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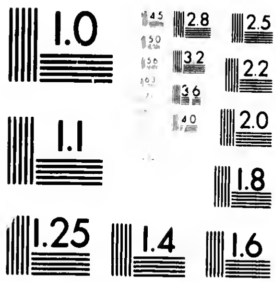

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GEOLOGY OF BRITISH COLUMBIA.

[*Extracted from the* GEOLOGICAL MAGAZINE, May, 1881.]

TRÜBNER & CO., 57 and 59, Ludgate Hill, London.

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[*Extracted from the* Geological Magazine, Decade II. Vol. VIII. Nos. 4 and 5, April and May, 1881.]

Sketch of the Geology of British Columbia.

By George M. Dawson, D.S., A.R.S.M., F.G.S.

TWENTY years ago the region now included in the Province of British Columbia was—with the exception of the coast-line—little known geographically, and quite unknown geologically. From the days of Cook and Vancouver, and the old territorial disputes with the Spaniards, this part of the west coast of North America attracted little attention till the discovery of gold in 1858. As among the first in the field geologically may be mentioned Dr. Hector and Messrs. H. Bauerman and G. Gibbs. The observations of these gentlemen, though bringing to light many facts of interest, were confined to a comparatively small part of the area of the province, and it was not till the inclusion of British Columbia in the Dominion of Canada in 1871 that the systematic operations of the Geological Survey of Canada were extended to this region. Since this date a number of reports treating of the geology of British Columbia have been published, and on these, together with a personal knowledge of the country, obtained during five seasons' work in it in connexion with the Survey, I shall chiefly depend in giving a brief account of the main geological features so far developed.

British Columbia includes the whole breadth of a portion of the great Cordillera belt which forms the Pacific margin of the Continent. This here consists of four parallel mountain ranges running in gene ' north-westerly and south-easterly bearings, which, beginning on the Pacific Margin, may be named as follows:—Vancouver Range, Coast or Cascade Range, Gold Range, and Rocky Mountain Range proper, the last constituting the western border of the great plains of the interior of the Continent.

The first mentioned, in a partially submerged condition, forms Vancouver and the Queen Charlotte Islands, and still rears some of its peaks to a height surpassing 6000 feet. The valley lying to the north-east of this is occupied by the sea, forming the Strait of Georgia, Queen Charlotte Sound, and Hecate Straits. The Coast Range is a rugged mountainous district with a width of about one hundred miles, and axial summits reaching in some places elevations surpassing 8000 feet. To the north-east of this stretches a region which may be called the Interior Plateau of British Columbia, the average width of which is nearly one hundred miles, and its mean elevation about 3500 feet. This plateau is, however, irregular, hilly, or even in some places mountainous, and is intersected by deep trough-like river valleys. It is only when it is occupied by Tertiary volcanic rocks that it assumes considerable uniformity of surface.

Bounding the plateau to the north-east is a third wide range, known locally as the Cariboo, Columbia and Purcell Mountains. It is broken to the north at the 54th parallel and resumes under the 56th as the Omineca Mountains. This mountain axis may be named the Gold Range, and it is probable that many summits in it surpass 8000 feet. Separated from it by a narrow but well-defined valley is the Rocky Mountain Range with an average width of fifty to sixty miles. This shows peaks of about 10,000 feet in height on the 49th parallel, is supposed to surpass 15,000 feet near the 52nd, and becomes comparatively low and narrow in the vicinity of the Peace River, about the 56th parallel.

Such are the main orographical features of British Columbia, a slight knowledge of which is necessary to render intelligible the description of its geological structure.

In describing the rocks, those of Tertiary and Cretaceous age of the coast will first be noticed, next those of the interior of the province referable to these periods, and lastly the older underlying metamorphic rocks.

Tertiary.—The Tertiary rocks do not form any wide or continuous belt on this part of the coast, as is the case farther south. They are found near Sooke, at the southern extremity of Vancouver's Island, in the form of sandstones, conglomerates, and shales, which are sometimes carbonaceous.[1] Tertiary rocks also probably occupy a considerable area about the mouth of the Fraser River; extending southward from Burrard Inlet, across the International boundary formed by the 49th parallel, to Bellingham Bay and beyond. Thin seams of lignite occur at Burrard Inlet. Sections of the Tertiary rocks at Bellingham Bay are given in Dr. Hector's official report. Lignite beds were here some years ago extensively worked, but the mine has been abandoned owing to the superior quality of the fuels now obtained from Nanaimo and Seattle. About the estuary of the Fraser the Tertiary beds are much covered by drift and alluvial deposits, and are consequently not well known. Lignites, and even true coals, have been found in connexion with them, but so far in beds too thin to be of value. Fossil plants from Burrard Inlet and Bellingham Bay have been described by Newberry and Lesquereux, and these are supposed to indicate a Miocene age for the deposits.[2]

Much farther north, in the Queen Charlotte Island, the whole north-eastern portion of Graham Island has now been shown to be underlain by Tertiary rocks, which produce a flat or gently undulating country, markedly different from that found on most parts of the coast. The prominent rocks are of volcanic origin, including basalts, dolerites, trachytic rocks, and in one locality obsidian. Numerous examples of fragmental volcanic rocks are also found. Below these, but seen in a few places only, are ordinary sedimentary deposits, consisting of sandstones or shales, and hard clays with lignites. At a single locality on the north end of Graham Island, beds with numerous marine fossils occur. These, in so far as they

[1] Report of Progress, Geol. Survey of Canada, 1876-77, p. 190.

