4 inches	45	860

American-Canadian Coal Company.

The following information has been supplied by Alexander Faulds, Esq.:

Bore-hole No. 1. Put down at Skonun point, near high-water mark behind a sand dune on lot 6. Depth of hole, 1,003 feet. Diamond drill used (?).

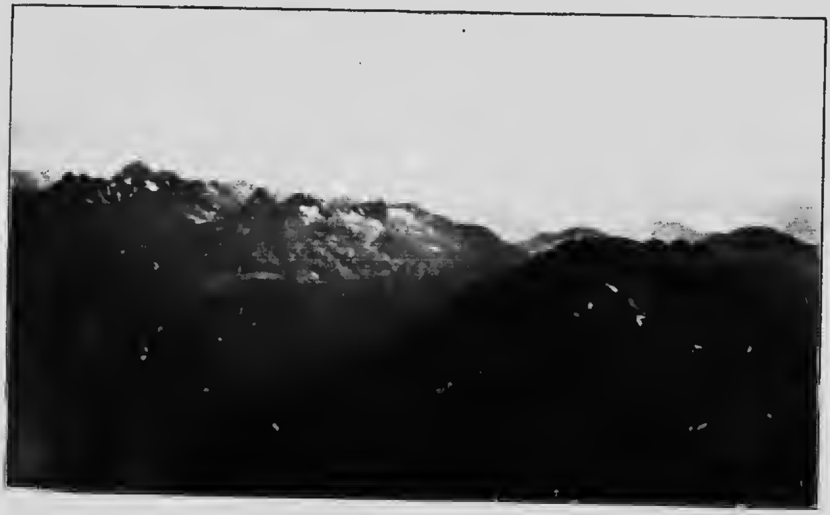
This hole is at an angle of 45 degrees with the horizontal and points in a northerly direction. It passed through thirteen lignite seams, three of them being 3, 4, and 6 feet thick respectively, and thirty-one beds of clay averaging 12 feet thick.

Bore-hole No. 2. Put down about 1½ miles west of No. 1 on border of slough on lot 10, about one-eighth mile from high-water mark. Depth of hole, 1,075 feet. Diamond drill used (?).

This vertical hole passed through seven lignite seams, of which two are 2 feet and 4 feet thick respectively, also sixteen beds of clay, averaging 34 feet thick.

Plate II.

A. Western part of Skidegate inlet and Queen Charlotte range. (See page 24.)



B. Serrated summits of the Queen Charlotte range, looking northwest from Slatechuck mountain. (See page 24.)

PLATE III.

A. Seal inlet. Typical of much of the west coast of the island. (See page 24.)

B. Rounded contours on Athlow mountain due to "equiplanation." (See pages 24, 27.)

PLATE IV.

A. Yakoun lake from Mount Etheline. Note rough, densely forested hills. (See page 25.)

B. Skidegate inlet, and (in background) Honna valley, from Maude island. The flat-topped hills on the right are characteristic of the plateau province. (See page 25.)

PLATE V.

A. Hanging valley west of Yakoun lake. (See page 25.)

B. Skidegate inlet, Table mountain, and Alliford bay from Queen Charlotte. Note accordant summit levels of plateau province—here on the north-eastern part of Moresby island. (See page 25.)

PLATE VI.

Summit muskeg on Wilson trail. Note pools of water, sloping surface, and bare, windswept, stunted trees. (See page 29.)

PLATE VII.

A. Tow hill, a basalt capped mesa, and northeastern lowland from Skonun point. Note dunes in foreground. (See page 25.)

B. Sand dunes at Skonun point. (See page 85.)

Plate VIII.

A. Parry passage from the west. Illustrates character of Northern lowland. (See page 25.)

B. Wave-cut bench at high tide level on soft Masset tuffs, with tilted flows of basalt forming the headland at Tian point. (See pages 33, 118.)

PLATE IX.

Pillar rock. (See pages 33, 41.)

Plate X.

A nearer view of Pillar rock. Note bedding, slanting downward to left. (See pages 33, 41.)

PLATE XI.

A. Flaggy, jointed argillites of the Maude formation on King creek. (See page 42.)

B. Faulted layer in the argillites of the Maude formation on King creek. The picture was made with the camera pointing downward at an angle of 30 degrees and looking through 10 inches of water. Figure 4 was sketched from this band. (See pages 42, 44.)

PLATE XII.

A. Agglomerates of the Yakoun formation east of Skidegate Indian village. (See page 48.)

B. Andesite dyke of the Etheline formation cutting Haida shales, shore of Bearskin bay. Note the hardened zone of baked shale that adheres to the wall of the dyke, and on which the man is sitting. Rude columnar jointing shown. (See page 69.)

PLATE XIII.

A. Cross-bedded sandstones of the Skonun formation at Skonun point. (See page 73.)

B. Columnar jointed basalt at Tian point. (See page 77.)

PLATE XIV.

Skidegate Indian village. Dawson in the G.S.C. Annual Report, 1878-79, gives a photograph showing twenty poles in a small section of this settlement at the time of his visit in 1878. Only the ones here shown remain in the whole village. Note the shelving beach, always required at a village site, on which to land the canoes. (See page 17.)

PLATE XV.

Hemlock timber west of the Honna river. Note undergrowth and fallen trees. (See page 34.)

A. "Augenkohle" from the tunnel of the British Pacific Coal Company, Slatechuck creek. (See page 123.)

B. Magnified polished surface of spheroidal concretion-like bodies embedded in bright anthracitic coal. (See page 124.)

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PUBLICATIONS OF THE GEOLOGICAL SURVEY.

The Geological Survey was established in 1842 and "Reports of Progress" were issued, generally in annual volumes, from that date to 1885, the first report being that for the year 1843 published in 1845. Beginning with the year 1885, "Annual Reports" (new series) were published in volumes until 1905, the last being Vol. XVI, 1904. Many of the individual reports and maps published before 1905 were issued separately and from 1905 to the present, all have been published as separates and no annual volume has been issued. Since 1910, the reports have been issued as Memoirs and Museum Bulletins, each divided into series, thus:—

Memoir 41, *Geological Series 38.*
Memoir 54, *Biological Series 2.*
Museum Bulletin 5, *Geological Series 21.*
Museum Bulletin 6, *Anthropological Series 3.*

In addition to the publications specified above, a Summary Report is issued annually; and miscellaneous publications of various kinds including Reports of Explorations, Guide Books, etc., have been issued from time to time.

Publications Issued 1910-1915 Inclusive.

MEMOIRS.

MEMOIR 1. *Geological Series 1.* Geology of the Nipigon basin, Ontario, 1910—by Alfred W. G Wilson.

MEMOIR 2. *Geological Series 2.* Geology and ore deposits of Hedley mining district, British Columbia, 1910—by Charles Camsell.

MEMOIR 3. *Geological Series 3.* Palæoniscid fishes from the Albert shales of New Brunswick, 1910—by Lawrence M. Lambe.

MEMOIR 4. *Geological Series 7.* Geological reconnaissance along the line of the National Transcontinental railway in western Quebec, 1911—by W. J. Wilson.

MEMOIR 5. *Geological Series 4.* Preliminary memoir on the Lewes and Nordenskiöld Rivers coal district, Yukon Territory, 1910—by D. D. Cairnes.

MEMOIR 6. *Geological Series 5.* Geology of the Haliburton and Bancroft areas, Province of Ontario, 1910—by Frank D. Adams and Alfred F Barlow.

MEMOIR 7. *Geological Series 6.* Geology of St. Bruno mountain, Province of Quebec, 1910—by John A. Dresser.

MEMOIR 8. *Geological Series 8.* The Edmonton coal field, Alberta, 1911—by D. B. Dowling.

MEMOIR 9. *Geological Series 9.* Bighorn coal basin, Alberta, 1911—by G. S. Malloch.

