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GEOLOGICAL RECORD OF THE ROCKY MOUNTAIN REGION IN CANADA

ADDRESS BY THE PRESIDENT, GEORGE M. DAWSON

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(Read before the Society December 29, 1900)

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INTRODUCTION

It is the privilege of the President of this Society, in his address, to bring to the notice of his fellow-members some subject possessed of more or less general interest, and preferably, I think, some subject that he has made particularly his own. On such an occasion a wider outlook upon various geological fields becomes admissible than in the case of papers presented to the Society, which, as a rule, should be devoted to original and unpublished observations. It has thus appeared to me that it may be of interest and utility at this time, to collect and review the main facts so far ascertained respecting the composition of the geological column of what may be called the Rocky Mountain region of Canada, including the province of British Columbia and the Yukon district—this region being identical with that part of the western Cordillera comprised in the Dominion of Canada. To its geological exploration a great part of my own time has been devoted for many years. The results, as obtained, have been published chiefly in the reports of the Geological Survey of Canada, but it is undoubtedly difficult for the inquirer, with only a limited amount of time at his disposal, to form a connected and balanced idea of the conditions, as a whole, from a series of such progress reports, dealing usually with particular districts.

Twenty years ago, after having worked in British Columbia or on its borders for six seasons, I read a paper before the Geological Section of the British Association for the Advancement of Science, at Swansea, entitled "Sketch of the geology of British Columbia," which was afterwards published in the Geological Magazine.* So far as they go, the general outlines then laid down still hold; but much has been accomplished since that time, the relative importance of the observations recorded has been considerably changed, and opinions expressed from time to time have had to be modified as the work progressed. All I shall attempt to do here is to review the principal geological features as they are now understood, but in order to render this address of more practical value as a clue to the geology of the region covered by its title, references to the principal reports and papers in which details may be found will be given throughout.

Special Features of the Region

The region dealt with is in many respects one of particular geological interest, and it is likewise remarkable as one which it has been necessary to work out as an almost entirely detached geological problem. Its older rocks are separated from those of the eastern parts of Canada by the whole width of the Great plains, and the newer formations found in it are generally unrepresented in other parts of Canada. Nor until the work was well advanced did any satisfactory standard of comparison exist in the far west. California could be referred to in regard to certain defined formations of the Tertiary and Cretaceous, but a great intervening region of the Cordillera remained practically unknown geologically, except for the earlier results of the Hayden surveys and some reconnaissance surveys by other explorers along lines of travel. Clarence King's great volume, the "Systematic Geology of the 40th Parallel," did not appear till 1878, and the relations of the region here referred to with others, which have become apparent, have been developed at later dates.

* Decade II, vol. viii, April and May, 188.

It was in this region also that the occurrence of contemporaneous volcanic materials as important constituents of the Mesozoic and Paleozoic rocks of the Cordilleran belt was first recognized. Previous to the earlier reports of the Canadian Geological Survey on British Columbia, the existence of such volcanic materials had been admitted only as regards the Tertiary formations, in the western portion of the continent.

Investigators

The geological exploration of British Columbia was begun in 1871 by Dr A. R. C. Selwyn, assisted by the late Mr James Richardson. Taking all the circumstances into consideration, the report then made by Dr Selwyn must, I think, be regarded as a remarkably valuable and important one. My own investigations in connection with the Geological Survey began in 1875 and in 1887 extended to the Yukon district. Work was carried on in the Cariboo district for some years under the control of the late Mr Amos Bowman, and in later years Messrs J. McEvoy, R. G. McConnell, J. B. Tyrrell, R. W. Brock, and J. C. Gwillim have also been in charge of parties in different parts of this Cordilleran region of Canada.

Physiographical Features

It is not my intention, however, here to follow the development of our knowledge of the region historically, through its various stages, but rather to enumerate the several formations now known to be represented, to briefly describe each of them, and then to review the main outlines of the geological evolution of this part of the continent in so far as it has been made apparent. For this purpose a few words must first be devoted to the existing physiographical features of the region.

Pleistocene events and matters connected with the glaciation and later superficial geology may be excluded from consideration, as these have been treated at some length elsewhere.*

As compared with the Cordilleran region in the Western states, that of British Columbia is much less diffuse and more strictly parallel with the corresponding part of the Pacific coast. Its length is approximately the same, but its width is usually about 400 miles only. The several mountain systems are separated by narrower intervals, and, except in the extreme north, may be more readily traced and defined. All the main physical features trend in a north-northwest direction for about 1,100 miles, after which the mountain axes turn somewhat abruptly westward,

* Trans. Royal Soc. Can., vol. viii. Presidential address to Section IV.

and, becoming less continuous and separated by wider intervening lowlands, run toward the eastern boundary of Alaska.

The geological features follow a similar rule, the rock series represented differing much in age and composition within comparatively short distances as the Cordilleran belt is crossed, while they run far and with closely accordant characters in the direction of its length.

This depends on two conditions, both imposed by the position of the zone of recurrent crustal movements coincident with the western border of the continent: (1) The occurrence of successive zones of deposition, whether sedimentary or volcanic, parallel to the continental edge; (2) the actual compression of the original area of deposition, by folding and fracture, produced by pressure from the Pacific side, by means of which the superficies may have been reduced by at least one-third of its original width since early Paleozoic times. It results, further, from these conditions that the local names applied to geological formations remain appropriate for long distances in the general direction of the strike, while the characters associated with such names can seldom be traced far without change in a transverse direction. The bearing of this on the nomenclature appropriate for the Cordilleran region as a whole is important, and the want of attention to it has already, I fear, led to the publication of some new formational names which are unnecessary and confusing rather than helpful.

The ruling orographic features of the Cordilleran region in Canada at the present time are the Rocky mountains proper, forming its high eastern border, and the Coast ranges of British Columbia on the west. It has been proposed by Dana to name the first of these systems the "Laramide range," as its origin was coeval with the close of the Laramie period. This mountain system appears to begin about the 46th or 47th parallel of latitude, from which it runs in a northerly direction to the Arctic ocean, with occasional echelon-like breaks, but forming throughout the western limit of the inland plain of the continent. Its width is about 60 miles, and although reduced in the far north, the height of many of its peaks exceeds 11,000 feet. The rocks composing it are for the most part referable to the Paleozoic, and it is found to be affected by numerous great faults parallel to its direction, overthrust to the eastward, and along the eastern margin, resulting in some cases in horizontal displacements of several miles, by which Paleozoic rocks override those of Cretaceous age in the foothills.

The Coast ranges of British Columbia form a belt of about 100 miles in width that extends along the border of the Pacific for at least 900 miles, beginning near the estuary of the Fraser and eventually running inland beyond the head of Lynn canal, where the coast changes its trend to the westward. These ranges are chiefly composed of granitic rocks, which may in the main be regarded as forming a gigantic "bathylite" with minor included masses of sedimentary rocks. It is later in date of origin than the Triassic period and probably experienced a second and much greater elevation at or about the close of the Cretaceous, but is neither so lofty nor so ragged as the Laramide range. The remarkable fiords of the Pacific coast, both those of British Columbia and those of the southern part of Alaska, are the submerged valleys of this coastal system of mountains, their erosion being probably referable to early Eocene and late Pliocene times, during which the land stood at relatively high levels.

To the west of the Laramide range, and separated from it by a remarkably long and direct structural valley, is a somewhat irregular and sometimes interrupted series of mountain systems to which the general name of the Gold ranges has been applied, and this is referred to further on as the Archean axis of this part of the Cordillera. It embraces the Purcell, Selkirk, Columbia and Cariboo mountains, all including very ancient rocks and evidently representing the oldest known axis of elevation in the province, although it has not remained unaffected by movements of much later date. Peaks surpassing 10,000 feet in elevation still occur in these mountains.

Between the Gold and Coast ranges, with a width of about 100 miles, is the Interior plateau of British Columbia, a peneplain referred in its main features to the early Tertiary, which has subsequently been greatly modified by volcanic accumulations of the Miocene, and has been dissected by river erosion at a still later period. This plateau country is well defined for a length of about 500 miles, declining northward from a height of over 4,000 feet near the 49th parallel to one of less than 3,000 feet, and with an average altitude of about 3,500 feet. It is then interrupted for some four degrees of latitude by a mountainous country chiefly composed of disturbed Cretaceous rocks, beyond which the surface again declines to the plateau lands of the upper Yukon basin, with its separated mountain ranges. The Interior plateau is throughout very complex in its geological structure, but except where covered by Tertiary accumulations it is found to be chiefly underlain by Paleozoic and Mesozoic rocks.

One more mountain system remains to be noted. This stands upon the real border of the Continental plateau, and is represented by the long ridge-like highlands of Vancouver island and the Queen Charlotte islands. It is evidently broken between these islands, and is not clearly continued in the archipelago of southern Alaska, which seems to be more closely connected with the Coast ranges of the mainland. The rocks principally comprised in this outer mountain system range from the Carboniferous to the Cretaceous in age.

Table of Geological Formations

Attention may now be directed to the general table of geological formations recognized in the region under review. This is arranged in two main columns, representing what I conceive to be the two great geosynclines of this part of the Cordillera. These are separated by what has already been referred to as an Archean axis. A further explanation of these main structural features will be given subsequently, but it is first proposed to define and briefly note the character of each of the geological units, beginning with the oldest.

	Western Geosyncline	Feet		Laramide Geosyncline	Feet
Pliocene	Horsefly gravels. Quartz drift of Klondike, etc.				
Miocene	Upper volcanic group	3,100			
	Tranquille beds	1,000			
	Lower volcanic group	5,300			
Oligocene	Coldwater group (Similkameen beds, etc.).	5,000			
Eocene	Puget group (on coast only 3,000′ +).			Upper Laramie	3,000
				Lower Laramie	2,500
Cretaceous	Nanaimo group	2,700		Montana; Colorado	3,140
	Queen Charlotte Island group (in Queen Charlotte islands).	9,500		Dakota; Kootanie	9,750
Triassic	Nicola group	13,500		(Red beds to south, marine to north) say	600
Carboniferous	Cache Creek group	9,500		Banff series	5,100
Devonian	(?)			Intermediate series	1,500
Silurian	(?)			Halysites beds	1,300
Ordovician	(?)			Graptolithic shales	1,500
				Castle Mountain group (upper part). Castle Mountain group (lower part).	8,000
Cambrian	Adams Lake series	25,000	Selkirk series, 25,000		
	Nisconlith	15,000		Bow River series	10,000
		89,600			46,390
Archean	Shuswap series	5,000′ +			

Archean

In 1881 it was possible only to allude to the existence of crystalline rocks probably referable to the Archean. The rocks referred to were those originally described by Dr Selwyn as the "Granite, gneiss, and mica-schist of the North Thompson, etc.," and recognized from the first by him as "the oldest rocks observed in the country." It was not, however, till 1889 that much further information was gained regarding these old rocks, when good sections of them were found by the writer on Kootenay lake, and as they were also well developed on Shuswap lake, the name Shuswap series was proposed for them.* The Shuswap rocks proper evidently represent highly metamorphosed sediments with perhaps the addition of contemporaneous bedded volcanic materials. They are grayish mica-gneisses, with some garnetiferous and hornblendic gneisses, glittering mica-schists, crystalline limestones and quartzites. Gneisses in association with the last-mentioned rocks often become highly calcareous or silicious and contain scales of graphite, which are also often present in the limestones. These bedded materials are, however, associated with a much greater volume of mica-schists and gneisses of more massive appearance, most of which are evidently foliated plutonic rocks, and are often found to pass into unfoliated granites. The association of these different classes of rocks is so close that it may never be possible to separate them on the map over any considerable area. The granites may often have been truly eruptive in origin, but the frequent recurrence of quartzites among them in some regions indicates that they are, at least in part, the result of a further alteration of the bedded rocks.†

Thus, up to the present time, the Shuswap series has been made to include this entire complex mass of crystalline rocks, although it might be more appropriately restricted to the originally bedded members. These, it will be observed, now very closely resemble those of the Grenville series of the province of Quebec, the resemblance extending to the nature of their association with the foliated rocks, which in turn closely resemble the so-called "Fundamental Gneiss" of the same region. The original materials and the conditions of alteration to which they have been subjected have in both localities been almost identical, producing like results. The age must be approximately the same, but the distance is too great to admit of any precise correlation on lithological grounds.

When the ruling lines of strike or foliation of the Shuswap are laid down, they are generally found to be parallel with each other in each particular region, but to run in great irregular sweeping curves over the face of the map as a whole, and sometimes to surround unfoliated granitic areas in a concentric manner, the whole appearance being very much like that met with in some parts of the Laurentian country in the east.

*Annual Report, Geol. Surv. Can., vol. iv (N. S.), p. 29 B. The name Kootanie (or Kootenay) was preoccupied.

†Cf. Shuswap map-sheet, Geol. Surv. Can., 1898.

A distinct tendency to parallelism of the strata or foliation with adjacent borders of the Cambrian system has moreover also been noted in a number of cases. This might imply that the foliation was largely produced at a time later than the Cambrian, but the materials of some of the Cambrian rocks show that the Shuswap series must have fully assumed their crystalline character before the Cambrian period, and there are other evidences of their extensive pre-Cambrian erosion. It seems, therefore, probable that the foliation of the Shuswap rocks may have been produced rather beneath the mere weight of superincumbent strata than by pressure of a tangential character accompanied by folding, and that both these rocks and those of the Cambrian were at a later date folded together. In the Archean of eastern Canada, foliation still nearly horizontal or inclined at low angles, often characterizes considerable areas and appears to call for some explanation similar to that above suggested.

The greatest thickness of the Shuswap rocks so far measured, where there is no suspicion of repetition, on Kootenay lake, is about 5,000 feet, but even here there are doubtles included considerable intercalations of foliated eruptives. The Shuswap series characterizes considerable areas of the Selkirk, Columbia, and adjacent ranges in the southern part of British Columbia. It is known also in the Cariboo mountains and near the sources of the North Thompson and Fraser, about latitude 53°.* It is again well developed on the Finlay river, where the country has been geologically examined, between the 56th and 57th parallels of latitude.†

Northward to this point these rocks appear to be confined to a belt lying to the west of the Laramide range and to come to the surface seldom, if at all, in that range. Farther north similar rocks occur in the Yukon district in several ranges lying more to the west, but still with nearly identical characters, in so far as they are known. ‡

The granitic rocks of the Coast ranges are probably much newer, nor have any crystalline schists yet been observed in association with these raeges to which an Archean date can be definitely assigned.

Cambrian

The importance of rocks assigned to the Cambrian in the Rocky Mountain region of Canada has become much more apparent as the result of later explorations. Their thickness is very great, and they appear under differing characters in different parts of the region, in

* Annual Report, Geol. Surv. Can., vol. xi (N. S.), p. 39 D.
† Ibid., vol. vii, p. 33 C.
‡ Ibid., vol. iii, p. 34 B, and vol. iv, p. 14 D.

such a manner as to require distinctive names and to admit, so far, of only a tentative correlation. Our typical and most carefully surveyed section is that in the Rocky mountains proper or Laramide range, on the line of the Bow River pass. This has been studied by Mr R. G. McConnell, and it is the only section for which some direct paleontological evidence exists.* The base of the Cambrian is, however, not seen in this section. In the Gold ranges, where the Cambrian is frequently found resting on the Archean, the Nisconlith, its lowest recognized member, varies by several thousand feet in volume, showing that the old surface was a very irregular one and had been greatly modified by denudation previous to the deposition of the Nisconlith. The same circumstance has been noticed by Mr McConnell in the case of the Bow River series of the Laramide range, where it is found resting on the Archean in the vicinity of the Finlay river, over 400 miles northwest of his typical section,† proving this denudation-interval to be a very important one, although, as already noted, there is often a parallelism in strike between the two series of rocks.

The Bow River series, in the pass of the same name, consists chiefly of dark-gray argillites, with some greenish and purplish bands, associated with quartzites and conglomerates, these coarser materials being most abundant in the upper parts of the formation. Pebbles of quartz and feldspar, evidently derived from the Archean, are abundant in the conglomerates, and scales of mica have in some places been developed on the divisional planes of the argillites. The known thickness of the series is 10,000 feet.

In the eastern part of the pass, resting conformably on the Bow River series, is the Castle Mountain group, with a known thickness of about 8,000 feet. This consists chiefly of ordinary gray limestones and dolomites, in frequent alternations and interstratified with shales and calc-schists. To the west of the main watershed, however, the character of this series becomes materially changed, and the heavy bedded dolomites and limestones are to a great extent replaced by greenish calc-schists and greenish and reddish shales and slates. The change may be traced in its various stages, and is due to the introduction on the west of a greater proportion of earthy matter.

Fossils of the lower Cambrian (*Olenellus*) fauna have been found 3,000 feet below the summit of the Bow River series. They are also known to characterize the lower part of the Castle Mountain series, which is fos-

* For details of the Bow River Pass section, see Annual Report, Geol. Surv. Can., vol. ii (N. S.), part D.

† Annual Report, Geol. Surv. Can., vol. vii (N. S.), p. 24 C.

siliferous at several horizons, and appears to pass up at its summit into the Ordovician.*

Following the general direction of the Laramide range northwestward, Cambrian rocks similar to those of the Bow pass are now known at intervals for many hundred miles, and it is probable that they will be found to form a continuous or nearly continuous belt. Both groups are recognized with practically identical characters on the Yellow Head pass and on the Finlay river. The Misinchinca schists of my report of 1879, no doubt represent the Bow River series, and similar rocks are again found at the sources of the Pelly branch of the Yukon.†

Passing now to the next mountain system, to the southwest of the Laramide range and parallel with it—the Gold ranges—we find in the Selkirk mountains a great thickness of rocks that have not yet yielded any fossils, but appear to represent, more or less exactly, the Cambrian of our typical section. Resting on the Archean rocks of the Shuswap series is an estimated volume of 15,000 feet of dark gray or blackish argillite schists or phyllites, usually calcareous, and toward the base with one or more beds of nearly pure limestone and a considerable thickness of gray flaggy quartzites. To these, where first defined in the vicinity of the Shuswap lakes, the name Nisconlith series has been applied.‡ The rocks vary a good deal in different areas, and on Great Shuswap lake are often locally represented by a considerable thickness of blackish flaggy limestone. It other portions of their extent dark-gray quartzites or graywackes are notably abundant. Their color is almost everywhere due to carbonaceous matter, probably often graphitic, and the abundance of carbon in them must be regarded as a somewhat notable and characteristic feature. These beds have also been recognized in the southern part of the West Kootenay district and in the western portion of the Interior plateau of British Columbia.

The Nisconlith series is believed, from its stratigraphical position and because of its lithological similarity, to represent in a general way the Bow River series of the adjacent and parallel Laramide range, but there is reason to think that its upper limit is somewhat below that assigned on lithological grounds to the Bow River series.

Conformably overlying the Nisconlith in the Selkirk mountains, and blending with it at the junction to somé extent, is the Selkirk series,

* For descriptions of the fossils from these beds, the following authors may be referred to: C. Rominger, Proc. Acad. Nat. Sci., Phila., 1887, pp. 12–19; C. D. Walcott, Proc. U. S. Nat. Mus., 1889, pp. 441–446; J. F. Whiteaves, Can. Rec. Sci., 1892, vol. v, pp. 205–208; F. R. C. Reed, Geol. Mag., 1899, Dec. 4, vol. vi, pp. 358-361; G. F. Matthews, Trans. Royal Soc. Can., series 2, vol. v, sec. 4.