[2] In the geology of the U. S. exploring expedition, Prof. Dana describes some Tertiary plants from Birch Bay. These were afterwards reported on by Newberry, Boston Journ. of Nat. Hist. vol. vii. No. 4. See also American Journal of Sc. and Arts, 2nd series, vol. xxvii. p. 359, and vol. xxviii. p. 85. Report on the Yellowstone and Niusain expedition, 1869, p. 166. Annals Lyc. of Nat. Hist. of N. Y., vol. ix. April, 1868.

admit of specific determination, represent shells found in the later Tertiary deposits of California, and some of which are still living on the north-west coast; and the assemblage is not such as to indicate any marked difference of climate from that now obtaining.[1]

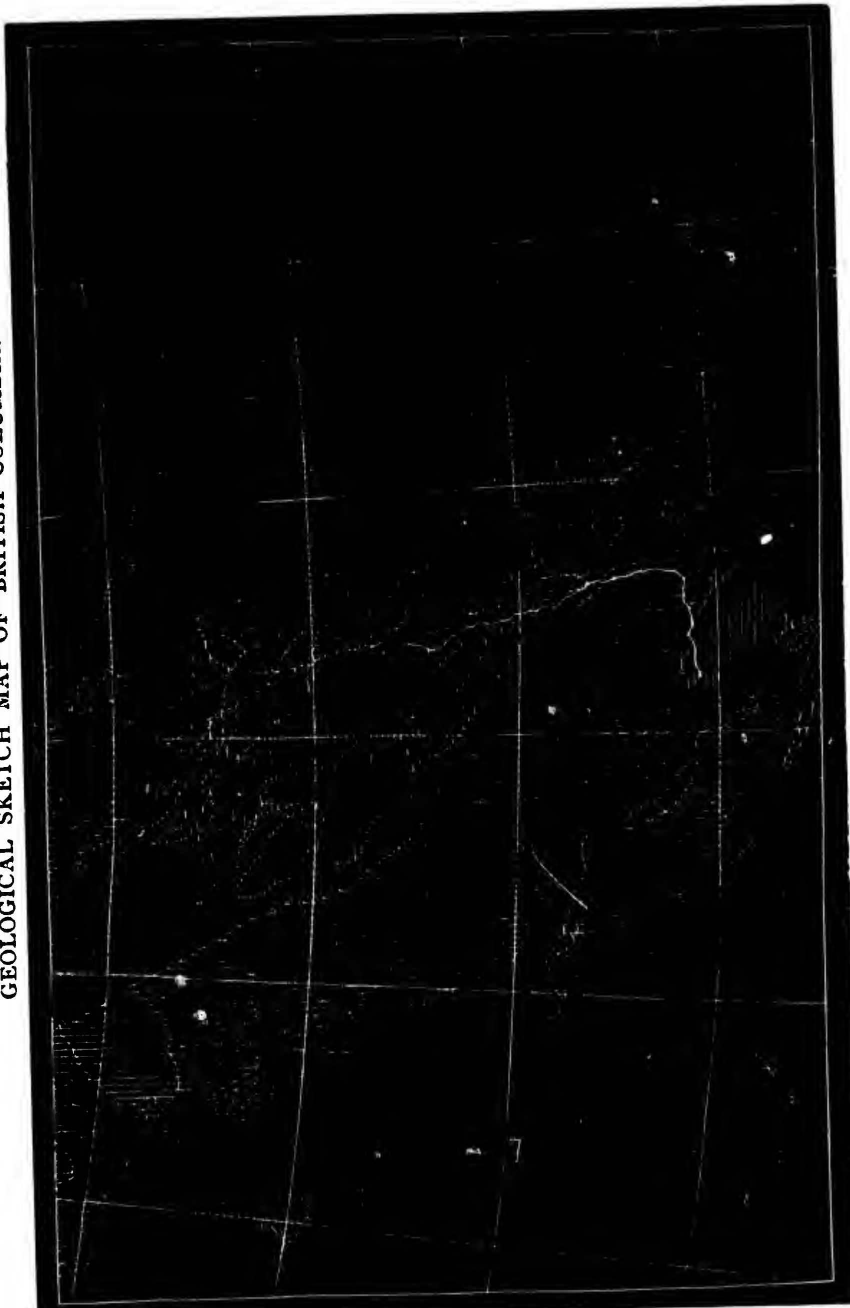
The Tertiary rocks of the coast are not anywhere much disturbed or altered. The relative level of sea and land must have been nearly as at present when they were formed, and it is probable that they originally spread much more widely, the preservation of such an area as that of Graham Island being due to the protective capping of volcanic rocks. The beds belong evidently to the more recent Tertiary, and though the palæontological evidence is scanty, it appears probable from this, and by comparison with other parts of the west coast, that they should be called Miocene.

To the east of the Coast or Cascade Range, Tertiary rocks are very extensively developed. They have not, however, yielded any marine fossils, and appear to have been formed in an extensive lake, or series of lakes, which may at one time have submerged nearly the entire area of the region described as the interior plateau. The Tertiary lake or lakes may not improbably have been produced by the interruption of the drainage of the region by a renewed elevation of the coast mountains proceeding in advance of the power of the rivers of the period to lower their beds; the movement culminating in a profound disturbance leading to very extensive volcanic action. The lower beds are sandstones, clays, and shales, generally pale-greyish or yellowish in colour, except where darkened by carbonaceous matter. They frequently hold lignite, coal, and in some even true bituminous coal occurs. These sedimentary beds rest generally on a very irregular surface, and consequently vary much in thickness and character in different parts of the extensive region over which they occur. The lignites appear in some places to rest on true "underclays," representing the soil on which the vegetation producing them has grown, while in others—as at Quesnel—they seem to be composed of drift-wood, and show much clay and sand interlaminated with the coaly matter.

In the northern portion of the interior the upper volcanic part of the Tertiary covers great areas, and is usually in beds nearly horizontal, or at least not extensively or sharply folded. Basalts, dolerites, and allied rocks of modern aspects occur in sheets, broken only here and there by valleys of denudation; and acidic rocks are seldom met with except in the immediate vicinity of the ancient volcanic vents. On the Lower Nechacco, and on the Parsnip River, the lower sedimentary rocks appear to be somewhat extensively developed without the overlying volcanic materials.