MEMOIR 10. *Geological Series 10.* An instrumental survey of the shorelines of the extinct lakes Algonquin and Nipissing in southwestern Ontario, 1911—by J. W. Goldthwait.

MEMOIR 11. *Topographical Series 1.* Triangulation and spirit levelling of Vancouver island, B.C., 1909, issued 1910—by R. H. Chapman.

MEMOIR 12. *Geological Series 11.* Insects from the Tertiary lake deposits of the southern interior of British Columbia, collected by Mr. Lawrence M. Lambe, in 1906, issued 1911—by Anton Handlirsch.

MEMOIR 13. *Geological Series 14.* Southern Vancouver island, 1912—by Charles H. Clapp.

MEMOIR 14. *Biological Series 1.* New species of shells collected by Mr. John Macoun at Barkley sound, Vancouver island, British Columbia, 1911—by William H. Dall and Paul Bartsch.

MEMOIR 15. *Geological Series 12.* On a Trenton Echinoderm fauna at Kirkfield, Ontario, 1911—by Frank Springer.

MEMOIR 16. *Geological Series 13.* The clay and shale deposits of Nova Scotia and portions of New Brunswick, 1911—by Heinrich Ries assisted by Joseph Keele.

MEMOIR 17. *Geological Series 28.* Geology and economic resources of the Larder Lake district, Ont., and adjoining portions of Pontiac county, Que., 1913—by Morley E. Wilson.

MEMOIR 18. *Geological Series 19.* Bathurst district, New Brunswick, 1913—by G. A. Young.

MEMOIR 19. *Geological Series 26.* Geology of Mother Lode and Sunset mines, Boundary district, B.C., 1914—by O. E. LeRoy.

MEMOIR 20. *Geological Series 41.* Gold fields of Nova Scotia, 1914—by W. Malcolm.

MEMOIR 21. *Geological Series 15.* The geology and ore deposits of Phoenix Boundary district, British Columbia, 1912—by O. E. LeRoy

MEMOIR 22. *Geological Series 27.* Preliminary report on the serpentines and associated rocks, in southern Quebec, 1914—by J. A. Dresser.

MEMOIR 23. *Geological Series 23.* Geology of the coast and islands between the Strait of Georgia and Queen Charlotte sound, B.C., 1914—by J. Austen Bancroft.

MEMOIR 24. *Geological Series 16.* Preliminary report on the clay and shale deposits of the western provinces, 1912—by Heinrich Ries and Joseph Keele.

MEMOIR 25. *Geological Series 21.* Report on the clay and shale deposits of the western provinces, Part II, 1914—by Heinrich Ries and Joseph Keele.

MEMOIR 26. *Geological Series 34.* Geology and mineral deposits of the Tulameen district, B.C., 1913—by C. Camsell.

MEMOIR 27. *Geological Series 17.* Report of the Commission appointed to investigate Turtle mountain, Frank, Alberta, 1911, issued 1912.

MEMOIR 28. *Geological Series 18.* The Geology of Steeprock lake, Ontario—by Andrew C. Lawson. Notes on fossils from limestone of Steeprock lake, Ontario, 1912—by Charles D. Walcott.

MEMOIR 29. *Geological Series 32.* Oil and gas prospects of the northwest provinces of Canada, 1913—by W. Malcolm.

MEMOIR 30. *Geological Series 40.* The basins of Nelson and Churchill rivers, 1914—by William McInnes.

MEMOIR 31. *Geological Series 20.* Wheaton district, Yukon Territory, 1913—by D. D. Cairnes.

MEMOIR 32. *Geological Series 25.* Portions of Portland Canal and Skeena Mining divisions, Skeena district, B.C., 1914—by R. G. McConnell.

MEMOIR 33. *Geological Series 30.* The geology of Gowganda Mining Division, 1913—by W. H. Collins.

MEMOIR 34. *Geological Series 63.* The Devonian of southwestern Ontario, 1915—by C. R. Stauffer.

MEMOIR 35. *Geological Series 29.* Reconnaissance along the National Transcontinental railway in southern Quebec, 1913—John A. Dresser.

MEMOIR 36. *Geological Series 33.* Geology of the Victoria and Saanich map-areas, Vancouver island, B.C., 1914—by C. H. Clapp.

MEMOIR 37. *Geological Series 22.* Portions of Atlin district, B.C., 1913—by D. D. Cairnes.

MEMOIR 38. *Geological Series 31.* Geology of the North American Cordillera at the forty-ninth parallel, Parts I and II, 1913—by Reginald Aldworth Daly.

MEMOIR 39. *Geological Series 35.* Kewagama Lake map-area, Quebec, 1914—by M. E. Wilson.

MEMOIR 40. *Geological Series 24.* The Archæan geology of Rainy lake, 1914—by Andrew C. Lawson.

MEMOIR 41. *Geological Series 38.* The "Fern Ledges" Carboniferous flora of St. John, New Brunswick, 1914—by Marie C. Stopes.

MEMOIR 42. *Anthropological Series 1.* The double-curve motive in northeastern Algonkian art, 1914—by Frank G. Speck.

MEMOIR 43. *Geological Series 36.* St. Hilaire (Beloeil) and Rougemont mountains, Quebec, 1914—by J. J. O'Neill.

MEMOIR 44. *Geological Series 37.* Clay and shale deposits of New Brunswick, 1914— by J. Keele.

MEMOIR 45. *Anthropological Series 3.* The inviting-in feast of the Alaska Eskimo, 1914—by E. W. Hawkes.

MEMOIR 46. *Anthropological Series 7.* Classification of Iroquoian radicals and subjective pronominal prefixes, 1915—by C. M. Barbeau.

MEMOIR 47. *Geological Series 39.* Clay and shale deposits of the western provinces, Part III, 1914—by Heinrich Ries.

MEMOIR 48. *Anthropological Series 2.* Some myths and tales of the Ojibwa of southeastern Ontario, 1914—by Paul Radin.

MEMOIR 49. *Anthropological Series 4.* Malecite tales, 1914—by W. H. Mechling.

MEMOIR 50. *Geological Series 51.* Upper White River district, Yukon, 1915—by D. D. Cairnes.

MEMOIR 51. *Geological Series 43.* Geology of the Nanaimo map-area, 1914—by C. H. Clapp.

MEMOIR 52. *Geological Series 42.* Geological notes to accompany map of Sheep River gas and oil field, Alberta, 1914—by D. B. Dowling.

MEMOIR 53. *Geological Series 44.* Coal fields of Manitoba, Saskatchewan, Alberta, and eastern British Columbia (revised edition), 1914—by D. B. Dowling.

MEMOIR 54. *Biological Series 2.* Annotated list of flowering plants and ferns of Point Pelee, Ont., and neighbouring districts,1914—by C. K. Dodge.

MEMOIR 55. *Geological Series 46.* Geology of Field map-area, Alberta and British Columbia, 1914—by John A. Allan.

MEMOIR 56. *Geological Series 56.* Geology of Franklin mining camp, B.C., 1915—by Chas. W. Drysdale.

MEMOIR 57. *Geological Series 50.* Corundum, its occurrence, distribution, exploitation, and uses, 1915—by A. E. Barlow.

MEMOIR 58. *Geological Series 48.* Texada island, 1915—by R. G. McConnell.

MEMOIR 59. *Geological Series 55.* Coal fields and coal resources of Canada, 1915—by D. B. Dowling.

MEMOIR 60. *Geological Series 47.* Arisaig-Antigonish district, 1915—by M. Y. Williams.

MEMOIR 61. *Geological Series 45.* Moose Mountain district, southern Alberta (second edition) 1914—by D. D. Cairnes.

MEMOIR 62. *Anthropological Series 5.* Abnormal types of speech in Nootka, 1915—by E. Sapir.

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MEMOIR 64. *Geological Series 52.* Preliminary report on the clay and shale deposits of the Province of Quebec, 1915—by J. Keele.

MEMOIR 65. *Geological Series 53.* Clay and shale deposits of the western provinces, Part IV, 1915—by H. Ries.