† Annual Report Geol. Surv. Can., vol. xi (N. S.), p. 31 D. Ibid., vol. vii, p. 34 C. Report of Progress, Geol. Suvr. Can., 1879–'80, p. 108 B.

‡ Annual Report Geol. Surv. Can., vol. iv (N. S.), p. 31 B. Bull. Geol. Soc. Am., vol. ii, p. 170. Annual Report Geol. Surv. Can., vol. vii (N. S.), p. 31 B. Shuswap map-sheet, Geol. Surv. Can.

with an estimated thickness of 25,000 feet, consisting, where not rendered micaceous by pressure, of gray and greenish-gray schists and quartzites, sometimes with conglomerates and occasional intercalations of blackish argillites like those of the Nisconlith. These rocks are evidently in the main equivalent to the Castle Mountain group, representing that group as affected by the further and nearly complete substitution of clastic materials for the limestones of its eastern development.

In the vicinity of Shuswap lakes and on the western border of the Interior plateau, the beds overlying the Nisconlith and there occupying the place of the Selkirk series are found to still further change their character. These rocks have been named the Adams Lake series.* They consist chiefly of green and gray chloritic, felspathic, sericitic, and sometimes nacreous schists, greenish colors preponderating in the lower and gray in the upper parts of the section. Silicious conglomerates are but rarely seen, and on following the series beyond the flexures of the mountain region it is found to be represented by volcanic agglomerates and ash-beds, with diabases and other effusive rocks, into which the passage may be traced by easy gradations.† The best sections are found where these materials have been almost completely foliated and much altered by dynamic metamorphism, but the approximate thickness of this series is again about 25,000 feet.‡

The upper part of the Cambrian system, above the Bow River and Nisconlith series, may thus be said to be represented chiefly by limestones in the eastern part of the Laramide range, calc-schists in the western part of the same range, quartzites, graywackes, and conglomerates in the Selkirk mountains, and by volcanic materials still further to the west. It is believed that a gradual passage exists from one to another of these zones, and that the finer ashy materials of volcanic origin have extended in appreciable quantity eastward to what is now the continental watershed in the Laramide range. No contemporaneous volcanic materials have, however, been observed in the underlying Bow River or Nisconlith series.

The beds first definitely referred to the Cambrian in the Rocky Mountain region of Canada are those found near the International boundary in the vicinity of the South Kootenay pass.§ These were further examined at a later date, as described in the report of the Geological Survey of Canada for 1885,|| and some additional observations in regard to them are given by Mr J. McEvoy.¶

* For the Selkirk and Adams Lake series see references above given for Nisconlith series.

† Annual Report, Geol. Surv. Can., vol. vii (N. S.), p. 35 B.

‡ Comprising greenish schists 8,100 feet, grayish schists 17,100 feet. In Bull. Geol. Soc. Am., vol. ii, p. 168, the thickness is given in error at half the above.

§ Geology and Resources of the 49th Parallel, p. 68. Geol. Mag., Decade II, vol. iii, p. 222.

|| Pp. 39 B-42 B.

¶ Summary Report, Geol. Surv. Can., 1899, p. 97 A.

A thickness of at least 11,000 feet of sandstones and shales of red, gray, and greenish colors, frequently alternating and including several contemporaneous trap flows, occurs between the Continental watershed and the Flathead river. This series has not been traced into connection with the sections previously described, but it shows some resemblance to the Selkirk and Castle Mountain groups. The occurrence of blackish calcareous argillites and sandstones at the base may indicate the presence of the Bow River series there, while a limestone at the top of the section in this part of the mountains may prove to be that of the Castle Mountain group.*

Along the eastern borders of the Coast ranges, in southern British Columbia, is a very considerable volume of argillites with some limestone and altered volcanic products, all more or less schistose or slaty. These were originally described by Selwyn as the "Anderson River and Boston Bar group."† They may be Cambrian, but it has not yet been found possible to separate them from newer Paleozoic rocks with which they are associated.

Additional Cambrian areas will no doubt also eventually be defined in the far north, including some of the rocks met with on the Stikine and Dease rivers and in the Klondike district.‡

Ordovician and Silurian

As already noted, the upper part of the Castle Mountain group in the Laramide range contains fossils referable to the Ordovician. In the same western part of the range, 1,500 feet or less of black shales lies above these, containing graptolites that have been referred to the Trenton-Utica fauna by Professor Lapworth.§ The same graptolitic fauna was found in 1887 on the Dease river, not far south of the 60th parallel of latitude.||

Above the graptolitic beds in the Bow Pass section, is a thickness of 1,300 feet or more of dolomites and quartzites, containing *Halysites catenulatus* and a few other forms that are believed to be Silurian.¶

The above-mentioned localities are the only ones in which Ordovician or Silurian rocks have been discovered in the entire region under review.

Devonian

East of the continental watershed, on the Bow pass, Mr McConnell's

* Annual Report, Geol. Surv. Can., vol. i (N. S.), pp. 50 B, 51 B.
† Ibid., vol. vii, pp. 38 B, 43 B.
‡ Ibid., vol. iii (N. S.), pp. 32 B, 94 B. Summary Report, Geol. Surv. Can., 1899, p. 18 A.
§ Annual Report, Geol. Surv. Can., vol. ii, (N. S.), p. 22 D.
|| Ibid., vol. iii, p. 95 B.
¶ Ibid., vol. ii, p. 21 D.

section shows a thickness of 1,500 feet of brownish-weathering dolomitic limestones, named by him the Intermediate limestones, that from their fauna and position are described as Devonian.* They pass conformably upward into beds of the Banff series, which are regarded as Carboniferous in the main, although, as so commonly occurs in the Rocky mountain region, they appear to contain also a certain number of forms usually referred to the Devonian.

A few fossils supposed to be distinctively Devonian, have likewise been found in several other isolated localities in this Laramide range, and as the Devonian system is well characterized and persistent along the Mackenzie river, as well as in the Manitoba region, it seems probable that a continuous zone of the same age may ultimately be traced throughout the eastern parts at least of the Laramide range. To the west of this range no distinct evidence of rocks of Devonian age has, however, been obtained, although it is quite probable that such rocks may yet be found as constituents of the lower part of the Cache Creek formation described below.†

Carboniferous

In describing the rocks of this period, it will be convenient first to refer to those of the Bow pass, continuing the general east-to-west order previously followed, but premising that this is not the order in which the respective rock-series have actually been studied or named.

The mountains of the eastern part of the Laramide range, in the vicinity of the Bow pass, are largely formed of the Banff Limestone series, having a thickness of about 5,100 feet. This is composed of two thicknesses of limestone, separated by one shaly zone, and the whole capped by a second zone of shales. The aggregate thickness of the shales is about 1,300 feet. Below the Banff series, in this part of the mountains, is the Intermediate limestone, already noted, and above it is the Earlier Cretaceous, resting upon it without any apparent unconformity.‡ Numerous fossils have been obtained from the limestones, showing their position to be in the lower part of the Carboniferous system, passing below into Devono-Carboniferous.§ Limestones of the Banff series have now been recognized in many localities scattered along almost the entire length of

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* Ibid., vol. ii, p. 19 D.

† The entire field of the Devonian in Canada has lately been reviewed by Dr J. F. Whiteaves (see Presidential address, Section E, Am. Assoc. Adv. Sci., 1899).

‡ Annual Report, Geol. Surv. Can., vol. ii (N. S.), p. 17 D.

§ The existence of Carboniferous and Devonian fossils in this range was first made known many years ago by Dr (now Sir James) Hector. Exploration of British North America, p. 239, Quart Jour. Geol. Soc., vol. vii, p. 443.

the Laramide range in Canada, in which direction the conditions of deposition appear to have been uniform.

Rocks of the Carboniferous period are probably present in several parts of the system of Gold ranges, but practically no paleontological evidence of their existence has yet been obtained.*

Between these mountains and the Coast ranges, however, the Carboniferous is again well represented, but in a manner very different from that found in the Laramide range, for although limestones are still important, clastic rocks of various kinds, with great masses of contemporaneous volcanic materials, preponderate. These rocks occupy a considerable part of the Interior plateau of southern British Columbia, and run northwestward, with practically identical characters, far into the Yukon district, probably to the eastern boundary of Alaska and beyond.

Fossils referable to the Carboniferous period are found sparingly in association with them, particularly *Fusulinæ*, and none of distinctively older or more recent date have been discovered. At the same time, it is not improbable that the series may include in its lower part beds older than the Carboniferous, and possible that its upper beds may be newer than those of that system. Its constant characters, however, render it appropriate to attach a distinctive name to the series, which has consequently been designated the Cache Creek series, with the understanding that should any part of it subsequently be discovered to be separable paleontologically, the name will be retained for the Carboniferous portion. This name is, in fact, somewhat more important than a purely local one, being intended to denote a peculiar development of the Carboniferous system, well defined in its nature and characterizing a wide middle zone in the northern part of the Cordilleran belt, but of which the upper and lower limits still remain somewhat indefinite.

The name is one of those of Selwyn's preliminary classification, where Lower and Upper Cache Creek groups are described, the term "Marble Canyon limestones" being given as an alternative for the latter. The division into lower and upper parts on lithological grounds is still recognized, but later investigations and the proved Carboniferous age of both parts have since caused the whole to be referred to as a single great group.†

The composition and approximate thickness of the Cache Creek strata are best known in the area of the Kamloops map-sheet, where it may be briefly characterized as follows: The lower division consists of argillites, generally as slates or schists, cherty quartzites or hornstones, vol-

*Summary Reports, Geol. Surv. Can., 1895, p. 24 A; 1896, p. 22 A; 1897, p. 29 A.

†See Report of Progress, Geol. Surv. Can., 1871–'72, pp. 52, 60, 61; also Annual Report, Geol. Surv. Can., vol. vii (N. S.), p. 32 B et seq.

canic materials with serpentine and interstratified limestones. The volcanic materials are most abundant in the upper part of this division, largely constituting it. The minimum volume of the strata of this division is about 6,500 feet. The upper division, or Marble Canyon limestones, consists almost entirely of massive limestones, but with occasional intercalations of rocks similar to those characterizing the lower part. Its volume is about 3,000 feet.

The total thickness of the group in this region would therefore be about 9,500 feet, and this is regarded as a minimum. The argillites are generally dark, often black, and the so-called cherty quartzites are probably often silicified argillites. The volcanic members are usually much decomposed diabases or diabase-porphyrites, both effusive and fragmental, and have frequently been rendered more or less schistose by pressure. The serpentine beds are associated with these volcanic rocks, and have evidently resulted from the alteration of some of them. The limestones of both lower and upper divisions hold *Fusulina* and a few other distinctive Carboniferous fossils, but in the Marble Canyon limestone the most characteristic form is the large foraminifer known as *Loftusia columbiana*, entire beds being made up of its débris.†

Fusuline limestones have now been found in a number of places in the central zone of the Cordillera throughont the length of British Columbia and beyond the 60th parallel, its northern boundary. Where these occur the clastic and volcanic rocks associated with them may be definitely referred to the Cache Creek group, but in consequence of the great resemblance of its volcanic rocks to those of the Triassic (as mentioned later), it is often impossible, without close study, to define the area occupied by this group, and its separate mapping has only as yet been attempted in detail over comparatively small areas.‡

In the southern part of British Columbia, the Cache Creek group shows some evidences of littoral conditions toward the west slopes of the Gold ranges, probably indicating the existence of land areas there. In this vicinity also the Campbell Creek beds, a somewhat peculiar development of argillites, graywackes, and amphibolites, occur. §

The granitic Coast ranges of British Columbia are much later in date of origin than the Carboniferous, but some of the highly altered beds now included in them or found along their margins are undoubtedly of that period. To the west of these ranges, on Vancouver island and in

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* Ibid., p. 46 B.

† Quart. Jour. Geol. Soc., vol. xxxv, p. 69.

‡ Areas included in the Kamloops and Shuswap map-sheets, covering together 12,800 square miles.

§ Annual Report, Geol. Surv. Can., vol. vii (N. S.), p. 44 B.

its vicinity, as well as on the Queen Charlotte islands, are rocks very similar in composition to those of the Cache Creek of the interior, but still differing somewhat from these in aspect. They comprise limestones and volcanic accumulations preponderantly, with occasional zones of argillite. The limestones are usually in the form of marbles, often coarsely crystalline, but from them a few fossils referred to the Carboniferous period have been obtained. The volcanic materials include amygdaloids, agglomerates, and tuffs, but are often converted to schists, and sometimes become mica-schists or imperfect gneisses, as in the vicinity of Victoria. Their degree of alteration is very different locally, and their aspect consequently varies much from place to place, but on the whole they evidence conditions of deposition much like those of the Cache Creek group.* They have unfortunately not yet been made the subject of any detailed study, and they are again involved with Triassic strata closely resembling them in aspect.

Triassic

In my report for 1877 † the existence in British Columbia of rocks shown by their fossils to be referable to the Triassic was made known, and these rocks, as developed in the Interior plateau region, were named the Nicola series or formation. This rests, at least in some places, unconformably upon the Carboniferous, and no rocks representing the Permean period have been identified. The Nicola formation is, however, chiefly composed of volcanic materials, the intercalated limestones or argillites in which fossils are occasionally found being few and far between. The greater part of its mass is undoubtedly Triassic, but the highest beds in a few places have yielded a small fauna that is referred by Professor Hyatt to the Lower Jurassic. All the fossils are marine.‡

Partial sections of the Nicola formation have been obtained in a number of places, but its study is attended with difficulty. owing to the very massive and uniform character of the most of its rocks, the region covered by it being best characterized as one of "greenstones." These rocks often closely resemble those of the Carboniferous, and in some places it is not easy to separate them, on the other hand, from the older Tertiary volcanic materials. Lithologically the rocks are chiefly altered diabases of green, gray, blackish, and purplish colors. In regard to state of aggregation, they comprise effusives (often amygdaloidal), agglomerates, and tuffs, the latter showing evidence of subaqueous deposition through-

* Geol. Mag., Decade II, vol. viii, p. 219.

† Report of Progress, Geol. Surv. Can., 1877–'78.

‡ Fossils of the Triassic rocks of British Columbia, J. F. Whiteaves, Contributions to Canadian Paleontology, vol. i, part 2. Annual Report, Geol. Surv. Can., vol. vii (N. S.), p. 49 B et seq.

out the entire series. The tuffs are occasionally calcareous, and there are some thin and probably irregular beds of limestone, with infrequent layers of argillite. The most complete section so far obtained is one on the Thompson river, showing a total thickness of 13,590 feet; another near Nicola lake gives a probable minimum of 7,500 feet, and in both places more than nine-tenths of the whole is of volcanic origin.

The Nicola formation, with the characteristics above noted, is well developed in the central parts of the Interior plateau of British Columbia, and it probably extends far to the north in the same belt of country between the Coast and Gold ranges, but in the general absence of paleontological evidence, can not there as yet be separated, even locally, from the Paleozoic.*

To the west of the Coast ranges, and now entirely separated from the Nicola formation by the granitic mass of these ranges of later age, Triassic rocks are again found largely developed in the Queen Charlotte islands and on Vancouver island. They were described and identified in the Queen Charlotte islands in 1878, and in 1885, when again found covering large areas in the northern part of Vancouver island, were defined as the Vancouver series.†

These rocks closely resemble those of the Nicola formation, with which they may probably at the time of their deposition have been continuous. The series is built up for the most part of volcanic materials, now in the state of altered diabases and felsites, but amygdaloidal, agglomeratic, or tuffaceous in character. Ordinary sedimentary materials, such as argillites, limestones, and felsites, are, however, more abundant than in the Nicola formation. These probably recur at several different horizons, but in the northern part of Vancouver island they are known to form an important zone, with a thickness of about 2,500 feet.‡ Marine fossils are abundant in some of these beds.

This group is of great thickness, but no trustworthy figures can yet be given for it. It is associated often with the very similar rocks of the Carboniferous period, already referred to as existing in the same orographic belt, and it yet remains to draw a distinct line between the two series. Following the coastal region northward, rocks pretty clearly referable to this formation have been noted in several places among the Alaskan islands as far up as Lynn canal.

To the north of the 56th degree of latitude, it would appear that the

* Annual Report, Geol. Surv. Can., vol. iii (N. S.), p. 33 B.

† Report of Progress, Geol. Surv. Can., 1878–'79, p. 49 B. Annual Report, Geol. Surv. Can., vol. ii (N. S.), p. 7 B et seq. The rocks named the Sooke series, in 1876, may probably also be included in the Vancouver series. Report of Progress, Geol. Surv. Can., 1876–'77, pp. 98–102.

‡ The same zone is probably represented in the southern part of the Queen Charlotte islands.

Triassic sea extended eastward, without important interruption, across the entire Cordilleran region, as marine fossils like those of the Vancouver group have been found not only on the Stikine (in the trend of the Nicola formation), but also on the Liard, Peace, and Pine rivers in the Laramide range.* In the last-named range, however, there is no evidence of contemporaneous volcanic action, which, it is probable, did not extend so far to the eastward.

Following the Laramide range southward from the occurrences last alluded to, there is a considerable interval in which no Triassic rocks have been recognized, after which, in the vicinity of the 49th parallel, a series of red sandstones and shales, with buff magnesian grits, three or four hundred feet thick, is found. This caps a number of the higher mountain ridges and was assigned by me in 1875 to the Triassic. It is believed to represent the northern extremity of the deposits of the Triassic Mediterranean that occupied so large a part of the Western states and which must have been separated from the open sea by land barriers of some width.†

Cretaceous

Apart from the beds capping the Nicola formation, to which allusion has been made, no strata distinctly referable to the Jurassic have been found in the Rocky Mountain region of Canada. Wherever their relations have been determined, the Cretaceous rocks lie unconformably on the Nicola and Vancouver formations, and it seems probable that this unconformity represents the greater part of the Jurassic period. It is proper, however, to state that the lower measures here included in the Cretaceous are still by some authorities called Jurassic; but it is believed that the paleontological evidence, when compared with the best recognized general standards (and not merely with local isolated developments to which a Jurassic age happens to have been assigned), is overwhelmingly in favor of the Cretaceous reference.‡

There is in the region here treated of an important Earlier Cretaceous series of rocks, mostly of marine origin, the distribution of which shows

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* Annual Report, Geol. Surv. Can., vol. iii (N. S.), p. 54 B. Ibid., vol. iv, p. 19 D. Report of Progress, Geol. Surv. Can., 1875-'76, p. 97. Bull. Geol. Soc. Am., vol. v, p. 122.

† Geology and Resources of 49th Parallel, 1875, p. 71. Trans. Royal Soc. Can., vol. i, sec. iv, p. 143 et seq.

‡ Cf. Whiteaves: Mesozoic Fossils, vol. i, part iv, 1900.

In a late article in the Journal of Geology (Chicago), vol. viii, pp. 245-258, Mr W. N. Logan groups the Jurassic beds found at the summit of the Nicola group (*not* at Nicola lake) with parts of the Queen Charlotte and Kootanie formations, here described as Earlier Cretaceous, and which we have found no reason to separate from the rest of that series, calling the whole Jurassic By so doing he gives a large part of the area of the Earlier Cretaceous sea to the Jurassic, in a manner which I believe to be incorrect (cf. Am. Jour. Sci., vol. xxxviii, p. 121).

that (except in the southern part of British Columbia), the Pacific at this time, as in the later Triassic, extended to the eastward quite across the Cordilleran belt. In different parts of the region these rocks have been included under two names—the Queen Charlotte Islands and Kootanie formations. The former, applied at first particularly to the Earlier Cretaceous of the coast, has been extended to cover that of the whole western part and interior of the Cordillera. The latter is used to denote the Earlier Cretaceous of the Laramide range and its vicinity, which differs considerably in character.*

In the Queen Charlotte islands we have the clearest succession of beds and the largest and best studied representation of marine organic remains. The entire Cretaceous section as known on these islands is as follows, in descending order: †

(A)	*Upper shales and sandstones*	1,500 feet.
(B)	*Coarse conglomerates*	2,000 "
(C)	Lower shales and sandstones (with coal)	5,000 "
(D)	Agglomerates	3,500 "
(E)	Lower sandstones	1,000 "
		13,000 feet.