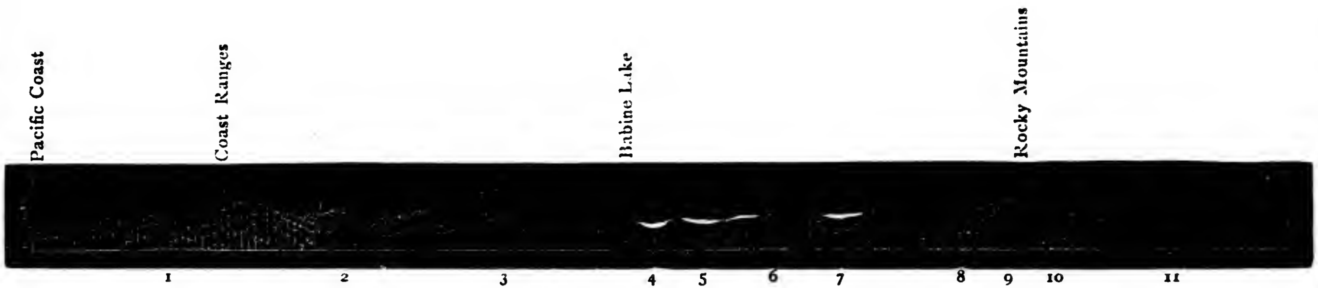
The southern part of the interior plateau is more irregular and mountainous. The Tertiary rocks here cover less extensive areas, and are much more disturbed, and sometimes over wide districts—as on the Nicola—are found dipping at an average angle of about thirty degrees. The volcanic materials are occasionally of great thickness, and the little disturbed basalts of the north are, for the

[1] Report of Progress, Geol. Survey of Canada, 1878-9, p. 84 B.



GEOLOGICAL SKETCH MAP OF BRITISH COLUMBIA.

SKETCH SECTION ACROSS THE CORDILLERA REGION IN THE VICINITY OF THE 55TH PARALLEL.



1. Gneiss mica- and hornblende-Schists of the Coast Ranges.
2. Granite.
3. Cretaceous Sandstones, Shales and Slates, with impure Coals.
4. Granite.
5. Outliers of Tertiary volcanic rocks.
6. Limestone, Schists and Quartzites Palæozoic, in part Carboniferous.
7. Highly Crystalline Gneiss and mica Schist Archæan (?).
8. Schists and Slates Triassic (?).
9. Limestones, Schists and Quartzites Palæozoic.
10. Triassic Monotis shales.
11. Cretaceous rocks of the Peace River Country.

HORIZONTAL SCALE

100 MILES

most part, replaced by agglomerates and tufas, with trachytes, porphyrites, and other felspathic rocks. It may indeed be questioned whether the character of these rocks does not indicate that they are of earlier date than those to the north, but, as no direct palæontological evidence of this has been obtained, it is presumed that their different composition and appearance is due to unlike conditions of deposition and greater subsequent disturbance.

No volcanic rocks or lava flows of Post-glacial age have been met with, though I believe that still farther to the north-west the rocks are of yet more recent origin than any of these here described, and I have even heard a tradition of the Indians of the Rasse River which relates that, at some time very remote in their history, an eruption covering a wide tract of country with lava was witnessed.

The organic remains so far obtained from these Tertiary rocks of the interior consist of plants, insects, and a few freshwater molluscs and fish scales, the last being the only indication of the vertebrate fauna of the period. The plants have been collected at a number of localities. They have been subjected to a preliminary examination by Principal Dawson, and several lists of species published. While they are certainly Tertiary, and represent a temperate flora like that elsewhere attributed to the Miocene, they do not afford a very definite criterion of age, being derived from places which must have differed much in their physical surroundings at the time of the deposition of the beds. Insect remains have been obtained in four localities. They have been examined by Mr. S. H. Scudder, who has contributed three papers on them to the Geological Reports,[1] in which he describes forty species, all of which are considered new. None of the insects have been found to occur in more than a single locality, which causes Mr. Scudder to observe that the deposits from which they came may either differ considerably in age, or, with the fact that duplicates have seldom been found even in the same locality, evidence the existence of different surroundings, and an exceedingly rich insect fauna.

Though the interior plateau may at one time have been pretty uniformly covered with Tertiary rocks, it is evident that some regions have never been overspread by them, while, owing to denudation, they have since been almost altogether removed from other districts, and the modern river valleys often cut completely through them to the older rocks. The outlines of the Tertiary areas are therefore now irregular and complicated.[2]

Cretaceous.—Lying everywhere quite unconformably below the Tertiary beds are the Cretaceous rocks, which constitute on the coast the true Coal-bearing horizon of British Columbia. These rocks probably at one time spread much more widely along the coast than they now do, but have since been folded and disturbed during the continuation of the process of mountain elevation, and

[1] Reports of Progress, Geol. Survey of Canada, 1875–6, p. 266; 1876–7, p. 457; 1877–8, p. 175, B.

[2] For additional information on the Tertiary rocks of the interior, see the following Reports of Progress, 1871–2, p. 56; 1875–6, pp. 70 and 225; 1876–7, pp. 75 and 112, B.

have been much reduced by denudation. Their most important area, including the coal-mining regions of Nanaimo and Comox, may be described as forming a narrow trough along the north-east border of Vancouver Island, 130 miles in length. The rocks are sandstones, conglomerates, and [illegible]les. They hold abundance of fossil plants and marine she[illegible] some places, and in appearance and degree of induration much resemble the true Carboniferous rocks of some parts of Eastern America. In the Nanaimo area the formation has been divided by Mr. J. Richardson as follows, in descending order:—

Sandstones, conglomerates, and shales	3290	feet.
Shales	660	,,
Productive Coal-measures	1316	,,
	5266	

The last named consists of sandstones and shales, and holds valuable coal-seams near its base. In the Comox area seven well-marked subdivisions occur, constituting a total thickness of 4911 feet.

Upper conglomerate	320	feet.
Upper shales	776	,,
Middle conglomerate	1100	,,
Middle shales	76	,,
Lower conglomerate	900	,,
Lower shales	1000	,,
Productive Coal-measures	739	,,
	4911	

The fuel obtained from these measures is a true bituminous coal, with—according to the analysis of Dr. Harrington—an average of 6·29 per cent. of ash, and 1·47 per cent. of water. It is admirably suited for most ordinary purposes, and is largely exported, chiefly to San Francisco, where, notwithstanding a heavy duty, it competes successfully with coals from the west coast of the United States, owing to its superior quality. The output of 1879 amounted to 241,000 tons, and is yearly increasing.