MEMOIR 66. *Geological Series 54.* Clay and shale deposits of the western provinces, Part V, 1915—by J. Keele.

MEMOIR 67. *Geological Series 49.* The Yukon-Alaska Boundary between Porcupine and Yukon rivers, 1915—by D. D. Cairnes.

MEMOIR 68. *Geological Series 59.* A geological reconnaissance between Golden and Kamloops, B.C., along the line of the Canadian Pacific railway, 1915—by R. A. Daly.

MEMOIR 69. *Geological Series 57.* Coal fields of British Columbia, 1915—D. B. Dowling.

MEMOIR 70. *Anthropological Series 8.* Family hunting territories and social life of the various Algonkian bands of the Ottawa valley, 1915—by F. G. Speck.

MEMOIR 71. *Anthropological Series 9.* Myths and folk-lore of the Timiskaming Algonquin and Timagami Ojibwa, 1915—by F. G. Speck.

MEMOIR 72. *Geological Series 60.* The artesian wells of Montreal, 1915—by C. L. Cumming.

MEMOIR 73. *Geological Series 58.* The Pleistocene and Recent deposits of the Island of Montreal, 1915—by J. Stansfield.

MEMOIR 74. *Geological Series 61.* A list of Canadian mineral occurrences, 1915—by R. A. A. Johnston.

MEMOIR 75. *Anthropological Series 10.* Decorative art of Indian tribes of Connecticut, 1915—by Frank G. Speck.

MEMOIR 76. *Geological Series 62.* Geology of the Cranbrook map-area, 1915—by S. J. Schofield.

MEMOIR 77. *Geological Series 64.* Geology and ore deposits of Rossland, B.C., 1915—by C. W. Drysdale.

MEMOIR 78. *Geological Series 66.* Wabana iron ore of Newfoundland, 1915—by A. O. Hayes.

MEMOIR 79. *Geological Series 65.* Ore deposits of the Beaverdell map-area, 1915—by L. Reinecke.

MEMOIR 80. *Anthropological Series 11.* Huron and Wyandot mythology, 1915—by C. M. Barbeau.

MEMOIR 81. *Geological Series 67.* Oil and gas fields of Ontario and Quebec, 1915—by Wyatt Malcolm.

MEMOIR 82. *Geological Series 68.* Rainy River district, Ontario. Surficial geology and soils, 1915—by W. A. Johnston.

MUSEUM BULLETINS.

The Museum Bulletins, published by the Geological Survey, are numbered consecutively and are given a series number in addition, thus: Geological Series No. 1, 2, 3, etc.; Biological Series No. 1, 2, 3, etc.; Anthropological Series No. 1, 2, 3, etc.

In the case of Bulletins 1 and 2, which contain articles on various subjects, each article has been assigned a separate series number.

The first Bulletin was entitled *Victoria Memorial Museum Bulletin;* subsequent issues have been called *Museum Bulletins.*

MUS. BULL. 1. (*Issued 1913*). *Geological Series 1.* The Trenton crinoid, Ottawacrinus, W. R. Billings—by F. A. Bather.

Geological Series 2. Note on Merocrinus, Walcott—by F. A. Bather.

Geological Series 3. The occurrence of Helodont teeth at Roche Miette and vicinity, Alberta—by L. M. Lambe.

Geological Series 4. Notes on Cyclocystoides—by P. E. Raymond.

Geological Series 5. Notes on some new and old Trilobites in the Victoria Memorial Museum—by P. E. Raymond.

Geological Series 6. Description of some new Asaphidae—by P. E. Raymond.

Geological Series 7. Two new species of Tetradium—by P. E. Raymond.

Geological Series 8. Revision of the species which have been referred to the genus Bathyurus (preliminary report)—by P. E. Raymond.

Geological Series 9. A new Brachiopod from the base of the Utica—by A. E. Wilson.

Geological Series 10. A new genus of dicotyledonous plant from the Tertiary of Kettle river, British Columbia—by W. J. Wilson.

Geological Series 11. A new species of Lepidostrobus—by W. J. Wilson.

Geological Series 12. Prehnite from Adams sound, Admiralty Inlet, Baffin island, Franklin—by R. A. A. Johnston.
Biological Series. 1. The marine algæ of Vancouver island—by F. S. Collins.
Biological Series 2. New species of mollusks from the Atlantic and Pacific coasts of Canada—by W. H. Dall and P. Bartsch.
Biological Series 3. Hydroids from Vancouver Island and Nova Scotia—by C. McLean Fraser.
Anthropological Series 1. The archæology of Blandford township, Oxford county, Ontario—by W. J. Wintemberg.

MUS. BULL. 2. (*Issued 1914*). *Geological Series 13.* The origin of granite (micropegmatite) in the Purcell sills—by S. J. Schofield.
Geological Series 14. Columnar structure in limestone—by E. M. Kindle.
Geological Series 15. Supposed evidences of subsidence of the coast of New Brunswick within modern time—by J. W. Goldthwait.
Geological Series 16. The Pre-Cambrian (Beltian) rocks of southeastern British Columbia and their correlation by S. J. Schofield.
Geological Series 17. Early Cambrian stratigraphy in the North American Cordillera, with discussion of Albertella and related faunas—by L. D. Burling.
Geological Series 18. A preliminary study of the variations of the plications of Parastrophia hemiplicata, Hall—by A. E. Wilson.
Anthropological Series 2. Some aspects of puberty fasting among the Ojibwa—by Paul Radin.

MUS. BULL. 3. *Geological Series 19.* The Anticosti Island faunas, 1914—by W. H. Twenhofel.

MUS. BULL. 4. *Geological Series 20.* The Crowsnest volcanics, 1914—by J. D MacKenzie.

MUS. BULL. 5. *Geological Series 21.* A Beatricea-like organism from the middle Ordovician, 1914—by P. E. Raymond.

MUS. BULL. 6. *Anthropological Series 3.* Prehistoric and present commerce among the Arctic Coast Eskimo, 1915—by V. Stefansson.

MUS. BULL. 7. *Biological Series 4.* A new species of Dendragapus (Dendragapus Obscurus Flemingi) from southern Yukon Territory, 1914—by P. A. Taverner.

MUS. BULL. 8. *Geological Series 22.* The Huronian formations of Timiskaming region, Canada, 1914—by W. H. Collins.

MUS. BULL. 9. *Anthropological Series 4.* The Glenoid Fossa in the skull of the Eskimo, 1915—by F. H. S. Knowles.

MUS. BULL. 10. *Anthropological Series 5.* The social organization of the Winnebago Indians, an interpretation, 1915—by P. Radin.

MUS. BULL. 11. *Geological Series 23.* Physiography of the Beaverdell map-area and the southern part of the Interior plateaus of British Columbia, 1915—by L. Reinecke.

MUS. BULL. 12. *Geological Series 24.* On Eoceratops Canadensis, gen. nov., with remarks on other genera of Cretaceous horned dinosaurs, 1915—by L. M. Lambe.

MUS. BULL. 13. *Biological Series 5.* The double-crested Cormorant (Phalacrocorax Auritus) and its relation to the salmon industries on the Gulf of St. Lawrence, 1915—by P. A. Taverner.

MUS. BULL. 14. *Geological Series 25.* The occurrence of glacial drift on the Magdalen islands, 1915—by J. W. Goldthwait.

Mus. Bull. 15. *Geological Series 26.* Gay Gulch and Skookum meteorites 1915—by R. A. A. Johnston.
Mus. Bull. 16. *Anthropological Series 6.* Literary aspects of North American mythology, 1915—by P. Radin.
Mus. Bull. 17. *Geological Series 27.* The Ordovician rocks of Lake Timiskaming, 1915—by M. Y. Williams.
Mus. Bull. 18. *Geological Series 28.* Structural relations of the Pre-Cambrian and Palæozoic rocks north of the Ottawa and St. Lawrence valleys, 1915—by E. M. Kindle and L. D. Burling.
Mus. Bull. 19. *Anthropological Series 7.* A sketch of the social organization of the Nass River Indians, 1915—by E. Sapir.
Mus. Bull. 20. *Geological Series 29.* An Eurypterid horizon in the Niagara formation of Ontario, 1915—by M. Y. Williams.
Mus. Bull. 21. *Geological Series 30.* Notes on the geology and palæontology of the lower Saskatchewan River valley, 1915—by E. M. Kindle.