It is the three lower members of this section that are regarded as composing the Queen Charlotte Islands formation. Subdivision C contains the greater number of fossils, eighty-nine species of invertebrates having now been described from it,‡ and most of the forms found in subdivision E are identical with these. The intervening agglomerates, of volcanic origin, may be local, and in any case probably represent but a comparatively short space of time. The overlying subdivisions, A and B, are believed to be Upper Cretaceous and approximately equivalent to the Niobrara, Benton, and Dakota of the interior portions of North America.

In the southern part of British Columbia, east of the Coast ranges (which are at least in great part of subsequent origin), the Earlier Cretaceous rocks of the Queen Charlotte islands are represented in the Tatlayoco beds (7,000 feet), Nechacco beds (6,000 feet), Skeena beds, Skagit beds (4,400 feet or more), and Jackass Mountain beds (5,000 feet). These inland terranes of the southwestern part of British Columbia are clearly comparable with the "Shasta group" of California and Oregon, and the fauna most abundantly represented in them is that of the Knox-

* The facts in regard to these rocks are somewhat fully summarized in Am. Jour. Sci., vol. xxxviii, p. 120 et seq., and in Annual Report, Geol. Surv. Can., vol. vii (N. S.), 1894, p. 62 B et seq., where numerous references to the literature may be found.

† Report of Progress, Geol. Surv. Can., 1878–'79, p. 63 B.

‡ Mesozoic Fossils, vol. i, part iv (1900), p. 305.

ville or lower division now made of that group, the characteristic *Aucella* of which is often the commonest fossil.* In the northern part of the province, between the 55th and 58th parallels of latitude, rocks chiefly referable to this period have lately been found to characterize a wide area of country east of the Coast ranges, and here, as well as in the south, they frequently hold coal.

On Tatlayoco lake, the beds of the same name are found to be underlain in apparent conformity by rocks of volcanic origin, to which the name "Porphyrite series" was originally applied.† No fossils have been found in these, but the similarly constituted Iltasyouco beds (latitude 53°) contain molluscs that are now referred by Dr Whiteaves to the Queen Charlotte formation.‡ Ash beds containing similar fossils have been discovered on the Skeena to the east of the Coast ranges, and it is thus evident that vulcanism played an important part in this Earlier Cretaceous time, not only in the Queen Charlotte islands, but also further to the eastward.

Fossils representing the same Earlier Cretaceous period have been found in late years far to the north, in the Yukon basin, on the Lewes river, and on the Porcupine, beyond the Arctic circle.§

The Kootanie formation was so named and characterized as Lower Cretaceous, because of its peculiar flora, by Sir J. Wm. Dawson in 1885.|| It represents the Earlier Cretaceous of the Laramide region in Canadian territory, and has since been found to extend a considerable distance into Montana. Its typical area is separated from the Cretaceous of the western part of British Columbia by the Selkirk and other ranges that appear to have existed as dry land at this time. It no doubt blends with the Queen Charlotte formation further to the north, and it may eventually be found that no useful line can be maintained between the two formations. The Kootanie seems, however, to have been for the most part deposited in a fresh or brackish water basin, and for some years scarcely any marine forms were known to occur in it.¶ A number of

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*Annual Report, Geol. Surv. Can., vol. vii (N. S.), p. 64 B.

†Geol. Mag., Decade II, vol. iv, July, 1877.

‡Originally described as Jurassic. See Geol. Mag., Decade II, vol. viii, p. 218, and Dr Whiteaves on the "Cretaceous system in Canada," Trans. Roy. Soc. Can., vol. xi, sec. iv (1893). For descriptions of invertebrate fossils of the Cretaceous, see especially the following works by Dr J. F. Whiteaves: Mesozoic Fossils, vol. i, parts 1, 2, 3, and 4; Contributions to Canadian Paleontology, vol. i, part 2; Trans. Roy. Soc. Can., vol. i, sec. iv, p. 81; ibid. (second series), vol. i, pp. 101, 119.

§Annual Report, Geol. Surv. Can., vol. iii (N. S.), p. 36 B. Ibid., vol. ix, pp. 21 D, 124 D. et seq.

||Science, vol. v, p. 531. Trans. Roy. Soc. Can., vol. iii, sec. iv. For descriptions of Cretaceous plants see particularly the following papers by Sir J. Wm. Dawson, in Trans. Roy. Soc. Can.: Cretaceous and Tertiary Floras of British Columbia, vol. i (1882); Mesozoic Floras of the Rocky Mountain Region, vol. iii (1895); Correlation of Early Cretaceous Floras, etc., vol. x (1892); New Cretaceous plants from Vancouver Island, vol. xi (1893).

¶Annual Report, Geol. Surv. Can., vol. i (N. S.), p. 162 B.

marine molluscs have, however, since been found at the base of the formation, in the Devils Lake deposits, not far north of the Bow river, and these Dr Whiteaves has provisionally referred to the age of the fossiliferous beds of Queen Charlotte islands, thus apparently confirming the general correlation already indicated by the fossil plants.

The Kootanie consists of alternating sandstones and shales with some thin bands of limestone toward the base and holding in parts of its extent numerous and thick seams of bituminous and anthracite coal, the latter occurring where it has been closely included in the mountain folding. Its thickness is about 7,000 feet, including only that part of the general section characterized by its fossils. Above this is a thickness of 4,000 or 5,000 feet, largely made up of conglomerates that are supposed to represent the Dakota group.

Conglomerates occupying about the same stratigraphical position in the Queen Charlotte islands have already been alluded to, and similar important conglomerates attached to or closely associated with the Earlier Cretaceous have been found in many places on the mainland of British Columbia and northward to the Yukon district. These conglomerates appear throughout to be approximately contemporaneous and are believed to be of more than local significance. They evidently mark a time of wide subsidence and of shorelines advancing on the land, and it was at this time that the Cretaceous Dakota sea spread itself eastward across the interior plain of the continent.

In the Fraser valley east of the Coast ranges, in addition to the occurrence of the conglomerates, the existence of beds of about the period of the Dakota is shown by the discovery of a few fossil plants;* but no evidence of higher members of the Cretaceous has been found in the inland region to the west of the Selkirks, although it is probable that such members are represented further north, in the Yukon district.

From a systematic point of view, it appears to be desirable to confine the Earlier Cretaceous, or Queen Charlotte formation, to rocks below the Dakota; but it will be understood that, over a considerable part of the inland country, the earlier rocks are intimately associated with those of about Dakota age, and that where those of still later date are not present, the most natural break, and one coinciding with some notable physical change, would be above the Dakota.

Beds referred to the Upper Cretaceous† in the Queen Charlotte Islands section have already been alluded to. Collectively it is supposed that the two upper members of that section represent the Dakota, Benton,

*Annual Report, Geol. Surv. Can., vol. vii (N. S.), p. 148 B.

† For references in regard to the Upper Cretaceous see Geol. Mag., Decade II, vol. viii, p. 216; also Am. Jour. Sci., vol. xxxix (1890), p. 180 et seq.

and Niobrara. In following the coast southeastward from the Queen Charlotte islands, the local base of the Cretaceous rocks is found at progressively higher horizons in that system. The two lowest members of the Queen Charlotte section are wanting in the northern part of Vancouver island, and farther on, in the Comox and Nanaimo coal fields, the base of the measures is approximately equivalent to the highest part of the Queen Charlotte Islands section.

The Cretaceous section at Comox has been divided on lithological grounds into seven, that at Nanaimo into three, members by Mr J. Richardson. While unnecessary to refer to these in detail here, it may be stated that they correspond pretty closely, and that the well marked and abundant fauna and flora of the Upper Cretaceous of the coast of British Columbia characterizes the four lower subdivisions at Nanaimo and the two lower subdivisions at Comox, the thickness of the strata being estimated at 2,715 and 2,020 feet respectively. These subdivisions have been united under the name of the Nanaimo group,* and this is believed to be almost exactly equivalent to the Chico of California and at least approximately to the Pierre of the Great plains. At both Nanaimo and Comox the workable coal seams occur in the lowest subdivision of this group.

As already noted, beds referable to the Upper or later Cretaceous are known to occur in the far north. The fossils indicate a horizon at least as high as that of the Benton, and it is very probable that further investigation may disclose the existence of a complete ascending series, like that found in the Laramide range and its adjacent foothills to the east.

In the Laramide range, the Upper Cretaceous includes representatives of all the Cretaceous groups of the Great plains, but generally with more massive developments and altered characters, resulting from proximity to an extensive land surface to the westward, from which abundant and often coarse sediments were derived. This is particularly notable in the case of the Dakota, to which allusion has already been made in connection with the Kootanie. It may here be added that contemporaneous volcanic materials, with a thickness of over 2,000 feet in one locality, have been found in this group in the eastern part of the Crows Nest pass.†

The aggregate thickness of the Upper Cretaceous in the southern part of the Laramide range (including the lower portion of the Laramie, which may be regarded as Cretaceous) is found to be about 10,000 feet.‡ It is unnecessary, however, to do more than allude to this section here, as it is

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* Am. Jour. Sci., loc. cit.

† Annual Report, Geol. Surv. Can., vol. i (N. S.), p. 69 B.

‡ Ibid., p. 166 B.

more properly to be regarded as the western margin of the Cretaceous of the plains than as characteristic of the Cordilleran region. Its characters have been, moreover, quite adequately summarized elsewhere, particularly by Dr Whiteaves in his paper previously referred to.

The Laramie is regarded as a series transitional between the Cretaceous and Tertiary, and in the Laramide range and its foothills passes up from a brackish-water to a purely fresh-water deposit. No beds probably referable to this time have been found between this range and the Pacific coast in the entire southern part of British Columbia, but in the extreme north of that province, some deposits apparently referable to the Upper Laramie occur,* while it is also present in considerable volume in parts of the Yukon district.†

On the Pacific coast, the Puget group of Washington has been referred with probability to the period represented by the Laramie, and rocks of this group have a somewhat extensive development about the estuary of the Fraser, with a thickness of at least 3,000 feet. They appear to have been deposited in fresh or brackish water, and hold some beds of lignite.‡ The upper subdivisions of the Nanaimo and Comox sections, from which no distinctive organic remains have yet been obtained, may also prove to represent the Puget group, or the marine Tejon of California, which is perhaps no lower.

Tertiary

It has been convenient to refer to the Laramie as a whole in connection with the Cretaceous, although the Upper Laramie is regarded as Eocene. The Puget beds of the Fraser estuary and Burrard inlet, just alluded to, have always been described as Tertiary, and were for a long time regarded as Miocene.

Subsequent to the Cretaceous period and the great orogenic movements that accompanied its close, the physical conditions in the Rocky Mountain region of Canada became much more like those existing today. The Eocene appears for the most part to have been a time of denudation,§ but later Tertiary deposits occur in many places and often in extensive development. On the coast these are usually marine, but no marine beds have been found to the east of the Coast ranges, although it seems possible that evidence may yet be found in the north of the extension of the sea at this time as far east as the upper Canadian portion of the Yukon basin.

* Ibid., vol. vii, p. 35 C.

† Ibid., vol. iii, p. 149 B.

‡ Am. Jour. Sci., vol. xxxiv, p. 182. For descriptions of plants see Trans. Royal Soc. Can., second series, vol. i, sec. iv (1895), p. 135.

§ Trans. Royal Soc. Can., vol. viii, sec. iv, p. 11.

The Tertiary sediments of the interior are chiefly those of lake basins, large or small, but the great mass of the Tertiary rocks is composed of volcanic materials, a circumstance accounting for the general paucity of organic remains, which, together with the isolated positions of the known fossiliferous localities, renders it very difficult to build up a satisfactory and connected section of the Tertiary formations.*

Some progress has, however, been made in this respect, particularly in the southern part of the Interior plateau of British Columbia, where the following scheme, which may be taken as a term of reference for the whole inland region, has been arrived at.† The order is descending:

	Feet
Later Miocene. Upper Volcanic group (maximum thickness)	3,100
Tranquille beds (maximum thickness)	1,000
Earlier Miocene. Lower Volcanic group (maximum thickness apart from centers of eruption)	5,300
Oligocene. Coldwater group (at Hat creek)	5,000
	14,400

Beginning with the oldest member of the above section, it may be explained that more or less isolated series of beds in different parts of the Interior plateau region have lately been classed together provisionally as the Coldwater group. These resemble each other lithologically, and all appear to antedate the beginning of Tertiary volcanic action in this part of the region. One of their developments, from which the greatest number of fossils has been derived, has frequently been referred to in earlier publications as the "Similkameen beds," but the name Coldwater group is preferred as a general one, including these as a local development. From the Similkameen beds, plants, insects, and a few fish remains have been obtained. These have been described by Sir J. Wm. Dawson, Dr S. H. Scudder, and Professor E. D. Cope, who agree in referring them with probability to the Oligocene. The fish is an *Amyzon*, like that from the Amyzon beds of Oregon.‡ Much farther north, on the Horsefly river, a tributary of the Quesnel, well preserved remains of another fish of the same genus have been found, and again in association with similar plant remains. Elsewhere plants only, or a few insects, have been discovered.

The deposits of the Coldwater group consist of conglomerates, shales, and sandstones which not infrequently hold beds of lignite or, as at the

* For earlier references to the Tertiary deposits of the region, see Geol. Mag., Decade II, vol. viii, foot-notes to pp. 158, 162.

† Annual Report, Geol. Surv. Can., vol. vii (N. S.), p. 76 B. Detailed descriptions of the several groups in the southern part of British Columbia are also given in this report.

‡ Tertiaryplants of the Similkameen river; Trans. Royal Soc. Can., vol. viii, sec. iv (1890), p. 75. Contributions to Can. Pal., vol. ii, part i. Proc. Acad. Nat. Sci. Phil., vol. xlv (1893), p. 401.

junction of the Coldwater and Nicola rivers, bituminous coal. At the base the conglomerates are often rough and coarse, composed of the local underlying rocks, upon which they rest irregularly, but above these, in several places in the southern part of the Interior plateau, are thick beds of well rolled and generally small pebbles derived for the most part from the cherty beds of the Cache Creek formation. The sandstones and shales are usually pale-colored, gray, buff, or drab, except where they become carbonaceous.*

Speaking of the southern part of British Columbia, where the Tertiary deposits have been examined with some care, it appears that the beds of the Coldwater group were, at least locally, disturbed and subjected to considerable erosion before the deposition of the overlying materials assigned to the Miocene. These are almost entirely of volcanic origin, and over a considerable area they admit of separation into lower and upper volcanic groups, between which are the water-laid Tranquille beds.

The principal volcanic vents of the early Miocene appear to have been situated near to and parallel with the inland border of the Coast ranges, their denuded remnants being now found in the Clear mountains, Ilgachuz mountain, etcetera. Both effusive and fragmental rocks are represented in the products of this period, which, petrographically considered, consist chiefly of augite-porphyrites, of gray, greenish, and purplish colors, with smaller amounts of mica-porphyrites, picrite-porphyrites, etc. These generally form massive beds, and are now found inclined in many places at angles as high as 30 degrees from the horizontal, although to what extent this may represent the natural slope of deposition and in how far it may be due to subsequent movement is often indeterminate.

The Tranquille beds consist generally of bedded tuffs, and are usually pale in color. They occasionally contain plant remains and some thin beds of coal or lignite, as at Kamloops.† The upper volcanic group is composed for the most part of basalts and basalt-breccias, with smaller quantities of various porphyrites, mica-trachyte, and mica-andesite. The basalts often occur in horizontal flows of great extent, their eruption having marked the closing stage of the great Tertiary period of vulcanism. Their sources may have been numerous and local, and they are often

* The Kenai formation of Dall, found in some parts of Alaska, is believed by Dall to be either Oligocene or Eocene. The statement, however, that the Kenai is also "widely spread in British Columbia" is too comprehensive. It may be supposed to refer to formations like that here described, widely separated geographically and differing in conditions of deposition from the typical Kenai of Cooks inlet. In such a case the elevation of a local formational name into a regional chronological term is in no way helpful and should, I think, be deprecated. (See Bull. No. 84, U. S. Geol. Survey, Annual Report, U. S. Geol. Survey, 1895–'96, part i, p. 481. Ibid., 1896–'97, part ii, p. 345.)

† Annual Report, Geol. Surv. Can. (N. S.), vol. vii, p. 169 B.

found forming a comparatively thin sheet that lies directly on the denuded surface of the older rocks without the intervention of any of the earlier members of the Tertiary. As these wide basaltic flows are in most cases known to antedate the great period of river erosion assigned to the Pliocene, they are supposed to be of later Miocene age. It is, of course, possible that local eruptions of more recent date may have occurred, but only one instance of a comparatively recent or postglacial lava flow has so far been found in the entire Cordilleran region of Canada. This is in the valley of the Nasse river.*

In the northern interior of British Columbia, lake deposits have been found, in some places, blending above with volcanic materials and capped by horizontal basalts, the whole being very probably referable to the Miocene. In other places, both in British Columbia and in the Yukon district, local flows of basalt are found which may belong either to the Miocene or to the Pliocene. The same is true of isolated basalt patches in the Kettle River country in the southen part of British Columbia and in East Kootenay. On the Nechacco river and elsewhere, Tertiary shales or clays, with sandstones, of indeterminate horizon are also found. It will be many years before all these deposits can be investigated and classified, and it may never be possible to assign an exact position to some of them in the general series. The great paucity, amounting almost to a complete absence, of the remains of the higher vertebrates being particularly unfortunate in this respect.

In the southern part of the Interior plateau of British Columbia, small areas have been found of sediments that are supposed to belong to the early Pliocene,† but no fossils have been obtained from them. On the Horsefly river, however, overlying the Oligocene beds already referred to in slight but distinct unconformity, and underlying the boulder-clay, is a deposit of yellowish and in part "cemented" gravels, to which a Pliocene age may be assigned with some confidence.‡ These gravels are worked for gold, and branches and stems of trees found in the workings have been determined by Professor D. P. Penhallow to represent *Sequoia gigantia*, *S. sempervirens*, *Juniperus californica*, *Cupressus macrocarpa*, *Thuya gigantia*, and *Picea sitchensis*.§

The presence of such an assemblage of trees in the inland region north of latitude 52°, indicates the existence of physical and climatic conditions very different from those now existing there and still more unlike those of the intervening glacial period, while the species themselves are still living ones.

*Summary Report, Geol. Surv. Can., 1893, p. 14 A.
†Annual Report, Geol. Surv. Can., vol. vii (N. S.), p. 74 B.
‡Ibid., p. 26 A.
§These determinations have not previously been published.

Similar yellow gravels have been found on the Upper Fraser and on its tributary, the Blackwater, in several places, and it is probable that they are somewhat widespread in this district.* It is very possible that they are at least approximately synchronous with the old auriferous preglacial stream gravels of the Cariboo mountains, and are also of the same age with the "yellow gravels" of the Atlin district.