In addition to the main area of Cretaceous rocks above described, there are numerous smaller patches, holding more or less coal, in different parts of Vancouver Island, several of which may yet prove important.

In the Queen Charlotte Islands, Cretaceous rocks cover a considerable area on the east coast, near Cumshewa and Skidegate Inlets. At Skidegate they hold true anthracite coal, which, besides being a circumstance of considerable geological interest, would become, if a really workable bed could be proved, a matter of great economic importance to the Pacific coast.

At Skidegate, where these rocks are most typically developed, they admit of subdivision as follows, the order being, as before, descending:

A. Upper shales and sandstones	1500	feet.
B. Coarse conglomerates	2000	,,
C. Lower shales with coal and clay ironstone	5000	,,
D. Agglomerates	3500	,,
E. Lower sandstones	1000	,,
	13,000	

The total thickness is thus estimated at about 13,000 feet. With the exception of the agglomerates, the rocks in their general appearance and degree of induration compare closely with those of Vancouver Island. The agglomerates represent an important intercalation of volcanic material, which varies in texture, from beds holding angular masses a yard in diameter, to fine ash rocks, and appears at the junction to blend completely with the next overlying subdivision. These beds are generally felspathic, and often more or less distinctly porphyritic.

At the eastern margin of the formation the rocks lie at low angles, but become more disturbed as they approach the mountainous axis of the Islands, showing eventually in some cases overturned dips. It is in this disturbed region that the anthracite coal has been found, and from the condition of included woody fragments in the eastern portion of the area, it is probable that any coal seams discovered there would be bituminous, like those of Vancouver Island.

Though it was originally supposed that the anthracite occurred in several beds, it has, I believe, now been shown[1] that this appearance is due to the folding of a single seam which immediately overlies the agglomerate beds of subdivision D. The coal is associated with carbonaceous shales holding a species of *Unio*, but is succeeded, in ascending order, by beds charged with marine fossils, and fresh-water conditions are not known to have recurred at other horizons. It was where opened nearly vertical, and about six feet in thickness, but became thinner, and after about 800 tons of anthracite had been obtained, the mine was abandoned; the locality, however, still appears worthy of further and closer examination.[2]

In regard to the geological horizon of the different Cretaceous areas above described, the most complete information has been obtained for the Nanaimo and Comox basins. Large collections made by Mr. Richardson, in connexion with the work of the Geological Survey, have now been described by Mr. J. F. Whiteaves.[3]

These fossils are all from the lower portion of the formation, which is conclusively shown to represent the Chico group of the Californian geologists, which, with the locally developed Martinez group, is considered to be equivalent to the Lower and Upper Chalk of Europe. The highest subdivision of the Californian Cretaceous, the Tejon group, is supposed to represent the Maestricht, and in the absence of fossils from the upper portion of the Vancouver Island formation, it is possible that it may be equally young. The flora of the Vancouver Cretaceous consists largely of modern angiospermous and gymnospermous genera, such as *Quercus*, *Platanus*, *Populus*, and *Sequoia*; several of the genera and a few of the species being com-

[1] Report of Progress, Geol. Survey of Canada, 1878-79, p. 72 B.

[2] For further information on the Cretaceous rocks of the coast, see Dr. Hector's report in Palliser's Exploration in North America, and Quart. Journ. Geol. Soc. vol. xvii. p. 428. Reports of Progress, Geol. Survey of Canada, 1871-2, p. 75; 1872-3, p. 32; 1873-4, p. 94; 1874-5, p. 82; 1876-7, p. 160; the last reference being Mr. J. Richardson's complete report on the Nanaimo and Comox Basins, also pp. 119 and 144, 1878-9, p. 63B, a detailed report on Queen Charlotte Islands by the writer.

[3] Mesozoic Fossils, vol. i. part ii.

mon to it and to the Dakota group of the Middle Cretaceous of the interior region of the continent. The botanical evidence, while yet imperfect, is therefore by no means in contradiction to that afforded by the animals and the stratigraphy.

A number of fossils from the Queen Charlotte Islands have also been described and figured[1] from Mr. Richardson's collections made during a visit to the islands in 1872. Additional collections made by the writer in 1878, while considerably increasing the fauna, will enable more exact conclusions as to the horizon of the beds to be arrived at. There are few cases of specific identity between the forms in the Vancouver Cretaceous, previously described, and those of the Queen Charlotte Islands, the latter representing a lower stage in the Cretaceous formation. The plants found in these rocks, embracing numerous coniferous trees and a species of Cycad, also indicate a greater age than those of Vancouver.

The coal-bearing beds at Quatsino Sound on the west coast of Vancouver Island, have also yielded a few fossils. These consist chiefly of well-characterized specimens of *Aucella Piochii*, which occurs but sparingly in the Queen Charlotte Islands, and brings the rocks into close relations with the Aucella beds of the mainland of British Columbia, and in Mr. Whiteaves' opinion probably indicate an "Upper Neocomian" age. The rocks of the Queen Charlotte Islands and Quatsino may therefore be taken together as representing upper and lower portions of the so-called Shasta group of California, which in British Columbia can now be readily distinguished by their fossils.

On the mainland, developed most characteristically along the north-eastern border of the Coast Range, is a massive series of rocks first referred to by Mr. Selwyn, in the provisional classification adopted by him in 1871, as the Jackass Mountain group, from the name of the locality in which they are best displayed on the main waggon-road. The age of these rocks was not known at this time, but fossils have since been discovered in the locality above mentioned and in several others, the most characteristic forms being *Aucella Piochii* and *Belemnites impressus*. The rocks are generally hard sandstones or quartzites, with occasional argillites, and very thick beds of coarse conglomerate. A measured section on the Skagit includes over 4400 feet, without comprising the entire thickness of the formation. Behind Boston Bar, on the Fraser River, the formation is represented by nearly 5000 feet of rocks, while on Tatlayoco Lake it probably does not fall short of 7000 feet. At the last-named place these beds are found to rest on a series of felspathic rocks, evidently volcanic in origin, and often more or less distinctly porphyritic. On the Iltasyouco River, near the 51st parallel, and in similar relation to the Coast Range, an extensive formation characterized by rocks of volcanic origin, and often porphyritic, has also been found. Its thickness must be very great, and has been roughly estimated at one locality as 10,000 feet. It has been supposed, on lithological grounds, to represent the porphyritic

[1] Mesozoic Fossils, vol. i. part i.

formation of the vicinity of Tatlayoco Lake, and fossils found in it have been described as Jurassic.[1] From analogy now developed with the Queen Charlotte Island fauna, however, Mr. Whiteaves believes that these beds are also Cretaceous.