UNCLASSIFIED.

Report on a geological reconnaissance of the region traversed by the National Transcontinental railway between Lake Nipigon and Clay lake, Ont., 1910—by W. H. Collins.

Report on the geological position and characteristics of the oil-shale deposits of Canada, 1910—by R. W. Ells.

A reconnaissance across the Mackenzie mountains on the Pelly, Ross, and Gravel rivers, Yukon and North West Territories, 1910—by Joseph Keele.

Summary Report for the calendar year 1909, issued 1910.

Report on a traverse through the southern part of the North West Territories, from Lac Seul to Cat lake, in 1902, issued 1911—by Alfred W. G. Wilson.

Report on a part of the North West Territories drained by the Winisk and Upper Attawapiskat rivers, 1911—by W. McInnes.

Report on the geology of an area adjoining the east side of Lake Timiskaming, 1911—by Morley E. Wilson.

Summary Report for the calendar year 1910, issued 1911.

Summary Report for the calendar year 1911, issued 1912.

Guide Book No. 1. Excursions in eastern Quebec and the Maritime Provinces, parts 1 and 2, 1913.

Guide Book No. 2. Excursions in the Eastern Townships of Quebec and the eastern part of Ontario, 1913.

Guide Book No. 3. Excursions in the neighbourhood of Montreal and Ottawa, 1913.

Guide Book No. 4. Excursions in southwestern Ontario, 1913.

Guide Book No. 5. Excursions in the western peninsula of Ontario and Manitoulin island, 1913.

Guide Book No. 8. Toronto to Victoria and return via Canadian Pacific and Canadian Northern railways; parts 1, 2, and 3, 1913.

Guide Book No. 9. Toronto to Victoria and return via Canadian Pacific, Grand Trunk Pacific, and National Transcontinental railways, 1913.

Guide Book No. 10. Excursions in northern British Columbia and Yukon Territory and along the north Pacific coast, 1913.

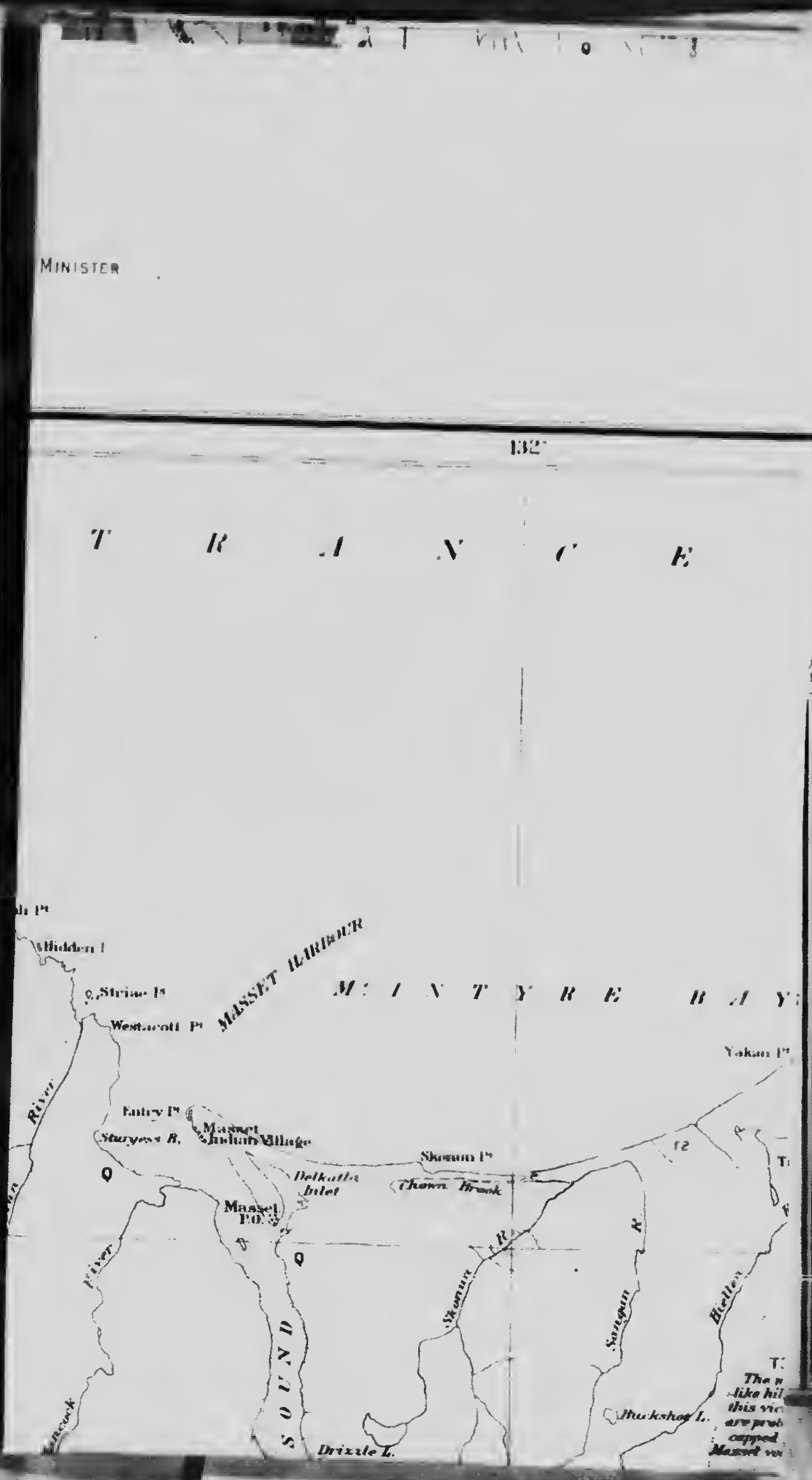
Summary Report for the calendar year 1912, issued 1914.

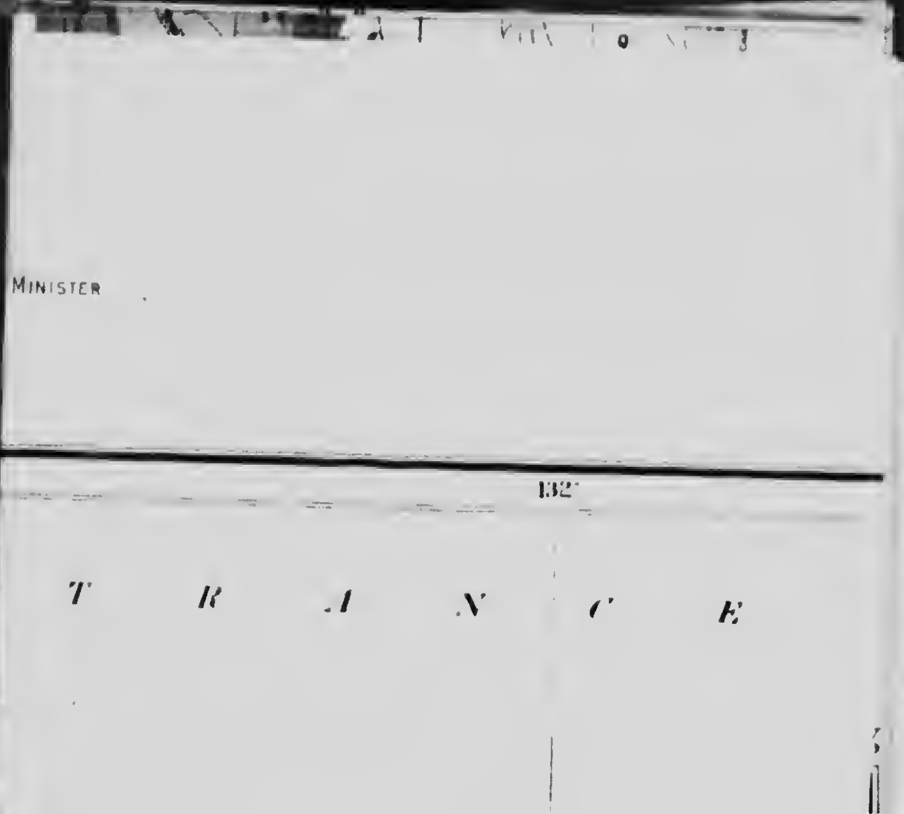
Prospector's Handbook No. 1. Notes on radium-bearing minerals, 1914—by Wyatt Malcolm.