The Tertiary deposits of the Coast region of British Columbia are wholly separated from those of the interior by the physical barrier of the Coast ranges. They are interesting, but not of great extent, occurring in isolated patches and not forming, as they do farther to the south, a nearly continuous border to the continent. The sedimentary beds are for the most part of marine origin, and are still found near the level of the sea, little disturbed or altered.

Sandstones holding marine shells occur at Sooke, on the southern coast of Vancouver island. These beds were first described by Mr J. Richardson.† Mr J. C. Merriam has since studied the fossils, and they appear to be referable to the Upper Miocene or Pliocene ("Middle Neocene").‡ Farther west, on the same coast, are the Carmanah beds, consisting of sandstones, shales, and conglomerates. These are referred by the same author to the "Astoria Miocene" § or Astoria group, and are recognized as older than the Sooke beds. A remarkable bird, *Cyphornis magnus*, had previously been described by Cope from the Carmanah beds, and this he states is not older than Eocene nor later than Oligocene.‖ Plant remains also occur, but they have not so far been studied. Elsewhere on the west coast of Vancouver island and farther north small patches of Tertiary rocks are found, which have not yet been examined, and from which no fossils have been obtained.

The most important development of Tertiary rocks on the coast is that forming the northeastern part of Graham island, the northern member of the Queen Charlotte group. The considerable tract of land underlain by these rocks is relatively low, and most of the prominent rock masses consist of basalt with some volcanic materials of a less basic character, and in one place obsidian, fragmental as well as effusive rocks being represented. In a few places, underlying sandstones and shales come to the surface, sometimes holding lignite, and at one locality marine shells are abundantly represented. These have been examined by

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* Annual Report, Geol. Surv. Can,, vol. vii (N. S.), p. 28 A ; also Report of Progress, Geol. Surv. Can., 1875-'76, pp. 263, 264.

† Report of Progress, Geol. Surv. Can., 1876-'77, p. 190.

‡ Bull. Univ. Cal., Geology, vol. ii, no. 3, p. 101 ; Proc. Cal. Acad. Sci., third series, vol. i, no. 6, p. 175.

§ Op. cit.

‖ Jour. Acad. Nat. Sci. Phila., vol. ix, p. 449. The bird is described from a single bone. The exact locality is not given in the paper, not being known to Cope at the time.

Dr. Whiteaves. They include a number of still living forms, but may be regarded as Pliocene or later Miocene.*

Physical History of the Region

It will now be endeavored to briefly review the orographic changes and the conditions of deposition of which the geological column gives evidence—in other words, to touch in outline the main facts of the physical history of the Rocky Mountain region of Canada.

As for the Archean, it need only be said that here, as in most parts of the world, we find beneath any rocks that can be assigned to the Cambrian in the most extended sense of that term, and apparently separated from these rocks by a great break and unconformity, a crystalline series or "fundamental complex" composed of plutonic rocks with highly metamorphosed and vanishing sedimentary rocks in seemingly inextricable association. The similarity of this basal series in different parts of the world is so great as apparently to imply world-wide and approximately contemporaneous conditions, of a kind perhaps differing from any that can have occurred at later periods. The region here described is not, however, an ideal one for the study of these Archean rocks, because of the extreme metamorphism by which much newer formations have often been affected in it; nor has any series yet been defined that appears here to bridge the gap between the Archean and the strata that may with propriety be attached to the Cambrian.

In the earlier series of deposits assigned to the Cambrian, we discover evidence of a more or less continuous land area occupying the position of the Gold ranges and their northern representatives and aligned in a general northwesterly direction. The Archean rocks were here undergoing denudation, and it is along this axis that they are still chiefly exposed, for although they may at more than one time have been entirely buried beneath accumulating strata, they have been brought to the surface again by succeeding uplifts and renewed denudation. We find here, in effect, an Archean axis or geanticline that constitutes, I believe, the key to the structure of this entire region of the Cordillera. To the east of it lies the Laramide geosyncline (with the conception of which Dana has familiarized us), on the west another and wider geosyncline, to which more detailed allusion will be made later.

Conglomerates in the Bow River series indicate sea margins on the east side of this old land, but these are not a marked feature in the Nisconlith, or corresponding series on its western side. Fossils have so far been discovered only in the upper part of the Bow River series, but the preva-

*See Report of Progress, Geol. Surv. Can., 1878–'79, p. 87 B.

lence of carbonaceous and calcareous material (particularly in the Nisconlith) appears to indicate the abundant presence of organisms of some kind at this time.

Although no evidence has been found of any great physical break, the conditions indicated by the upper half of the Cambrian are very different from those of the lower. Volcanic materials, due to local eruptions, were accumulated in great mass in the region bordering on the Archean axis to the west, while on the east materials of this kind appear to be mingled with the preponderant shore deposits of that side of the Archean land, and to enter sparingly into the composition of the generally calcareous sediments lying still farther eastward. Where these sediments now appear in the eastern part of the Laramide range they are chiefly limestone, indicating marine deposition at a considerable distance from any land.

The history of the Ordovician, Silurian, and Devonian times is very imperfectly known. Marine conditions still prevailed to the eastward of the Archean axis and were probably continuous there, but our knowledge of the region to the west, while as yet almost entirely negative in its character, is not sufficiently complete to enable us to assume the existence of any extensive land area in that quarter. In the Devonian the sea is known to have covered a great area in the interior of the continent, extending far to the north in the Mackenzie basin, and it appears probable that considerable portions of the western part of the Cordilleran region were also submerged, particularly to the north.

About the beginning of the Carboniferous period and thence onward the evidence becomes much more satisfactory and complete. In the earlier part of the Carboniferous, marine sediments, chiefly limestones, were laid down everywhere to the east of the Archean axis, while to the west of that axis (which was probably in large part itself submerged) ordinary clastic deposits, mingled with contemporaneous volcanic materials, were formed, tranquil epochs being marked by the intercalation of occasional limestone beds. It is not clearly apparent from what land the clastic materials were derived, but the area of vulcanism at this time was very great, covering the entire western part of British Columbia to the edge of the continental plateau and, as now known, extending northwestward into Alaska and southward to California.

In the later time of the Carboniferous, however, the volcanic forces declined in their activity, and a great thickness of calcareous marine deposits occurred with little interruption of any kind. The area of land to the eastward was probably increased, for there is some evidence to show a first gentle uprising in the Laramide region at this time (or at least a cessation of subsidence), and no late Carboniferous strata have so far been found there.

No separate record for the Permian has yet been found in this part of the continent, but it must be remembered that, in view of the scanty character of the paleontological evidence, strict taxonomic boundaries can seldom be drawn. At about this time, however, very important changes occurred, for in the Triassic a great part of what is now the inland plain of the continent is found to have become the bed of a sea shut off from the main ocean, in which red rocks with salt and gypsum in some places were laid down. The northern part of this sea appears to have extended into the Canadian region for a short distance, covering the southern portion of the Laramide area. Farther north must have been the land boundary of this sea, and beyond this an extension of the Pacific ocean which swept entirely across the Cordillera. In the southern part of British Columbia, however, this ocean found its shore against the Gold ranges of the Archean axis, where the preceding Carboniferous beds had already been upturned and subjected to denudation. The Laramide region was not affected by volcanic action at this time, but vulcanism on a great scale was resumed in the entire western part of the Cordillera that had previously been similarly affected in the Carboniferous, and the ordinary marine sediments there form intercalations only in a great mass of volcanic products, probably in large part the result of submarine eruptions.

Such definite indications as exist of the Jurassic must, as already noted, be considered as physically attached to the Triassic of the Interior plateau of British Columbia. It is probable that the greater part of the Jurassic period was characterized by renewed orogenic movements and by denudation, for when we are next able to form a connected idea of the physical conditions of the region these are found to have been profoundly modified.

It is to about this time that the elevation of the Sierra Nevada and some other mountain systems in the western states is attributed. In the region here particularly described, the Triassic and older rocks of the Vancouver range, or that forming Vancouver and the Queen Charlotte islands, were upturned, while a similar movement affected the zone now occupied by the British Columbian Coast ranges. These may not have been elevated into a continuous mountain system and barrier to the sea, but in any case the ranges then formed were, before the beginning of the Cretaceous period, largely broken down by denudation, so that the underlying granitic rocks supplied abundant arkose material to some of the lowest Cretaceous beds.

It is also probable that subsidence marked the close of the Jurassic, for in southern British Columbia the Pacific of the Earlier Cretaceous extended more or less continuously across the line of the Coast ranges, finding its shore not far to the east of this line. Farther north, although not without insular interruptions, it spread over the entire width of the Cordilleran belt, repeating the conditions found in the Triassic, but with the difference that it extended far to the south along the axis of the Laramide geosyncline, in which rapid subsidence had been renewed. In this early Cretaceous sea and along its margins and lagoons the massive fossiliferous rocks of the Queen Charlotte islands and Kootanie formations were accumulated and coal beds were produced. Volcanic activity was renewed in some places, particularly near the present seaward margin of British Columbia. Sedimentation evidently proceeded more rapidly than subsidence in many localities and coal-producing forests, largely composed of cycadaceous plants took possession of the newly formed lands from time to time.

The era of the later Cretaceous appears, however, eventually to have been introduced by a marked general subsidence, which, as already noted, carried the Dakota sea entirely across the inland plain of the continent. The distribution and character of the ensuing Cretaceous formations show that the whole southern part of what is now the mainland of British Columbia soon after became and remained a land area, while the sea was more gradually excluded from the northern part of the Cordillera and continued to occupy the area of the Great plains and the present position of the Laramide range. Along the margin of the continental plateau, however, a renewed subsidence was in the main progressing southward and resulted ultimately in carrying the later Cretaceous sediments into the region of Puget sound.

The closing event of this cycle was the deposition of the Laramie beds on the east and in some places to the north, with probably the Puget group and its representatives on the coast, and this was followed by the most important and widespread orogenic movement of which we find evidence in the entire Rocky Mountain region. At this time the great Laramide range, or Rocky Mountain range proper, was produced, rising on the eastern side of the Archean axis along a zone that had previously been characterized from the dawn of the Paleozoic by almost uninterrupted subsidence and sedimentation. That the pressure causing this upthrust of the Laramide range was from the westward is clearly shown by the great overthrust faults in this range. The stability of the old Archean axis, which it may be supposed had previously sustained the tangential thrust from the Pacific basin, must at this time have been at last overcome. As a part of the result of this, the chief belt of faulted strata in the Laramide range, originally about 50 miles wide, became reduced in width by one-half. How rapidly this great revolution may have occurred we do not know, but it probably occupied no long time from a geological point of view, and the Laramide range, as first produced, may very possibly have attained a height approaching 20,000 feet.* The thickness of stratified rocks in the geosyncline was at the time probably more than 40,000 feet.

It is difficult to determine to what extent the Archean axis with the Gold ranges and other preexisting mountains were affected at this period of orogenic movement, because of the absence of the newer formations there, but it seems probable that no very important change took place. Farther west, however, the great zone of Coast ranges was elevated, and the corrugated and vertical Cretaceous beds met with even on their inland side, show that large parts of the Interior plateau of British Columbia and of the country in line with it to the northward were flexed and broken. Similar conditions are found to have affected the Cretaceous rocks of Vancouver and the Queen Charlotte islands, of which the mountain axis, previously in existence, was evidently greatly increased in elevation.

The Laramide geosyncline has already been particularly referred to and allusion has been made to the now well recognized fact that by such zones of continued subsidence and deposition the lines of most mountain systems have been determined. To the Laramide geosyncline here, the mountains of the Archean axis—the Gold ranges—stood in much the same relation as the Archean western border of the Wasatch to the Laramide geosyncline in Utah (as described by Dana), but on a larger scale.

On the other or western side of this axis, as already noted, I am now led to regard the zone of country extending to the Vancouver range as a second and wider geosyncline, with a breadth of about 200 miles, in which a thickness of deposits perhaps greater than that of the Laramide, but in the main composed of volcanic ejectamenta, had by this time been accumulated. The volume of the Carboniferous and Triassic rocks alone must have exceeded 20,000 feet. It is probable that to this may be added a great thickness of older rocks,† for the circumstance that volcanic action was so persistent here, and the amount of extravasation resulting from it was so enormous, implies a recognition of the fact that, along this zone (not far from the edge of the continental plateau) the

* This refers particularly to the better known region near the Bow pass. See Annual Report, Geol. Surv. Can. (N. S.), vol. ii, p. 31 D, and Am. Jour. Sci., vol. xlix, p. 463. The base of the mountains may at this time have been nearly at sealevel, or 4,000 feet lower than at present, while the actual height at any time attained would depend upon the rapidity of uplift relatively to denudation. The total height of folded strata is estimated at from 32,000 to 35,000 feet.

† Several thousand feet of Cretaceous rocks must also be added to this thickness near the line of the present Coast ranges, and the total thickness of deposits in the center of this geosyncline must probably have exceeded 40,000 feet.

isogeotherms, with what we may call the plane of granitic fusion, had crept up to a position abnormally near the surface. It is to this probably that we may attribute the apparent absence of Archean rocks in the Coast ranges, or at least the impossibility of defining any rocks of that period there, for these, together no doubt with great volumes of later deposits, may be assumed to have become merged in the rising granitic magma, on which strata of Triassic age are now often found lying directly, arrested in the very process of absorption.*

When the Laramide revolution occurred, by reason of the increasing tangential pressure from the Pacific basin and the growing failure of resistance of the two great geosynclines of this part of the Cordillera, the Laramide range was produced by the folding and fracture of a very thick mass of beds, of which the crystalline base has not yet been revealed by denudation, while in the western trough an eversion of the axis of settlement seems to have occurred, resulting in the appearance of a granitic bathylite of nearly a thousand miles in length, from which the comparatively thin covering of unabsorbed beds was soon afterward almost completely stripped away by ensuing processes of waste.

This last great epoch of mountain making doubtless left the surface of the Cordilleran belt generally with a very strong and newly made relief, which, before the middle of the Tertiary period, is found to have become greatly modified by denudation. Chiefly because no deposits referable to the Eocene or earliest Tertiary have been found in this part of the Cordillera, it is assumed with probability that this was a time of denudation. It is further indicated that it was a time of stability in elevation, by the fact that the prolonged wearing down resulted, in the interior zone of the Cordillera, in the production of a great peneplain, the base-level of which shows that the area affected stood 2,000 or 3,000 feet lower in relation to the sea than it now does, and that for a very long time. If, however, the Puget beds of the coast are correctly referred to the Eocene, it follows that the coast region was at the same period only slightly lower than at present, and that the movements in subsidence and elevation between this and the interior region must have been differential in character and very unequal in amount.

As already noted, the earliest Tertiary sediments of the Interior plateau of the Cordillera are referred to the Oligocene. Probably some further subsidence at that time interrupted the long preceding time of waste. This period of deposition was in turn closed by renewed disturbance of an orogenic kind, comparatively slight in amount and local, chiefly affecting certain lines in a northwest and southeast direction. Next

* Annual Report, Geol. Surv. Can., vol. ii (N. S.), 1886, p. 11 B et seq.

came renewed denudation or "planation," and this continued until the enormous volcanic extravasations of the Miocene began.

It is not proposed in this place to recapitulate in detail the physical conditions of the Tertiary period, for it has already been necessary to refer to these in connection with the description of the beds themselves, which, because they have not been materially changed since their deposition, really tell their own tale.

It need only be said that, after the Oligocene lake deposits had been formed, disturbed, and denuded, new series of lakes were from time to time produced at different stages during the Miocene, their beds now generally appearing as intercalations in volcanic deposits of great mass. Both the coast and the interior region appear to have been subject to these conditions, while the Laramide range stood high, with the inland plain of the continent sloping eastward from its base.

Following the close of, or at least a great reduction in volcanic activity, in the early Pliocene, the interior zone of the Cordillera again assumed a condition of stability for a considerable time, during which wide and "mature" stream valleys were formed. The elevation of the Interior plateau region of British Columbia must then have been about 2,000 feet less than it is at present.* Farther north, the yellow Pliocene gravels of Horsefly river, aud other places, are attributed to this period, and the southern aspect of their contained fossil plants is such as to indicate that, in the given latitude, the height of that part of the interior can not have been much above the sealevel.

In the later Pliocene a very marked reëlevation of the Cordilleran region evidently occurred, leading to the renewed activity of river erosion, the cutting out of deep valleys and canyons, and the shaping of the surface to a form much like that held by it at the present day. This elevation in all probability affected the coast as well as the interior, and it would appear that the rivers for a time extended their courses to the edge of the continental plateau.

The excavation of the remarkable fiords of British Columbia and the southern part of Alaska must, I think, be chiefly attributed to the later portion of the Pliocene, although it is quite possible that the cutting out of the valleys may have been begun soon after the Laramide upheaval. The antiquity of these valleys is evidenced by the fact that several comparatively small rivers still flow completely across the Coast ranges in their deep troughs. The fiords are now essentially the submerged lower parts of these and other drainage valleys of the old land, not very materially affected by the later glacial action, important as this has un-

* Trans. Royal Soc. Can., vol. viii, sec. iv, p. 18.

doubtedly been from other points of view. The valleys of the fiord-like lakes that occur along the flanks of the Archean axis of the interior may probably also be referred to river erosion in the later Pliocene, but if so this mountain region must have been affected by a relatively greater uplift at that time, followed later by a subsidence of its central part. It appears, however, that the excavation of valleys or gorges like these by rivers, when the slope and water supply are favorable, occurs with such rapidity relatively to the wider effects of denudation, as to be almost negligible in any general view of the physical changes of an extensive region or in the accounting of geological time.

There is as yet some difficulty in connecting the later physical changes particularly referred to above with those which have recently come under observation far to the north in the Klondike region. It is probable, however, that the auriferous "quartz drift" of that region, implying long subaerial decay and stability of level, may be attributed to the early Pliocene; while the river gravels found in the newer and deeper-cut valleys may be assigned to the later Pliocene time of greater elevation. During the Pliocene, and probably until its close, the mammoth, one or two species of bison, the moose, and other large mammals roamed northward to the Arctic sea. Then came the Glacial period, with renewed great changes in levels and climate and its own peculiar records and history, which in many respects are more difficult of interpretation than those of more remote periods, because the whole time occupied by them has been relatively so brief. I have elsewhere endeavored to follow this history in detail, and do not propose on this occasion to deal with this latest chapter of the physical history of the Rocky Mountain region of Canada.

In conclusion, what appear to be the most striking points evidenced by the geological record of this northern part of the Cordillera perhaps be specified as follows:

(1) The great thickness of strata accumulated both to the east and west of an Archean axis. In the Laramide geosyncline the strata no doubt actually attained the volume stated. In the western and wider syncline it is not so certain that all the formations in their full thickness were ever actually superposed at any one place or time (for reasons already alluded to), but the volume was probably not less than in the Laramide region.

(2) The great proportion of volcanic materials accumulated in the western geosyncline and the recurrence of vulcanism throughout the geological time-scale in this region, resulting in the production of massive volcanic formations in the Cambrian, Carboniferous, Triassic, Cretaceous, and Miocene.

(3) The recurrence of folding and disturbance parallel to the border of the Pacific basin and the concurrent great changes in elevation of the land relatively to the sea, both continued down to quite recent geological times, the latter even into the Pleistocene.

(4) The tremendous energy of denudation, in part due to the events last referred to, but also dependent upon the position of the region on the eastern border of a great ocean, where, in northern latitudes, an excessive rainfall must have occurred at all periods on the seaward mountain ranges. No comparable denuding forces were probably ever operative on the east side of the continent in similar latitudes since the definition of the ocean basins of the Pacific and Atlantic.