Still further north the Cretaceous formation is not confined to the vicinity of the Coast Range, but spreads more widely eastward, being in all probability represented by the argillites and felspathic and calcareous sandstones of the Lower Nechacco; and, as the explorations of 1879 have shown, occupying a great extent of country on the 55th parallel about the upper part of the Skeena and Babine Lake. They here include felspathic rocks of volcanic origin similar to those of the Iltasyouco, which are most abundant on the eastern flanks of the Coast Range, and probably form the lower portion of the group. Besides these volcanic rocks, there is, however, a great thickness of comparatively soft sandstones and argillites, with beds of impure coal. The strata are arranged in a series of folds more or less abrupt, and have a general north-west and south-east strike. It is not impossible, from the general palæontological identity of the rocks of the interior with the older of those of the coast, that the Skeena region may eventually be found to contain valuable coal-seams, but this part of the country is at present very difficult of access, and there is no inducement to explore it.[2]

Rocks of the Vancouver and Coast Ranges.—Previous to the deposit of the Cretaceous, the older formations had been folded and disturbed, and were in degree of alteration much as at present. While there is therefore no difficulty in distinguishing the Cretaceous from the Pre-cretaceous rocks, the subdivision of the latter becomes in many instances a difficult matter, the generally wooded and inaccessible character of the country adding to the obscurity in many districts. Without therefore entering into detail in regard to the various groups, which it has been found necessary provisionally to constitute and name, I shall attempt to give a short connected sketch of these older rocks, beginning with those of the Coast. In 1872 Mr. Richardson described a section across the centre of Vancouver Island,[3] comprising a great thickness of beds which have been closely folded together and overturned. These consist of limestones, generally crystalline, but varying in texture and colour, interbedded with compact amygdaloidal and slaty volcanic rocks of contemporaneous origin. These are classed generally as "diorites" in the report cited, but admit of separation into several different species of igneous rocks, not here necessary to detail. Argillites also occur, but are apparently not prominent in the section. Fossils are found abundantly in some of the limestones, and though invariably in a poor state of preservation, the late Mr. Billings was able to distinguish, besides crinoidal remains,

[1] Report of Progress, Geol. Survey of Canada, 1876-77, p. 150.

[2] I am indebted to Mr. J. F. Whiteaves for facts in regard to the palæontological evidence of the horizons of the subdivisions of the Cretaceous, communicated in advance of the publication of part iii. of the *Mesozoic Fossils.*

[3] Report of Progress, Geol. Survey of Canada, 1872-73, pp. 52-56.

a *Zaphrentis*, a *Diphiphyllum*, a *Productus*, and a *Spirifer*, and pronounced the beds to be probably Carboniferous in age.

Rocks belonging to the older series, unconformably underlying the Cretaceous, have now been examined in many additional localities on Vancouver Island, and, while no palæontological facts have been obtained to prove that they are older than those of the section above described, much circumstantial evidence has been collected to show that rocks even much more highly crystalline than those of the above section, and which, judged by standards locally adopted in Eastern America, would be supposed to be of great antiquity, represent approximately, at least, the same horizon.

At the south-eastern extremity of the island, in the vicinity of Victoria, a series of rocks occurs which was placed by Mr. Selwyn, in his provisional classification of the rocks of British Columbia, under the title of the *Vancouver Island* and *Cascade Crystalline Series*.[1] Mr. Selwyn, in speaking of these, remarks on their lithological similarity to the Huronian rocks, or those of the altered Quebec group of Eastern Canada. A somewhat detailed examination of this series has since been made, and shows it to be built up in great part of dioritic and felspathic materials, which in places become well characterized mica-schists, or even gneisses, while still elsewhere distinctly maintaining the character of volcanic ash-beds and agglomerates. With these are interbedded limestones, and occasionally ordinary blackish argillites. No more certain palæontological evidence of the age of these beds than that afforded by some large crinoidal columns which occur in the limestones, has yet been obtained. These, however, suffice to show that they cannot be referred to a pre-Silurian date, and it is highly probable that they are actually a more altered portion of the series represented in the first described section, from which their greatest point of difference is found in the smaller proportionate importance of limestones. They occur in the continuation of the same axis of elevation at no very great distance, and the greater disturbance which they have suffered would serve to account for the higher degree of alteration in materials so susceptible of crystallization as those of volcanic origin.

Elsewhere, in the vicinity of Vancouver Island, rocks holding fossils, which seem to be Carboniferous, and formed in part of volcanic materials, occur; and on Texada Island, beds probably of the same age are found, consisting of interstratified limestone or marble, magnetic iron ore, epidotic rock, diorite, and serpentine.

Passing north-westward, along the same mountainous axis, to the Queen Charlotte Islands, we find the rocks there underlying the Cretaceous Coal series to present, in the main, features not dissimilar to those of Vancouver Island. Massive limestones, generally fine-grained, grey, and often cherty, are folded together with felspathic and dioritic rocks, sometimes so much altered as to have lost the evidence as to whether they were originally fragmental or molten.

[1] Report of Progress, Geol. Survey of Canada, 1871-2, p. 52.

In other places they are still well-marked rough agglomerates, or amygdaloids.