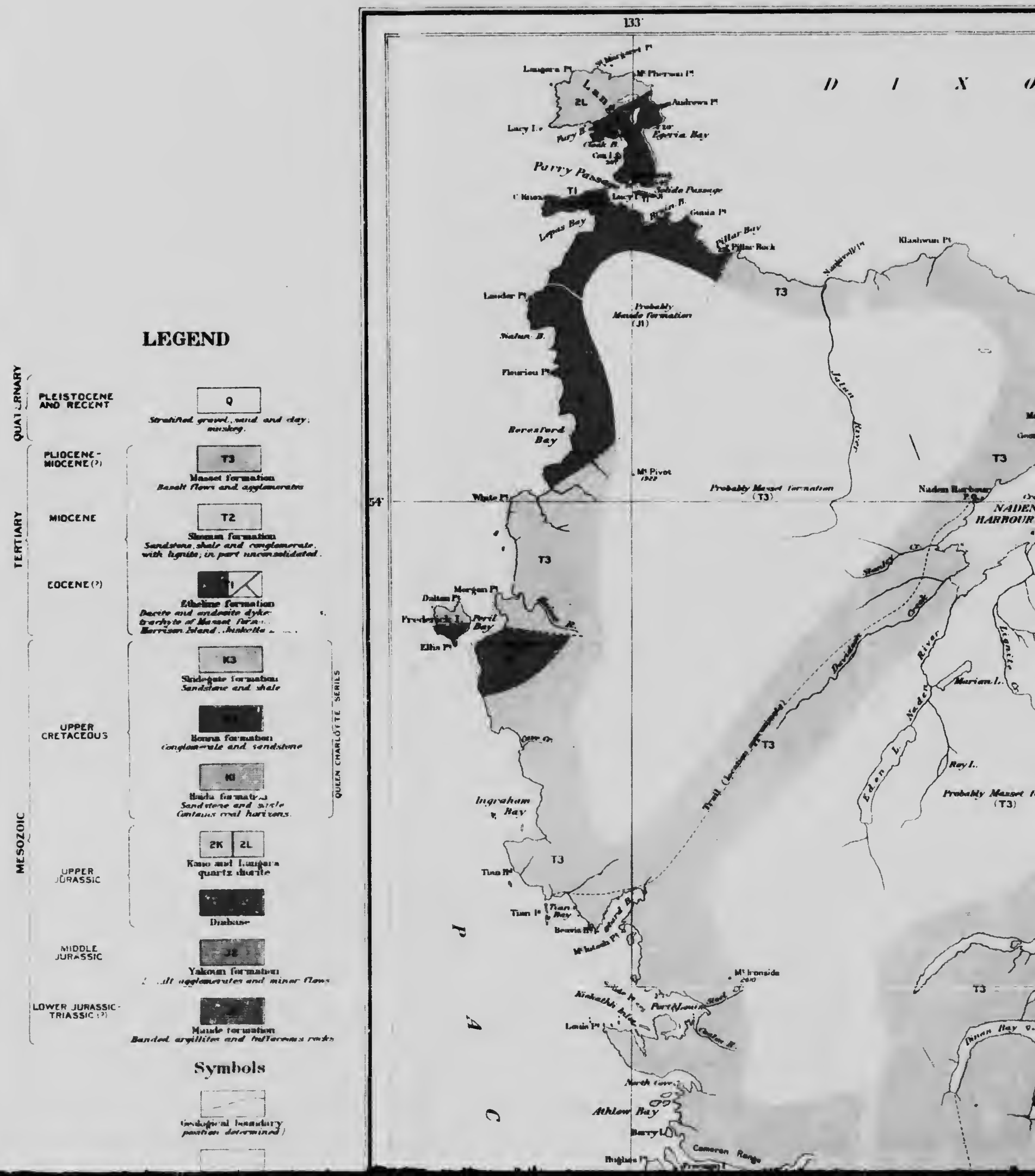
The archæological collection from the southern interior of British Columbia, 1914—by Harlan I. Smith.

Summary Report for the calendar year 1913, issued 1915.

Summary Report for the calendar year 1914, issued 1915.


MINISTER
132°
T R A N C E
MASSET HARBOUR
M'I N T Y R E B A Y
Striae Pt
Westacott Pt
Yakan Pt
River
Entry Pt
Masset Indian Village
Sturgess B.
Skonun Pt
Delkatla Inlet
Chown Brook
Masset P.O.
River
S O U N D
Skonun R.
Sangan R.
Hiellen
Drizzle L.
Duckshoe L.


MINISTER
132°
T R A N C E


LEGEND
QUATERNARY
PLEISTOCENE AND RECENT
Q
Stratified gravel, sand and clay; muskeg.
TERTIARY
PLIOCENE-MIOCENE(?)
T3
Masset formation
Basalt flows and agglomerates
MIOCENE
T2
Skonun formation
Sandstone, shale and conglomerate, with lignite; in part unconsolidated.
EOCENE(?)
T1
Etheline formation
MESOZOIC
UPPER CRETACEOUS
QUEEN CHARLOTTE SERIES
K3
Skidegate formation
Sandstone and shale
Honna formation
conglomerate and sandstone
K1
Haida formation
UPPER JURASSIC
2K
2L
quartz diorite
Diabase
MIDDLE JURASSIC
J2
Yakoun formation
LOWER JURASSIC-TRIASSIC(?)
Maude formation
Banded argillites and tuffaceous rocks
Symbols
Geological boundary
133°
54°
D I X
Langara Pt
Lucy I.
Parry Passage
Egeria Bay
Andrews Pt
Lepas Bay
Pillar Bay
Pillar Rock
Klashwun Pt
T3
Lauder Pt
Probably Maude formation (J1)
Fleurieu Pt
Beresford Bay
Mt Pivot
Probably Masset formation (T3)
Naden Harbour
NADEN HARBOUR
White Pt
T3
Morgan Pt
Dalton Pt
Frederick I.
Peril Bay
Ellis Pt
Jalun River
Davidson Creek
Naden River
Marian L.
Eden L.
Ray L.
Lignite Cr.
Ingraham Bay
T3
Tian Pt
Tian Bay
Mt Ironside
Port Louis
Louis Pt
Athlow Bay
Barry I.
Hughes Pt
Cameron Range
P
A
C

Canada
Department of Mines

HON P E BLONDIN, MINISTER, R G McCONNELL, DEPUTY MINISTER

GEOLOGICAL SURVEY

Yakoun formation
Basalt agglomerates and minor flows

LOWER JURASSIC
TRIASSIC

Maude formation
Banded argillites and tuffaceous rocks

Symbols

Geological boundary
(position determined)

Geological boundary
(probable error of location less than half a mile)

Geological boundary
(probable error of location less than one mile)

Geological boundary
(position assumed)

Fault
(position determined)

Fault
(probable error of location less than one mile)