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GEOLOGICAL RECORD OF THE ROCKY MOUNTAIN REGION IN CANADA

ADDRESS BY THE PRESIDENT, GEORGE M. DAWSON

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(*Read before the Society December 29, 1900*)

CONTENTS

Introduction

It is the privilege of the President of this Society, in his address, to bring to the notice of his fellow-members some subject possessed of more or less general interest, and preferably, I think, some subject that he has made particularly his own. On such an occasion a wider outlook upon various geological fields becomes admissible than in the case of papers presented to the Society, which, as a rule, should be devoted to original and unpublished observations. It has thus appeared to me that it may be of interest and utility at this time, to collect and review the main facts so far ascertained respecting the composition of the geological column of what may be called the Rocky Mountain region of Canada, including the province of British Columbia and the Yukon district—this region being identical with that part of the western Cordillera comprised in the Dominion of Canada. To its geological exploration a great part of my own time has been devoted for many years. The results, as obtained, have been published chiefly in the reports of the Geological Survey of Canada, but it is undoubtedly difficult for the inquirer, with only a limited amount of time at his disposal, to form a connected and balanced idea of the conditions, as a whole, from a series of such progress reports, dealing usually with particular districts.

Twenty years ago, after having worked in British Columbia or on its borders for six seasons, I read a paper before the Geological Section of the British Association for the Advancement of Science, at Swansea, entitled "Sketch of the geology of British Columbia," which was afterwards published in the Geological Magazine.* So far as they go, the general outlines then laid down still hold; but much has been accomplished since that time, the relative importance of the observations recorded has been considerably changed, and opinions expressed from time to time have had to be modified as the work progressed. All I shall attempt to do here is to review the principal geological features as they are now understood, but in order to render this address of more practical value as a clue to the geology of the region covered by its title, references to the principal reports and papers in which details may be found will be given throughout.

Special Features of the Region

The region dealt with is in many respects one of particular geological interest, and it is likewise remarkable as one which it has been necessary to work out as an almost entirely detached geological problem. Its older rocks are separated from those of the eastern parts of Canada by the whole width of the Great plains, and the newer formations found in it are generally unrepresented in other parts of Canada. Nor until the work was well advanced did any satisfactory standard of comparison exist in the far west. California could be referred to in regard to certain defined formations of the Tertiary and Cretaceous, but a great intervening region of the Cordillera remained practically unknown geologically, except for the earlier results of the Hayden surveys and some reconnaissance surveys by other explorers along lines of travel. Clarence King's great volume, the "Systematic Geology of the 40th Parallel," did not appear till 1878, and the relations of the region here referred to with others, which have become apparent, have been developed at later dates.

* Decade II, vol. viii, April and May, 1881.

It was in this region also that the occurrence of contemporaneous volcanic materials as important constituents of the Mesozoic and Paleozoic rocks of the Cordilleran belt was first recognized. Previous to the earlier reports of the Canadian Geological Survey on British Columbia, the existence of such volcanic materials had been admitted only as regards the Tertiary formations, in the western portion of the continent.

Investigators

The geological exploration of British Columbia was begun in 1871 by Dr A. R. C. Selwyn, assisted by the late Mr James Richardson. Taking all the circumstances into consideration, the report then made by Dr Selwyn must, I think, be regarded as a remarkably valuable and important one. My own investigations in connection with the Geological Survey began in 1875 and in 1887 extended to the Yukon district. Work was carried on in the Cariboo district for some years under the control of the late Mr Amos Bowman, and in later years Messrs J. McEvoy, R. G. McConnell, J. B. Tyrrell, R. W. Brock, and J. C. Gwillim have also been in charge of parties in different parts of this Cordilleran region of Canada.

Physiographical Features

It is not my intention, however, here to follow the development of our knowledge of the region historically, through its various stages, but rather to enumerate the several formations now known to be represented, to briefly describe each of them, and then to review the main outlines of the geological evolution of this part of the continent in so far as it has been made apparent. For this purpose a few words must first be devoted to the existing physiographical features of the region.

Pleistocene events and matters connected with the glaciation and later superficial geology may be excluded from consideration, as these have been treated at some length elsewhere.*

As compared with the Cordilleran region in the Western states, that of British Columbia is much less diffuse and more strictly parallel with the corresponding part of the Pacific coast. Its length is approximately the same, but its width is usually about 400 miles only. The several mountain systems are separated by narrower intervals, and, except in the extreme north, may be more readily traced and defined. All the main physical features trend in a north-northwest direction for about 1,100 miles, after which the mountain axes turn somewhat abruptly westward,

*Trans. Royal Soc. Can., vol. viii. Presidential address to Section IV.

and, becoming less continuous and separated by wider intervening lowlands, run toward the eastern boundary of Alaska.

The geological features follow a similar rule, the rock series represented differing much in age and composition within comparatively short distances as the Cordilleran belt is crossed, while they run far and with closely accordant characters in the direction of its length.

This depends on two conditions, both imposed by the position of the zone of recurrent crustal movements coincident with the western border of the continent: (1) The occurrence of successive zones of deposition, whether sedimentary or volcanic, parallel to the continental edge; (2) the actual compression of the original area of deposition, by folding and fracture, produced by pressure from the Pacific side, by means of which the superficies may have been reduced by at least one-third of its original width since early Paleozoic times. It results, further, from these conditions that the local names applied to geological formations remain appropriate for long distances in the general direction of the strike, while the characters associated with such names can seldom be traced far without change in a transverse direction. The bearing of this on the nomenclature appropriate for the Cordilleran region as a whole is important, and the want of attention to it has already, I fear, led to the publication of some new formational names which are unnecessary and confusing rather than helpful.

The ruling orographic features of the Cordilleran region in Canada at the present time are the Rocky mountains proper, forming its high eastern border, and the Coast ranges of British Columbia on the west. It has been proposed by Dana to name the first of these systems the "Laramide range," as its origin was coeval with the close of the Laramie period. This mountain system appears to begin about the 46th or 47th parallel of latitude, from which it runs in a northerly direction to the Arctic ocean, with occasional echelon-like breaks, but forming throughout the western limit of the inland plain of the continent. Its width is about 60 miles, and although reduced in the far north, the height of many of its peaks exceeds 11,000 feet. The rocks composing it are for the most part referable to the Paleozoic, and it is found to be affected by numerous great faults parallel to its direction, overthrust to the eastward, and along the eastern margin, resulting in some cases in horizontal displacements of several miles, by which Paleozoic rocks override those of Cretaceous age in the foothills.

The Coast ranges of British Columbia form a belt of about 100 miles in width that extends along the border of the Pacific for at least 900 miles, beginning near the estuary of the Fraser and eventually running inland beyond the head of Lynn canal, where the coast changes its trend to the westward. These ranges are chiefly composed of granitic rocks, which may in the main be regarded as forming a gigantic "bathylite" with minor included masses of sedimentary rocks. It is later in date of origin than the Triassic period and probably experienced a second and much greater elevation at or about the close of the Cretaceous, but is neither so lofty nor so ragged as the Laramide range. The remarkable fiords of the Pacific coast, both those of British Columbia and those of the southern part of Alaska, are the submerged valleys of this coastal system of mountains, their erosion being probably referable to early Eocene and late Pliocene times, during which the land stood at relatively high levels.

To the west of the Laramide range, and separated from it by a remarkably long and direct structural valley, is a somewhat irregular and sometimes interrupted series of mountain systems to which the general name of the Gold ranges has been applied, and this is referred to further on as the Archean axis of this part of the Cordillera. It embraces the Purcell, Selkirk, Columbia and Cariboo mountains, all including very ancient rocks and evidently representing the oldest known axis of elevation in the province, although it has not remained unaffected by movements of much later date. Peaks surpassing 10,000 feet in elevation still occur in these mountains.

Between the Gold and Coast ranges, with a width of about 100 miles, is the Interior plateau of British Columbia, a peneplain referred in its main features to the early Tertiary, which has subsequently been greatly modified by volcanic accumulations of the Miocene, and has been dissected by river erosion at a still later period. This plateau country is well defined for a length of about 500 miles, declining northward from a height of over 4,000 feet near the 49th parallel to one of less than 3,000 feet, and with an average altitude of about 3,500 feet. It is then interrupted for some four degrees of latitude by a mountainous country chiefly composed of disturbed Cretaceous rocks, beyond which the surface again declines to the plateau lands of the upper Yukon basin, with its separated mountain ranges. The Interior plateau is throughout very complex in its geological structure, but except where covered by Tertiary accumulations it is found to be chiefly underlain by Paleozoic and Mesozoic rocks.

One more mountain system remains to be noted. This stands upon the real border of the Continental plateau, and is represented by the long ridge-like highlands of Vancouver island and the Queen Charlotte islands. It is evidently broken between these islands, and is not clearly continued in the archipelago of southern Alaska, which seems to be more closely connected with the Coast ranges of the mainland. The rocks principally comprised in this outer mountain system range from the Carboniferous to the Cretaceous in age.

Table of Geological Formations

Attention may now be directed to the general table of geological formations recognized in the region under review. This is arranged in two main columns, representing what I conceive to be the two great geosynclines of this part of the Cordillera. These are separated by what has already been referred to as an Archean axis. A further explanation of these main structural features will be given subsequently, but it is first proposed to define and briefly note the character of each of the geological units, beginning with the oldest.

	Western Geosyncline	Feet		Laramide Geosyncline	Feet
Pliocene	Horsefly gravels. Quartz drift of Klondike, etc.				
Miocene	Upper volcanic group	3,100			
	Tranquille beds	1,000			
	Lower volcanic group	5,300			
Oligocene	Coldwater group (Similkameen beds, etc.).	5,000			
Eocene	Puget group (on coast only 3,000′ +).			Upper Laramie	3,000
				Lower Laramie	2,500
Cretaceous	Nanaimo group	2,700		Montana Colorado	3,140
	Queen Charlotte Island group (in Queen Charlotte islands).	9,500		Dakota Kootanie	9,750
Triassic	Nicola group	13,500		(Red beds to south, marine to north) say	600
Carboniferous	Cache Creek group	9,500		Banff series	5,100
Devonian	(?)			Intermediate series	1,500
Silurian	(?)			Halysites beds	1,300
Ordovician	(?)			Graptolithic shales	1,500
				Castle Mountain group (upper part).	
Cambrian	Adams Lake series	25,000	Selkirk series, 25,000	Castle Mountain group (lower part).	8,000
	Nisconlith	15,000		Bow River series	10,000
		89,600			46,390
Archean	Shuswap series	5,000′ +			

Archean

In 1881 it was possible only to allude to the existence of crystalline rocks probably referable to the Archean. The rocks referred to were those originally described by Dr Selwyn as the "Granite, gneiss, and mica-schist of the North Thompson, etc.," and recognized from the first by him as "the oldest rocks observed in the country." It was not, however, till 1889 that much further information was gained regarding these old rocks, when good sections of them were found by the writer on Kootenay lake, and as they were also well developed on Shuswap lake, the name Shuswap series was proposed for them.* The Shuswap rocks proper evidently represent highly metamorphosed sediments with perhaps the addition of contemporaneous bedded volcanic materials. They are grayish mica-gneisses, with some garnetiferous and hornblendic gneisses, glittering mica-schists, crystalline limestones and quartzites. Gneisses in association with the last-mentioned rocks often become highly calcareous or silicious and contain scales of graphite, which are also often present in the limestones. These bedded materials are, however, associated with a much greater volume of mica-schists and gneisses of more massive appearance, most of which are evidently foliated plutonic rocks, and are often found to pass into unfoliated granites. The association of these different classes of rocks is so close that it may never be possible to separate them on the map over any considerable area. The granites may often have been truly eruptive in origin, but the frequent recurrence of quartzites among them in some regions indicates that they are, at least in part, the result of a further alteration of the bedded rocks.†

Thus, up to the present time, the Shuswap series has been made to include this entire complex mass of crystalline rocks, although it might be more appropriately restricted to the originally bedded members. These, it will be observed, now very closely resemble those of the Grenville series of the province of Quebec, the resemblance extending to the nature of their association with the foliated rocks, which in turn closely resemble the so-called "Fundamental Gneiss" of the same region. The original materials and the conditions of alteration to which they have been subjected have in both localities been almost identical, producing like results. The age must be approximately the same, but the distance is too great to admit of any precise correlation on lithological grounds.

When the ruling lines of strike or foliation of the Shuswap are laid down, they are generally found to be parallel with each other in each particular region, but to run in great irregular sweeping curves over the face of the map as a whole, and sometimes to surround unfoliated granitic areas in a concentric manner, the whole appearance being very much like that met with in some parts of the Laurentian country in the east.

*Annual Report, Geol. Surv. Can., vol. iv (N. S.), p. 29 B. The name Kootanie (or Kootenay) was preoccupied.

†Cf. Shuswap map-sheet, Geol. Surv. Can., 1898.

A distinct tendency to parallelism of the strata or foliation with adjacent borders of the Cambrian system has moreover also been noted in a number of cases. This might imply that the foliation was largely produced at a time later than the Cambrian, but the materials of some of the Cambrian rocks show that the Shuswap series must have fully assumed their crystalline character before the Cambrian period, and there are other evidences of their extensive pre-Cambrian erosion. It seems, therefore, probable that the foliation of the Shuswap rocks may have been produced rather beneath the mere weight of superincumbent strata than by pressure of a tangential character accompanied by folding, and that both these rocks and those of the Cambrian were at a later date folded together. In the Archean of eastern Canada, foliation still nearly horizontal or inclined at low angles, often characterizes considerable areas and appears to call for some explanation similar to that above suggested.

The greatest thickness of the Shuswap rocks so far measured, where there is no suspicion of repetition, on Kootenay lake, is about 5,000 feet, but even here there are doubtles included considerable intercalations of foliated eruptives. The Shuswap series characterizes considerable areas of the Selkirk, Columbia, and adjacent ranges in the southern part of British Columbia. It is known also in the Cariboo mountains and near the sources of the North Thompson and Fraser, about latitude 53°.* It is again well developed on the Finlay river, where the country has been geologically examined, between the 56th and 57th parallels of latitude.†

Northward to this point these rocks appear to be confined to a belt lying to the west of the Laramide range and to come to the surface seldom, if at all, in that range. Farther north similar rocks occur in the Yukon district in several ranges lying more to the west, but still with nearly identical characters, in so far as they are known. ‡

The granitic rocks of the Coast ranges are probably much newer, nor have any crystalline schists yet been observed in association with these raeges to which an Archean date can be definitely assigned.

Cambrian

The importance of rocks assigned to the Cambrian in the Rocky Mountain region of Canada has become much more apparent as the result of later explorations. Their thickness is very great, and they appear under differing characters in different parts of the region, in

*Annual Report, Geol. Surv. Can., vol. xi (N. S.), p. 39 D.
† Ibid., vol. vii, p. 33 C.
‡ Ibid., vol. iii, p. 34 B, and vol. iv, p. 14 D.

such a manner as to require distinctive names and to admit, so far, of only a tentative correlation. Our typical and most carefully surveyed section is that in the Rocky mountains proper or Laramide range, on the line of the Bow River pass. This has been studied by Mr R. G. McConnell, and it is the only section for which some direct paleontological evidence exists.* The base of the Cambrian is, however, not seen in this section. In the Gold ranges, where the Cambrian is frequently found resting on the Archean, the Nisconlith, its lowest recognized member, varies by several thousand feet in volume, showing that the old surface was a very irregular one and had been greatly modified by denudation previous to the deposition of the Nisconlith. The same circumstance has been noticed by Mr McConnell in the case of the Bow River series of the Laramide range, where it is found resting on the Archean in the vicinity of the Finlay river, over 400 miles northwest of his typical section,† proving this denudation-interval to be a very important one, although, as already noted, there is often a parallelism in strike between the two series of rocks.

The Bow River series, in the pass of the same name, consists chiefly of dark-gray argillites, with some greenish and purplish bands, associated with quartzites and conglomerates, these coarser materials being most abundant in the upper parts of the formation. Pebbles of quartz and feldspar, evidently derived from the Archean, are abundant in the conglomerates, and scales of mica have in some places been developed on the divisional planes of the argillites. The known thickness of the series is 10,000 feet.

In the eastern part of the pass, resting conformably on the Bow River series, is the Castle Mountain group, with a known thickness of about 8,000 feet. This consists chiefly of ordinary gray limestones and dolomites, in frequent alternations and interstratified with shales and calcschists. To the west of the main watershed, however, the character of this series becomes materially changed, and the heavy bedded dolomites and limestones are to a great extent replaced by greenish calcschists and greenish and reddish shales and slates. The change may be traced in its various stages, and is due to the introduction on the west of a greater proportion of earthy matter.

Fossils of the lower Cambrian (*Olenellus*) fauna have been found 3,000 feet below the summit of the Bow River series. They are also known to characterize the lower part of the Castle Mountain series, which is fos-

* For details of the Bow River Pass section, see Annual Report, Geol. Surv. Can., vol. ii (N. S.), part D.

† Annual Report, Geol. Surv. Can., vol. vii (N. S.), p. 24 C.

siliferous at several horizons, and appears to pass up at its summit into the Ordovician.*

Following the general direction of the Laramide range northwestward, Cambrian rocks similar to those of the Bow pass are now known at intervals for many hundred miles, and it is probable that they will be found to form a continuous or nearly continuous belt. Both groups are recognized with practically identical characters on the Yellow Head pass and on the Finlay river. The Misinchinca schists of my report of 1879, no doubt represent the Bow River series, and similar rocks are again found at the sources of the Pelly branch of the Yukon.†

Passing now to the next mountain system, to the southwest of the Laramide range and parallel with it—the Gold ranges—we find in the Selkirk mountains a great thickness of rocks that have not yet yielded any fossils, but appear to represent, more or less exactly, the Cambrian of our typical section. Resting on the Archean rocks of the Shuswap series is an estimated volume of 15,000 feet of dark gray or blackish argillite schists or phyllites, usually calcareous, and toward the base with one or more beds of nearly pure limestone and a considerable thickness of gray flaggy quartzites. To these, where first defined in the vicinity of the Shuswap lakes, the name Nisconlith series has been applied.‡ The rocks vary a good deal in different areas, and on Great Shuswap lake are often locally represented by a considerable thickness of blackish flaggy limestone. It other portions of their extent dark-gray quartzites or graywackes are notably abundant. Their color is almost everywhere due to carbonaceous matter, probably often graphitic, and the abundance of carbon in them must be regarded as a somewhat notable and characteristic feature. These beds have also been recognized in the southern part of the West Kootenay district and in the western portion of the Interior plateau of British Columbia.

The Nisconlith series is believed, from its stratigraphical position and because of its lithological similarity, to represent in a general way the Bow River series of the adjacent and parallel Laramide range, but there is reason to think that its upper limit is somewhat below that assigned on lithological grounds to the Bow River series.

Conformably overlying the Nisconlith in the Selkirk mountains, and blending with it at the junction to some extent, is the Selkirk series,

* For descriptions of the fossils from these beds, the following authors may be referred to: C. Rominger, Proc. Acad. Nat. Sci., Phila., 1887, pp. 12–19; C. D. Walcott, Proc. U. S. Nat. Mus., 1889, pp. 441–446; J. F. Whiteaves, Can. Rec. Sci., 1892, vol. v, pp. 205–208; F. R. C. Reed, Geol. Mag., 1899, Dec. 4, vol. vi, pp. 358–361; G. F. Matthews, Trans. Royal Soc. Can., series 2, vol. v, sec. 4.