No characteristic fossils have been obtained from these rocks, but at the summit of this part of the series, and adhering closely to a limestone which apparently forms its upper member, occurs a great thickness of regularly-bedded blackish calcareous argillite, generally quite hard and much fractured, but holding numerous well-preserved fossils, including *Monotis subcircularis* and other characteristic forms of the so-called "Alpine Trias" of California and the 40th parallel region, which represents the Hollstadt and St. Cassian beds of Europe. The resemblance of the lower unfossiliferous rocks first described to the probably Carboniferous beds of Vancouver, leads to the belief that these may also be of the same age, while any slight unconformity between these and the Triassic may be masked by subsequent folding and disturbance.

In the extreme north-western part of Vancouver Island Triassic rocks like those of the Queen Charlotte Islands occupy extensive but yet undefined areas, while the slaty auriferous rocks of Leach River, near Victoria, may also represent the Triassic argillites in a more altered state.[1]

As already mentioned, Mr. Selwyn, in his provisional classification, unites under one title the older rocks of Vancouver Island, above described, and those which form the greater part of the Cascade or Coast Ranges. The progress in the investigation of the country seems to favour the correctness of this view, and to show a blending and interlocking of such characters of difference as the typical or originally examined localities of the two series present. Tracing the rocks eastward from the shores of Vancouver Island, we find them becoming more disturbed and altered, the limestones always in the condition of marbles, and seldom or never showing organic traces, the other rocks represented chiefly by grey or green diorites, gneisses—generally hornblendic—and various species of felspathic rocks, such as may well be supposed to have resulted from the more complete crystallization of the volcanic members of the series. Recurring in a number of places, and folded with these rocks, is a zone of micaceous schists or argillites.

The rocks classed as the Anderson River and Boston Bar series[2] in the provisional classification represent one fold of these schists, which may be supposed to be more or less exactly equivalent to the Triassic flaggy argillites of the first mountainous axis.

The Coast Range constitutes an uplift on a much greater scale than that of Vancouver and the Queen Charlotte Islands to the south-west of it, a circumstance which appears to have resulted in a more complete crystallization of its strata, and has also led to the introduction of great masses of hornblendic granite. These may in many places represent portions of the strata which have undergone incipient or complete fusion, in place. There is every evidence that in the Appalachian-like folding of this region the same rocks are

[1] Reports of Progress, Geol. Survey of Canada, 1878-9, p. 46 B; 1876-7, p. 95.

[2] Report of Progress, Geol. Survey of Canada, 1871-2, p. 62.

many times repeated. East of the lower part of the Fraser River the folds have been completely overturned to the eastward.

These rocks of the Coast Range have with other features of the country a great extension in a north-east and south-east bearing, stretching, with an average width of 100 miles at least, from the 49th parallel to Alaska, a distance of 500 or 600 miles.

Pre-Cretaceous Rocks of the Interior.—North-east of the Coast Range the older rocks of the interior plateau are more varied, but have in their different developments characters in common with each other and with those of the Coast Range, which draw them closely together. These rocks, which were included under the Lower and Upper Cache Creek groups of the original classification, may be said as a whole, in their present state, to consist of massive limestones, diorites or allied materials, felspathic rocks, compact agglomeritic or slaty quartzites and serpentines. The last-named rock occurs in association with the contemporaneous volcanic materials, and doubtless represents the alteration product of olivine rocks. It is in beds of considerable thickness and wide-spread, and is of interest as being of a period so recent as the Carboniferous. The limestones are not unfrequently converted to coarse-grained marbles, and together with the quartzite appear in greatest force on the south-western side of the area they occupy. They have now been traced, maintaining their character pretty uniformly throughout, from the 49th to the 53rd parallel. Schistose, or slaty argillite rocks, which may represent those already described as folded with the Coast Range series, also occur, and a portion of these at least probably belongs to the overlying Triassic or Jurassic division.

In regard to the evidence of the age of the great mass of these rocks, forming the so-called Upper and Lower Cache Creek groups, the following points may be mentioned. A portion at least of the formation was in 1871 shown, by fossils collected by Mr. Selwyn, to belong to a horizon between the base of the Devonian and summit of the Permian. Additional fossils have since been procured, of which the most characteristic is the peculiarly Carboniferous foraminifer *Fusulina*. This has now been found in several localities, scattered over a wide area, and is associated at Marble Cañon with the remarkable *Loftusia Columbiana*.[1]

In the southern portion at least of the interior plateau region there exist, besides the Palæozoic rocks just described, and in addition to the probably in part Triassic argillites, extensive but as yet undefined areas of Triassic rocks of another character. These are in great part of volcanic origin, and have been designated the Nicola series. They have generally a characteristically green colour, but are occasionally purplish, and consist chiefly of felspathic rocks and diorites, the latter often more or less decomposed. The rocks are in some cases quite evidently amygdaloidal or fragmental, and hold toward the base beds of grey sub-crystalline limestone, intermingled in some places with volcanic material, and containing occasional layers of water-rounded detritus. The distinctly unconformable junction of this

[1] Quart. Journ. Geol. Soc., 1879, p. 69.

series with the Cache Creek rocks is seen on the South Thompson, a few miles above Kamloops.

In the Gold Range which borders on the interior plateau to the north-east, the conditions found in the Coast Range appear in many respects to be repeated. The rocks just described, but with less quartzite and limestone, and probably an added proportion of volcanic material, are found in a more or less highly altered state as gneisses, dioritic, hornblendic, and micaceous schists, and coarsely crystalline marbles, while a belt of schistose and argillaceous beds, probably the same with that already several times referred to, and newer than the rocks just mentioned, is tightly folded with them, giving to this axis of elevation its famed auriferous character. No fossils have yet been found in the crystalline rocks of this range. Respecting the proved existence in it of a series of rocks older than elsewhere known in the province, the facts are given on a succeeding page.

For the region to the north-east of the Gold Range, including the eastern flanks of the range, and the country between it and the Rocky Mountains proper, little information has been obtained. It is one exceedingly difficult of access, owing to its mountainous and densely-wooded character; but the transition from the much-flexed rocks of the first-mentioned range to the comparatively little bent though much broken masses of the Rocky Mountains is probably pretty abrupt.