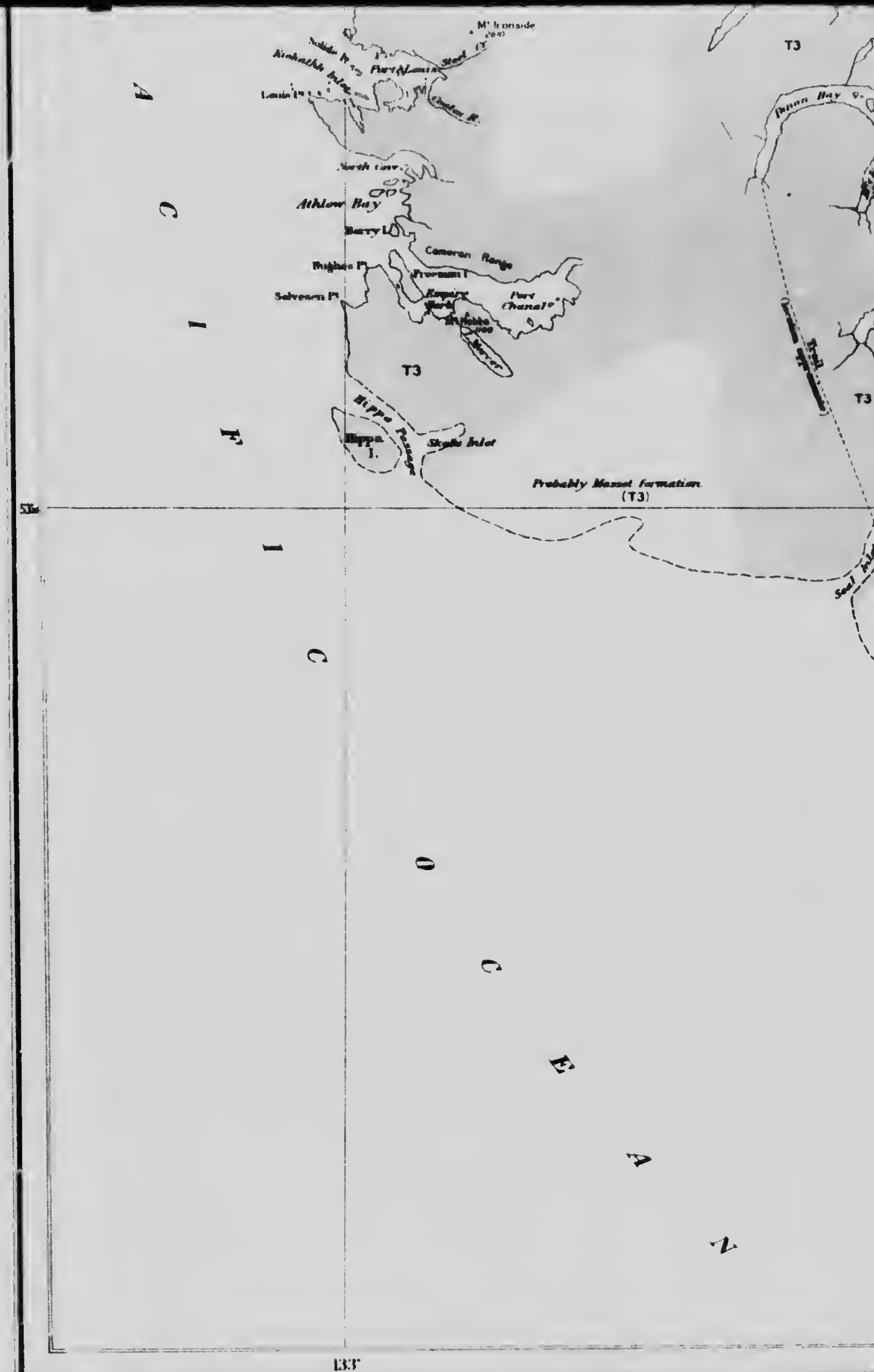
Fault
(position assumed)

Outcrop of coal horizon

Borehole

3200
Elevation in feet above sea level

30°
Dip and strike



C.O. Senecal, *Geographer and Chief Draughtsman*
A. McGregor, *Draughtsman*.

MAP 176 A
(Issued 1916)

GRAHAM ISLAND

QUEEN CHARLOTTE ISLANDS

BRITISH COLUMBIA

Scale: $\frac{1}{253,440}$

Miles

Kilometres

4 MILES TO 1 INCH

GEOLOGY

J.D. MacKENZIE, 1913, 1914

GEOGRAPHY

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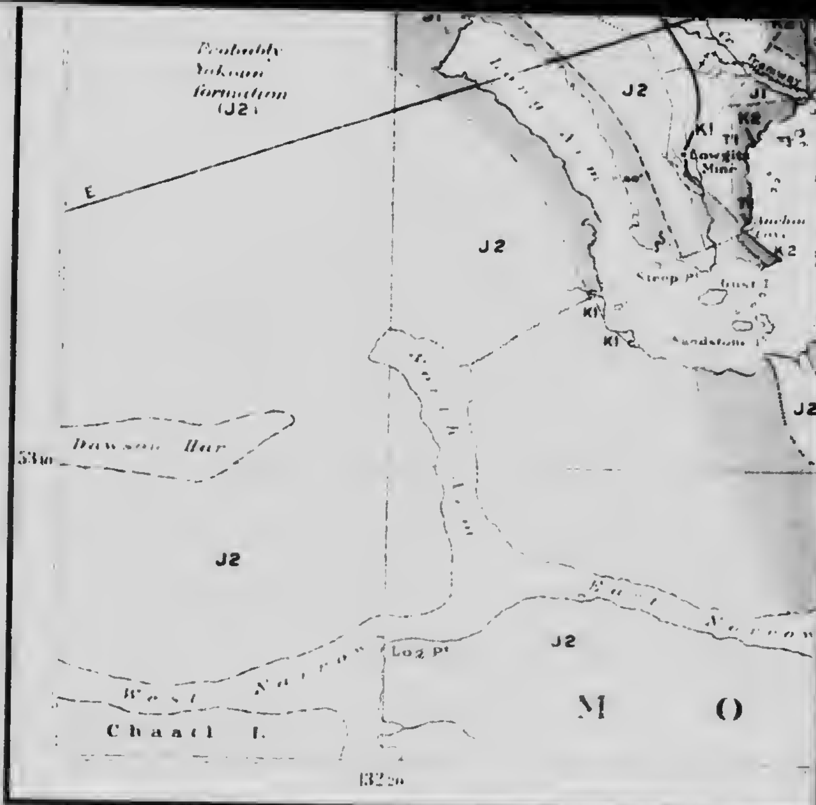

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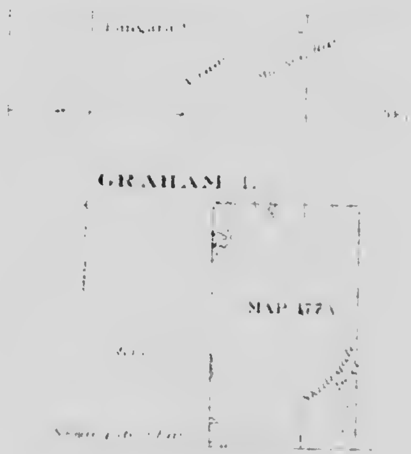
A. McGregor, Draughtsman



Scale ... Miles to 1 Inch

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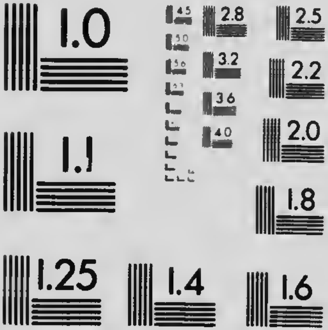