† Annual Report Geol. Surv. Can., vol. xi (N. S.), p. 31 D. Ibid., vol. vii, p. 34 C. Report of Progress, Geol. Suvr. Can., 1879–'80, p. 108 B.

‡ Annual Report Geol. Surv. Can., vol. iv (N. S.), p. 31 B. Bull. Geol. Soc. Am., vol. ii, p. 170. Annual Report Geol. Surv. Can., vol. vii (N. S.), p. 31 B. Shuswap map-sheet, Geol. Surv. Can.

with an estimated thickness of 25,000 feet, consisting, where not rendered micaceous by pressure, of gray and greenish-gray schists and quartzites, sometimes with conglomerates and occasional intercalations of blackish argillites like those of the Nisconlith. These rocks are evidently in the main equivalent to the Castle Mountain group, representing that group as affected by the further and nearly complete substitution of clastic materials for the limestones of its eastern development.

In the vicinity of Shuswap lakes and on the western border of the Interior plateau, the beds overlying the Nisconlith and there occupying the place of the Selkirk series are found to still further change their character. These rocks have been named the Adams Lake series.* They consist chiefly of green and gray chloritic, felspathic, sericitic, and sometimes nacreous schists, greenish colors preponderating in the lower and gray in the upper parts of the section. Silicious conglomerates are but rarely seen, and on following the series beyond the flexures of the mountain region it is found to be represented by volcanic agglomerates and ash-beds, with diabases and other effusive rocks, into which the passage may be traced by easy gradations.† The best sections are found where these materials have been almost completely foliated and much altered by dynamic metamorphism, but the approximate thickness of this series is again about 25,000 feet.‡

The upper part of the Cambrian system, above the Bow River and Nisconlith series, may thus be said to be represented chiefly by limestones in the eastern part of the Laramide range, calc-schists in the western part of the same range, quartzites, graywackes, and conglomerates in the Selkirk mountains, and by volcanic materials still further to the west. It is believed that a gradual passage exists from one to another of these zones, and that the finer ashy materials of volcanic origin have extended in appreciable quantity eastward to what is now the continental watershed in the Laramide range. No contemporaneous volcanic materials have, however, been observed in the underlying Bow River or Nisconlith series.

The beds first definitely referred to the Cambrian in the Rocky Mountain region of Canada are those found near the International boundary in the vicinity of the South Kootenay pass.§ These were further examined at a later date, as described in the report of the Geological Survey of Canada for 1885,‖ and some additional observations in regard to them are given by Mr J. McEvoy.¶

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* For the Selkirk and Adams Lake series see references above given for Nisconlith series.

† Annual Report, Geol. Surv. Can., vol. vii (N. S.), p. 35 B.

‡ Comprising greenish schists 8,100 feet, grayish schists 17,100 feet. In Bull. Geol. Soc. Am., vol. ii, p. 168, the thickness is given in error at half the above.

§ Geology and Resources of the 49th Parallel, p. 68. Geol. Mag., Decade II, vol. iii, p. 222.

‖ Pp. 39 B–42 B.

¶ Summary Report, Geol. Surv. Can., 1899, p. 97 A.

A thickness of at least 11,000 feet of sandstones and shales of red, gray, and greenish colors, frequently alternating and including several contemporaneous trap flows, occurs between the Continental watershed and the Flathead river. This series has not been traced into connection with the sections previously described, but it shows some resemblance to the Selkirk and Castle Mountain groups. The occurrence of blackish calcareous argillites and sandstones at the base may indicate the presence of the Bow River series there, while a limestone at the top of the section in this part of the mountains may prove to be that of the Castle Mountain group.*

Along the eastern borders of the Coast ranges, in southern British Columbia, is a very considerable volume of argillites with some limestone and altered volcanic products, all more or less schistose or slaty. These were originally described by Selwyn as the "Anderson River and Boston Bar group." † They may be Cambrian, but it has not yet been found possible to separate them from newer Paleozoic rocks with which they are associated.

Additional Cambrian areas will no doubt also eventually be defined in the far north, including some of the rocks met with on the Stikine and Dease rivers and in the Klondike district.‡

Ordovician and Silurian

As already noted, the upper part of the Castle Mountain group in the Laramide range contains fossils referable to the Ordovician. In the same western part of the range, 1,500 feet or less of black shales lies above these, containing graptolites that have been referred to the Trenton-Utica fauna by Professor Lapworth.§ The same graptolitic fauna was found in 1887 on the Dease river, not far south of the 60th parallel of latitude.||

Above the graptolitic beds in the Bow Pass section, is a thickness of 1,300 feet or more of dolomites and quartzites, containing *Halysites catenulatus* and a few other forms that are believed to be Silurian.¶

The above-mentioned localities are the only ones in which Ordovician or Silurian rocks have been discovered in the entire region under review.

Devonian

East of the continental watershed, on the Bow pass, Mr McConnell's

* Annual Report, Geol. Surv. Can., vol. i (N. S.), pp. 50 B, 51 B.
† Ibid., vol. vii, pp. 38 B, 43 B.
‡ Ibid., vol. iii (N. S.), pp. 32 B, 94 B. Summary Report, Geol. Surv. Can., 1899, p. 18 A.
§ Annual Report, Geol. Surv. Can., vol. ii, (N. S.), p. 22 D.
|| Ibid., vol. iii, p. 95 B.
¶ Ibid., vol. ii, p. 21 D.

section shows a thickness of 1,500 feet of brownish-weathering dolomitic limestones, named by him the Intermediate limestones, that from their fauna and position are described as Devonian.* They pass conformably upward into beds of the Banff series, which are regarded as Carboniferous in the main, although, as so commonly occurs in the Rocky mountain region, they appear to contain also a certain number of forms usually referred to the Devonian.

A few fossils supposed to be distinctively Devonian, have likewise been found in several other isolated localities in this Laramide range, and as the Devonian system is well characterized and persistent along the Mackenzie river, as well as in the Manitoba region, it seems probable that a continuous zone of the same age may ultimately be traced throughout the eastern parts at least of the Laramide range. To the west of this range no distinct evidence of rocks of Devonian age has, however, been obtained, although it is quite probable that such rocks may yet be found as constituents of the lower part of the Cache Creek formation described below.†

Carboniferous

In describing the rocks of this period, it will be convenient first to refer to those of the Bow pass, continuing the general east-to-west order previously followed, but premising that this is not the order in which the respective rock-series have actually been studied or named.

The mountains of the eastern part of the Laramide range, in the vicinity of the Bow pass, are largely formed of the Banff Limestone series, having a thickness of about 5,100 feet. This is composed of two thicknesses of limestone, separated by one shaly zone, and the whole capped by a second zone of shales. The aggregate thickness of the shales is about 1,300 feet. Below the Banff series, in this part of the mountains, is the Intermediate limestone, already noted, and above it is the Earlier Cretaceous, resting upon it without any apparent unconformity.‡ Numerous fossils have been obtained from the limestones, showing their position to be in the lower part of the Carboniferous system, passing below into Devono-Carboniferous.§ Limestones of the Banff series have now been recognized in many localities scattered along almost the entire length of

* Ibid., vol. ii, p. 19 D.

† The entire field of the Devonian in Canada has lately been reviewed by Dr J. F. Whiteaves (see Presidential address, Section E, Am. Assoc. Adv. Sci., 1899).

‡ Annual Report, Geol. Surv. Can., vol. ii (N. S.), p. 17 D.

§ The existence of Carboniferous and Devonian fossils in this range was first made known many years ago by Dr (now Sir James) Hector. Exploration of British North America, p. 239, Quart Jour. Geol. Soc., vol. vii, p. 443.

the Laramide range in Canada, in which direction the conditions of deposition appear to have been uniform.

Rocks of the Carboniferous period are probably present in several parts of the system of Gold ranges, but practically no paleontological evidence of their existence has yet been obtained.*

Between these mountains and the Coast ranges, however, the Carboniferous is again well represented, but in a manner very different from that found in the Laramide range, for although limestones are still important, clastic rocks of various kinds, with great masses of contemporaneous volcanic materials, preponderate. These rocks occupy a considerable part of the Interior plateau of southern British Columbia, and run northwestward, with practically identical characters, far into the Yukon district, probably to the eastern boundary of Alaska and beyond.

Fossils referable to the Carboniferous period are found sparingly in association with them, particularly *Fusulinæ*, and none of distinctively older or more recent date have been discovered. At the same time, it is not improbable that the series may include in its lower part beds older than the Carboniferous, and possible that its upper beds may be newer than those of that system. Its constant characters, however, render it appropriate to attach a distinctive name to the series, which has consequently been designated the Cache Creek series, with the understanding that should any part of it subsequently be discovered to be separable paleontologically, the name will be retained for the Carboniferous portion. This name is, in fact, somewhat more important than a purely local one, being intended to denote a peculiar development of the Carboniferous system, well defined in its nature and characterizing a wide middle zone in the northern part of the Cordilleran belt, but of which the upper and lower limits still remain somewhat indefinite.

The name is one of those of Selwyn's preliminary classification, where Lower and Upper Cache Creek groups are described, the term "Marble Canyon limestones" being given as an alternative for the latter. The division into lower and upper parts on lithological grounds is still recognized, but later investigations and the proved Carboniferous age of both parts have since caused the whole to be referred to as a single great group.†

The composition and approximate thickness of the Cache Creek strata are best known in the area of the Kamloops map-sheet, where it may be briefly characterized as follows: The lower division consists of argillites, generally as slates or schists, cherty quartzites or hornstones, vol-

*Summary Reports, Geol. Surv. Can., 1895, p. 24 A; 1896, p. 22 A; 1897, p. 29 A.

†See Report of Progress, Geol. Surv. Can., 1871-'72, pp. 52, 60, 61; also Annual Report, Geol. Surv. Can., vol. vii (N. S.), p. 32 B et seq.

canic materials with serpentine and interstratified limestones. The volcanic materials are most abundant in the upper part of this division, largely constituting it. The minimum volume of the strata of this division is about 6,500 feet. The upper division, or Marble Canyon limestones, consists almost entirely of massive limestones, but with occasional intercalations of rocks similar to those characterizing the lower part. Its volume is about 3,000 feet.

The total thickness of the group in this region would therefore be about 9,500 feet, and this is regarded as a minimum. The argillites are generally dark, often black, and the so-called cherty quartzites are probably often silicified argillites. The volcanic members are usually much decomposed diabases or diabase-porphyrites, both effusive and fragmental, and have frequently been rendered more or less schistose by pressure. The serpentine beds are associated with these volcanic rocks, and have evidently resulted from the alteration of some of them. The limestones of both lower and upper divisions hold *Fusulina* and a few other distinctive Carboniferous fossils, but in the Marble Canyon limestone the most characteristic form is the large foraminifer known as *Loftusia columbiana*, entire beds being made up of its débris.†

Fusuline limestones have now been found in a number of places in the central zone of the Cordillera throughont the length of British Columbia and beyond the 60th parallel, its northern boundary. Where these occur the clastic and volcanic rocks associated with them may be definitely referred to the Cache Creek group, but in consequence of the great resemblance of its volcanic rocks to those of the Triassic (as mentioned later), it is often impossible, without close study, to define the area occupied by this group, and its separate mapping has only as yet been attempted in detail over comparatively small areas.‡

In the southern part of British Columbia, the Cache Creek group shows some evidences of littoral conditions toward the west slopes of the Gold ranges, probably indicating the existence of land areas there. In this vicinity also the Campbell Creek beds, a somewhat peculiar development of argillites, graywackes, and amphibolites, occur.§

The granitic Coast ranges of British Columbia are much later in date of origin than the Carboniferous, but some of the highly altered beds now included in them or found along their margins are undoubtedly of that period. To the west of these ranges, on Vancouver island and in

* Ibid., p. 46 B.

† Quart. Jour. Geol. Soc., vol. xxxv, p. 69.

‡ Areas included in the Kamloops and Shuswap map-sheets, covering together 12,800 square miles.

§ Annual Report, Geol. Surv. Can., vol. vii (N. S.), p. 44 B.

its vicinity, as well as on the Queen Charlotte islands, are rocks very similar in composition to those of the Cache Creek of the interior, but still differing somewhat from these in aspect. They comprise limestones and volcanic accumulations preponderantly, with occasional zones of argillite. The limestones are usually in the form of marbles, often coarsely crystalline, but from them a few fossils referred to the Carboniferous period have been obtained. The volcanic materials include amygdaloids, agglomerates, and tuffs, but are often converted to schists, and sometimes become mica-schists or imperfect gneisses, as in the vicinity of Victoria. Their degree of alteration is very different locally, and their aspect consequently varies much from place to place, but on the whole they evidence conditions of deposition much like those of the Cache Creek group.* They have unfortunately not yet been made the subject of any detailed study, and they are again involved with Triassic strata closely resembling them in aspect.

Triassic

In my report for 1877 † the existence in British Columbia of rocks shown by their fossils to be referable to the Triassic was made known, and these rocks, as developed in the Interior plateau region, were named the Nicola series or formation. This rests, at least in some places, unconformably upon the Carboniferous, and no rocks representing the Permean period have been identified. The Nicola formation is, however, chiefly composed of volcanic materials, the intercalated limestones or argillites in which fossils are occasionally found being few and far between. The greater part of its mass is undoubtedly Triassic, but the highest beds in a few places have yielded a small fauna that is referred by Professor Hyatt to the Lower Jurassic. All the fossils are marine.‡

Partial sections of the Nicola formation have been obtained in a number of places, but its study is attended with difficulty. owing to the very massive and uniform character of the most of its rocks, the region covered by it being best characterized as one of "greenstones." These rocks often closely resemble those of the Carboniferous, and in some places it is not easy to separate them, on the other hand, from the older Tertiary volcanic materials. Lithologically the rocks are chiefly altered diabases of green, gray, blackish, and purplish colors. In regard to state of aggregation, they comprise effusives (often amygdaloidal), agglomerates, and tuffs, the latter showing evidence of subaqueous deposition through-

* Geol. Mag., Decade II, vol. viii, p. 219.

† Report of Progress, Geol. Surv. Can., 1877-'78.

‡ Fossils of the Triassic rocks of British Columbia, J. F. Whiteaves, Contributions to Canadian Paleontology, vol. i, part 2. Annual Report, Geol. Surv. Can., vol. vii (N. S.), p. 49 B et seq.

out the entire series. The tuffs are occasionally calcareous, and there are some thin and probably irregular beds of limestone, with infrequent layers of argillite. The most complete section so far obtained is one on the Thompson river, showing a total thickness of 13,590 feet; another near Nicola lake gives a probable minimum of 7,500 feet, and in both places more than nine-tenths of the whole is of volcanic origin.

The Nicola formation, with the characteristics above noted, is well developed in the central parts of the Interior plateau of British Columbia, and it probably extends far to the north in the same belt of country between the Coast and Gold ranges, but in the general absence of paleontological evidence, can not there as yet be separated, even locally, from the Paleozoic.*

To the west of the Coast ranges, and now entirely separated from the Nicola formation by the granitic mass of these ranges of later age, Triassic rocks are again found largely developed in the Queen Charlotte islands and on Vancouver island. They were described and identified in the Queen Charlotte islands in 1878, and in 1885, when again found covering large areas in the northern part of Vancouver island, were defined as the Vancouver series.†

These rocks closely resemble those of the Nicola formation, with which they may probably at the time of their deposition have been continuous. The series is built up for the most part of volcanic materials, now in the state of altered diabases and felsites, but amygdaloidal, agglomeratic, or tuffaceous in character. Ordinary sedimentary materials, such as argillites, limestones, and felsites, are, however, more abundant than in the Nicola formation. These probably recur at several different horizons, but in the northern part of Vancouver island they are known to form an important zone, with a thickness of about 2,500 feet.‡ Marine fossils are abundant in some of these beds.

This group is of great thickness, but no trustworthy figures can yet be given for it. It is associated often with the very similar rocks of the Carboniferous period, already referred to as existing in the same orographic belt, and it yet remains to draw a distinct line between the two series. Following the coastal region northward, rocks pretty clearly referable to this formation have been noted in several places among the Alaskan islands as far up as Lynn canal.

To the north of the 56th degree of latitude, it would appear that the

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* Annual Report, Geol. Surv. Can., vol. iii (N. S.), p. 33 B.

† Report of Progress, Geol. Surv. Can., 1878–'79, p. 49 B. Annual Report, Geol. Surv. Can., vol. ii (N. S.), p. 7 B et seq. The rocks named the Sooke series, in 1876, may probably also be included in the Vancouver series. Report of Progress, Geol. Surv. Can., 1876–'77, pp. 98–102.

‡ The same zone is probably represented in the southern part of the Queen Charlotte islands.

Triassic sea extended eastward, without important interruption, across the entire Cordilleran region, as marine fossils like those of the Vancouver group have been found not only on the Stikine (in the trend of the Nicola formation), but also on the Liard, Peace, and Pine rivers in the Laramide range.* In the last-named range, however, there is no evidence of contemporaneous volcanic action, which, it is probable, did not extend so far to the eastward.

Following the Laramide range southward from the occurrences last alluded to, there is a considerable interval in which no Triassic rocks have been recognized, after which, in the vicinity of the 49th parallel, a series of red sandstones and shales, with buff magnesian grits, three or four hundred feet thick, is found. This caps a number of the higher mountain ridges and was assigned by me in 1875 to the Triassic. It is believed to represent the northern extremity of the deposits of the Triassic Mediterranean that occupied so large a part of the Western states and which must have been separated from the open sea by land barriers of some width.†

Cretaceous

Apart from the beds capping the Nicola formation, to which allusion has been made, no strata distinctly referable to the Jurassic have been found in the Rocky Mountain region of Canada. Wherever their relations have been determined, the Cretaceous rocks lie unconformably on the Nicola and Vancouver formations, and it seems probable that this unconformity represents the greater part of the Jurassic period. It is proper, however, to state that the lower measures here included in the Cretaceous are still by some authorities called Jurassic; but it is believed that the paleontological evidence, when compared with the best recognized general standards (and not merely with local isolated developments to which a Jurassic age happens to have been assigned), is overwhelmingly in favor of the Cretaceous reference.‡

There is in the region here treated of an important Earlier Cretaceous series of rocks, mostly of marine origin, the distribution of which shows

*Annual Report, Geol. Surv. Can., vol. iii (N. S.), p. 54 B. Ibid., vol. iv, p. 19 D. Report of Progress, Geol. Surv. Can., 1875-'76, p. 97. Bull. Geol. Soc. Am., vol. v, p. 122.

†Geology and Resources of 49th Parallel, 1875, p. 71. Trans. Royal Soc. Can., vol. i, sec. iv, p. 143 et seq.

‡Cf. Whiteaves: Mesozoic Fossils, vol. i, part iv, 1900.

In a late article in the Journal of Geology (Chicago), vol. viii, pp. 245-258, Mr W. N. Logan groups the Jurassic beds found at the summit of the Nicola group (*not* at Nicola lake) with parts of the Queen Charlotte and Kootanie formations, here described as Earlier Cretaceous, and which we have found no reason to separate from the rest of that series, calling the whole Jurassic. By so doing he gives a large part of the area of the Earlier Cretaceous sea to the Jurassic, in a manner which I believe to be incorrect (cf. Am. Jour. Sci., vol. xxxviii, p. 121).

that (except in the southern part of British Columbia), the Pacific at this time, as in the later Triassic, extended to the eastward quite across the Cordilleran belt. In different parts of the region these rocks have been included under two names—the Queen Charlotte Islands and Kootanie formations. The former, applied at first particularly to the Earlier Cretaceous of the coast, has been extended to cover that of the whole western part and interior of the Cordillera. The latter is used to denote the Earlier Cretaceous of the Laramide range and its vicinity, which differs considerably in character.*

In the Queen Charlotte islands we have the clearest succession of beds and the largest and best studied representation of marine organic remains. The entire Cretaceous section as known on these islands is as follows, in descending order: †

(A)	*Upper shales and sandstones*	1,500 feet.
(B)	*Coarse conglomerates*	2,000 "
(C)	Lower shales and sandstones (with coal)	5,000 "
(D)	Agglomerates	3,500 "
(E)	Lower sandstones	1,000 "
		13,000 feet.