Structure of the Rocky Mountains.—In the Rocky Mountains we have the broken margin of the undisturbed sheets of strata which underlie the great plains, projecting in block-like masses. In British America our geological knowledge of the range is confined to the observations of its extreme northern part by Sir J. Richardson, of its southern portions by Dr. Hector, a traverse on the Peace River by Mr. Selwyn, and my own observations in the last-named locality and on the 49th parallel.

The most complete section is that in the vicinity of the 49th parallel,[1] to which I shall briefly refer, and then indicate points of difference between the rocks shown in it and those of the north-western continuation of the range. The total thickness of the beds here seen is about 4500 feet. The lowest are impure dolomites and fine dolomitic quartzites, dark purplish or grey, with a thickness of 700 feet or more. These may be of Cambrian age, and are supposed to represent the Pogonip formation of Clarence King's 40th parallel section.[2] Overlying this is a pale grey cherty magnesian limestone, with magnesian grits, estimated at 200 feet in thickness, which is supposed to represent the Ute-Pogonip limestone of Silurian age of the 40th parallel section. Next in order is 2000 feet or more of sandstones, quartzites, and slaty rocks of various tints, but chiefly

[1] Though the investigation of the rocks of this part of the Rocky Mountains was carried on quite independently, and reported on in 1875, it has been thought desirable to refer the formations as far as possible to King's section, as being much the best hitherto published for the Rocky Mountain Region.

[2] Geol. and Resources of 49th Parallel, p. 56.

reddish or greenish grey, holding also magnesian grits, and a well-marked zone of bright red beds. These may be equivalent to the Nevada Devonian and Ogden quartzites of the same age, on the 40th parallel. The Carboniferous is next represented by a massive bluish limestone 1000 feet in thickness, above which lies an amygdaloidal trap 50 to 100 feet thick, which maintains its place for at least twenty-five miles along the mountains. Above this are flaggy beds of magnesian limestone and sandstone with red sandstone, which become especially abundant towards the top, the thickness of the series being about 200 feet. The position of the upper line of the portion of the formation which should be referred to the Carboniferous is uncertain, but it is probable that a part at least of the beds last described belong to it. Passing gradually upwards from this series is about 400 feet of beds, characterized by a predominant red colour, and chiefly thin-bedded red sandstones, often ripple-marked, and showing on some surfaces impressions of salt crystals. Fawn-coloured magnesian sandstones and limestones occur towards the top. These without doubt represent the Triassic or Jura-Triassic red beds extensively developed everywhere to the southward, in the eastern ranges of the Cordillera region.

North-westward, to the Athabasca River, Dr. Hector's numerous excursions in this mountain axis prove the great mass of the range to be composed of Carboniferous and Devonian beds, which are predominantly limestones, but it is also probable that some of the older rocks above described may occur.

In the Peace River region, on the 55th and 56th parallels, the conditions are somewhat changed. Massive limestones of Devonian and probably also of Carboniferous age, associated with saccharoidal quartzites, here form the axial mountains. On the west side these are overlain by an extensive schistose series, in which micaceous schists and argillites, more or less altered, predominate. These are known to occupy a long trough east of the Parsnip River, and cross the Misinchinka, with considerable width. They are doubtless of the same age as the gold-bearing schists of Cariboo, before referred to, and while no fossils have here been found in them, a series of dark argillites on the eastern slope of the mountain axis which contain several Triassic forms—more particularly the characteristic *Monotis*—may, it is supposed, represent the continuation of the same series in a less altered state. These marine *Monotis* shales, it will be observed, seem to represent in this section the red beds of the region further south. Volcanic material appears to be entirely absent from the limestone series.

While in the Rocky Mountains on the 49th parallel, formations extending downwards to the Cambrian have been identified with some degree to certainty, it will be observed that none older than Carboniferous or Devonian have so far been mentioned as occurring in other parts of the region. It is quite possible, however, that rocks of Silurian or even Cambrian age may exist, though the disturbed nature of the country has so far prevented their discovery. It has been attempted here merely to give a general sketch of the more important groups of rocks, which constitute the mass of the formations of the Province. Still older rocks, which may indeed represent part of the Archæan of the 40th parallel area, are known to occur, but about them little has yet been certainly determined. They appear at intervals in the Gold Range, and in the region between it and the Rocky Mountains. The rocks appear to be gneisses and granites, holding orthoclase felspar, and with abundant quartz and mica, very often garnetiferous and coarsely crystalline. They were originally classed with the schistose gold-bearing rocks of Cariboo and their representatives elsewhere, but we have already found reason to believe that these schists are much newer, and during the past summer those on the Misinchinka have been found to be charged with half-rounded quartz and felspar from the old rocks above mentioned, which must have been fully metamorphosed at the time of their deposition. A small area of these oldest and possibly Laurentian rocks occurs near Carp Lake in the northern part of the Province. They also exist in the Cariboo district, though they have not yet been defined there. They are described by Mr. Selwyn as occurring on the upper part of the North Thompson, and the gneissic rocks noted by Dr. Hector near the sources of the Athabasca, on the western side of the Rocky Mountain axis, probably belong to the same fundamental series.

Physical Conditions implied by the Deposits.—This review of the state of knowledge of the rock series of British Columbia may well be concluded by glancing rapidly at the physical conditions implied in the production of the different formations. The oldest land surface of which we have any knowledge is that of the probably Archæan rocks just described, and must have been in the region of the Gold Range of to-day. It may have extended farther westward in early Palæozoic time, forming a continental area like that supposed by King to have stretched west from the Wahsatch Mountains on the 40th parallel, but no trace of its existence to the eastward of the western margin of the Rocky Mountain Range has yet been found. In Devonian and Carboniferous times the geography of the region begins to outline itself more definitely. The probably Archæan rocks at this time formed a more or less continuous barrier of land along the line of the Gold Range, between the interior continental basin to the north-east and the Carboniferous Pacific to the south-west. In the eastern sea organic limestones with sandy and shaly beds were being deposited, and in the vicinity of the 49th parallel at least one well-marked flow of igneous material evidences the existence of volcanic phenomena. In the west and south-west of the land barrier the conditions were widely different. Here, too, limestones were in process of formation, but extensive siliceous deposits were also forming, while a great chain of volcanic vents—submarine or partly subaerial—nearly coincident with the present position of the Coast Range and those of Vancouver and the Queen Charlotte Islands. Trap and agglomerate rocks were thus added to the series. Similar centres of volcanic activity may have existed in the vicinity of the land barrier on the west, whilst the finer felspathic material affected the composition of the argillites and other rocks, in progress of deposition, even at a great distance from any of the vents, and the series acquired a great thickness.