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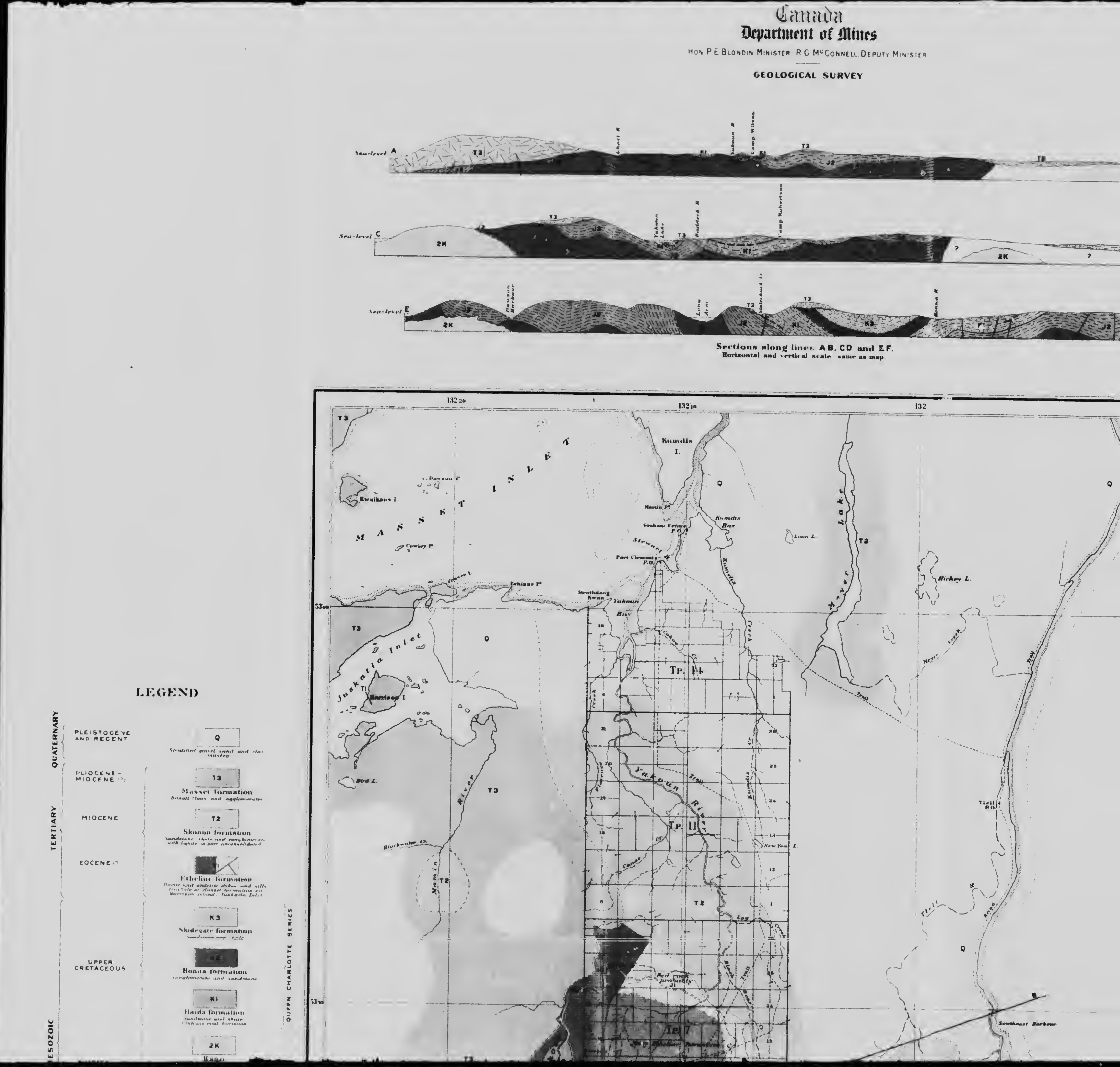
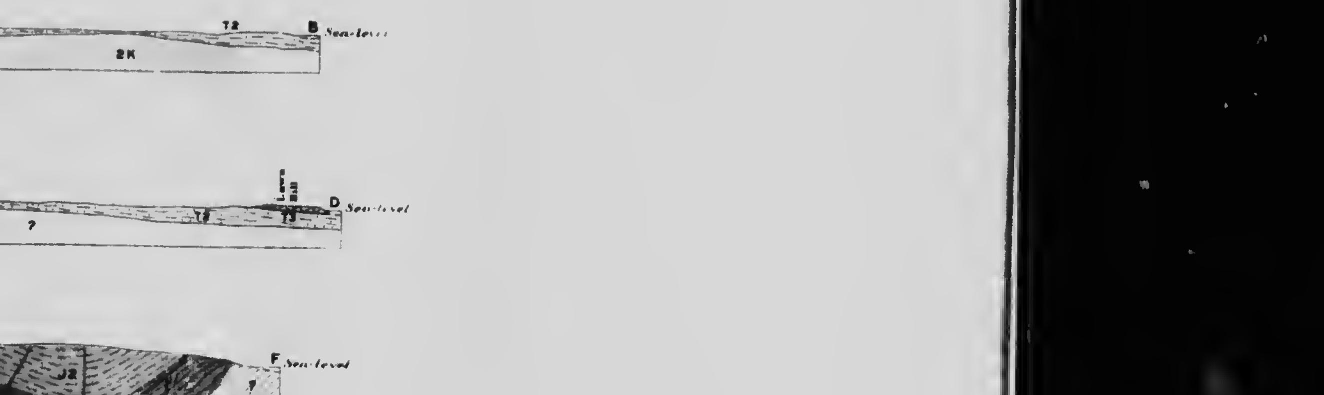
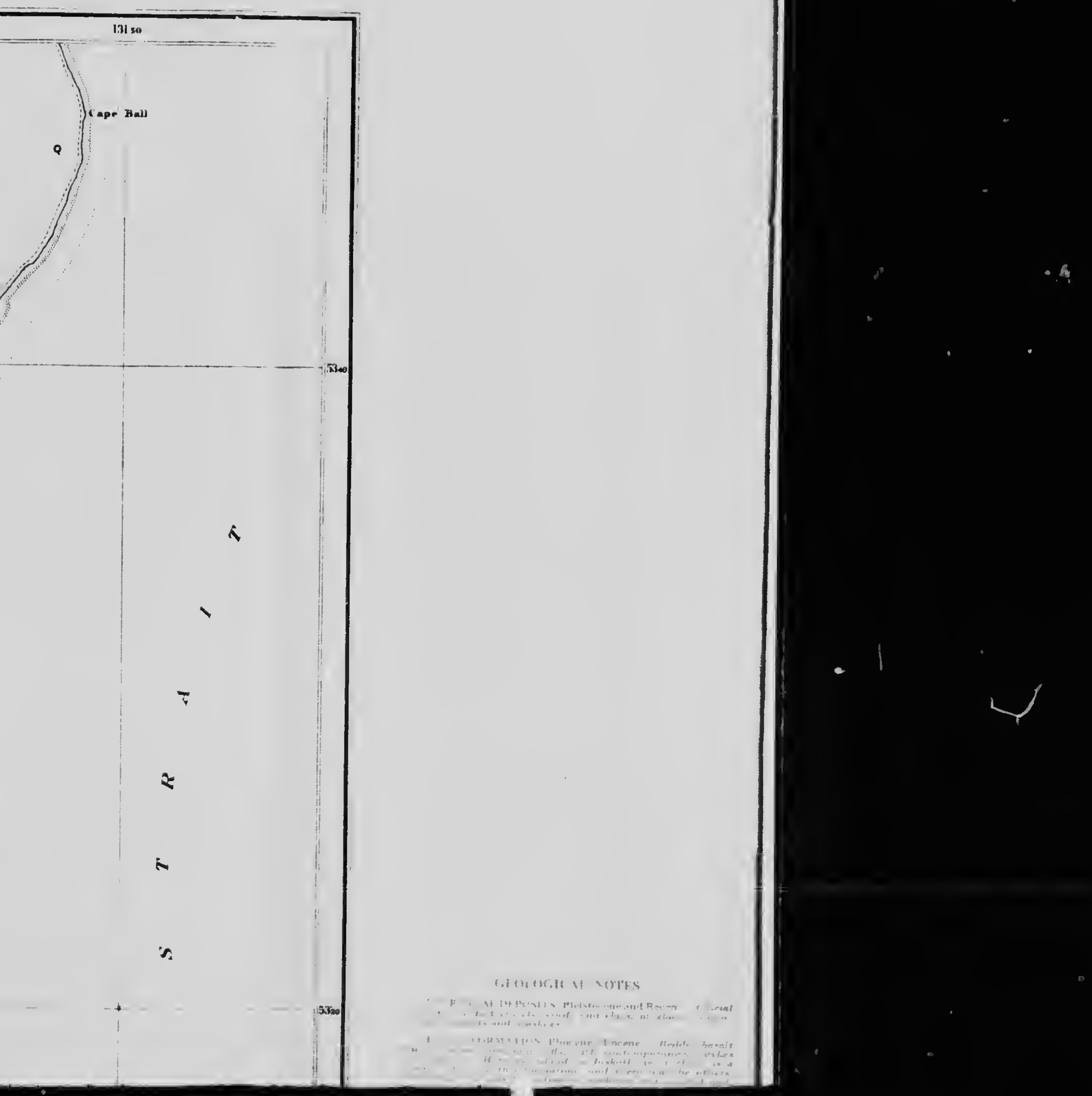