It is the three lower members of this section that are regarded as composing the Queen Charlotte Islands formation. Subdivision C contains the greater number of fossils, eighty-nine species of invertebrates having now been described from it,‡ and most of the forms found in subdivision E are identical with these. The intervening agglomerates, of volcanic origin, may be local, and in any case probably represent but a comparatively short space of time. The overlying subdivisions, A and B, are believed to be Upper Cretaceous and approximately equivalent to the Niobrara, Benton, and Dakota of the interior portions of North America.

In the southern part of British Columbia, east of the Coast ranges (which are at least in great part of subsequent origin), the Earlier Cretaceous rocks of the Queen Charlotte islands are represented in the Tatlayoco beds (7,000 feet), Nechacco beds (6,000 feet), Skeena beds, Skagit beds (4,400 feet or more), and Jackass Mountain beds (5,000 feet). These inland terranes of the southwestern part of British Columbia are clearly comparable with the "Shasta group" of California and Oregon, and the fauna most abundantly represented in them is that of the Knox-

* The facts in regard to these rocks are somewhat fully summarized in Am. Jour. Sci., vol. xxxviii, p. 120 et seq., and in Annual Report, Geol. Surv. Can., vol. vii (N. S.), 1894, p. 62 B et seq., where numerous references to the literature may be found.

† Report of Progress, Geol. Surv. Can., 1878-'79, p. 63 B.

‡ Mesozoic Fossils, vol. i, part iv (1900), p. 305.

ville or lower division now made of that group, the characteristic *Aucella* of which is often the commonest fossil.* In the northern part of the province, between the 55th and 58th parallels of latitude, rocks chiefly referable to this period have lately been found to characterize a wide area of country east of the Coast ranges, and here, as well as in the south, they frequently hold coal.

On Tatlayoco lake, the beds of the same name are found to be underlain in apparent conformity by rocks of volcanic origin, to which the name "Porphyrite series" was originally applied.† No fossils have been found in these, but the similarly constituted Iltasyouco beds (latitude 53°) contain molluscs that are now referred by Dr Whiteaves to the Queen Charlotte formation.‡ Ash beds containing similar fossils have been discovered on the Skeena to the east of the Coast ranges, and it is thus evident that vulcanism played an important part in this Earlier Cretaceous time, not only in the Queen Charlotte islands, but also further to the eastward.

Fossils representing the same Earlier Cretaceous period have been found in late years far to the north, in the Yukon basin, on the Lewes river, and on the Porcupine, beyond the Arctic circle.§

The Kootanie formation was so named and characterized as Lower Cretaceous, because of its peculiar flora, by Sir J. Wm. Dawson in 1885.|| It represents the Earlier Cretaceous of the Laramide region in Canadian territory, and has since been found to extend a considerable distance into Montana. Its typical area is separated from the Cretaceous of the western part of British Columbia by the Selkirk and other ranges that appear to have existed as dry land at this time. It no doubt blends with the Queen Charlotte formation further to the north, and it may eventually be found that no useful line can be maintained between the two formations. The Kootanie seems, however, to have been for the most part deposited in a fresh or brackish water basin, and for some years scarcely any marine forms were known to occur in it.¶ A number of

* Annual Report, Geol. Surv. Can., vol. vii (N. S.), p. 64 B.

† Geol. Mag., Decade II, vol. iv, July, 1877.

‡ Originally described as Jurassic. See Geol. Mag., Decade II, vol. viii, p. 218, and Dr Whiteaves on the "Cretaceous system in Canada," Trans. Roy. Soc. Can., vol. xi, sec. iv (1893). For descriptions of invertebrate fossils of the Cretaceous, see especially the following works by Dr J. F. Whiteaves: Mesozoic Fossils, vol. i, parts 1, 2, 3, and 4; Contributions to Canadian Paleontology, vol. i, part 2; Trans. Roy. Soc. Can., vol. i, sec. iv, p. 81; ibid. (second series), vol. i, pp. 101, 119.

§ Annual Report, Geol. Surv. Can., vol. iii (N. S.), p. 36 B. Ibid., vol. ix, pp. 21 D, 124 D. et seq.

|| Science, vol. v, p. 531. Trans. Roy. Soc. Can., vol. iii, sec. iv. For descriptions of Cretaceous plants see particularly the following papers by Sir J. Wm. Dawson, in Trans. Roy. Soc. Can.: Cretaceous and Tertiary Floras of British Columbia, vol. i (1882); Mesozoic Floras of the Rocky Mountain Region, vol. iii (1895); Correlation of Early Cretaceous Floras, etc., vol. x (1892); New Cretaceous plants from Vancouver Island, vol. xi (1893).

¶ Annual Report, Geol. Surv. Can., vol. i (N. S.), p. 162 B.

marine molluscs have, however, since been found at the base of the formation, in the Devils Lake deposits, not far north of the Bow river, and these Dr Whiteaves has provisionally referred to the age of the fossiliferous beds of Queen Charlotte islands, thus apparently confirming the general correlation already indicated by the fossil plants.

The Kootanie consists of alternating sandstones and shales with some thin bands of limestone toward the base and holding in parts of its extent numerous and thick seams of bituminous and anthracite coal, the latter occurring where it has been closely included in the mountain folding. Its thickness is about 7,000 feet, including only that part of the general section characterized by its fossils. Above this is a thickness of 4,000 or 5,000 feet, largely made up of conglomerates that are supposed to represent the Dakota group.

Conglomerates occupying about the same stratigraphical position in the Queen Charlotte islands have already been alluded to, and similar important conglomerates attached to or closely associated with the Earlier Cretaceous have been found in many places on the mainland of British Columbia and northward to the Yukon district. These conglomerates appear throughout to be approximately contemporaneous and are believed to be of more than local significance. They evidently mark a time of wide subsidence and of shorelines advancing on the land, and it was at this time that the Cretaceous Dakota sea spread itself eastward across the interior plain of the continent.

In the Fraser valley east of the Coast ranges, in addition to the occurrence of the conglomerates, the existence of beds of about the period of the Dakota is shown by the discovery of a few fossil plants;* but no evidence of higher members of the Cretaceous has been found in the inland region to the west of the Selkirks, although it is probable that such members are represented further north, in the Yukon district.

From a systematic point of view, it appears to be desirable to confine the Earlier Cretaceous, or Queen Charlotte formation, to rocks below the Dakota; but it will be understood that, over a considerable part of the inland country, the earlier rocks are intimately associated with those of about Dakota age, and that where those of still later date are not present, the most natural break, and one coinciding with some notable physical change, would be above the Dakota.

Beds referred to the Upper Cretaceous† in the Queen Charlotte Islands section have already been alluded to. Collectively it is supposed that the two upper members of that section represent the Dakota, Benton,

*Annual Report, Geol. Surv. Can., vol. vii (N. S.), p. 148 B.

† For references in regard to the Upper Cretaceous see Geol. Mag., Decade II, vol. viii, p. 216; also Am. Jour. Sci., vol. xxxix (1890), p. 180 et seq.

and Niobrara. In following the coast southeastward from the Queen Charlotte islands, the local base of the Cretaceous rocks is found at progressively higher horizons in that system. The two lowest members of the Queen Charlotte section are wanting in the northern part of Vancouver island, and farther on, in the Comox and Nanaimo coal fields, the base of the measures is approximately equivalent to the highest part of the Queen Charlotte Islands section.

The Cretaceous section at Comox has been divided on lithological grounds into seven, that at Nanaimo into three, members by Mr J. Richardson. While unnecessary to refer to these in detail here, it may be stated that they correspond pretty closely, and that the well marked and abundant fauna and flora of the Upper Cretaceous of the coast of British Columbia characterizes the four lower subdivisions at Nanaimo and the two lower subdivisions at Comox, the thickness of the strata being estimated at 2,715 and 2,020 feet respectively. These subdivisions have been united under the name of the Nanaimo group,* and this is believed to be almost exactly equivalent to the Chico of California and at least approximately to the Pierre of the Great plains. At both Nanaimo and Comox the workable coal seams occur in the lowest subdivision of this group.

As already noted, beds referable to the Upper or later Cretaceous are known to occur in the far north. The fossils indicate a horizon at least as high as that of the Benton, and it is very probable that further investigation may disclose the existence of a complete ascending series, like that found in the Laramide range and its adjacent foothills to the east.

In the Laramide range, the Upper Cretaceous includes representatives of all the Cretaceous groups of the Great plains, but generally with more massive developments and altered characters, resulting from proximity to an extensive land surface to the westward, from which abundant and often coarse sediments were derived. This is particularly notable in the case of the Dakota, to which allusion has already been made in connection with the Kootanie. It may here be added that contemporaneous volcanic materials, with a thickness of over 2,000 feet in one locality, have been found in this group in the eastern part of the Crows Nest pass.†

The aggregate thickness of the Upper Cretaceous in the southern part of the Laramide range (including the lower portion of the Laramie, which may be regarded as Cretaceous) is found to be about 10,000 feet.‡ It is unnecessary, however, to do more than allude to this section here, as it is

* Am. Jour. Sci., loc. cit.
† Annual Report, Geol. Surv. Can., vol. i (N. S.), p. 69 B.
‡ Ibid., p. 166 B.

more properly to be regarded as the western margin of the Cretaceous of the plains than as characteristic of the Cordilleran region. Its characters have been, moreover, quite adequately summarized elsewhere, particularly by Dr Whiteaves in his paper previously referred to.

The Laramie is regarded as a series transitional between the Cretaceous and Tertiary, and in the Laramide range and its foothills passes up from a brackish-water to a purely fresh-water deposit. No beds probably referable to this time have been found between this range and the Pacific coast in the entire southern part of British Columbia, but in the extreme north of that province, some deposits apparently referable to the Upper Laramie occur,* while it is also present in considerable volume in parts of the Yukon district.†

On the Pacific coast, the Puget group of Washington has been referred with probability to the period represented by the Laramie, and rocks of this group have a somewhat extensive development about the estuary of the Fraser, with a thickness of at least 3,000 feet. They appear to have been deposited in fresh or brackish water, and hold some beds of lignite.‡ The upper subdivisions of the Nanaimo and Comox sections, from which no distinctive organic remains have yet been obtained, may also prove to represent the Puget group, or the marine Tejon of California, which is perhaps no lower.

Tertiary

It has been convenient to refer to the Laramie as a whole in connection with the Cretaceous, although the Upper Laramie is regarded as Eocene. The Puget beds of the Fraser estuary and Burrard inlet, just alluded to, have always been described as Tertiary, and were for a long time regarded as Miocene.

Subsequent to the Cretaceous period and the great orogenic movements that accompanied its close, the physical conditions in the Rocky Mountain region of Canada became much more like those existing today. The Eocene appears for the most part to have been a time of denudation,§ but later Tertiary deposits occur in many places and often in extensive development. On the coast these are usually marine, but no marine beds have been found to the east of the Coast ranges, although it seems possible that evidence may yet be found in the north of the extension of the sea at this time as far east as the upper Canadian portion of the Yukon basin.

* Ibid., vol. vii, p. 35 C.

† Ibid., vol. iii, p. 149 B.

‡ Am. Jour. Sci., vol. xxxiv, p. 182. For descriptions of plants see Trans. Royal Soc. Can., second series, vol. i, sec. iv (1895), p. 135.

§ Trans. Royal Soc. Can., vol. viii, sec. iv, p. 11.

The Tertiary sediments of the interior are chiefly those of lake basins, large or small, but the great mass of the Tertiary rocks is composed of volcanic materials, a circumstance accounting for the general paucity of organic remains, which, together with the isolated positions of the known fossiliferous localities, renders it very difficult to build up a satisfactory and connected section of the Tertiary formations.*

Some progress has, however, been made in this respect, particularly in the southern part of the Interior plateau of British Columbia, where the following scheme, which may be taken as a term of reference for the whole inland region, has been arrived at.† The order is descending:

		Feet
Later Miocene.	Upper Volcanic group (maximum thickness)	3,100
	Tranquille beds (maximum thickness)	1,000
Earlier Miocene.	Lower Volcanic group (maximum thickness apart from centers of eruption)	5,300
Oligocene.	Coldwater group (at Hat creek)	5,000
		14,400

Beginning with the oldest member of the above section, it may be explained that more or less isolated series of beds in different parts of the Interior plateau region have lately been classed together provisionally as the Coldwater group. These resemble each other lithologically, and all appear to antedate the beginning of Tertiary volcanic action in this part of the region. One of their developments, from which the greatest number of fossils has been derived, has frequently been referred to in earlier publications as the "Similkameen beds," but the name Coldwater group is preferred as a general one, including these as a local development. From the Similkameen beds, plants, insects, and a few fish remains have been obtained. These have been described by Sir J. Wm. Dawson, Dr S. H. Scudder, and Professor E. D. Cope, who agree in referring them with probability to the Oligocene. The fish is an *Amyzon*, like that from the Amyzon beds of Oregon.‡ Much farther north, on the Horsefly river, a tributary of the Quesnel, well preserved remains of another fish of the same genus have been found, and again in association with similar plant remains. Elsewhere plants only, or a few insects, have been discovered.

The deposits of the Coldwater group consist of conglomerates, shales, and sandstones which not infrequently hold beds of lignite or, as at the

* For earlier references to the Tertiary deposits of the region, see Geol. Mag., Decade II, vol. viii, foot-notes to pp. 158, 162.

† Annual Report, Geol. Surv. Can., vol. vii (N. S.), p. 76 B. Detailed descriptions of the several groups in the southern part of British Columbia are also given in this report.

‡ Tertiaryplants of the Similkameen river; Trans. Royal Soc. Can., vol. viii, sec. iv (1890), p. 75. Contributions to Can. Pal., vol. ii, part i. Proc. Acad. Nat. Sci. Phil., vol. xlv (1893), p. 401.

junction of the Coldwater and Nicola rivers, bituminous coal. At the base the conglomerates are often rough and coarse, composed of the local underlying rocks, upon which they rest irregularly, but above these, in several places in the southern part of the Interior plateau, are thick beds of well rolled and generally small pebbles derived for the most part from the cherty beds of the Cache Creek formation. The sandstones and shales are usually pale-colored, gray, buff, or drab, except where they become carbonaceous.*

Speaking of the southern part of British Columbia, where the Tertiary deposits have been examined with some care, it appears that the beds of the Coldwater group were, at least locally, disturbed and subjected to considerable erosion before the deposition of the overlying materials assigned to the Miocene. These are almost entirely of volcanic origin, and over a considerable area they admit of separation into lower and upper volcanic groups, between which are the water-laid Tranquille beds.

The principal volcanic vents of the early Miocene appear to have been situated near to and parallel with the inland border of the Coast ranges, their denuded remnants being now found in the Clear mountains, Ilgachuz mountain, etcetera. Both effusive and fragmental rocks are represented in the products of this period, which, petrographically considered, consist chiefly of augite-porphyrites, of gray, greenish, and purplish colors, with smaller amounts of mica-porphyrites, picrite-porphyrites, etc. These generally form massive beds, and are now found inclined in many places at angles as high as 30 degrees from the horizontal, although to what extent this may represent the natural slope of deposition and in how far it may be due to subsequent movement is often indeterminate.

The Tranquille beds consist generally of bedded tuffs, and are usually pale in color. They occasionally contain plant remains and some thin beds of coal or lignite, as at Kamloops.† The upper volcanic group is composed for the most part of basalts and basalt-breccias, with smaller quantities of various porphyrites, mica-trachyte, and mica-andesite. The basalts often occur in horizontal flows of great extent, their eruption having marked the closing stage of the great Tertiary period of vulcanism. Their sources may have been numerous and local, and they are often

* The Kenai formation of Dall, found in some parts of Alaska, is believed by Dall to be either Oligocene or Eocene. The statement, however, that the Kenai is also "widely spread in British Columbia" is too comprehensive. It may be supposed to refer to formations like that here described, widely separated geographically and differing in conditions of deposition from the typical Kenai of Cooks inlet. In such a case the elevation of a local formational name into a regional chronological term is in no way helpful and should, I think, be deprecated. (See Bull. No. 84, U. S. Geol. Survey, Annual Report, U. S. Geol. Survey, 1895–'96, part i, p. 481. Ibid., 1896–'97, part ii, p. 345.)

† Annual Report, Geol. Surv. Can. (N. S.), vol. vii, p. 169 B.

found forming a comparatively thin sheet that lies directly on the denuded surface of the older rocks without the intervention of any of the earlier members of the Tertiary. As these wide basaltic flows are in most cases known to antedate the great period of river erosion assigned to the Pliocene, they are supposed to be of later Miocene age. It is, of course, possible that local eruptions of more recent date may have occurred, but only one instance of a comparatively recent or postglacial lava flow has so far been found in the entire Cordilleran region of Canada. This is in the valley of the Nasse river.*

In the northern interior of British Columbia, lake deposits have been found, in some places, blending above with volcanic materials and capped by horizontal basalts, the whole being very probably referable to the Miocene. In other places, both in British Columbia and in the Yukon district, local flows of basalt are found which may belong either to the Miocene or to the Pliocene. The same is true of isolated basalt patches in the Kettle River country in the southen part of British Columbia and in East Kootenay. On the Nechacco river and elsewhere, Tertiary shales or clays, with sandstones, of indeterminate horizon are also found. It will be many years before all these deposits can be investigated and classified, and it may never be possible to assign an exact position to some of them in the general series. The great paucity, amounting almost to a complete absence, of the remains of the higher vertebrates being particularly unfortunate in this respect.

In the southern part of the Interior plateau of British Columbia, small areas have been found of sediments that are supposed to belong to the early Pliocene,† but no fossils have been obtained from them. On the Horsefly river, however, overlying the Oligocene beds already referred to in slight but distinct unconformity, and underlying the boulder-clay, is a deposit of yellowish and in part "cemented" gravels, to which a Pliocene age may be assigned with some confidence.‡ These gravels are worked for gold, and branches and stems of trees found in the workings have been determined by Professor D. P. Penhallow to represent *Sequoia gigantia*, *S. sempervirens*, *Juniperus californica*, *Cupressus macrocarpa*, *Thuya gigantia*, and *Picea sitchensis*.§

The presence of such an assemblage of trees in the inland region north of latitude 52°, indicates the existence of physical and climatic conditions very different from those now existing there and still more unlike those of the intervening glacial period, while the species themselves are still living ones.

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*Summary Report, Geol. Surv. Can., 1893, p. 14 A.

†Annual Report, Geol. Surv. Can., vol. vii (N. S.), p. 74 B.

‡Ibid., p. 26 A.

§These determinations have not previously been published.

Similar yellow gravels have been found on the Upper Fraser and on its tributary, the Blackwater, in several places, and it is probable that they are somewhat widespread in this district.* It is very possible that they are at least approximately synchronous with the old auriferous preglacial stream gravels of the Cariboo mountains, and are also of the same age with the "yellow gravels" of the Atlin district.