Evidence of some disturbance at the close of the Carboniferous period is found in the unconformable superposition of the Nicola Triassic on these rocks, in the southern portion of the interior of the Province. This, however, appears to have affected the region to the west of the land barrier alone, and to have resulted in the more complete definition of this barrier, and probably to its increased elevation; for in Triassic and Jurassic times we find the deposition of the red beds and flaggy dolomitic limestones with salt, going on to the east near the 49th parallel, and further south the actual inclusion of salt and beds of gypsum, proving that this region was then a shallow inland sea cut off from communication with the ocean. To the west of the land barrier on the contrary, in the Triassic, and probably also in the Jurassic, a great thickness of volcanic rocks with limestones and argillites was being formed along the border of the Pacific. The argillites of this period probably afterwards became the chief gold-bearing formation of the country, as is proved to have been the case in California. These with the volcanic accumulations doubtless represent the Star Peak and Koipato groups of the Triassic as described by King on the 40th parallel between the Sierra Nevada and the Wahsatch Ranges; and though, as elsewhere stated,[1] I have not been able to find that the existence of Carboniferous volcanic rocks has been recognized in the Sierra Nevada of California, it seems probable, from the description and appearance of the rocks, that more or less altered volcanic materials, perhaps both of Mesozoic and Palæozoic age, enter into its composition. A further circumstance of interest in connexion with the Jura-Trias period is the evidence now obtained that the sea apparently spread uninterruptedly eastward across the Rocky Mountains and into the Peace River country, at least as far south as the 55th parallel. This is proved both by the lithological character of the rocks, and the fossils they contain,[2] and we thus arrive at an approximate definition, not only of the western but also of the northern limits of the great inland sea, which extended south-eastward to New Mexico, though we still remain ignorant of the precise character of the northern barrier. This period was closed by a great disturbance along the whole Cordillera region. In California the Sierra Nevada rose up as a mass of crumpled and compressed folds. In the southern part of British Columbia the disturbance affected the region from the Gold Range to the coast, extending the land area westward to the 121st meridian, and giving, so far as is known, the first upthrust to the mountains of Vancouver and Queen Charlotte Islands, but forming no continuous range where the great belt of coast mountains now is.

In the earliest beds of the Cretaceous there is evidence of a general slight subsidence in progress, with the formation of conglomerates, and we can trace the shore-line of the Cretaceous Pacific, which

[1] Geol. Mag. 1877, p. 315.

[2] See, on the latter point, Report of Progress, Geol. Survey, 1876-7, p. 158.

crosses the 49th parallel near the 121st meridian, southward to the Blue Mountains of Oregon, south-westward to Mount Shasta, and from this, according to Whitney, still further southward along the western slope of the Sierra Nevada. To the north it appears nearly to follow the present north-eastern line of the Coast Range to the 52nd parallel, when it turns north-eastward, passing completely across the line of the Gold Range, and by straits and openings through the Rocky Mountains on the 55th parallel, connecting this with the great Cretaceous Mediterranean Sea of the interior of the continent. In the southern part of British Columbia it would appear that the Rocky Mountains proper were not at this time elevated, but that the Cretaceous Mediterranean washed the eastern shore of the Gold Range. In the Peace River region, however, just mentioned, there is ample proof that the Rocky Mountains formed even at this time a more or less continuous shore-line or series of islands, around which the Cretaceous beds were deposited.

The existence of a great thickness of rocks of volcanic origin in the Cretaceous of several parts of the Province has already been alluded to. Their resemblance to those described as occurring in the Cordillera region in Chile, by Darwin, has been pointed out by the writer in a former communication to the Geological Magazine.[1]

The Cretaceous closed with another period of folding, in which additional height was given to the Vancouver and Queen Charlotte Island Ranges, the Coast Ranges were produced, as well as corrugations doubtless caused still further eastward which cannot now be separated from those of other periods. At this time, or shortly after, the Rocky Mountains attained their full height and development.

No trace of the earlier or Eocene Tertiary has been found in British Columbia, and it is probable that the Province was throughout at that time a land area. In the Miocene, the relative elevation of sea and land was much as at present, but the great inland lake formerly alluded to was in existence. This lake was doubtless the northern continuation or homologue of that which has been called the Pah-Ute Lake by Clarence King, and which lay east of the Sierra Nevada on the 40th parallel. The rocks formed in it thus represent the Truckee Miocene of King's section.

The Miocene closed with extensive volcanic disturbances throughout the country south-west of the Gold Range, and eventually by still another epoch of corrugation and crumpling probably synchronous with that which produced the Tertiary Coast Hills of California, and which may have given to the northern part of the coast the greater elevation, which it appears to have possessed during Pliocene times, when the wonderful system of fiords, by which it is now dissected, were cut out.

The most striking points brought out by the study of this region are probably the following. First, the repeated corrugation, parallel in the main to a single axis, which has occurred in the Cordillera region. Second, the occurrence of great and wide-spread masses of

[1] Geol. Mag. 1877, p. 314. The rocks elsewhere described were at the time the article in question was written supposed to be Jurassic.

volcanic material at at least four distinct horizons, proving the activity for an immense period of the volcanic forces along this portion of the Pacific margin. Lastly, the sometimes almost insuperable difficulty of distinguishing between volcanic rocks of different periods when they have suffered a like degree of metamorphism, and the inappropriateness of attempting to apply lithological standards, which have in eastern America or elsewhere been found locally useful in distinguishing between different series of crystalline rocks, in a region characterized by the abundance of easily crystallizable volcanic materials, and in which rocks of as late date as the Carboniferous have suffered a degree of metamorphism comparable to that of the Huronian or altered Quebec group of Eastern Canada.

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