Canada
Department of Mines
Hon P E Blondin Minister R G McConnell, Deputy Minister
GEOLOGICAL SURVEY
Sea-level A
Sea-level C
Sea-level E
Sections along lines AB, CD and EF.
Horizontal and vertical scale, same as map.
MASSET INLET
Juskatla Inlet
Kumdis I.
Kumdis Bay
Port Clements P.O.
Yakoun Bay
Yakoun River
Mayer Lake
Hickey L.
Loon L.
Tp. 11
Tiell P.O.
Southeast Harbour
LEGEND
QUATERNARY
PLEISTOCENE AND RECENT
Q
Stratified gravel sand and clay muskeg
TERTIARY
PLIOCENE-MIOCENE (?)
T3
Masset formation
Basalt flows and agglomerates
MIOCENE
T2
Skonun formation
Sandstone, shale and conglomerate with lignite in part unconsolidated
EOCENE (?)
Etheline formation
UPPER CRETACEOUS
K3
Skidegate formation
K2
Honna formation
conglomerate and sandstone
K1
Haida formation
QUEEN CHARLOTTE SERIES
MESOZOIC
2K





GEOLOGICAL NOTES

quartz diorite

MIDDLE JURASSIC

LOWER JURASSIC TRIASSIC

Diabase

J2 Yakoun formation

J1 Maude formation

Symbols

Geological boundary
position determined

Geological boundary
probable error of location less than half a mile

Geological boundary
probable error of location less than one mile

Geological boundary
position assumed

Fault
position determined

Fault
probable error of location less than one mile

Fault
position assumed

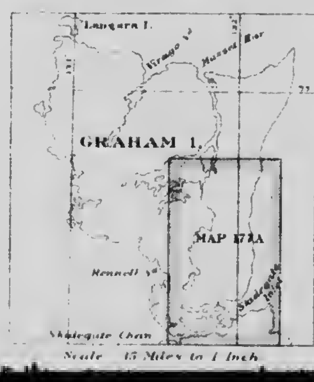
Outcrop of coal horizon

Borehole

Elevation in feet above sea level

Dip and strike

G. O. Senecal, Geographer and Chief Draughtsman
A. M^c Gregor, Draughtsman



To accompany Memoir by J. D. MacKenzie

MA

Southern

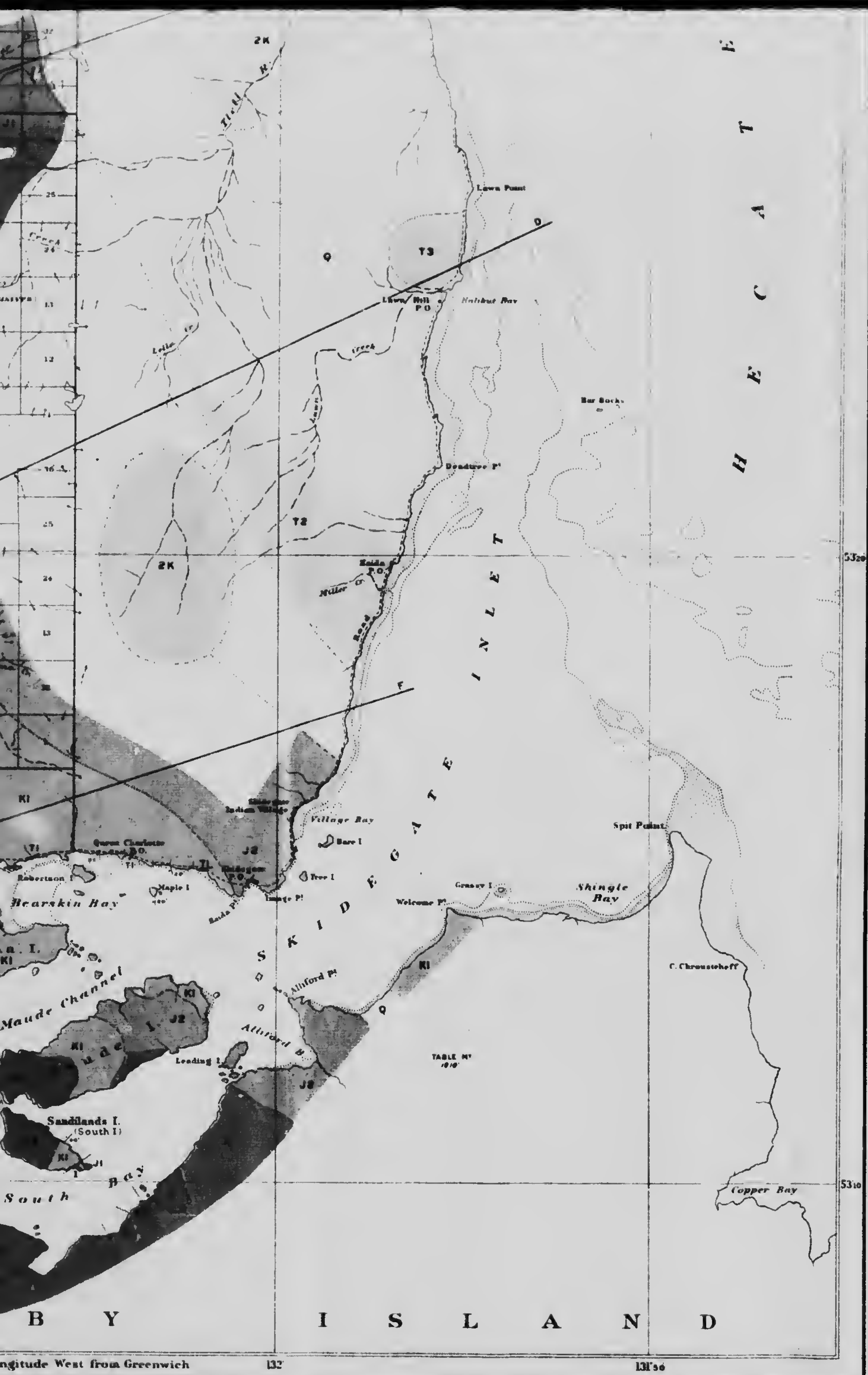
GRAHAM

QUEEN CHAR

BRITISH

Scale

2 MILES



MAP 177A
(Issued 1916)

...thern portion of ...HAM ISLAND
... CHARLOTTE ISLANDS
BRITISH COLUMBIA

Scale $\frac{1}{126,720}$

Miles

Kilometres

2 MILES TO 1 INCH

GEOLOGY

J. D. MACKENZIE 1913. 1914.

GEOGRAPHY

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