The Tertiary deposits of the Coast region of British Columbia are wholly separated from those of the interior by the physical barrier of the Coast ranges. They are interesting, but not of great extent, occurring in isolated patches and not forming, as they do farther to the south, a nearly continuous border to the continent. The sedimentary beds are for the most part of marine origin, and are still found near the level of the sea, little disturbed or altered.

Sandstones holding marine shells occur at Sooke, on the southern coast of Vancouver island. These beds were first described by Mr J. Richardson.† Mr J. C. Merriam has since studied the fossils, and they appear to be referable to the Upper Miocene or Pliocene ("Middle Neocene").‡ Farther west, on the same coast, are the Carmanah beds, consisting of sandstones, shales, and conglomerates. These are referred by the same author to the "Astoria Miocene" § or Astoria group, and are recognized as older than the Sooke beds. A remarkable bird, *Cyphornis magnus*, had previously been described by Cope from the Carmanah beds, and this he states is not older than Eocene nor later than Oligocene.‖ Plant remains also occur, but they have not so far been studied. Elsewhere on the west coast of Vancouver island and farther north small patches of Tertiary rocks are found, which have not yet been examined, and from which no fossils have been obtained.

The most important development of Tertiary rocks on the coast is that forming the northeastern part of Graham island, the northern member of the Queen Charlotte group. The considerable tract of land underlain by these rocks is relatively low, and most of the prominent rock masses consist of basalt with some volcanic materials of a less basic character, and in one place obsidian, fragmental as well as effusive rocks being represented. In a few places, underlying sandstones and shales come to the surface, sometimes holding lignite, and at one locality marine shells are abundantly represented. These have been examined by

* Annual Report, Geol. Surv. Can., vol. vii (N. S.), p. 28 A; also Report of Progress, Geol. Surv. Can., 1875-'76, pp. 263, 264.

† Report of Progress, Geol. Surv. Can., 1876-'77, p. 190.

‡ Bull. Univ. Cal., Geology, vol. ii, no. 3, p. 101; Proc. Cal. Acad. Sci., third series, vol. i, no. 6, p. 175.

§ Op. cit.

‖ Jour. Acad. Nat. Sci. Phila., vol. ix, p. 449. The bird is described from a single bone. The exact locality is not given in the paper, not being known to Cope at the time.

Dr. Whiteaves. They include a number of still living forms, but may be regarded as Pliocene or later Miocene.*

Physical History of the Region

It will now be endeavored to briefly review the orographic changes and the conditions of deposition of which the geological column gives evidence—in other words, to touch in outline the main facts of the physical history of the Rocky Mountain region of Canada.

As for the Archean, it need only be said that here, as in most parts of the world, we find beneath any rocks that can be assigned to the Cambrian in the most extended sense of that term, and apparently separated from these rocks by a great break and unconformity, a crystalline series or "fundamental complex" composed of plutonic rocks with highly metamorphosed and vanishing sedimentary rocks in seemingly inextricable association. The similarity of this basal series in different parts of the world is so great as apparently to imply world-wide and approximately contemporaneous conditions, of a kind perhaps differing from any that can have occurred at later periods. The region here described is not, however, an ideal one for the study of these Archean rocks, because of the extreme metamorphism by which much newer formations have often been affected in it; nor has any series yet been defined that appears here to bridge the gap between the Archean and the strata that may with propriety be attached to the Cambrian.

In the earlier series of deposits assigned to the Cambrian, we discover evidence of a more or less continuous land area occupying the position of the Gold ranges and their northern representatives and aligned in a general northwesterly direction. The Archean rocks were here undergoing denudation, and it is along this axis that they are still chiefly exposed, for although they may at more than one time have been entirely buried beneath accumulating strata, they have been brought to the surface again by succeeding uplifts and renewed denudation. We find here, in effect, an Archean axis or geanticline that constitutes, I believe, the key to the structure of this entire region of the Cordillera. To the east of it lies the Laramide geosyncline (with the conception of which Dana has familiarized us), on the west another and wider geosyncline, to which more detailed allusion will be made later.

Conglomerates in the Bow River series indicate sea margins on the east side of this old land, but these are not a marked feature in the Nisconlith, or corresponding series on its western side. Fossils have so far been discovered only in the upper part of the Bow River series, but the preva-

*See Report of Progress, Geol. Surv. Can., 1878–'79, p. 87 B.

lence of carbonaceous and calcareous material (particularly in the Nisconlith) appears to indicate the abundant presence of organisms of some kind at this time.

Although no evidence has been found of any great physical break, the conditions indicated by the upper half of the Cambrian are very different from those of the lower. Volcanic materials, due to local eruptions, were accumulated in great mass in the region bordering on the Archean axis to the west, while on the east materials of this kind appear to be mingled with the preponderant shore deposits of that side of the Archean land, and to enter sparingly into the composition of the generally calcareous sediments lying still farther eastward. Where these sediments now appear in the eastern part of the Laramide range they are chiefly limestone, indicating marine deposition at a considerable distance from any land.

The history of the Ordovician, Silurian, and Devonian times is very imperfectly known. Marine conditions still prevailed to the eastward of the Archean axis and were probably continuous there, but our knowledge of the region to the west, while as yet almost entirely negative in its character, is not sufficiently complete to enable us to assume the existence of any extensive land area in that quarter. In the Devonian the sea is known to have covered a great area in the interior of the continent, extending far to the north in the Mackenzie basin, and it appears probable that considerable portions of the western part of the Cordilleran region were also submerged, particularly to the north.

About the beginning of the Carboniferous period and thence onward the evidence becomes much more satisfactory and complete. In the earlier part of the Carboniferous, marine sediments, chiefly limestones, were laid down everywhere to the east of the Archean axis, while to the west of that axis (which was probably in large part itself submerged) ordinary clastic deposits, mingled with contemporaneous volcanic materials, were formed, tranquil epochs being marked by the intercalation of occasional limestone beds. It is not clearly apparent from what land the clastic materials were derived, but the area of vulcanism at this time was very great, covering the entire western part of British Columbia to the edge of the continental plateau and, as now known, extending northwestward into Alaska and southward to California.

In the later time of the Carboniferous, however, the volcanic forces declined in their activity, and a great thickness of calcareous marine deposits occurred with little interruption of any kind. The area of land to the eastward was probably increased, for there is some evidence to show a first gentle uprising in the Laramide region at this time (or at least a cessation of subsidence), and no late Carboniferous strata have so far been found there.

No separate record for the Permian has yet been found in this part of the continent, but it must be remembered that, in view of the scanty character of the paleontological evidence, strict taxonomic boundaries can seldom be drawn. At about this time, however, very important changes occurred, for in the Triassic a great part of what is now the inland plain of the continent is found to have become the bed of a sea shut off from the main ocean, in which red rocks with salt and gypsum in some places were laid down. The northern part of this sea appears to have extended into the Canadian region for a short distance, covering the southern portion of the Laramide area. Farther north must have been the land boundary of this sea, and beyond this an extension of the Pacific ocean which swept entirely across the Cordillera. In the southern part of British Columbia, however, this ocean found its shore against the Gold ranges of the Archean axis, where the preceding Carboniferous beds had already been upturned and subjected to denudation. The Laramide region was not affected by volcanic action at this time, but vulcanism on a great scale was resumed in the entire western part of the Cordillera that had previously been similarly affected in the Carboniferous, and the ordinary marine sediments there form intercalations only in a great mass of volcanic products, probably in large part the result of submarine eruptions.

Such definite indications as exist of the Jurassic must, as already noted, be considered as physically attached to the Triassic of the Interior plateau of British Columbia. It is probable that the greater part of the Jurassic period was characterized by renewed orogenic movements and by denudation, for when we are next able to form a connected idea of the physical conditions of the region these are found to have been profoundly modified.

It is to about this time that the elevation of the Sierra Nevada and some other mountain systems in the western states is attributed. In the region here particularly described, the Triassic and older rocks of the Vancouver range, or that forming Vancouver and the Queen Charlotte islands, were upturned, while a similar movement affected the zone now occupied by the British Columbian Coast ranges. These may not have been elevated into a continuous mountain system and barrier to the sea, but in any case the ranges then formed were, before the beginning of the Cretaceous period, largely broken down by denudation, so that the underlying granitic rocks supplied abundant arkose material to some of the lowest Cretaceous beds.

It is also probable that subsidence marked the close of the Jurassic, for in southern British Columbia the Pacific of the Earlier Cretaceous extended more or less continuously across the line of the Coast ranges, finding its shore not far to the east of this line. Farther north, although not without insular interruptions, it spread over the entire width of the Cordilleran belt, repeating the conditions found in the Triassic, but with the difference that it extended far to the south along the axis of the Laramide geosyncline, in which rapid subsidence had been renewed. In this early Cretaceous sea and along its margins and lagoons the massive fossiliferous rocks of the Queen Charlotte islands and Kootanie formations were accumulated and coal beds were produced. Volcanic activity was renewed in some places, particularly near the present seaward margin of British Columbia. Sedimentation evidently proceeded more rapidly than subsidence in many localities and coal-producing forests, largely composed of cycadaceous plants took possession of the newly formed lands from time to time.

The era of the later Cretaceous appears, however, eventually to have been introduced by a marked general subsidence, which, as already noted, carried the Dakota sea entirely across the inland plain of the continent. The distribution and character of the ensuing Cretaceous formations show that the whole southern part of what is now the mainland of British Columbia soon after became and remained a land area, while the sea was more gradually excluded from the northern part of the Cordillera and continued to occupy the area of the Great plains and the present position of the Laramide range. Along the margin of the continental plateau, however, a renewed subsidence was in the main progressing southward and resulted ultimately in carrying the later Cretaceous sediments into the region of Puget sound.

The closing event of this cycle was the deposition of the Laramie beds on the east and in some places to the north, with probably the Puget group and its representatives on the coast, and this was followed by the most important and widespread orogenic movement of which we find evidence in the entire Rocky Mountain region. At this time the great Laramide range, or Rocky Mountain range proper, was produced, rising on the eastern side of the Archean axis along a zone that had previously been characterized from the dawn of the Paleozoic by almost uninterrupted subsidence and sedimentation. That the pressure causing this upthrust of the Laramide range was from the westward is clearly shown by the great overthrust faults in this range. The stability of the old Archean axis, which it may be supposed had previously sustained the tangential thrust from the Pacific basin, must at this time have been at last overcome. As a part of the result of this, the chief belt of faulted strata in the Laramide range, originally about 50 miles wide, became reduced in width by one-half. How rapidly this great revolution may have occurred we do not know, but it probably occupied no long time from a geological point of view, and the Laramide range, as first produced, may very possibly have attained a height approaching 20,000 feet.* The thickness of stratified rocks in the geosyncline was at the time probably more than 40,000 feet.

It is difficult to determine to what extent the Archean axis with the Gold ranges and other preexisting mountains were affected at this period of orogenic movement, because of the absence of the newer formations there, but it seems probable that no very important change took place. Farther west, however, the great zone of Coast ranges was elevated, and the corrugated and vertical Cretaceous beds met with even on their inland side, show that large parts of the Interior plateau of British Columbia and of the country in line with it to the northward were flexed and broken. Similar conditions are found to have affected the Cretaceous rocks of Vancouver and the Queen Charlotte islands, of which the mountain axis, previously in existence, was evidently greatly increased in elevation.

The Laramide geosyncline has already been particularly referred to and allusion has been made to the now well recognized fact that by such zones of continued subsidence and deposition the lines of most mountain systems have been determined. To the Laramide geosyncline here, the mountains of the Archean axis—the Gold ranges—stood in much the same relation as the Archean western border of the Wasatch to the Laramide geosyncline in Utah (as described by Dana), but on a larger scale.

On the other or western side of this axis, as already noted, I am now led to regard the zone of country extending to the Vancouver range as a second and wider geosyncline, with a breadth of about 200 miles, in which a thickness of deposits perhaps greater than that of the Laramide, but in the main composed of volcanic ejectamenta, had by this time been accumulated. The volume of the Carboniferous and Triassic rocks alone must have exceeded 20,000 feet. It is probable that to this may be added a great thickness of older rocks,† for the circumstance that volcanic action was so persistent here, and the amount of extravasation resulting from it was so enormous, implies a recognition of the fact that, along this zone (not far from the edge of the continental plateau) the

*This refers particularly to the better known region near the Bow pass. See Annual Report, Geol. Surv. Can. (N. S.), vol. ii, p. 31 D, and Am. Jour. Sci., vol. xlix, p. 463. The base of the mountains may at this time have been nearly at sealevel, or 4,000 feet lower than at present, while the actual height at any time attained would depend upon the rapidity of uplift relatively to denudation. The total height of folded strata is estimated at from 32,000 to 35,000 feet.

†Several thousand feet of Cretaceous rocks must also be added to this thickness near the line of the present Coast ranges, and the total thickness of deposits in the center of this geosyncline must probably have exceeded 40,000 feet.

isogeotherms, with what we may call the plane of granitic fusion, had crept up to a position abnormally near the surface. It is to this probably that we may attribute the apparent absence of Archean rocks in the Coast ranges, or at least the impossibility of defining any rocks of that period there, for these, together no doubt with great volumes of later deposits, may be assumed to have become merged in the rising granitic magma, on which strata of Triassic age are now often found lying directly, arrested in the very process of absorption.*

When the Laramide revolution occurred, by reason of the increasing tangential pressure from the Pacific basin and the growing failure of resistance of the two great geosynclines of this part of the Cordillera, the Laramide range was produced by the folding and fracture of a very thick mass of beds, of which the crystalline base has not yet been revealed by denudation, while in the western trough an eversion of the axis of settlement seems to have occurred, resulting in the appearance of a granitic bathylite of nearly a thousand miles in length, from which the comparatively thin covering of unabsorbed beds was soon afterward almost completely stripped away by ensuing processes of waste.

This last great epoch of mountain making doubtless left the surface of the Cordilleran belt generally with a very strong and newly made relief, which, before the middle of the Tertiary period, is found to have become greatly modified by denudation. Chiefly because no deposits referable to the Eocene or earliest Tertiary have been found in this part of the Cordillera, it is assumed with probability that this was a time of denudation. It is further indicated that it was a time of stability in elevation, by the fact that the prolonged wearing down resulted, in the interior zone of the Cordillera, in the production of a great peneplain, the base-level of which shows that the area affected stood 2,000 or 3,000 feet lower in relation to the sea than it now does, and that for a very long time. If, however, the Puget beds of the coast are correctly referred to the Eocene, it follows that the coast region was at the same period only slightly lower than at present, and that the movements in subsidence and elevation between this and the interior region must have been differential in character and very unequal in amount.

As already noted, the earliest Tertiary sediments of the Interior plateau of the Cordillera are referred to the Oligocene. Probably some further subsidence at that time interrupted the long preceding time of waste. This period of deposition was in turn closed by renewed disturbance of an orogenic kind, comparatively slight in amount and local, chiefly affecting certain lines in a northwest and southeast direction. Next

* Annual Report, Geol. Surv. Can., vol. ii (N. S.), 1886, p. 11 B et seq.

came renewed denudation or "planation," and this continued until the enormous volcanic extravasations of the Miocene began.

It is not proposed in this place to recapitulate in detail the physical conditions of the Tertiary period, for it has already been necessary to refer to these in connection with the description of the beds themselves, which, because they have not been materially changed since their deposition, really tell their own tale.

It need only be said that, after the Oligocene lake deposits had been formed, disturbed, and denuded, new series of lakes were from time to time produced at different stages during the Miocene, their beds now generally appearing as intercalations in volcanic deposits of great mass. Both the coast and the interior region appear to have been subject to these conditions, while the Laramide range stood high, with the inland plain of the continent sloping eastward from its base.

Following the close of, or at least a great reduction in volcanic activity, in the early Pliocene, the interior zone of the Cordillera again assumed a condition of stability for a considerable time, during which wide and "mature" stream valleys were formed. The elevation of the Interior plateau region of British Columbia must then have been about 2,000 feet less than it is at present.* Farther north, the yellow Pliocene gravels of Horsefly river, aud other places, are attributed to this period, and the southern aspect of their contained fossil plants is such as to indicate that, in the given latitude, the height of that part of the interior can not have been much above the sealevel.

In the later Pliocene a very marked reëlevation of the Cordilleran region evidently occurred, leading to the renewed activity of river erosion, the cutting out of deep valleys and canyons, and the shaping of the surface to a form much like that held by it at the present day. This elevation in all probability affected the coast as well as the interior, and it would appear that the rivers for a time extended their courses to the edge of the continental plateau.

The excavation of the remarkable fiords of British Columbia and the southern part of Alaska must, I think, be chiefly attributed to the later portion of the Pliocene, although it is quite possible that the cutting out of the valleys may have been begun soon after the Laramide upheaval. The antiquity of these valleys is evidenced by the fact that several comparatively small rivers still flow completely across the Coast ranges in their deep troughs. The fiords are now essentially the submerged lower parts of these and other drainage valleys of the old land, not very materially affected by the later glacial action, important as this has un-

* Trans. Royal Soc. Can., vol. viii, sec. iv, p. 18.

doubtedly been from other points of view. The valleys of the fiord-like lakes that occur along the flanks of the Archean axis of the interior may probably also be referred to river erosion in the later Pliocene, but if so this mountain region must have been affected by a relatively greater uplift at that time, followed later by a subsidence of its central part. It appears, however, that the excavation of valleys or gorges like these by rivers, when the slope and water supply are favorable, occurs with such rapidity relatively to the wider effects of denudation, as to be almost negligible in any general view of the physical changes of an extensive region or in the accounting of geological time.

There is as yet some difficulty in connecting the later physical changes particularly referred to above with those which have recently come under observation far to the north in the Klondike region. It is probable, however, that the auriferous "quartz drift" of that region, implying long subaerial decay and stability of level, may be attributed to the early Pliocene; while the river gravels found in the newer and deeper-cut valleys may be assigned to the later Pliocene time of greater elevation. During the Pliocene, and probably until its close, the mammoth, one or two species of bison, the moose, and other large mammals roamed northward to the Arctic sea. Then came the Glacial period, with renewed great changes in levels and climate and its own peculiar records and history, which in many respects are more difficult of interpretation than those of more remote periods, because the whole time occupied by them has been relatively so brief. I have elsewhere endeavored to follow this history in detail, and do not propose on this occasion to deal with this latest chapter of the physical history of the Rocky Mountain region of Canada.

In conclusion, what appear to be the most striking points evidenced by the geological record of this northern part of the Cordillera perhaps be specified as follows:

(1) The great thickness of strata accumulated both to the east and west of an Archean axis. In the Laramide geosyncline the strata no doubt actually attained the volume stated. In the western and wider syncline it is not so certain that all the formations in their full thickness were ever actually superposed at any one place or time (for reasons already alluded to), but the volume was probably not less than in the Laramide region.

(2) The great proportion of volcanic materials accumulated in the western geosyncline and the recurrence of vulcanism throughout the geological time-scale in this region, resulting in the production of massive volcanic formations in the Cambrian, Carboniferous, Triassic, Cretaceous, and Miocene.

(3) The recurrence of folding and disturbance parallel to the border of the Pacific basin and the concurrent great changes in elevation of the land relatively to the sea, both continued down to quite recent geological times, the latter even into the Pleistocene.

(4) The tremendous energy of denudation, in part due to the events last referred to, but also dependent upon the position of the region on the eastern border of a great ocean, where, in northern latitudes, an excessive rainfall must have occurred at all periods on the seaward mountain ranges. No comparable denuding forces were probably ever operative on the east side of the continent in similar latitudes since the definition of the ocean basins of the Pacific and Atlantic.